CHAPTER 11

# Behind the Supply Curve: Inputs and Costs

### What You Will Learn in This Chapter

- The importance of the firm's **production function,** the relationship between quantity of inputs and quantity of output
- Why production is often subject to **diminishing returns to inputs**
- The various types of costs a firm faces and how they generate the firm's marginal and average cost curves
- Why a firm's costs may differ in the **short run** versus the **long run**
- How the firm's technology of production can generate **increasing returns to scale**

## THE FARMER'S MARGIN



**How intensively an acre of land is worked—a decision at the margin—depends on the price of wheat a farmer faces.**

"O BEAUTIFUL FOR SPACIOUS skies, for amber waves of grain." So begins the song "America the Beautiful." And those amber waves of grain are for real: though farmers are now only a small minority of America's population, our agricultural industry is immensely productive and feeds much of the world.

If you look at agricultural statistics, however, something may seem a bit surprising: when it comes to yield per acre, U.S. farmers are often nowhere near the top. For example, farmers in Western European countries grow about three times as much wheat per acre as their U.S. counterparts. Are the Europeans better at growing wheat than we are?

No: European farmers are very skillful, but no more so than Americans. They produce more wheat per acre because they employ more inputs—more fertilizer and, especially, more labor—per acre. Of course, this means that European farmers have higher costs than their American counterparts. But because of government policies, European farmers receive a much higher price for their wheat than American farmers. This gives them an incentive to use more inputs and to expend more effort at the margin to increase the crop yield per acre.

Notice our use of the phrase "at the margin." Like most decisions that involve a comparison of benefits and costs, decisions about inputs and production involve a comparison of marginal quantities—the marginal cost versus the marginal benefit of producing a bit more from each acre.

In Chapter 9 we considered the case of Alex, who had to choose the number of years of schooling that maximized his profit from schooling. There we used the profit-maximizing principle of marginal analysis to find the optimal quantity of years of schooling. In this chapter, we will encounter producers who have to make similar "how much" decisions: choosing the quantity of output produced to maximize profit.

Here and in Chapter 12, we will show how marginal analysis can be used to understand these output decisions—decisions that lie behind the supply curve. The first step in this analysis is to show how the relationship between a firm's inputs and its output—its *production function*—determines its *cost curves,* the relationship between cost and quantity of output produced. That is what we do in this chapter. In Chapter 12, we will use our understanding of the firm's cost curves to derive the individual and the market supply curves.

A **production function** is the relationship between the quantity of inputs a firm uses and the quantity of output it produces.

A **fixed input** is an input whose quantity is fixed for a period of time and cannot be varied.

A **variable input** is an input whose quantity the firm can vary at any time.

The **long run** is the time period in which all inputs can be varied.

The **short run** is the time period in which at least one input is fixed.

The **total product curve** shows how the quantity of output depends on the quantity of the variable input, for a given quantity of the fixed input.

# The Production Function

A *firm* is an organization that produces goods or services for sale. To do this, it must transform inputs into output. The quantity of output a firm produces depends on the quantity of inputs; this relationship is known as the firm's **production function.** As we'll see, a firm's production function underlies its *cost curves*. As a first step, let's look at the characteristics of a hypothetical production function.

## Inputs and Output

To understand the concept of a production function, let's consider a farm that we assume, for the sake of simplicity, produces only one output, wheat, and uses only two inputs, land and labor. This particular farm is owned by a couple named George and Martha. They hire workers to do the actual physical labor on the farm. Moreover, we will assume that all potential workers are of the same quality—they are all equally knowledgeable and capable of performing farmwork.

George and Martha's farm sits on 10 acres of land; no more acres are available to them, and they are currently unable to either increase or decrease the size of their farm by selling, buying, or leasing acreage. Land here is what economists call a **fixed input—**an input whose quantity is fixed for a period of time and cannot be varied. George and Martha are, however, free to decide how many workers to hire. The labor provided by these workers is called a **variable input—**an input whose quantity the firm can vary at any time.

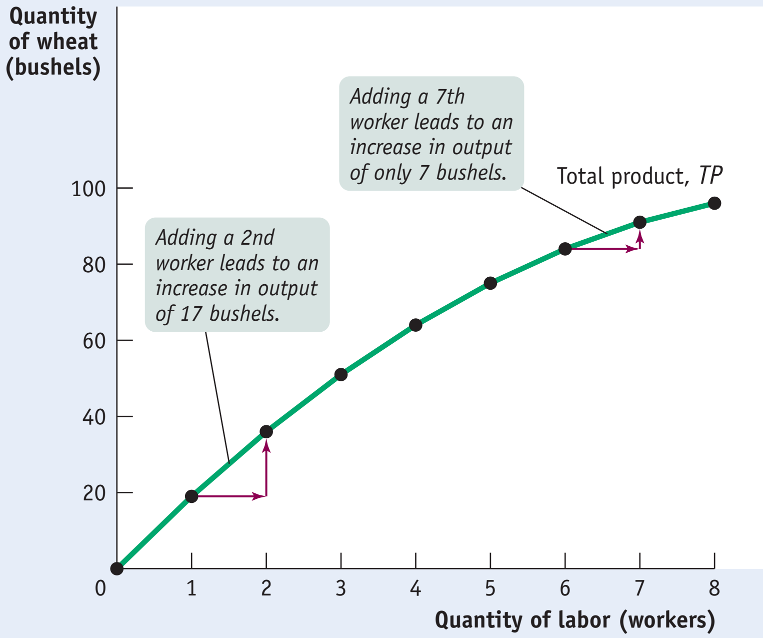
In reality, whether or not the quantity of an input is really fixed depends on the time horizon. In the **long run** that is, given that a long enough period of time has elapsed—firms can adjust the quantity of any input. For example, in the long run, George and Martha can vary the amount of land they farm by buying or selling land. So there are no fixed inputs in the long run. In contrast, the **short run** is defined as the time period during which at least one input is fixed. Later in this chapter, we'll look more carefully at the distinction between the short run and the long run. But for now, we will restrict our attention to the short run and assume that at least one input is fixed.

George and Martha know that the quantity of wheat they produce depends on the number of workers they hire. Using modern farming techniques, one worker can cultivate the 10-acre farm, albeit not very intensively. When an additional worker is added, the land is divided equally among all the workers: each worker has 5 acres to cultivate when 2 workers are employed, each cultivates $3\frac{1}{3}$ acres when 3 are employed, and so on. So as additional workers are employed, the 10 acres of land are cultivated more intensively and more bushels of wheat are produced.

The relationship between the quantity of labor and the quantity of output, for a given amount of the fixed input, constitutes the farm's production function. The production function for George and Martha's farm, where land is the fixed input and labor is a variable input, is shown in the first two columns of the table in Figure 11-1; the diagram there shows the same information graphically. The curve in Figure 11-1 shows how the quantity of output depends on the quantity of the variable input, for a given quantity of the fixed input; it is called the farm's **total product curve.**

The physical quantity of output, bushels of wheat, is measured on the vertical axis; the quantity of the variable input, labor (that is, the number of workers employed), is measured on the horizontal axis. The total product curve here slopes upward, reflecting the fact that more bushels of wheat are produced as more workers are employed.

**FIGURE 11-1** **Production Function and Total Product Curve for George and Martha's Farm**




| Quantity of labor $L$ (workers) | Quantity of wheat $Q$ (bushels) | Marginal product of labor $MPL = \Delta Q/\Delta L$ (bushels per worker) |
|---|---|---|
| 0 | 0 | |
| | | 19 |
| 1 | 19 | |
| | | 17 |
| 2 | 36 | |
| | | 15 |
| 3 | 51 | |
| | | 13 |
| 4 | 64 | |
| | | 11 |
| 5 | 75 | |
| | | 9 |
| 6 | 84 | |
| | | 7 |
| 7 | 91 | |
| | | 5 |
| 8 | 96 | |

The table shows the production function, the relationship between the quantity of the variable input (labor, measured in number of workers) and the quantity of output (wheat, measured in bushels) for a given quantity of the fixed input. It also calculates the marginal product of labor on George and Martha's farm. The total product curve shows the production function graphically. It slopes upward because more wheat is produced as more workers are employed. It also becomes flatter because the marginal product of labor declines as more and more workers are employed.

Although the total product curve in Figure 11-1 slopes upward along its entire length, the slope isn't constant: as you move up the curve to the right, it flattens out. To understand why the slope changes, look at the third column of the table in Figure 11-1, which shows the *change in the quantity of output* that is generated by adding one more worker. This is called the *marginal product* of labor, or *MPL:* the additional quantity of output from using one more unit of labor (where one unit of labor is equal to one worker). In general, the **marginal product** of an input is the additional quantity of output that is produced by using one more unit of that input.

In this example, we have data on changes in output at intervals of 1 worker. Sometimes data aren't available in increments of 1 unit—for example, you might have information only on the quantity of output when there are 40 workers and when there are 50 workers. In this case, we use the following equation to calculate the marginal product of labor:

$$\textbf{(11-1)} \quad \begin{matrix}\text{Marginal}\\ \text{product}\\ \text{of labor}\end{matrix} = \begin{matrix}\text{Change in quantity of}\\ \text{output produced by one}\\ \text{additional unit of labor}\end{matrix} = \frac{\text{Change in quantity of output}}{\text{Change in quantity of labor}}$$

or

$$MPL = \frac{\Delta Q}{\Delta L}$$

In this equation, Δ, the Greek uppercase delta, represents the change in a variable.

Now we can explain the significance of the slope of the total product curve: it is equal to the marginal product of labor. The slope of a line is equal to "rise"

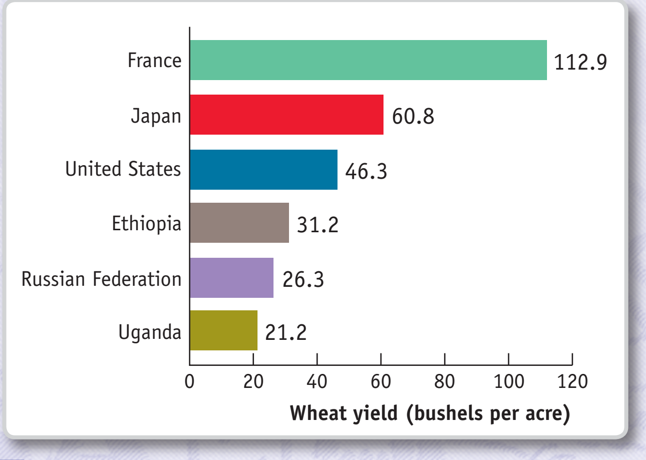
The **marginal product** of an input is the additional quantity of output that is produced by using one more unit of that input.

GLOBAL COMPARISION

## Wheat Yields Around the World

Wheat yields differ substantially around the world. The disparity between France and the United States that you see in this graph is particularly striking, given that they are both wealthy countries with comparable agricultural technology. Yet the reason for that disparity is straightforward: differing government policies. In the United States, farmers receive payments from the government to supplement their incomes, but European farmers benefit from price floors. Since European farmers get higher prices for their output than American farmers, they employ more variable inputs and produce significantly higher yields.

Interestingly, in poor countries like Uganda and Ethiopia, foreign aid can lead to significantly depressed yields. Foreign aid from wealthy countries has often taken the form of surplus food, which depresses local market prices, severely hurting the local agriculture that poor countries normally depend on. Charitable organizations like OXFAM have asked wealthy food-producing countries to modify their aid policies—principally, to give aid in cash rather than in food products except in the case of acute food shortages—to avoid this problem.




Source: Food and Agriculture Organization of the United Nations. Data are from 2012.

over "run" (see the appendix to Chapter 2). This implies that the slope of the total product curve is the change in the quantity of output (the "rise", $\Delta Q$) divided by the change in the quantity of labor (the "run", $\Delta L$). And this, as we can see from Equation 11-1, is simply the marginal product of labor. So in Figure 11-1, the fact that the marginal product of the first worker is 19 also means that the slope of the total product curve in going from 0 to 1 worker is 19. Similarly, the slope of the total product curve in going from 1 to 2 workers is the same as the marginal product of the second worker, 17, and so on.

In this example, the marginal product of labor steadily declines as more workers are hired—that is, each successive worker adds less to output than the previous worker. So as employment increases, the total product curve gets flatter.

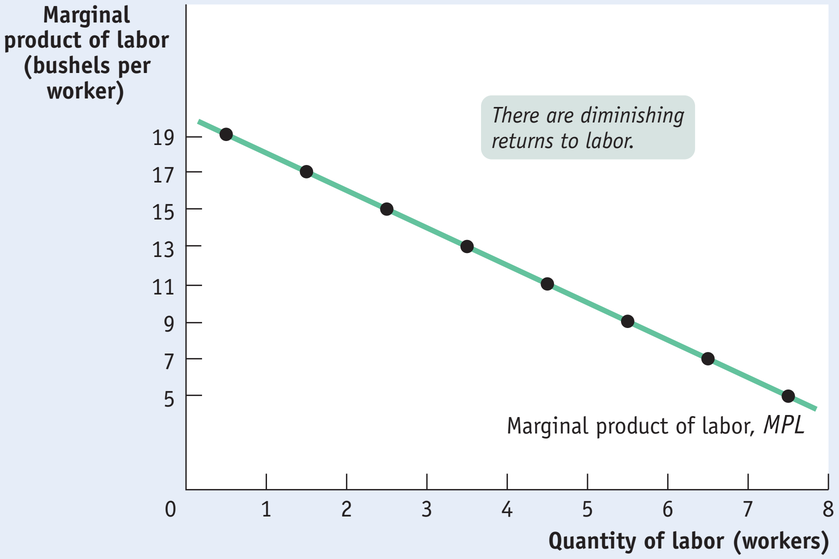
Figure 11-2 shows how the marginal product of labor depends on the number of workers employed on the farm. The marginal product of labor, *MPL,* is measured on the vertical axis in units of physical output—bushels of wheat—produced per additional worker, and the number of workers employed is measured on the horizontal axis. You can see from the table in Figure 11-1 that if 5 workers are employed instead of 4, output rises from 64 to 75 bushels; in this case the marginal product of labor is 11 bushels—the same number found in Figure 11-2. To indicate that 11 bushels is the marginal product when employment rises from 4 to 5, we place the point corresponding to that information halfway between 4 and 5 workers.

In this example the marginal product of labor falls as the number of workers increases. That is, there are *diminishing returns to labor* on George and Martha's farm. In general, there are **diminishing returns to an input** when an increase in the quantity of that input, holding the quantity of all other inputs fixed, reduces that input's marginal product. Due to diminishing returns to labor, the *MPL* curve is negatively sloped.

There are **diminishing returns to an input** when an increase in the quantity of that input, holding the levels of all other inputs fixed, leads to a decline in the marginal product of that input.

**FIGURE 11-2** **Marginal Product of Labor Curve for George and Martha's Farm**

The marginal product of labor curve plots each worker's marginal product, the increase in the quantity of output generated by each additional worker. The change in the quantity of output is measured on the vertical axis and the number of workers employed on the horizontal axis. The first worker employed generates an increase in output of 19 bushels, the second worker generates an increase of 17 bushels, and so on. The curve slopes downward due to diminishing returns to labor.




To grasp why diminishing returns can occur, think about what happens as George and Martha add more and more workers without increasing the number of acres of land. As the number of workers increases, the land is farmed more intensively and the number of bushels produced increases. But each additional worker is working with a smaller share of the 10 acres—the fixed input—than the previous worker. As a result, the additional worker cannot produce as much output as the previous worker. So it's not surprising that the marginal product of the additional worker falls.

The crucial point to emphasize about diminishing returns is that, like many propositions in economics, it is an "other things equal" proposition: each successive unit of an input will raise production by less than the last *if the quantity of all other inputs is held fixed.*

What would happen if the levels of other inputs were allowed to change? You can see the answer illustrated in Figure 11-3. Panel (a) shows two total product curves, $TP_{10}$ and $TP_{20}$. $TP_{10}$ is the farm's total product curve when its total area is 10 acres (the same curve as in Figure 11-1). $TP_{20}$ is the total product curve when the farm has increased to 20 acres. Except when 0 workers are employed, $TP_{20}$ lies everywhere above $TP_{10}$ because with more acres available, any given number of workers produces more output. Panel (b) shows the corresponding marginal product of labor curves. $MPL_{10}$ is the marginal product of labor curve given 10 acres to cultivate (the same curve as in Figure 11-2), and $MPL_{20}$ is the marginal product of labor curve given 20 acres.

Both curves slope downward because, in each case, the amount of land is fixed, albeit at different levels. But $MPL_{20}$ lies everywhere above $MPL_{10}$, reflecting the fact that the marginal product of the same worker is higher when he or she has more of the fixed input to work with.

Figure 11-3 demonstrates a general result: the position of the total product curve of a given input depends on the quantities of other inputs. If you change the quantity of the other inputs, both the total product curve and the marginal product curve of the remaining input will shift.

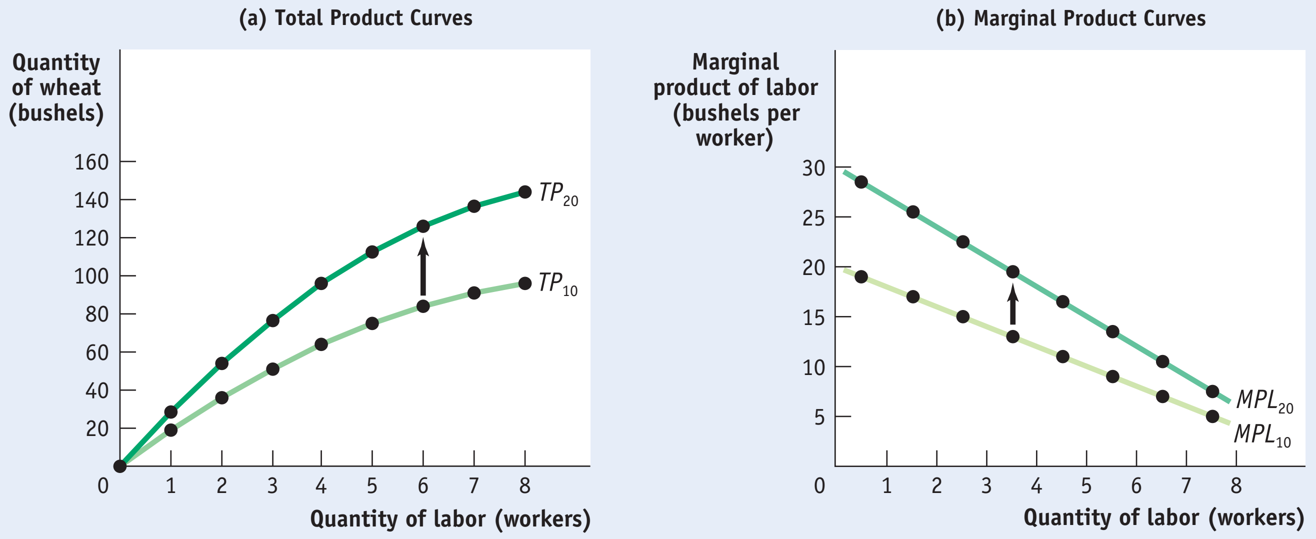
## PITFALLS

### WHAT'S A UNIT?

The marginal product of labor (or any other input) is defined as the increase in the quantity of output when you increase the quantity of that input by one unit. But what do we mean by a "unit" of labor? Is it an additional hour of labor, an additional week, or a person-year?

The answer is that it doesn't matter, *as long as you are consistent.* One common source of error in economics is getting units confused—say, comparing the output added by an additional *hour* of labor with the cost of employing a worker for a *week.* Whatever units you use, always be careful that you use the same units throughout your analysis of any problem.

**FIGURE 11-3 Total Product, Marginal Product, and the Fixed Input**




This figure shows how the quantity of output and the marginal product of labor depend on the level of the fixed input. Panel (a) shows two total product curves for George and Martha's farm, $TP_{10}$ when their farm is 10 acres and $TP_{20}$ when it is 20 acres. With more land, each worker can produce more wheat. So an increase in the fixed input shifts the total product curve up from $TP_{10}$ to $TP_{20}$. This implies that the marginal product of each worker is higher when the farm is 20 acres than when it is 10 acres. Panel (b) shows the marginal product of labor curves. The increase in acreage also shifts the marginal product of labor curve up from $MPL_{10}$ to $MPL_{20}$. Note that both marginal product of labor curves still slope downward due to diminishing returns to labor.

## From the Production Function to Cost Curves

Once George and Martha know their production function, they know the relationship between inputs of labor and land and output of wheat. But if they want to maximize their profits, they need to translate this knowledge into information about the relationship between the quantity of output and cost. Let's see how they can do this.

To translate information about a firm's production function into information about its costs, we need to know how much the firm must pay for its inputs. We will assume that George and Martha face either an explicit or an implicit cost of $400 for the use of the land. As we learned in Chapter 9, it is irrelevant whether George and Martha must rent the ten acres of land for $400 from someone else or whether they own the land themselves and forgo earning $400 from renting it to someone else. Either way, they pay an opportunity cost of $400 by using the land to grow wheat. Moreover, since the land is a fixed input, the $400 George and Martha pay for it is a **fixed cost,** denoted by *FC*—a cost that does not depend on the quantity of output produced (in the short run). In business, fixed cost is often referred to as "overhead cost."

A **fixed cost** is a cost that does not depend on the quantity of output produced. It is the cost of the fixed input.

A **variable cost** is a cost that depends on the quantity of output produced. It is the cost of the variable input.

The **total cost** of producing a given quantity of output is the sum of the fixed cost and the variable cost of producing that quantity of output.

We also assume that George and Martha must pay each worker $200. Using their production function, George and Martha know that the number of workers they must hire depends on the amount of wheat they intend to produce. So the cost of labor, which is equal to the number of workers multiplied by $200, is a **variable cost,** denoted by *VC*—a cost that depends on the quantity of output produced. It is variable because in order to produce more they have to employ more units of input. Adding the fixed cost and the variable cost of a given quantity of output gives the **total cost,** or *TC,* of that quantity of output. We can express the relationship among fixed cost, variable cost, and total cost as an equation:

**(11-2)** Total cost = Fixed cost + Variable cost

or

$$TC = FC + VC$$

The **total cost curve** shows how total cost depends on the quantity of output.

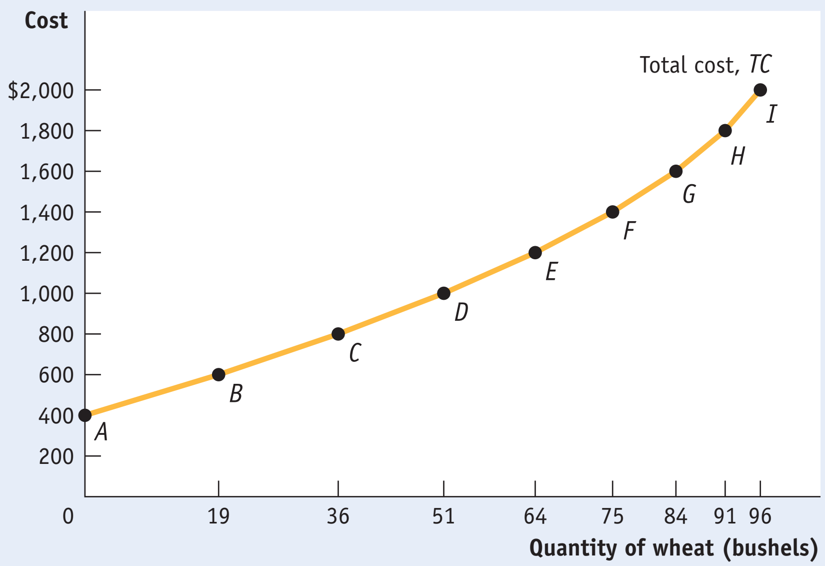
The table in Figure 11-4 shows how total cost is calculated for George and Martha's farm. The second column shows the number of workers employed, $L$. The third column shows the corresponding level of output, $Q$, taken from the table in Figure 11-1. The fourth column shows the variable cost, $VC$, equal to the number of workers multiplied by $200, the cost per worker. The fifth column shows the fixed cost, $FC$, which is $400 regardless of how many workers are employed. The sixth column shows the total cost of output, $TC$, which is the variable cost plus the fixed cost.

The first column labels each row of the table with a letter, from *A* to *I*. These labels will be helpful in understanding our next step: drawing the **total cost curve,** a curve that shows how total cost depends on the quantity of output.

George and Martha's total cost curve is shown in the diagram in Figure 11-4, where the horizontal axis measures the quantity of output in bushels of wheat and the vertical axis measures total cost in dollars. Each point on the curve corresponds to one row of the table in Figure 11-4. For example, point *A* shows

## FIGURE 11-4 Total Cost Curve for George and Martha's Farm

The table shows the variable cost, fixed cost, and total cost for various output quantities on George and Martha's 10-acre farm. The total cost curve shows how total cost (measured on the vertical axis) depends on the quantity of output (measured on the horizontal axis). The labeled points on the curve correspond to the rows of the table. The total cost curve slopes upward because the number of workers employed, and hence total cost, increases as the quantity of output increases. The curve gets steeper as output increases due to diminishing returns to labor.




| Point on graph | Quantity of labor $L$ (workers) | Quantity of wheat $Q$ (bushels) | Variable cost $VC$ | Fixed cost $FC$ | Total cost $TC = FC + VC$ |
|---|---|---|---|---|---|
| *A* | 0 | 0 | $0 | $400 | $400 |
| *B* | 1 | 19 | 200 | 400 | 600 |
| *C* | 2 | 36 | 400 | 400 | 800 |
| *D* | 3 | 51 | 600 | 400 | 1,000 |
| *E* | 4 | 64 | 800 | 400 | 1,200 |
| *F* | 5 | 75 | 1,000 | 400 | 1,400 |
| *G* | 6 | 84 | 1,200 | 400 | 1,600 |
| *H* | 7 | 91 | 1,400 | 400 | 1,800 |
| *I* | 8 | 96 | 1,600 | 400 | 2,000 |

the situation when 0 workers are employed: output is 0, and total cost is equal to fixed cost, $400. Similarly, point *B* shows the situation when 1 worker is employed: output is 19 bushels, and total cost is $600, equal to the sum of $400 in fixed cost and $200 in variable cost.

Like the total product curve, the total cost curve slopes upward: due to the variable cost, the more output produced, the higher the farm's total cost. But unlike the total product curve, which gets flatter as employment rises, the total cost curve gets *steeper*. That is, the slope of the total cost curve is greater as the amount of output produced increases. As we will soon see, the steepening of the total cost curve is also due to diminishing returns to the variable input. Before we can understand this, we must first look at the relationships among several useful measures of cost.

## ECONOMICS in Action

### The Mythical Man-Month

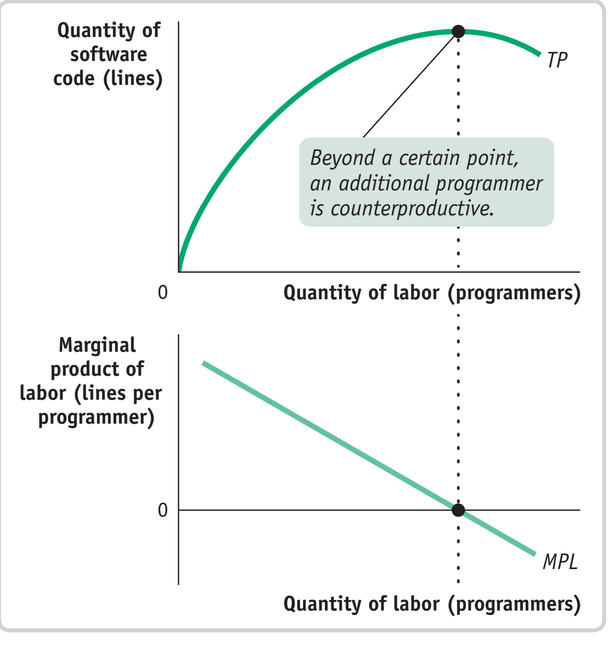
The concept of diminishing returns to an input was first formulated by economists during the late eighteenth century. These economists, notably including Thomas Malthus, drew their inspiration from agricultural examples. However, the idea of diminishing returns to an input applies with equal force to the most modern of economic activities—such as, say, the design of software. In 1975 Frederick P. Brooks Jr., a project manager at IBM during the days when it dominated the computer business, published a book titled *The Mythical Man-Month* that soon became a classic—so much so that a special anniversary edition was published 20 years later.

The chapter that gave its title to the book is basically about diminishing returns to labor in the writing of software. Brooks observed that multiplying the number of programmers assigned to a project did not produce a proportionate reduction in the time it took to get the program written. A project that could be done by 1 programmer in 12 months could *not* be done by 12 programmers in 1 month—hence the "mythical man-month." It is the false notion that the number of lines of programming code produced was proportional to the number of code writers employed. In fact, above a certain number, adding another programmer on a project actually *increased* the time to completion.

The argument of *The Mythical Man-Month* is summarized in Figure 11-5. The upper part of the figure shows how the quantity of the project's output, as measured by the number of lines of code produced per month, varies with the number of programmers. Each additional programmer accomplishes less than the previous one, and beyond a certain point an additional programmer is actually counterproductive. The lower part of the figure shows the marginal product of each successive programmer, which falls as more programmers are employed and eventually becomes negative.

In other words, programming is subject to diminishing returns so severe that at some point more programmers actually have negative marginal product. The source of the diminishing returns lies in the nature of the production function for a programming project: each programmer must coordinate his or her work with that of all the other programmers on the project, leading each person to spend more time communicating with others as the number of

FIGURE 11-5 The Mythical Man-Month



programmers increases. In other words, other things equal, there are diminishing returns to labor. It is likely, however, that if fixed inputs devoted to programming projects are increased—say, installing a faster and more accurate programming bug-detection system—the problem of diminishing returns for additional programmers can be mitigated.

A reviewer of the reissued edition of *The Mythical Man-Month* summarized the reasons for these diminishing returns: "There is an inescapable overhead to yoking up programmers in parallel. The members of the team must 'waste time' attending meetings, drafting project plans, exchanging e-mail, negotiating interfaces, enduring performance reviews, and so on. . . . At Microsoft, there will be at least one team member that just designs T-shirts for the rest of the team to wear."

### Quick Review

- The firm's **production function** is the relationship between quantity of inputs and quantity of output. The **total product curve** shows how the quantity of output depends on the quantity of the **variable input** for a given quantity of the **fixed input,** and its slope is equal to the **marginal product** of the variable input. In the **short run,** the fixed input cannot be varied; in the **long run** all inputs are variable.
- When the levels of all other inputs are fixed, **diminishing returns to an input** may arise, yielding a downward-sloping marginal product curve and a total product curve that becomes flatter as more output is produced.
- The **total cost** of a given quantity of output equals the **fixed cost** plus the **variable cost** of that output. The **total cost curve** becomes steeper as more output is produced due to diminishing returns to the variable input.

### Check Your Understanding 11-1

1. Bernie's ice-making company produces ice cubes using a 10-ton machine and electricity. The quantity of output, measured in terms of pounds of ice, is given in the accompanying table.
   - **a.** What is the fixed input? What is the variable input?
   - **b.** Construct a table showing the marginal product of the variable input. Does it show diminishing returns?
   - **c.** Suppose a 50% increase in the size of the fixed input increases output by 100% for any given amount of the variable input. What is the fixed input now? Construct a table showing the quantity of output and marginal product in this case.

| Quantity of electricity (kilowatts) | Quantity of ice (pounds) |
|---|---|
| 0 | 0 |
| 1 | 1,000 |
| 2 | 1,800 |
| 3 | 2,400 |
| 4 | 2,800 |

Solutions appear at back of book.

# Two Key Concepts: Marginal Cost and Average Cost

We've just learned how to derive a firm's total cost curve from its production function. Our next step is to take a deeper look at total cost by deriving two extremely useful measures: *marginal cost* and *average cost*. As we'll see, these two measures of the cost of production have a somewhat surprising relationship to each other. Moreover, they will prove to be vitally important in Chapter 12, where we will use them to analyze the firm's output decision and the market supply curve.

## Marginal Cost

We defined marginal cost in Chapter 9: it is the change in total cost generated by producing one more unit of output. We've already seen that the marginal product of an input is easiest to calculate if data on output are available in increments of one unit of that input. Similarly, marginal cost is easiest to calculate if data on total cost are available in increments of one unit of output. When the data come in less convenient increments, it's still possible to calculate marginal cost. But for the sake of simplicity, let's work with an example in which the data come in convenient one-unit increments.

Selena's Gourmet Salsas produces bottled salsa and Table 11-1 shows how its costs per day depend on the number of cases of salsa it produces per day. The firm has fixed cost of $108 per day, shown in the second column, which represents the daily cost of its food-preparation equipment. The third column shows the variable cost, and the fourth column shows the total cost. Panel (a) of Figure 11-6 plots the total cost curve. Like the total cost curve for George and Martha's farm in Figure 11-4, this curve slopes upward, getting steeper as you move up it to the right.

The significance of the slope of the total cost curve is shown by the fifth column of Table 11-1, which calculates *marginal cost:* the additional cost of each additional unit. The general formula for marginal cost is:

$$\textbf{(11-3)}\ \text{Marginal cost} = \begin{array}{l}\text{Change in total cost}\\ \text{generated by one}\\ \text{additional unit of}\\ \text{output}\end{array} = \frac{\text{Change in total cost}}{\text{Change in quantity of output}}$$

or

$$MC = \frac{\Delta TC}{\Delta Q}$$

As in the case of marginal product, marginal cost is equal to "rise" (the increase in total cost) divided by "run" (the increase in the quantity of output). So just as marginal product is equal to the slope of the total product curve, marginal cost is equal to the slope of the total cost curve.

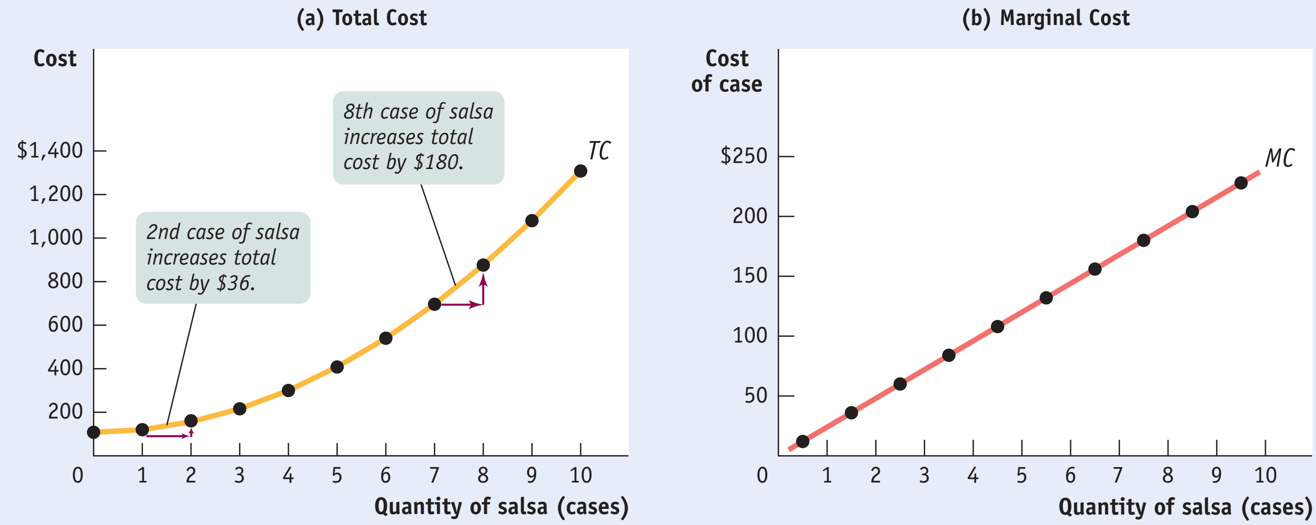
Now we can understand why the total cost curve gets steeper as we move up it to the right: as you can see in Table 11-1, marginal cost at Selena's Gourmet Salsas rises as output increases. Panel (b) of Figure 11-6 shows the marginal cost curve corresponding to the data in Table 11-1. Notice that, as in Figure 11-2, we plot the marginal cost for increasing output from 0 to 1 case of salsa halfway between 0 and 1, the marginal cost for increasing output from 1 to 2 cases of salsa halfway between 1 and 2, and so on.

Why does the marginal cost curve slope upward? Because there are diminishing returns to inputs in this example. As output increases, the marginal product of the variable input declines. This implies that more and more of the variable input must be used to produce each additional unit of output as the amount of output already produced rises. And since each unit of the variable input must be paid for, the additional cost per additional unit of output also rises.

**TABLE 11-1** Costs at Selena's Gourmet Salsas

| Quantity of salsa *Q* (cases) | Fixed cost *FC* | Variable cost *VC* | Total cost *TC = FC + VC* | Marginal cost of case *MC = ΔTC/ΔQ* |
|---|---|---|---|---|
| 0 | $108 | $0 | $108 | |
| | | | | $12 |
| 1 | 108 | 12 | 120 | |
| | | | | 36 |
| 2 | 108 | 48 | 156 | |
| | | | | 60 |
| 3 | 108 | 108 | 216 | |
| | | | | 84 |
| 4 | 108 | 192 | 300 | |
| | | | | 108 |
| 5 | 108 | 300 | 408 | |
| | | | | 132 |
| 6 | 108 | 432 | 540 | |
| | | | | 156 |
| 7 | 108 | 588 | 696 | |
| | | | | 180 |
| 8 | 108 | 768 | 876 | |
| | | | | 204 |
| 9 | 108 | 972 | 1,080 | |
| | | | | 228 |
| 10 | 108 | 1,200 | 1,308 | |

FIGURE 11-6 Total Cost and Marginal Cost Curves for Selena's Gourmet Salsas




Panel (a) shows the total cost curve from Table 11-1. Like the total cost curve in Figure 11-4, it slopes upward and gets steeper as we move up it to the right. Panel (b) shows the marginal cost curve. It also slopes upward, reflecting diminishing returns to the variable input.

In addition, recall that the flattening of the total product curve is also due to diminishing returns: the marginal product of an input falls as more of that input is used if the quantities of other inputs are fixed. The flattening of the total product curve as output increases and the steepening of the total cost curve as output increases are just flip-sides of the same phenomenon. That is, as output increases, the marginal cost of output also increases because the marginal product of the variable input decreases.

We will return to marginal cost in Chapter 12, when we consider the firm's profit-maximizing output decision. Our next step is to introduce another measure of cost: *average cost.*

## Average Total Cost

In addition to total cost and marginal cost, it's useful to calculate another measure, **average total cost,** often simply called **average cost.** The average total cost is total cost divided by the quantity of output produced; that is, it is equal to total cost per unit of output. If we let *ATC* denote average total cost, the equation looks like this:

$$\textbf{(11-4)}\ ATC = \frac{\text{Total cost}}{\text{Quantity of output}} = \frac{TC}{Q}$$

Average total cost is important because it tells the producer how much the *average* or *typical* unit of output costs to produce. Marginal cost, meanwhile, tells the producer how much *one more* unit of output costs to produce. Although they may look very similar, these two measures of cost typically differ. And confusion between them is a major source of error in economics, both in the classroom and in real life, as illustrated by the upcoming Economics in Action.

Table 11-2 uses data from Selena's Gourmet Salsas to calculate average total cost. For example, the total cost of producing 4 cases of salsa is $300, consisting of $108 in fixed cost and $192 in variable cost (from Table 11-1). So the average total

**Average total cost,** often referred to simply as **average cost,** is total cost divided by quantity of output produced.

A **U-shaped average total cost curve** falls at low levels of output, then rises at higher levels.

**Average fixed cost** is the fixed cost per unit of output.

**Average variable cost** is the variable cost per unit of output.

**TABLE 11-2 Average Costs for Selena's Gourmet Salsas**

| Quantity of salsa *Q* (cases) | Total cost *TC* | Average total cost of case *ATC = TC/Q* | Average fixed cost of case *AFC = FC/Q* | Average variable cost of case *AVC = VC/Q* |
|---|---|---|---|---|
| 1 | $120 | $120.00 | $108.00 | $12.00 |
| 2 | 156 | 78.00 | 54.00 | 24.00 |
| 3 | 216 | 72.00 | 36.00 | 36.00 |
| 4 | 300 | 75.00 | 27.00 | 48.00 |
| 5 | 408 | 81.60 | 21.60 | 60.00 |
| 6 | 540 | 90.00 | 18.00 | 72.00 |
| 7 | 696 | 99.43 | 15.43 | 84.00 |
| 8 | 876 | 109.50 | 13.50 | 96.00 |
| 9 | 1,080 | 120.00 | 12.00 | 108.00 |
| 10 | 1,308 | 130.80 | 10.80 | 120.00 |

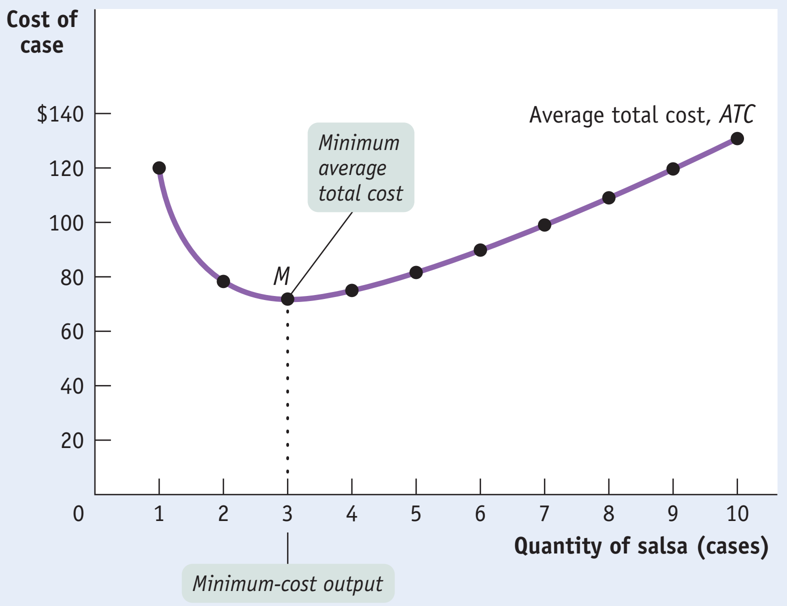
cost of producing 4 cases of salsa is $300/4 = $75. You can see from Table 11-2 that as quantity of output increases, average total cost first falls, then rises.

Figure 11-7 plots that data to yield the *average total cost curve,* which shows how average total cost depends on output. As before, cost in dollars is measured on the vertical axis and quantity of output is measured on the horizontal axis. The average total cost curve has a distinctive U shape that corresponds to how average total cost first falls and then rises as output increases. Economists believe that such **U-shaped average total cost curves** are the norm for producers in many industries.

To help our understanding of why the average total cost curve is U-shaped, Table 11-2 breaks average total cost into its two underlying components, *average fixed cost* and *average variable cost*. **Average fixed cost,** or *AFC,* is fixed cost divided by the quantity of output, also known as the fixed cost per unit of output. For example, if Selena's Gourmet Salsas produces 4 cases of salsa, average fixed cost is $108/4 = $27 per case. **Average variable cost,** or *AVC,* is variable cost divided by the quantity of

**FIGURE 11-7 Average Total Cost Curve for Selena's Gourmet Salsas**

The average total cost curve at Selena's Gourmet Salsas is U-shaped. At low levels of output, average total cost falls because the "spreading effect" of falling average fixed cost dominates the "diminishing returns effect" of rising average variable cost. At higher levels of output, the opposite is true and average total cost rises. At point *M,* corresponding to an output of three cases of salsa per day, average total cost is at its minimum level, the minimum average total cost.



output, also known as variable cost per unit of output. At an output of 4 cases, average variable cost is \$192/4 = \$48 per case. Writing these in the form of equations:

$$\textbf{(11-5)}\quad AFC = \frac{\text{Fixed cost}}{\text{Quantity of output}} = \frac{FC}{Q}$$

$$AVC = \frac{\text{Variable cost}}{\text{Quantity of output}} = \frac{VC}{Q}$$

Average total cost is the sum of average fixed cost and average variable cost. It has a U shape because these components move in opposite directions as output rises.

Average fixed cost falls as more output is produced because the numerator (the fixed cost) is a fixed number but the denominator (the quantity of output) increases as more is produced. Another way to think about this relationship is that, as more output is produced, the fixed cost is spread over more units of output; the end result is that the fixed cost *per unit of output*—the average fixed cost—falls. You can see this effect in the fourth column of Table 11-2: average fixed cost drops continuously as output increases.

Average variable cost, however, rises as output increases. As we've seen, this reflects diminishing returns to the variable input: each additional unit of output incurs more variable cost to produce than the previous unit. So variable cost rises at a faster rate than the quantity of output increases.

So increasing output has two opposing effects on average total cost—the "spreading effect" and the "diminishing returns effect":

- *The spreading effect.* The larger the output, the greater the quantity of output over which fixed cost is spread, leading to lower average fixed cost.
- *The diminishing returns effect.* The larger the output, the greater the amount of variable input required to produce additional units, leading to higher average variable cost.

At low levels of output, the spreading effect is very powerful because even small increases in output cause large reductions in average fixed cost. So at low levels of output, the spreading effect dominates the diminishing returns effect and causes the average total cost curve to slope downward. But when output is large, average fixed cost is already quite small, so increasing output further has only a very small spreading effect.

Diminishing returns, however, usually grow increasingly important as output rises. As a result, when output is large, the diminishing returns effect dominates the spreading effect, causing the average total cost curve to slope upward. At the bottom of the U-shaped average total cost curve, point *M* in Figure 11-7, the two effects exactly balance each other. At this point average total cost is at its minimum level, the minimum average total cost.

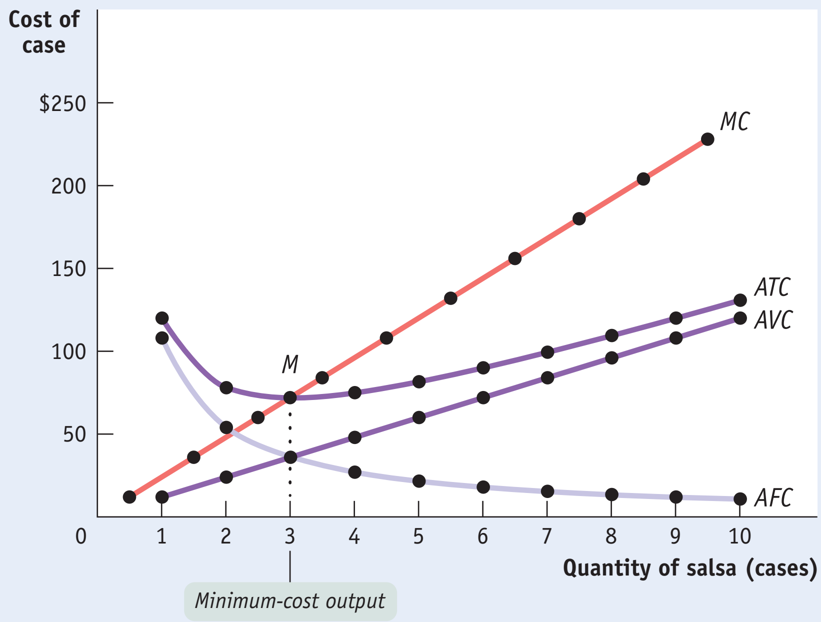
Figure 11-8 brings together in a single picture four members of the family of cost curves that we have derived from the total cost curve for Selena's Gourmet Salsas: the marginal cost curve (*MC*), the average total cost curve (*ATC*), the average variable cost curve (*AVC*), and the average fixed cost curve (*AFC*). All are based on the information in Tables 11-1 and 11-2. As before, cost is measured on the vertical axis and the quantity of output is measured on the horizontal axis.

Let's take a moment to note some features of the various cost curves. First of all, marginal cost slopes upward—the result of diminishing returns that make an additional unit of output more costly to produce than the one before. Average variable cost also slopes upward—again, due to diminishing returns—but is flatter than the marginal cost curve. This is because the higher cost of an additional unit of output is averaged across all units, not just the additional units, in the average variable cost measure. Meanwhile, average fixed cost slopes downward because of the spreading effect.

Finally, notice that the marginal cost curve intersects the average total cost curve from below, crossing it at its lowest point, point *M* in Figure 11-8. This last feature is our next subject of study.

**FIGURE 11-8** Marginal Cost and Average Cost Curves for Selena's Gourmet Salsas

Here we have the family of cost curves for Selena's Gourmet Salsas: the marginal cost curve (*MC*), the average total cost curve (*ATC*), the average variable cost curve (*AVC*), and the average fixed cost curve (*AFC*). Note that the average total cost curve is U-shaped and the marginal cost curve crosses the average total cost curve at the bottom of the U, point *M*, corresponding to the minimum average total cost from Table 11-2 and Figure 11-7.




The **minimum-cost output** is the quantity of output at which average total cost is lowest—the bottom of the U-shaped average total cost curve.

## Minimum Average Total Cost

For a U-shaped average total cost curve, average total cost is at its minimum level at the bottom of the U. Economists call the quantity of output that corresponds to the minimum average total cost the **minimum-cost output.** In the case of Selena's Gourmet Salsas, the minimum-cost output is three cases of salsa per day.

In Figure 11-8, the bottom of the U is at the level of output at which the marginal cost curve crosses the average total cost curve from below. Is this an accident? No—it reflects three general principles that are always true about a firm's marginal cost and average total cost curves:

1. At the minimum-cost output, average total cost *is equal to* marginal cost.
2. At output less than the minimum-cost output, marginal cost *is less than* average total cost and average total cost is falling.
3. At output greater than the minimum-cost output, marginal cost *is greater than* average total cost and average total cost is rising.

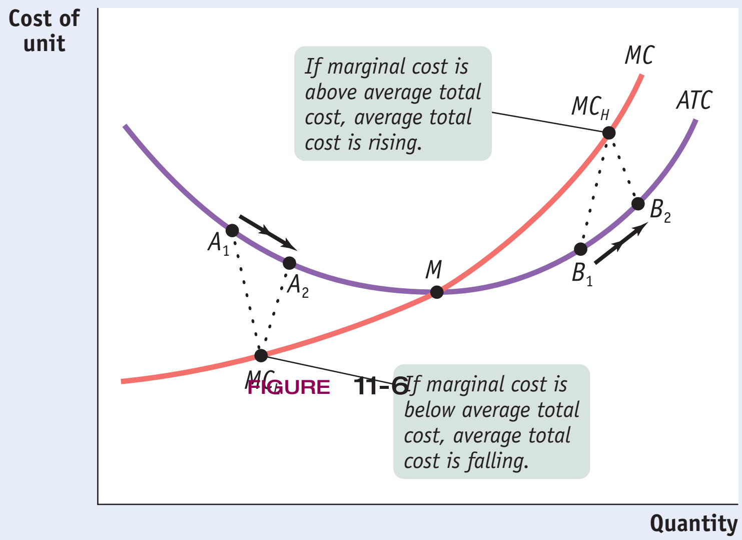
To understand these principles, think about how your grade in one course—say, a 3.0 in physics—affects your overall grade point average. If your GPA before receiving that grade was more than 3.0, the new grade lowers your average.

Similarly, if marginal cost—the cost of producing one more unit—is less than average total cost, producing that extra unit lowers average total cost. This is shown in Figure 11-9 by the movement from $A_1$ to $A_2$. In this case, the marginal cost of producing an additional unit of output is low, as indicated by the point $MC_L$ on the marginal cost curve. When the cost of producing the next unit of output is less than average total cost, increasing production reduces average total cost. So any quantity of output at which marginal cost is less than average total cost must be on the downward-sloping segment of the U.

But if your grade in physics is more than the average of your previous grades, this new grade raises your GPA. Similarly, if marginal cost is greater than average total cost, producing that extra unit raises average total cost. This is illustrated by the movement from $B_1$ to $B_2$ in Figure 11-9, where the marginal cost, $MC_H$, is

**FIGURE 11-9** **The Relationship Between the Average Total Cost and the Marginal Cost Curves**

To see why the marginal cost curve (*MC*) must cut through the average total cost curve at the minimum average total cost (point *M*), corresponding to the minimum-cost output, we look at what happens if marginal cost is different from average total cost. If marginal cost is *less* than average total cost, an increase in output must reduce average total cost, as in the movement from $A_1$ to $A_2$. If marginal cost is *greater* than average total cost, an increase in output must increase average total cost, as in the movement from $B_1$ to $B_2$.




higher than average total cost. So any quantity of output at which marginal cost is greater than average total cost must be on the upward-sloping segment of the U.

Finally, if a new grade is exactly equal to your previous GPA, the additional grade neither raises nor lowers that average—it stays the same. This corresponds to point *M* in Figure 11-9: when marginal cost equals average total cost, we must be at the bottom of the U, because only at that point is average total cost neither falling nor rising.

## Does the Marginal Cost Curve Always Slope Upward?

Up to this point, we have emphasized the importance of diminishing returns, which lead to a marginal product curve that always slopes downward and a marginal cost curve that always slopes upward. In practice, however, economists believe that marginal cost curves often slope *downward* as a firm increases its production from zero up to some low level, sloping upward only at higher levels of production: they look like the curve *MC* in Figure 11-10.

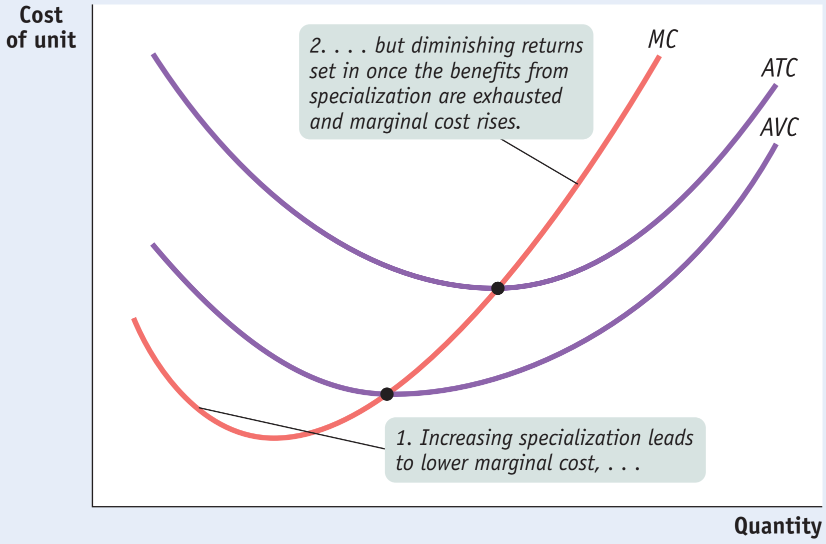
This initial downward slope occurs because a firm often finds that, when it starts with only a very small number of workers, employing more workers and expanding output allows its workers to specialize in various tasks. This, in turn, lowers the firm's marginal cost as it expands output. For example, one individual producing salsa would have to perform all the tasks involved: selecting and preparing the ingredients, mixing the salsa, bottling and labeling it, packing it into cases, and so on. As more workers are employed, they can divide the tasks, with each worker specializing in one or a few aspects of salsa-making.

This specialization leads to *increasing returns* to the hiring of additional workers and results in a marginal cost curve that initially slopes downward. But once there are enough workers to have completely exhausted the benefits of further specialization, diminishing returns to labor set in and the marginal cost curve changes direction and slopes upward. So typical marginal cost curves actually have the "swoosh" shape shown by *MC* in Figure 11-10. For the same reason, average variable cost curves typically look like *AVC* in Figure 11-10: they are U-shaped rather than strictly upward sloping.

However, as Figure 11-10 also shows, the key features we saw from the example of Selena's Gourmet Salsas remain true: the average total cost curve is U-shaped, and the marginal cost curve passes through the point of minimum average total cost.

**FIGURE 11-10** **More Realistic Cost Curves**

A realistic marginal cost curve has a "swoosh" shape. Starting from a very low output level, marginal cost often falls as the firm increases output. That's because hiring additional workers allows greater specialization of their tasks and leads to increasing returns. Once specialization is achieved, however, diminishing returns to additional workers set in and marginal cost rises. The corresponding average variable cost curve is now U-shaped, like the average total cost curve.




## ECONOMICS ▶ *in Action*

## Smart Grid Economics

If you are a night owl who likes to listen to music, write term papers, or do laundry in the middle of the night, your local electricity grid would like to thank you. Why? Because you are using electricity when it is least costly to generate.

The problem is that energy cannot be stored efficiently on a large scale. So power plant operators maintain both the main power stations that are designed to run continuously, as well as smaller power plants that operate only during periods of peak demand—such as during daytime working hours or periods of extreme outside temperatures.

These smaller power plants are more expensive to operate, incurring higher marginal cost per kilowatt generated than the average cost of generating a kilowatt (that is, cost averaged over kilowatts generated by the large and small plants). According to the U.S. Government Accountability Office, it can cost up to 10 times more to generate electricity during a summer afternoon (when air conditioners are running at maximum capacity) compared to nighttime.

Caiaimage/Getty Images

With SMART Grid technology, consumers save money by basing their demand for electricity on marginal cost rather than average cost.

But consumers typically aren't aware that the marginal cost of electricity varies over the course of a day or according to the weather. Instead, consumers see prices on their electricity bills based on the average cost of electricity generation. As a result, electricity demand is inefficient—too high during high marginal cost periods and too low during low marginal cost periods. In the end, consumers end up paying more than they should for their electricity, as utility companies must eventually raise their prices to cover production costs.

To solve this inefficiency, utility companies, appliance manufacturers, and the federal government are working together to develop SMART Grid technologies—that help consumers adjust their usage according to the true marginal cost of a kilowatt in real time. "Smart" meters have been developed for home use, which allow the price to the consumer to vary according to the true marginal cost—which the consumer can see. And appliances such as dishwashers, refrigerators, dryers, and hot water heaters have been developed to run when electricity rates are lowest.

Studies have consistently shown that when consumers see the real marginal cost fluctuations and are asked to pay accordingly, they scale back their consumption during peak demand times. Clearly, SMART Grid technologies are just an application of smart economics.

## Quick Review

- Marginal cost is equal to the slope of the total cost curve. Diminishing returns cause the marginal cost curve to slope upward.
- **Average total cost** (or **average cost**) is equal to the sum of **average fixed cost** and **average variable cost.** When the **U-shaped average total cost curve** slopes downward, the spreading effect dominates: fixed cost is spread over more units of output. When it slopes upward, the diminishing returns effect dominates: an additional unit of output requires more variable inputs.
- Marginal cost is equal to average total cost at the **minimum-cost output.** At higher output levels, marginal cost is greater than average total cost and average total cost is rising. At lower output levels, marginal cost is lower than average total cost and average total cost is falling.
- At low levels of output there are often increasing returns to the variable input due to the benefits of specialization, making the marginal cost curve "swoosh"-shaped: initially sloping downward before sloping upward.

## Check Your Understanding 11-2

1. Alicia's Apple Pies is a roadside business. Alicia must pay $9.00 in rent each day. In addition, it costs her $1.00 to produce the first pie of the day, and each subsequent pie costs 50% more to produce than the one before. For example, the second pie costs $1.00 × 1.5 = $1.50 to produce, and so on.
   a. Calculate Alicia's marginal cost, variable cost, average total cost, average variable cost, and average fixed cost as her daily pie output rises from 0 to 6. (*Hint:* The variable cost of two pies is just the marginal cost of the first pie, plus the marginal cost of the second, and so on.)
   b. Indicate the range of pies for which the spreading effect dominates and the range for which the diminishing returns effect dominates.
   c. What is Alicia's minimum-cost output? Explain why making one more pie lowers Alicia's average total cost when output is lower than the minimum-cost output. Similarly, explain why making one more pie raises Alicia's average total cost when output is greater than the minimum-cost output.

Solutions appear at back of book.

# Short-Run versus Long-Run Costs

Up to this point, we have treated fixed cost as completely outside the control of a firm because we have focused on the short run. But as we noted earlier, all inputs are variable in the long run: this means that in the long run fixed cost may also be varied. *In the long run, in other words, a firm's fixed cost becomes a variable it can choose.* For example, given time, Selena's Gourmet Salsas can acquire additional food-preparation equipment or dispose of some of its existing equipment. In this section, we will examine how a firm's costs behave in the short run and in the long run. We will also see that the firm will choose its fixed cost in the long run based on the level of output it expects to produce.

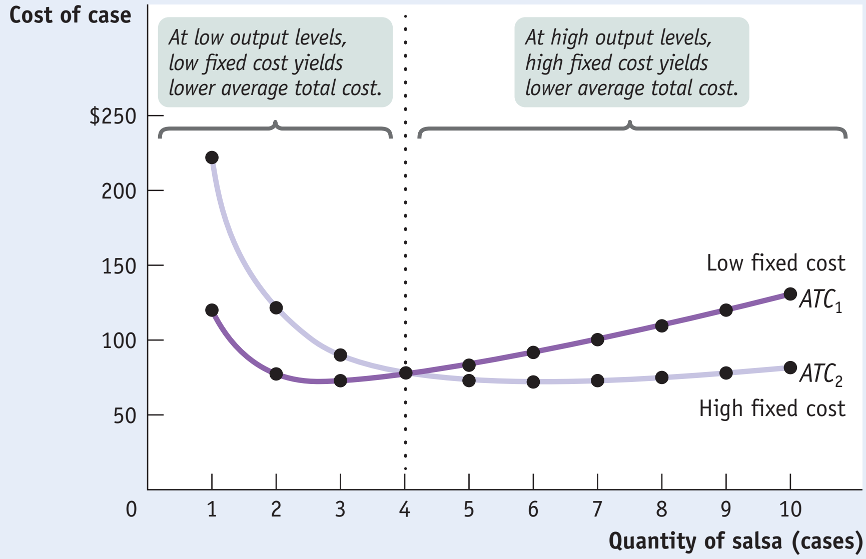
Let's begin by supposing that Selena's Gourmet Salsas is considering whether to acquire additional food-preparation equipment. Acquiring additional machinery will affect its total cost in two ways. First, the firm will have to either rent or buy the additional equipment; either way, that will mean higher fixed cost in the short run. Second, if the workers have more equipment, they will be more productive: fewer workers will be needed to produce any given output, so variable cost for any given output level will be reduced.

The table in Figure 11-11 shows how acquiring an additional machine affects costs. In our original example, we assumed that Selena's Gourmet Salsas had a fixed cost of $108. The left half of the table shows variable cost as well as total cost and average total cost assuming a fixed cost of $108. The average total cost curve for this level of fixed cost is given by $ATC_1$ in Figure 11-11. Let's compare that to a situation in which the firm buys additional food-preparation equipment, doubling its fixed cost to $216 but reducing its variable cost at any given level of output. The right half of the table shows the firm's variable cost, total cost, and average total cost with this higher level of fixed cost. The average total cost curve corresponding to $216 in fixed cost is given by $ATC_2$ in Figure 11-11.

From the figure you can see that when output is small, 4 cases of salsa per day or fewer, average total cost is smaller when Selena forgoes the additional equipment

**FIGURE 11-11** **Choosing the Level of Fixed Cost for Selena's Gourmet Salsas**

For any given level of output, there is a tradeoff: a choice between lower fixed cost and higher variable cost, or higher fixed cost and lower variable cost. $ATC_1$ is the average total cost curve corresponding to a fixed cost of $108; it leads to lower fixed cost and higher variable cost. $ATC_2$ is the average total cost curve corresponding to a higher fixed cost of $216 but lower variable cost. At low output levels, at 4 or fewer cases of salsa per day, $ATC_1$ lies below $ATC_2$: average total cost is lower with only $108 in fixed cost. But as output goes up, average total cost is lower with the higher amount of fixed cost, $216: at more than 4 cases of salsa per day, $ATC_2$ lies below $ATC_1$.




| | Low fixed cost ($FC$ = $108) | | | High fixed cost ($FC$ = $216) | | |
|---|---|---|---|---|---|---|
| Quantity of salsa (cases) | High variable cost | Total cost | Average total cost of case $ATC_1$ | Low variable cost | Total cost | Average total cost of case $ATC_2$ |
| 1 | $12 | $120 | $120.00 | $6 | $222 | $222.00 |
| 2 | 48 | 156 | 78.00 | 24 | 240 | 120.00 |
| 3 | 108 | 216 | 72.00 | 54 | 270 | 90.00 |
| 4 | 192 | 300 | 75.00 | 96 | 312 | 78.00 |
| 5 | 300 | 408 | 81.60 | 150 | 366 | 73.20 |
| 6 | 432 | 540 | 90.00 | 216 | 432 | 72.00 |
| 7 | 588 | 696 | 99.43 | 294 | 510 | 72.86 |
| 8 | 768 | 876 | 109.50 | 384 | 600 | 75.00 |
| 9 | 972 | 1,080 | 120.00 | 486 | 702 | 78.00 |
| 10 | 1,200 | 1,308 | 130.80 | 600 | 816 | 81.60 |

and maintains the lower fixed cost of $108: $ATC_1$ lies below $ATC_2$. For example, at 3 cases per day, average total cost is $72 without the additional machinery and $90 with the additional machinery. But as output increases beyond 4 cases per day, the firm's average total cost is lower if it acquires the additional equipment, raising its fixed cost to $216. For example, at 9 cases of salsa per day, average total cost is $120 when fixed cost is $108 but only $78 when fixed cost is $216.

Why does average total cost change like this when fixed cost increases? When output is low, the increase in fixed cost from the additional equipment outweighs the reduction in variable cost from higher worker productivity—that is, there are too few units of output over which to spread the additional fixed cost. So if Selena plans to produce 4 or fewer cases per day, she would be better off choosing the lower level of fixed cost, $108, to achieve a lower average total cost of production. When planned output is high, however, she should acquire the additional machinery.

In general, for each output level there is some choice of fixed cost that minimizes the firm's average total cost for that output level. So when the firm has a desired output level that it expects to maintain over time, it should choose the level of fixed cost optimal for that level—that is, the level of fixed cost that minimizes its average total cost.

Now that we are studying a situation in which fixed cost can change, we need to take time into account when discussing average total cost. All of the average total cost curves we have considered until now are defined for a given level of fixed cost—that is, they are defined for the short run, the period of time over which fixed cost doesn't vary. To reinforce that distinction, for the rest of this chapter we will refer to these average total cost curves as "short-run average total cost curves."

For most firms, it is realistic to assume that there are many possible choices of fixed cost, not just two. The implication: for such a firm, many possible short-run average total cost curves will exist, each corresponding to a different choice of fixed cost and so giving rise to what is called a firm's "family" of short-run average total cost curves.

At any given point in time, a firm will find itself on one of its short-run cost curves, the one corresponding to its current level of fixed cost; a change in output will cause it to move along that curve. If the firm expects that change in output level to be long-standing, then it is likely that the firm's current level of fixed cost is no longer optimal. Given sufficient time, it will want to adjust its fixed cost to a new level that minimizes average total cost for its new output level. For example, if Selena had been producing 2 cases of salsa per day with a fixed cost of $108 but found herself increasing her output to 8 cases per day for the foreseeable future, then in the long run she should purchase more equipment and increase her fixed cost to a level that minimizes average total cost at the 8-cases-per-day output level.

The **long-run average total cost curve** shows the relationship between output and average total cost when fixed cost has been chosen to minimize average total cost for each level of output.

Suppose we do a thought experiment and calculate the lowest possible average total cost that can be achieved for each output level if the firm were to choose its fixed cost for each output level. Economists have given this thought experiment a name: the *long-run average total cost curve*. Specifically, the **long-run average total cost curve,** or *LRATC,* is the relationship between output and average total cost when fixed cost has been chosen to minimize average total cost *for each level of output*. If there are many possible choices of fixed cost, the long-run average total cost curve will have the familiar, smooth U shape, as shown by *LRATC* in Figure 11-12.

We can now draw the distinction between the short run and the long run more fully. In the long run, when a producer has had time to choose the fixed cost appropriate for its desired level of output, that producer will be at some point on the long-run average total cost curve. But if the output level is altered, the firm will no longer be on its long-run average total cost curve and will instead be moving along its current short-run average total cost curve. It will not be on its long-run average total cost curve again until it readjusts its fixed cost for its new output level.

Figure 11-12 illustrates this point. The curve $ATC_3$ shows short-run average total cost if Selena has chosen the level of fixed cost that minimizes average total cost at an output of 3 cases of salsa per day. This is confirmed by the fact that at 3 cases per day, $ATC_3$ touches *LRATC,* the long-run average total cost curve. Similarly, $ATC_6$ shows short-run average total cost if Selena has chosen the level of fixed cost that minimizes average total cost if her output is 6 cases per day. It touches *LRATC* at 6 cases per day. And $ATC_9$ shows short-run average total cost if Selena has chosen the level of fixed cost that minimizes average total cost if her output is 9 cases per day. It touches *LRATC* at 9 cases per day.

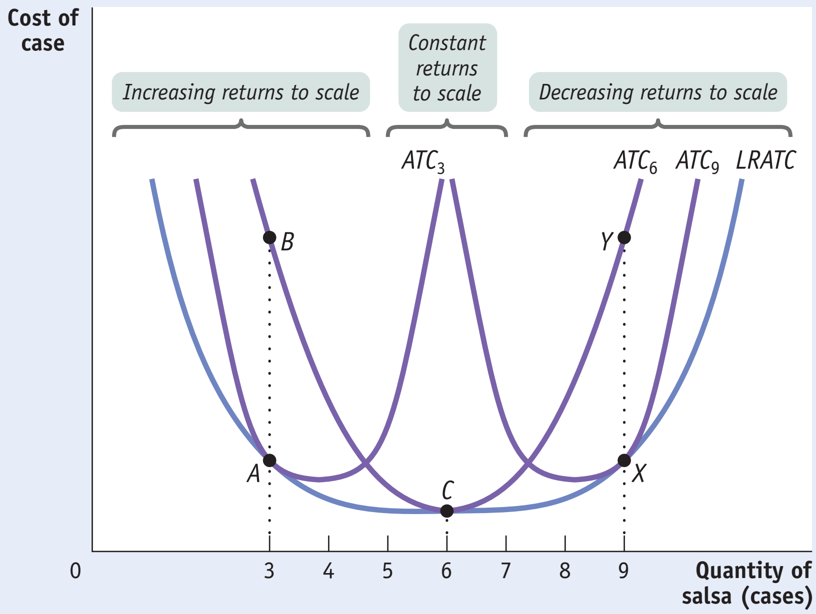
Suppose that Selena initially chose to be on $ATC_6$. If she actually produces 6 cases of salsa per day, her firm will be at point *C* on both its short-run and long-run average total cost curves. Suppose, however, that Selena ends up producing only 3 cases of salsa per day. In the short run, her average total cost is indicated by point *B* on $ATC_6$; it is no longer on *LRATC*. If Selena had known that she would be producing only 3 cases per day, she would have been

Egmont Strigl/Westend61/Superstock

To understand how firms operate over time, be sure to distinguish between short-run and long-run average total costs.

**FIGURE 11-12 Short-Run and Long-Run Average Total Cost Curves**

Short-run and long-run average total cost curves differ because a firm can choose its fixed cost in the long run. If Selena has chosen the level of fixed cost that minimizes short-run average total cost at an output of 6 cases, and actually produces 6 cases, then she will be at point *C* on *LRATC* and $ATC_6$. But if she produces only 3 cases, she will move to point *B*. If she expects to produce only 3 cases for a long time, in the long run she will reduce her fixed cost and move to point *A* on $ATC_3$. Likewise, if she produces 9 cases (putting her at point *Y*) and expects to continue this for a long time, she will increase her fixed cost in the long run and move to point *X* on $ATC_9$.




better off choosing a lower level of fixed cost, the one corresponding to $ATC_3$, thereby achieving a lower average total cost. She could do this, for example, by selling her production plant and purchasing a smaller one. Then her firm would have found itself at point *A* on the long-run average total cost curve, which lies below point *B*.

Suppose, conversely, that Selena ends up producing 9 cases per day even though she initially chose to be on $ATC_6$. In the short run her average total cost is indicated by point *Y* on $ATC_6$. But she would be better off purchasing more equipment and incurring a higher fixed cost in order to reduce her variable cost and move to $ATC_9$. This would allow her to reach point *X* on the long-run average total cost curve, which lies below *Y*.

The distinction between short-run and long-run average total costs is extremely important in making sense of how real firms operate over time. A company that has to increase output suddenly to meet a surge in demand will typically find that in the short run its average total cost rises sharply because it is hard to get extra production out of existing facilities. But given time to build new factories or add machinery, short-run average total cost falls.

## Returns to Scale

What determines the shape of the long-run average total cost curve? The answer is that *scale,* the size of a firm's operations, is often an important determinant of its long-run average total cost of production. Firms that experience scale effects in production find that their long-run average total cost changes substantially depending on the quantity of output they produce. There are **increasing returns to scale** (also known as *economies of scale*) when long-run average total cost declines as output increases.

There are **increasing returns to scale** when long-run average total cost declines as output increases.

There are **decreasing returns to scale** when long-run average total cost increases as output increases.

As you can see in Figure 11-12, Selena's Gourmet Salsas experiences increasing returns to scale over output levels ranging from 0 up to 5 cases of salsa per day—the output levels over which the long-run average total cost curve is declining. In contrast, there are **decreasing returns to scale** (also known as *diseconomies of scale*) when long-run average total cost increases as output increases. For Selena's Gourmet Salsas, decreasing returns to scale occur at output levels greater than 7 cases, the output levels over which its long-run average total cost curve is rising.

There are **constant returns to scale** when long-run average total cost is constant as output increases.

There is also a third possible relationship between long-run average total cost and scale: firms experience **constant returns to scale** when long-run average total cost is constant as output increases. In this case, the firm's long-run average total cost curve is horizontal over the output levels for which there are constant returns to scale. As you see in Figure 11-12, Selena's Gourmet Salsas has constant returns to scale when it produces anywhere from 5 to 7 cases of salsa per day.

What explains these scale effects in production? The answer ultimately lies in the firm's technology of production. Increasing returns often arise from the increased *specialization* that larger output levels allow—a larger scale of operation means that individual workers can limit themselves to more specialized tasks, becoming more skilled and efficient at doing them.

Another source of increasing returns is very large initial setup cost; in some industries—such as auto manufacturing, electricity generating, or petroleum refining—incurring a high fixed cost in the form of plant and equipment is necessary to produce any output.

A third source of increasing returns, found in certain high-tech industries such as software development, is that the value of a good or service to an individual increases when a large number of others own or use the same good or service (known as *network externalities* and covered in Chapter 16). As we'll see in Chapter 13, where we study monopoly, increasing returns have very important implications for how firms and industries interact and behave.

Decreasing returns—the opposite scenario—typically arise in large firms due to problems of coordination and communication: as the firm grows in size, it becomes ever more difficult and so more costly to communicate and to organize its activities. Although increasing returns induce firms to get larger, decreasing returns tend to limit their size. And when there are constant returns to scale, scale has no effect on a firm's long-run average total cost: it is the same regardless of whether the firm produces 1 unit or 100,000 units.

## Summing Up Costs: The Short and Long of It

If a firm is to make the best decisions about how much to produce, it has to understand how its costs relate to the quantity of output it chooses to produce. Table 11-3 provides a quick summary of the concepts and measures of cost you have learned about.

**TABLE 11-3 Concepts and Measures of Cost**

| | Measurement | Definition | Mathematical term |
|---|---|---|---|
| **Short run** | Fixed cost | Cost that does not depend on the quantity of output produced | $FC$ |
| | Average fixed cost | Fixed cost per unit of output | $AFC = FC/Q$ |
| **Short run and long run** | Variable cost | Cost that depends on the quantity of output produced | $VC$ |
| | Average variable cost | Variable cost per unit of output | $AVC = VC/Q$ |
| | Total cost | The sum of fixed cost (short run) and variable cost | $TC = FC$ (short run) $+ VC$ |
| | Average total cost (average cost) | Total cost per unit of output | $ATC = TC/Q$ |
| | Marginal cost | The change in total cost generated by producing one more unit of output | $MC = \Delta TC/\Delta Q$ |
| **Long run** | Long-run average total cost | Average total cost when fixed cost has been chosen to minimize average total cost for each level of output | $LRATC$ |

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Cities with higher average annual snow-fall maintain larger snowplow fleets.

## ECONOMICS in Action

### There's No Business Like Snow Business

Anyone who has lived both in a snowy city, like Chicago, and in a city that only occasionally experiences significant snowfall, like Washington, D.C., is aware of the differences in total cost that arise from making different choices about fixed cost.

In Washington, even a minor snowfall—say, an inch or two overnight—is enough to create chaos during the next morning's commute. The same snowfall in Chicago has hardly any effect at all. The reason is not that Washingtonians are wimps and Chicagoans are made of sterner stuff; it is that Washington, where it rarely snows, has only a fraction as many snowplows and other snowclearing equipment as cities where heavy snow is a fact of life.

In this sense Washington and Chicago are like two producers who expect to produce different levels of output, where the "output" is snow removal. Washington, which rarely has significant snow, has chosen a low level of fixed cost in the form of snow-clearing equipment. This makes sense under normal circumstances but leaves the city unprepared when major snow does fall. Chicago, which knows that it will face lots of snow, chooses to accept the higher fixed cost that leaves it in a position to respond effectively.

### Quick Review

- In the long run, firms choose fixed cost according to expected output. Higher fixed cost reduces average total cost when output is high. Lower fixed cost reduces average total cost when output is low.
- There are many possible short-run average total cost curves, each corresponding to a different level of fixed cost. The **long-run average total cost curve, *LRATC*,** shows average total cost over the long run, when the firm has chosen fixed cost to minimize average total cost for each level of output.
- A firm that has fully adjusted its fixed cost for its output level will operate at a point that lies on both its current short-run and long-run average total cost curves. A change in output moves the firm along its current short-run average total cost curve. Once it has readjusted its fixed cost, the firm will operate on a new short-run average total cost curve and on the long-run average total cost curve.
- Scale effects arise from the technology of production. **Increasing returns to scale** tend to make firms larger. **Decreasing returns to scale** tend to limit their size. With **constant returns to scale,** scale has no effect.

### Check Your Understanding 11-3

**1.** The accompanying table shows three possible combinations of fixed cost and average variable cost. Average variable cost is constant in this example (it does not vary with the quantity of output produced).

**a.** For each of the three choices, calculate the average total cost of producing 12,000, 22,000, and 30,000 units. For each of these quantities, which choice results in the lowest average total cost?

**b.** Suppose that the firm, which has historically produced 12,000 units, experiences a sharp, permanent increase in demand that leads it to produce 22,000 units. Explain how its average total cost will change in the short run and in the long run.

| Choice | Fixed cost | Average variable cost |
|---|---|---|
| 1 | $8,000 | $1.00 |
| 2 | 12,000 | 0.75 |
| 3 | 24,000 | 0.25 |

**c.** Explain what the firm should do instead if it believes the change in demand is temporary.

**2.** In each of the following cases, explain what kind of scale effects you think the firm will experience and why.

**a.** A telemarketing firm in which employees make sales calls using computers and telephones

**b.** An interior design firm in which design projects are based on the expertise of the firm's owner

**c.** A diamond-mining company

**3.** Draw a graph like Figure 11-12 and insert a short-run average total cost curve corresponding to a long-run output choice of 5 cases of salsa per day. Use the graph to show why Selena should change her fixed cost if she expects to produce only 4 cases per day for a long period of time.

Solutions appear at back of book.

BUSINESS CASE

# Kiva Systems' Robots versus Humans: The Challenge of Holiday Order Fulfillment

For those who like to procrastinate when it comes to holiday shopping, the rise of e-commerce has been a welcome phenomenon. In 2103 Amazon.com boasted that customers living in 12 cities in the United States could receive same-day delivery for orders placed on the day before Christmas.

E-commerce retailers like Amazon.com and CrateandBarrel.com can see their sales quadruple for the holidays. With advances in order fulfillment technology that get customers' orders to them quickly, e-commerce sellers have been able to capture an ever-greater share of sales from brick-and-mortar retailers. Holiday sales at e-commerce sites grew by over 10% from 2012 to 2013.

Beth Hail/Bloomberg via Getty Images

Behind these technological advances, however, lies an intense debate: people versus robots. Amazon.com has relied on a large staff of temporary human workers to get it through the previous holiday seasons, often quadrupling its staff and operating 24 hours a day. In contrast, CrateandBarrel.com only doubled its workforce, thanks to a cadre of orange robots that allows each worker to do the work of six people.

But Amazon.com is set to increase its robotic work force in the future. In May 2012, Amazon.com bought Kiva Systems, the leader in order fulfillment robotics, for $775 million, with the hope of tailoring Kiva's systems to fit Amazon.com's warehouse and fulfillment needs.

Although many retailers—Staples, Gap, Saks Fifth Avenue, and Walgreens, for example—also use Kiva equipment, installation of a robotic system can be expensive, with some costing as much as $20 million. Yet hiring workers has a cost, too: during the 2013 holiday season, before it had installed an extensive robotic system, Amazon.com hired some 70,000 temporary workers at its 94 distribution centers around the United States.

As one industry analyst noted, an obstacle to the purchase of a robotic system for many e-commerce retailers is that it often doesn't make economic sense: it's too expensive to buy sufficient robots for the busiest time of the year because they would be idle at other times. Before Amazon.com's purchase, Kiva was testing a program to rent out its robots seasonally so that retailers could "hire" enough robots to handle their holiday orders just as Amazon.com used to hire more humans.

## QUESTIONS FOR THOUGHT

1. Assume that a firm can sell a robot, but that the sale takes time and the firm is likely to get less than what it paid. Other things equal, which system, human-based or robotic, will have a higher fixed cost? Which will have a higher variable cost? Explain.
2. Predict the pattern of off-holiday sales versus holiday sales that would induce a retailer to keep a human-based system. Predict the pattern that would induce a retailer to move to a robotic system.
3. How would a "robot-for-hire" program affect your answer to Question 2? Explain.

## SUMMARY

1. The relationship between inputs and output is a producer's **production function.** In the **short run,** the quantity of a **fixed input** cannot be varied but the quantity of a **variable input** can. In the **long run,** the quantities of all inputs can be varied. For a given amount of the fixed input, the **total product curve** shows how the quantity of output changes as the quantity of the variable input changes. We may also calculate the **marginal product** of an input, the increase in output from using one more unit of that input.
2. There are **diminishing returns to an input** when its marginal product declines as more of the input is used, holding the quantity of all other inputs fixed.
3. **Total cost,** represented by the **total cost curve,** is equal to the sum of **fixed cost,** which does not depend on output, and **variable cost,** which does depend on output. Due to diminishing returns, marginal cost, the increase in total cost generated by producing one more unit of output, normally increases as output increases.
4. **Average total cost** (also known as **average cost**), total cost divided by quantity of output, is the cost of the average unit of output, and marginal cost is the cost of one more unit produced. Economists believe that **U-shaped average total cost curves** are typical, because average total cost consists of two parts: **average fixed cost,** which falls when output increases (the spreading effect), and **average variable cost,** which rises with output (the diminishing returns effect).
5. When average total cost is U-shaped, the bottom of the U is the level of output at which average total cost is minimized, the point of **minimum-cost output.** This is also the point at which the marginal cost curve crosses the average total cost curve from below. Due to gains from specialization, the marginal cost curve may slope downward initially before sloping upward, giving it a "swoosh" shape.
6. In the long run, a producer can change its fixed input and its level of fixed cost. By accepting higher fixed cost, a firm can lower its variable cost for any given output level, and vice versa. The **long-run average total cost curve** shows the relationship between output and average total cost when fixed cost has been chosen to minimize average total cost at each level of output. A firm moves along its short-run average total cost curve as it changes the quantity of output, and it returns to a point on both its short-run and long-run average total cost curves once it has adjusted fixed cost to its new output level.
7. As output increases, there are **increasing returns to scale** if long-run average total cost declines; **decreasing returns to scale** if it increases; and **constant returns to scale** if it remains constant. Scale effects depend on the technology of production.

## KEY TERMS

Production function, p. 330
Fixed input, p. 330
Variable input, p. 330
Long run, p. 330
Short run, p. 330
Total product curve, p. 330
Marginal product, p. 331
Diminishing returns to an input, p. 332
Fixed cost, p. 334
Variable cost, p. 334
Total cost, p. 334
Total cost curve, p. 335
Average total cost, p. 339
Average cost, p. 339
U-shaped average total cost curve, p. 340
Average fixed cost, p. 340
Average variable cost, p. 340
Minimum-cost output, p. 342
Long-run average total cost curve, p. 347
Increasing returns to scale, p. 348
Decreasing returns to scale, p. 348
Constant returns to scale, p. 349

## PROBLEMS

1. Changes in the price of key commodities have a significant impact on a company's bottom line. For virtually all companies, the price of energy is a substantial portion of their costs. In addition, many industries—such as those that produce beef, chicken, high-fructose corn syrup and ethanol—are highly dependent on the price of corn. In particular, corn has seen a significant increase in price.
   **a.** Explain how the cost of energy can be both a fixed cost and a variable cost for a company.
   **b.** Suppose energy is a fixed cost and energy prices rise. What happens to the company's average total cost curve? What happens to its marginal cost curve? Illustrate your answer with a diagram.
   **c.** Explain why the cost of corn is a variable cost but not a fixed cost for an ethanol producer.
   **d.** When the cost of corn goes up, what happens to the average total cost curve of an ethanol producer? What happens to its marginal cost curve? Illustrate your answer with a diagram.

**2.** Marty's Frozen Yogurt is a small shop that sells cups of frozen yogurt in a university town. Marty owns three frozen-yogurt machines. His other inputs are refrigerators, frozen-yogurt mix, cups, sprinkle toppings, and, of course, workers. He estimates that his daily production function when he varies the number of workers employed (and at the same time, of course, yogurt mix, cups, and so on) is as shown in the accompanying table.

| Quantity of labor (workers) | Quantity of frozen yogurt (cups) |
|---|---|
| 0 | 0 |
| 1 | 110 |
| 2 | 200 |
| 3 | 270 |
| 4 | 300 |
| 5 | 320 |
| 6 | 330 |

**a.** What are the fixed inputs and variable inputs in the production of cups of frozen yogurt?

**b.** Draw the total product curve. Put the quantity of labor on the horizontal axis and the quantity of frozen yogurt on the vertical axis.

**c.** What is the marginal product of the first worker? The second worker? The third worker? Why does marginal product decline as the number of workers increases?

**3.** The production function for Marty's Frozen Yogurt is given in Problem 2. Marty pays each of his workers $80 per day. The cost of his other variable inputs is $0.50 per cup of yogurt. His fixed cost is $100 per day.

**a.** What is Marty's variable cost and total cost when he produces 110 cups of yogurt? 200 cups? Calculate variable and total cost for every level of output given in Problem 2.

**b.** Draw Marty's variable cost curve. On the same diagram, draw his total cost curve.

**c.** What is the marginal cost per cup for the first 110 cups of yogurt? For the next 90 cups? Calculate the marginal cost for all remaining levels of output.

**4.** The production function for Marty's Frozen Yogurt is given in Problem 2. The costs are given in Problem 3.

**a.** For each of the given levels of output, calculate the average fixed cost (*AFC*), average variable cost (*AVC*), and average total cost (*ATC*) per cup of frozen yogurt.

**b.** On one diagram, draw the *AFC*, *AVC*, and *ATC* curves.

**c.** What principle explains why the *AFC* declines as output increases? What principle explains why the *AVC* increases as output increases? Explain your answers.

**d.** How many cups of frozen yogurt are produced when average total cost is minimized?

**5.** Labor costs represent a large percentage of total costs for many firms. According to data from the Bureau of Labor Statistics, U.S. labor costs were up 0.8% in 2013, compared to 2012.

**a.** When labor costs increase, what happens to average total cost and marginal cost? Consider a case in which labor costs are only variable costs and a case in which they are both variable and fixed costs.

An increase in labor productivity means each worker can produce more output. Recent data on productivity show that labor productivity in the U.S. nonfarm business sector grew by 1.7% between 1970 and 1999, by 2.6% between 2000 and 2009, and by 1.1% between 2010 and 2013.

**b.** When productivity growth is positive, what happens to the total product curve and the marginal product of labor curve? Illustrate your answer with a diagram.

**c.** When productivity growth is positive, what happens to the marginal cost curve and the average total cost curve? Illustrate your answer with a diagram.

**d.** If labor costs are rising over time on average, why would a company want to adopt equipment and methods that increase labor productivity?

**6.** Magnificent Blooms is a florist specializing in floral arrangements for weddings, graduations, and other events. Magnificent Blooms has a fixed cost associated with space and equipment of $100 per day. Each worker is paid $50 per day. The daily production function for Magnificent Blooms is shown in the accompanying table.

| Quantity of labor (workers) | Quantity of floral arrangements |
|---|---|
| 0 | 0 |
| 1 | 5 |
| 2 | 9 |
| 3 | 12 |
| 4 | 14 |
| 5 | 15 |

**a.** Calculate the marginal product of each worker. What principle explains why the marginal product per worker declines as the number of workers employed increases?

**b.** Calculate the marginal cost of each level of output. What principle explains why the marginal cost per floral arrangement increases as the number of arrangements increases?

**7.** You have the information shown in the accompanying table about a firm's costs. Complete the missing data.

| Quantity of output | *TC* | *MC* | *ATC* | *AVC* |
|---|---|---|---|---|
| 0 | $20 | | — | — |
| | | $20 | | |
| 1 | ? | | ? | ? |
| | | 10 | | |
| 2 | ? | | ? | ? |
| | | 16 | | |
| 3 | ? | | ? | ? |
| | | 20 | | |
| 4 | ? | | ? | ? |
| | | 24 | | |
| 5 | ? | | ? | ? |

**8.** Evaluate each of the following statements. If a statement is true, explain why; if it is false, identify the mistake and try to correct it.

**a.** A decreasing marginal product tells us that marginal cost must be rising.

**b.** An increase in fixed cost increases the minimum-cost output.

**c.** An increase in fixed cost increases marginal cost.

**d.** When marginal cost is above average total cost, average total cost must be falling.

**9.** Mark and Jeff operate a small company that produces souvenir footballs. Their fixed cost is $2,000 per month. They can hire workers for $1,000 per worker per month. Their monthly production function for footballs is as given in the accompanying table.

| Quantity of labor (workers) | Quantity of footballs |
|---|---|
| 0 | 0 |
| 1 | 300 |
| 2 | 800 |
| 3 | 1,200 |
| 4 | 1,400 |
| 5 | 1,500 |

**a.** For each quantity of labor, calculate average variable cost (*AVC*), average fixed cost (*AFC*), average total cost (*ATC*), and marginal cost (*MC*).

**b.** On one diagram, draw the *AVC*, *ATC*, and *MC* curves.

**c.** At what level of output is Mark and Jeff's average total cost minimized?

**10.** You produce widgets. Currently you produce four widgets at a total cost of $40.

**a.** What is your average total cost?

**b.** Suppose you could produce one more (the fifth) widget at a marginal cost of $5. If you do produce that fifth widget, what will your average total cost be? Has your average total cost increased or decreased? Why?

**c.** Suppose instead that you could produce one more (the fifth) widget at a marginal cost of $20. If you do produce that fifth widget, what will your average total cost be? Has your average total cost increased or decreased? Why?

**11.** In your economics class, each homework problem set is graded on the basis of a maximum score of 100. You have completed 9 out of 10 of the problem sets for the term, and your current average grade is 88. What range of grades for your 10th problem set will raise your overall average? What range will lower your overall average? Explain your answer.

**12.** Don owns a small concrete-mixing company. His fixed cost is the cost of the concrete-batching machinery and his mixer trucks. His variable cost is the cost of the sand, gravel, and other inputs for producing concrete; the gas and maintenance for the machinery and trucks; and his workers. He is trying to decide how many mixer trucks to purchase. He has estimated the costs shown in the accompanying table based on estimates of the number of orders his company will receive per week.

| Quantity of trucks | *FC* | *VC* 20 orders | 40 orders | 60 orders |
|---|---|---|---|---|
| 2 | $6,000 | $2,000 | $5,000 | $12,000 |
| 3 | 7,000 | 1,800 | 3,800 | 10,800 |
| 4 | 8,000 | 1,200 | 3,600 | 8,400 |

**a.** For each level of fixed cost, calculate Don's total cost for producing 20, 40, and 60 orders per week.

**b.** If Don is producing 20 orders per week, how many trucks should he purchase and what will his average total cost be? Answer the same questions for 40 and 60 orders per week.

**13.** Consider Don's concrete-mixing business described in Problem 12. Assume that Don purchased 3 trucks, expecting to produce 40 orders per week.

**a.** Suppose that, in the short run, business declines to 20 orders per week. What is Don's average total cost per order in the short run? What will his average total cost per order in the short run be if his business booms to 60 orders per week?

**b.** What is Don's long-run average total cost for 20 orders per week? Explain why his short-run average total cost of producing 20 orders per week when the number of trucks is fixed at 3 is greater than his long-run average total cost of producing 20 orders per week.

**c.** Draw Don's long-run average total cost curve. Draw his short-run average total cost curve if he owns 3 trucks.

**14.** True or false? Explain your reasoning.

**a.** The short-run average total cost can never be less than the long-run average total cost.

**b.** The short-run average variable cost can never be less than the long-run average total cost.

**c.** In the long run, choosing a higher level of fixed cost shifts the long-run average total cost curve upward.

**15.** Wolfsburg Wagon (WW) is a small automaker. The accompanying table shows WW's long-run average total cost.

| Quantity of cars | *LRATC* of car |
|---|---|
| 1 | $30,000 |
| 2 | 20,000 |
| 3 | 15,000 |
| 4 | 12,000 |
| 5 | 12,000 |
| 6 | 12,000 |
| 7 | 14,000 |
| 8 | 18,000 |

**a.** For which levels of output does WW experience increasing returns to scale?

**b.** For which levels of output does WW experience decreasing returns to scale?

**c.** For which levels of output does WW experience constant returns to scale?

WORK IT OUT

Macmillan Education LaunchPad

**For interactive, step-by-step help in solving the following problem, visit LaunchPad by using the URL on the back cover of this book.**

**16.** The accompanying table shows a car manufacturer's total cost of producing cars.

| Quantity of cars | *TC* |
|---|---|
| 0 | $500,000 |
| 1 | 540,000 |
| 2 | 560,000 |
| 3 | 570,000 |
| 4 | 590,000 |
| 5 | 620,000 |
| 6 | 660,000 |
| 7 | 720,000 |
| 8 | 800,000 |
| 9 | 920,000 |
| 10 | 1,100,000 |

**a.** What is this manufacturer's fixed cost?

**b.** For each level of output, calculate the variable cost (*VC*). For each level of output except zero output, calculate the average variable cost (*AVC*), average total cost (*ATC*), and average fixed cost (*AFC*). What is the minimum-cost output?

**c.** For each level of output, calculate this manufacturer's marginal cost (*MC*).

**d.** On one diagram, draw the manufacturer's *AVC*, *ATC*, and *MC* curves.

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CHAPTER 12

# Perfect Competition and the Supply Curve

## What You Will Learn in This Chapter

- **What a perfectly competitive market is and the characteristics of a perfectly competitive industry**
- **How a price-taking producer determines its profit-maximizing quantity of output**
- **How to assess whether or not a producer is profitable and why an unprofitable producer may continue to operate in the short run**
- **Why industries behave differently in the short run and the long run**
- **What determines the industry supply curve in both the short run and the long run**

## DECK THE HALLS

Stockbyte/Exactostock/Superstock

**Whether it's Christmas trees or smartphones, how a good is produced determines its cost of production.**

ONE SURE SIGN THAT it's the holiday season is the sudden appearance of Christmas tree sellers, who set up shop in vacant lots, parking lots, and garden centers all across the country. Until the 1950s, virtually all Christmas trees were obtained by individuals going to local forests to cut down their own. However, by the 1950s increased demand from population growth and diminished supply from the loss of forests created a market opportunity. Seeing an ability to profit by growing and selling Christmas trees, farmers responded. So rather than venturing into the forest to cut your own tree, you now have a wide range of sizes and varieties of trees to choose from—and they are available close to home. In 2013, nearly 25 million farmed trees were sold in the United States for a total of over $1 billion.

Note that the supply of Christmas trees is relatively price inelastic for two reasons: it takes time to acquire land for planting, and it takes time for the trees to grow. However, these limits apply only in the short run. Over time, farms that are already in operation can increase their capacity and new tree farmers can enter the business. And, over time, the trees will mature and be ready to harvest. So the increase in the quantity supplied in response to an increase in price will be much larger in the long run than in the short run.

Where does the supply curve come from? Why is there a difference between the short-run and the long-run supply curve? In this chapter we will use our understanding of costs, developed in Chapter 11, as the basis for an analysis of the supply curve. As we'll see, this will require that we understand the behavior both of individual firms and of an entire industry, composed of these many individual firms.

Our analysis in this chapter assumes that the industry in question is characterized by *perfect competition*. We begin by explaining the concept of perfect competition, providing a brief introduction to the conditions that give rise to a perfectly competitive industry. We then show how a producer under perfect competition decides how much to produce. Finally, we use the cost curves of the individual producers to derive the *industry supply curve* under perfect competition.

By analyzing the way a competitive industry evolves over time, we will come to understand the distinction between the short-run and long-run effects of changes in demand on a competitive industry—such as, for example, the effect of America's preference for readily available trees for the holidays on the Christmas tree farming industry. We will conclude with a deeper discussion of the conditions necessary for an industry to be perfectly competitive.

A **price-taking producer** is a producer whose actions have no effect on the market price of the good or service it sells.

A **price-taking consumer** is a consumer whose actions have no effect on the market price of the good or service he or she buys.

A **perfectly competitive market** is a market in which all market participants are price-takers.

A **perfectly competitive industry** is an industry in which producers are price-takers.

# Perfect Competition

Suppose that Yves and Zoe are neighboring farmers, both of whom grow Christmas trees. Both sell their output to the same set of Christmas tree consumers so, in a real sense, Yves and Zoe compete with each other.

Does this mean that Yves should try to stop Zoe from growing Christmas trees or that Yves and Zoe should form an agreement to grow less? Almost certainly not: there are thousands of Christmas tree farmers, and Yves and Zoe are competing with all those other growers as well as with each other. Because so many farmers sell Christmas trees, if any one of them produced more or less, there would be no measurable effect on market prices.

When people talk about business competition, the image they often have in mind is a situation in which two or three rival firms are intensely struggling for advantage. But economists know that when an industry consists of a few main competitors, it's actually a sign that competition is fairly limited. As the example of Christmas trees suggests, when there is enough competition, it doesn't even make sense to identify your rivals: there are so many competitors that you cannot single out any one of them as a rival.

We can put it another way: Yves and Zoe are **price-taking producers.** A producer is a price-taker when its actions cannot affect the market price of the good or service it sells. As a result, a price-taking producer considers the market price as given. When there is enough competition—when competition is what economists call "perfect"—then every producer is a price-taker.

And there is a similar definition for consumers: a **price-taking consumer** is a consumer who cannot influence the market price of the good or service by his or her actions. That is, the market price is unaffected by how much or how little of the good the consumer buys.

## Defining Perfect Competition

In a **perfectly competitive market,** all market participants, both consumers and producers, are price-takers. That is, neither consumption decisions by individual consumers nor production decisions by individual producers affect the market price of the good.

The supply and demand model, which we introduced in Chapter 3 and have used repeatedly since then, is a model of a perfectly competitive market. It depends fundamentally on the assumption that no individual buyer or seller of a good, such as coffee beans or Christmas trees, believes that it is possible to affect the price at which he or she can buy or sell the good.

As a general rule, consumers are indeed price-takers. Instances in which consumers are able to affect the prices they pay are rare. It is, however, quite common for producers to have a significant ability to affect the prices they receive, a phenomenon we'll address in the next chapter. So the model of perfect competition is appropriate for some but not all markets. An industry in which producers are price-takers is called a **perfectly competitive industry.** Clearly, some industries aren't perfectly competitive; in later chapters we'll learn how to analyze industries that don't fit the perfectly competitive model.

Under what circumstances will all producers be price-takers? In the next section we will find that there are two necessary conditions for a perfectly competitive industry and that a third condition is often present as well.

## Two Necessary Conditions for Perfect Competition

The markets for major grains, like wheat and corn, are perfectly competitive: individual wheat and corn farmers, as well as individual buyers of wheat and corn, take market prices as given. In contrast, the markets for some of the food items made from these grains—in particular, breakfast cereals—are by no means perfectly competitive. There is intense competition among cereal brands, but not *perfect* competition. To understand the difference between the market for wheat and the market for shredded wheat cereal is to understand the importance of the two necessary conditions for perfect competition.

*First, for an industry to be perfectly competitive, it must contain many producers, none of whom have a large* **market share.** A producer's market share is the fraction of the total industry output accounted for by that producer's output. The distribution of market share constitutes a major difference between the grain industry and the breakfast cereal industry. There are thousands of wheat farmers, none of whom account for more than a tiny fraction of total wheat sales.

The breakfast cereal industry, however, is dominated by four producers: Kellogg's, General Mills, Post Foods, and the Quaker Oats Company. Kellogg's alone accounts for about one-third of all cereal sales. Kellogg's executives know that if they try to sell more cornflakes, they are likely to drive down the market price of cornflakes. That is, they know that their actions influence market prices, simply because they are such a large part of the market that changes in their production will significantly affect the overall quantity supplied. It makes sense to assume that producers are price-takers only when an industry does *not* contain any large producers like Kellogg's.

Second, an industry can be perfectly competitive only if consumers regard the products of all producers as equivalent. This clearly isn't true in the breakfast cereal market: consumers don't consider Cap'n Crunch to be a good substitute for Wheaties. As a result, the maker of Wheaties has some ability to increase its price without fear that it will lose all its customers to the maker of Cap'n Crunch.

Contrast this with the case of a **standardized product,** which is a product that consumers regard as the same good even when it comes from different producers, sometimes known as a **commodity.** Because wheat is a standardized product, consumers regard the output of one wheat producer as a perfect substitute for that of another producer. Consequently, one farmer cannot increase the price for his or her wheat without losing all sales to other wheat farmers. *So the second necessary condition for a competitive industry is that the industry output is a standardized product* (see the upcoming For Inquiring Minds).

A producer's **market share** is the fraction of the total industry output accounted for by that producer's output.

A good is a **standardized product,** also known as a **commodity,** when consumers regard the products of different producers as the same good.

An industry has **free entry and exit** when new producers can easily enter into an industry and existing producers can easily leave that industry.

## Free Entry and Exit

All perfectly competitive industries have many producers with small market shares, producing a standardized product. Most perfectly competitive industries are also characterized by one more feature: it is easy for new firms to enter the industry or for firms that are currently in the industry to leave. That is, no obstacles in the form of government regulations or limited access to key resources prevent new producers from entering the market. And no additional costs are associated with shutting down a company and leaving the industry.

Economists refer to the arrival of new firms into an industry as *entry;* they refer to the departure of firms from an industry as *exit.* When there are no obstacles to entry into or exit from an industry, we say that the industry has **free entry and exit.**

Free entry and exit is not strictly necessary for perfect competition. In Chapter 5 we described the case of Alaskan crab fishing, where regulations place a quota on the amount of Alaskan crab that can be caught during a season, so entry is limited to established boat owners that have been given quotas. Despite this, there are enough boats operating that the crab fisherman are price-takers. But free entry and exit is a key factor in most competitive industries. It ensures that the number of producers in an industry can adjust to changing market conditions. And, in particular, it ensures that producers in an industry cannot act to keep new firms out.

To sum up, then, perfect competition depends on two necessary conditions. First, the industry must contain many producers, each having a small

## FOR INQUIRING MINDS | What's a Standardized Product?

A perfectly competitive industry must produce a standardized product. But is it enough for the products of different firms actually to be the same? No: people must also *think* that they are the same. And producers often go to great lengths to convince consumers that they have a distinctive, or *differentiated,* product, even when they don't.

Consider, for example, champagne—not the superexpensive premium champagnes but the more ordinary stuff. Most people cannot tell the difference between champagne actually produced in the Champagne region of France, where the product originated, and similar products from Spain or California. But the French government has sought and obtained legal protection for the winemakers of Champagne, ensuring that around the world only bubbly wine from that region can be called champagne. If it's from someplace else, all the seller can do is say that it was produced using the *méthode Champenoise.* This creates a differentiation in the minds of consumers and lets the champagne producers of Champagne charge higher prices.


In the end, only *kimchi* eaters can tell you if there is truly a difference between Korean-produced *kimchi* and the Japanese-produced variety.

Similarly, Korean producers of *kimchi,* the spicy fermented cabbage that is the Korean national side dish, are doing their best to convince consumers that the same product packaged by Japanese firms is just not the real thing. The purpose is, of course, to ensure higher prices for Korean *kimchi.*

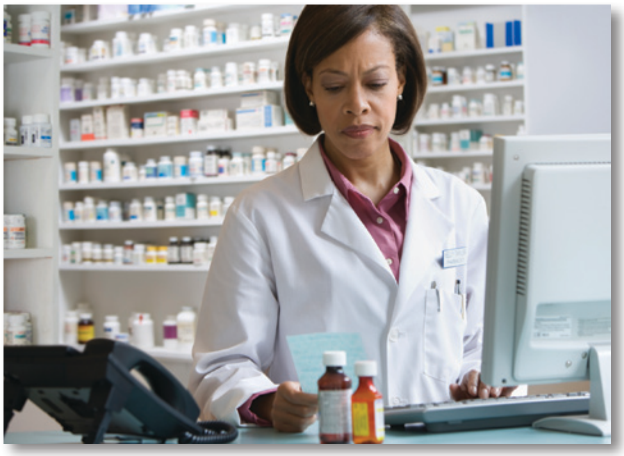
So is an industry perfectly competitive if it sells products that are indistinguishable except in name but that consumers, for whatever reason, don't think are standardized? No. When it comes to defining the nature of competition, the consumer is always right. ■

market share. Second, the industry must produce a standardized product. In addition, perfectly competitive industries are normally characterized by free entry and exit.

How does an industry that meets these three criteria behave? As a first step toward answering that question, let's look at how an individual producer in a perfectly competitive industry maximizes profit.

## ECONOMICS ▶ *in Action*

### Paid to Delay




Patents allow drug makers to have a legal monopoly on new medications for 20 years.

Sometimes it is possible to see an industry become perfectly competitive. In fact, it happens frequently in the case of pharmaceuticals when the patent on a popular drug expires.

When a company develops a new drug, it is usually able to receive a patent, which gives it a *legal monopoly*—the exclusive right to sell the drug—for 20 years from the date of filing. Legally, no one else can sell that drug without the patent owner's permission.

When the patent expires, the market is open for other companies to sell their own versions of the drug, known collectively as *generics*. Generics are standardized products, much like aspirin, and are often sold by many producers. On average, a generic drug costs about 15% of the price of the equivalent patent-protected drug and quickly causes the patent-protected drug to lose up to 90% of its market share.

Not surprisingly, the makers of patent-protected drugs are eager to forestall the entry of generic competitors and have tried a variety of strategies. One especially successful tactic, called "pay-to-delay," is an agreement between the original drug maker and a potential generic competitor to delay the introduction of the generic drug for a specific period of time in return for compensation. As a result, the original drug maker continues to charge high prices and reap high profits. These agreements have been fiercely contested by government regulators, who view them as anti-competitive practices that hurt consumers. According to the Federal Trade Commission, the federal agency tasked with implementing antitrust law (laws regulating monopolies), between 2005 and 2013 pay-for-delay deals cost consumers $3.5 billion annually.

The defenders of pay-for-delay agreements argue that the deals are not anti-competitive and that they allow generics to come to market without their makers having to face the threat of costly patent litigation battles. In 2013 the Supreme Court ruled that pay-for-delay deals could in fact be anti-competitive, thus giving the Federal Trade Commission the green light to challenge the deals on a case-by-case basis.

### Quick Review

- Neither the actions of a **price-taking producer** nor those of a **price-taking consumer** can influence the market price of a good.
- In a **perfectly competitive market** all producers and consumers are price-takers. Consumers are almost always price-takers, but this is often not true of producers. An industry in which producers are price-takers is a **perfectly competitive industry.**
- A perfectly competitive industry contains many producers, each of which produces a **standardized product** (also known as a **commodity**) but none of which has a large **market share.**
- Most perfectly competitive industries are also characterized by **free entry and exit.**

### Check Your Understanding 12-1

1. In each of the following situations, do you think the industry described will be perfectly competitive or not? Explain your answer.
   a. There are two producers of aluminum in the world, a good sold in many places.
   b. The price of natural gas is determined by global supply and demand. A small share of that global supply is produced by a handful of companies located in the North Sea.
   c. Dozens of designers sell high-fashion clothes. Each designer has a distinctive style and a loyal clientele.
   d. There are many baseball teams in the United States, one or two in each major city and each selling tickets to its hometown events.

Solutions appear at back of book.

## Production and Profits

Consider Noelle, who runs a Christmas tree farm. Suppose that the market price of Christmas trees is $18 per tree and that Noelle is a price-taker—she can sell as many as she likes at that price. Then we can use the data in Table 12-1 to find her profit-maximizing level of output by direct calculation.

The first column shows the quantity of output in number of trees, and the second column shows Noelle's total revenue from her output: the market value of trees she produced. Total revenue, *TR*, is equal to the market price multiplied by the quantity of output:

**(12-1)** $TR = P \times Q$

In this example, total revenue is equal to $18 per tree times the quantity of output in trees.

The third column of Table 12-1 shows Noelle's total cost. The fourth column shows her profit, equal to total revenue minus total cost:

**(12-2)** Profit $= TR - TC$

**TABLE 12-1 Profit for Noelle's Farm When Market Price Is $18**

| Quantity of trees *Q* | Total revenue *TR* | Total cost *TC* | Profit *TR − TC* |
|---|---|---|---|
| 0 | $0 | $140 | –$140 |
| 10 | 180 | 300 | –120 |
| 20 | 360 | 360 | 0 |
| 30 | 540 | 440 | 100 |
| 40 | 720 | 560 | 160 |
| 50 | 900 | 720 | 180 |
| 60 | 1,080 | 920 | 160 |
| 70 | 1,260 | 1,160 | 100 |

As indicated by the numbers in the table, profit is maximized at an output of 50 trees, where profit is equal to $180. But we can gain more insight into the profit-maximizing choice of output by viewing it as a problem of marginal analysis, a task we'll do next.

**Marginal revenue** is the change in total revenue generated by an additional unit of output.

According to the **optimal output rule,** profit is maximized by producing the quantity of output at which the marginal revenue of the last unit produced is equal to its marginal cost.

According to the **price-taking firm's optimal output rule,** a price-taking firm's profit is maximized by producing the quantity of output at which the market price is equal to the marginal cost of the last unit produced.

## Using Marginal Analysis to Choose the Profit-Maximizing Quantity of Output

Recall from Chapter 9 the *profit-maximizing principle of marginal analysis:* the optimal amount of an activity is the level at which marginal benefit is equal to marginal cost. To apply this principle, consider the effect on a producer's profit of increasing output by one unit. The marginal benefit of that unit is the additional revenue generated by selling it; this measure has a name—it is called the **marginal revenue** of that unit of output. The general formula for marginal revenue is:

$$\textbf{(12-3)}\ \text{Marginal revenue} = \begin{array}{l}\text{Change in total revenue}\\ \text{generated by one}\\ \text{additional unit of output}\end{array} = \frac{\text{Change in total revenue}}{\text{Change in quantity of output}}$$

or

$$MR = \Delta TR/\Delta Q$$

So Noelle maximizes her profit by producing trees up to the point at which the marginal revenue is equal to marginal cost. We can summarize this as the producer's **optimal output rule:** profit is maximized by producing the quantity at which the marginal revenue of the last unit produced is equal to its marginal cost. That is, $MR = MC$ at the optimal quantity of output.

We can learn how to apply the optimal output rule with the help of Table 12-2, which provides various short-run cost measures for Noelle's farm. The second column contains the farm's variable cost, and the third column shows its total cost of output based on the assumption that the farm incurs a fixed cost of $140. The fourth column shows marginal cost. Notice that, in this example, the marginal cost initially falls as output rises but then begins to increase. This gives the marginal cost curve the "swoosh" shape described in the Selena's Gourmet Salsas example in Chapter 11. Shortly it will become clear that this shape has important implications for short-run production decisions.

**TABLE 12-2 Short-Run Costs for Noelle's Farm**

| Quantity of trees *Q* | Variable cost *VC* | Total cost *TC* | Marginal cost of tree *MC* = Δ*TC*/Δ*Q* | Marginal revenue of tree *MR* | Net gain of tree = *MR* − *MC* |
|---|---|---|---|---|---|
| 0 | $0 | $140 | | | |
| | | | $16 | $18 | $2 |
| 10 | 160 | 300 | | | |
| | | | 6 | 18 | 12 |
| 20 | 220 | 360 | | | |
| | | | 8 | 18 | 10 |
| 30 | 300 | 440 | | | |
| | | | 12 | 18 | 6 |
| 40 | 420 | 560 | | | |
| | | | 16 | 18 | 2 |
| 50 | 580 | 720 | | | |
| | | | 20 | 18 | −2 |
| 60 | 780 | 920 | | | |
| | | | 24 | 18 | −6 |
| 70 | 1,020 | 1,160 | | | |

The fifth column contains the farm's marginal revenue, which has an important feature: Noelle's marginal revenue equal to price is constant at $18 for every output level. The sixth and final column shows the calculation of the net gain per tree, which is equal to marginal revenue minus marginal cost—or, equivalently in this case, market price minus marginal cost. As you can see, it is positive for the 10th through 50th trees; producing each of these trees raises Noelle's profit. For the 60th through 70th trees, however, net gain is negative: producing them would decrease, not increase, profit. (You can verify this by examining Table 12-1.) So a quantity of 50 trees is Noelle's profit-maximizing output; it is the level of output at which marginal cost is equal to the market price, $18.

This example, in fact, illustrates another general rule derived from marginal analysis—the **price-taking firm's optimal output rule,** which says that a price-taking firm's profit is maximized by producing the quantity of output at which the market price is equal to the marginal cost of the last unit produced. That is, *P = MC at the price-taking firm's optimal quantity of output.* In fact, the price-taking firm's optimal output rule is just an application of the optimal output rule to the particular case of a price-taking firm. Why? Because *in the case of a price-taking firm, marginal revenue is equal to the market price.*

A price-taking firm cannot influence the market price by its actions. It always takes the market price as given because it cannot lower the market price by selling more or raise the market price by selling less. So, for a price-taking firm, the additional revenue generated by producing one more unit is always the market price. We will need to keep this fact in mind in future chapters, where we will learn that marginal revenue is not equal to the market price if the industry is not perfectly competitive. As a result, firms are not price-takers when an industry is not perfectly competitive.

For the remainder of this chapter, we will assume that the industry in question is like Christmas tree farming, perfectly competitive. Figure 12-1 shows that Noelle's profit-maximizing quantity of output is, indeed, the number of trees at which the marginal cost of production is equal to price. The figure shows the marginal cost curve, *MC,* drawn from the data in the fourth column of Table 12-2. As in Chapter 9, we plot the marginal cost of increasing output from 10 to 20 trees halfway between 10 and 20, and so on. The horizontal line at $18 is Noelle's **marginal revenue curve.**

Note that whenever a firm is a price-taker, its marginal revenue curve is a horizontal line at the market price: it can sell as much as it likes at the market price. Regardless of whether it sells more or less, the market price is unaffected. *In effect, the individual firm faces a horizontal, perfectly elastic demand curve for its output—an individual demand curve for its output that is equivalent to its marginal revenue curve.* The marginal cost curve crosses the marginal revenue curve at point *E* where *MC* = *MR*. Sure enough, the quantity of output at *E* is 50 trees.

Does this mean that the price-taking firm's production decision can be entirely summed up as "produce up to the point where the marginal cost of production is equal to the price"? No, not quite. Before applying the profit-maximizing principle of marginal analysis to determine how much to produce, a potential producer must as a

The **marginal revenue curve** shows how marginal revenue varies as output varies.

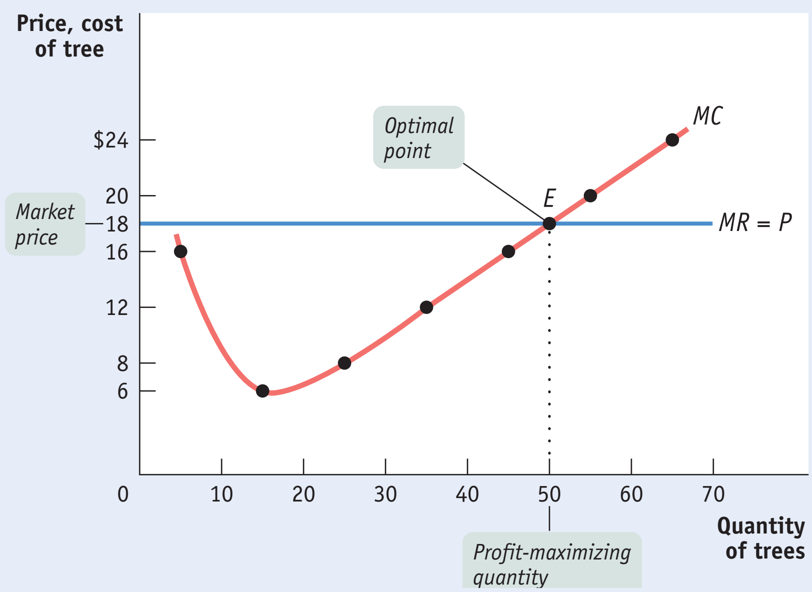
## PITFALLS

### WHAT IF MARGINAL REVENUE AND MARGINAL COST AREN'T EXACTLY EQUAL?

The optimal output rule says that to maximize profit, you should produce the quantity at which marginal revenue is equal to marginal cost. But what do you do if there is no output level at which marginal revenue equals marginal cost? In that case, you produce the largest quantity for which marginal revenue exceeds marginal cost. This is the case in Table 12-2 at an output of 50 trees. The simpler version of the optimal output rule applies when production involves large numbers, such as hundreds or thousands of units. In such cases marginal cost comes in small increments, and there is always a level of output at which marginal cost almost exactly equals marginal revenue.

**FIGURE 12-1 The Price-Taking Firm's Profit-Maximizing Quantity of Output**

At the profit-maximizing quantity of output, the market price is equal to marginal cost. It is located at the point where the marginal cost curve crosses the marginal revenue curve, which is a horizontal line at the market price. Here, the profit-maximizing point is at an output of 50 trees, the output quantity at point *E*.



first step answer an "either–or" question: should it produce at all? If the answer to that question is yes, it then proceeds to the second step—a "how much" decision: maximizing profit by choosing the quantity of output at which marginal cost is equal to price.

To understand why the first step in the production decision involves an "either–or" question, we need to ask how we determine whether it is profitable or unprofitable to produce at all.

## When Is Production Profitable?

Recall from Chapter 9 that a firm's decision whether or not to stay in a given business depends on its *economic profit*—the measure of profit based on the opportunity cost of resources used in the business. To put it a slightly different way: in the calculation of economic profit, a firm's total cost incorporates the implicit cost—the benefits forgone in the next best use of the firm's resources—as well as the explicit cost in the form of actual cash outlays.

In contrast, *accounting profit* is profit calculated using only the explicit costs incurred by the firm. This means that economic profit incorporates the opportunity cost of resources owned by the firm and used in the production of output, while accounting profit does not.

A firm may make positive accounting profit while making zero or even negative economic profit. It's important to understand clearly that a firm's decision to produce or not, to stay in business or to close down permanently, should be based on economic profit, not accounting profit.

So we will assume, as we always do, that the cost numbers given in Tables 12-1 and 12-2 include all costs, implicit as well as explicit, and that the profit numbers in Table 12-1 are therefore economic profit. So what determines whether Noelle's farm earns a profit or generates a loss? The answer is that, *given the farm's cost curves, whether or not it is profitable depends on the market price of trees—specifically, whether the market price is more or less than the farm's minimum average total cost.*

In Table 12-3 we calculate short-run average variable cost and short-run average total cost for Noelle's farm. These are short-run values because we take fixed cost as given. (We'll turn to the effects of changing fixed cost shortly.) The short-run average total cost curve, *ATC*, is shown in Figure 12-2, along with the marginal cost curve, *MC*, from Figure 12-1. As you can see, average total cost is minimized at point *C*, corresponding to an output of 40 trees—the *minimum-cost output*—and an average total cost of $14 per tree.

**TABLE 12-3 Short-Run Average Costs for Noelle's Farm**

| Quantity of trees *Q* | Variable cost *VC* | Total cost *TC* | Short-run average variable cost of tree *AVC = VC/Q* | Short-run average total cost of tree *ATC = TC/Q* |
|---|---|---|---|---|
| 10 | $160.00 | $300.00 | $16.00 | $30.00 |
| 20 | 220.00 | 360.00 | 11.00 | 18.00 |
| 30 | 300.00 | 440.00 | 10.00 | 14.67 |
| 40 | 420.00 | 560.00 | 10.50 | 14.00 |
| 50 | 580.00 | 720.00 | 11.60 | 14.40 |
| 60 | 780.00 | 920.00 | 13.00 | 15.33 |
| 70 | 1,020.00 | 1,160.00 | 14.57 | 16.57 |

To see how these curves can be used to decide whether production is profitable or unprofitable, recall that profit is equal to total revenue minus total cost, $TR - TC$. This means:

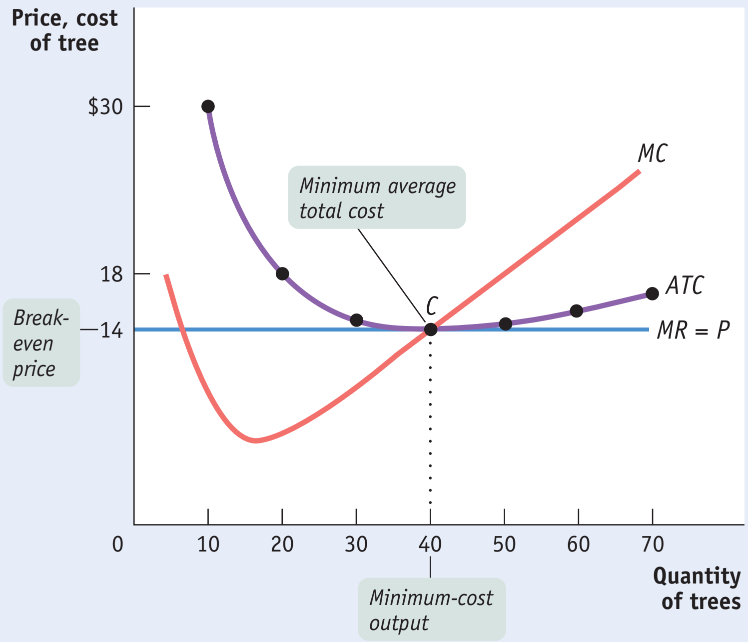
- If the firm produces a quantity at which $TR > TC$, the firm is profitable.
- If the firm produces a quantity at which $TR = TC$, the firm breaks even.
- If the firm produces a quantity at which $TR < TC$, the firm incurs a loss.

We can also express this idea in terms of revenue and cost per unit of output. If we divide profit by the number of units of output, $Q$, we obtain the following expression for profit per unit of output:

**(12-4)** $\text{Profit}/Q = TR/Q - TC/Q$

**FIGURE 12-2 Costs and Production in the Short Run**

This figure shows the marginal cost curve, *MC*, and the short-run average total cost curve, *ATC*. When the market price is $14, output will be 40 trees (the minimum-cost output), represented by point *C*. The price of $14, equal to the firm's minimum average total cost, is the firm's *break-even price.*




*TR/Q* is average revenue, which is the market price. *TC/Q* is average total cost. So a firm is profitable if the market price for its product is more than the average total cost of the quantity the firm produces; a firm loses money if the market price is less than average total cost of the quantity the firm produces. This means:

- If the firm produces a quantity at which $P > ATC$, the firm is profitable.
- If the firm produces a quantity at which $P = ATC$, the firm breaks even.
- If the firm produces a quantity at which $P < ATC$, the firm incurs a loss.

Figure 12-3 illustrates this result, showing how the market price determines whether a firm is profitable. It also shows how profits are depicted graphically. Each panel shows the marginal cost curve, *MC,* and the short-run average total cost curve, *ATC*. Average total cost is minimized at point *C*. Panel (a) shows the case we have already analyzed, in which the market price of trees is $18 per tree. Panel (b) shows the case in which the market price of trees is lower, $10 per tree.

In panel (a), we see that at a price of $18 per tree the profit-maximizing quantity of output is 50 trees, indicated by point *E,* where the marginal cost curve, *MC,* intersects the marginal revenue curve—which for a price-taking firm is a horizontal line at the market price. At that quantity of output, average total cost is $14.40 per tree, indicated by point *Z.* Since the price per tree exceeds average total cost per tree, Noelle's farm is profitable.

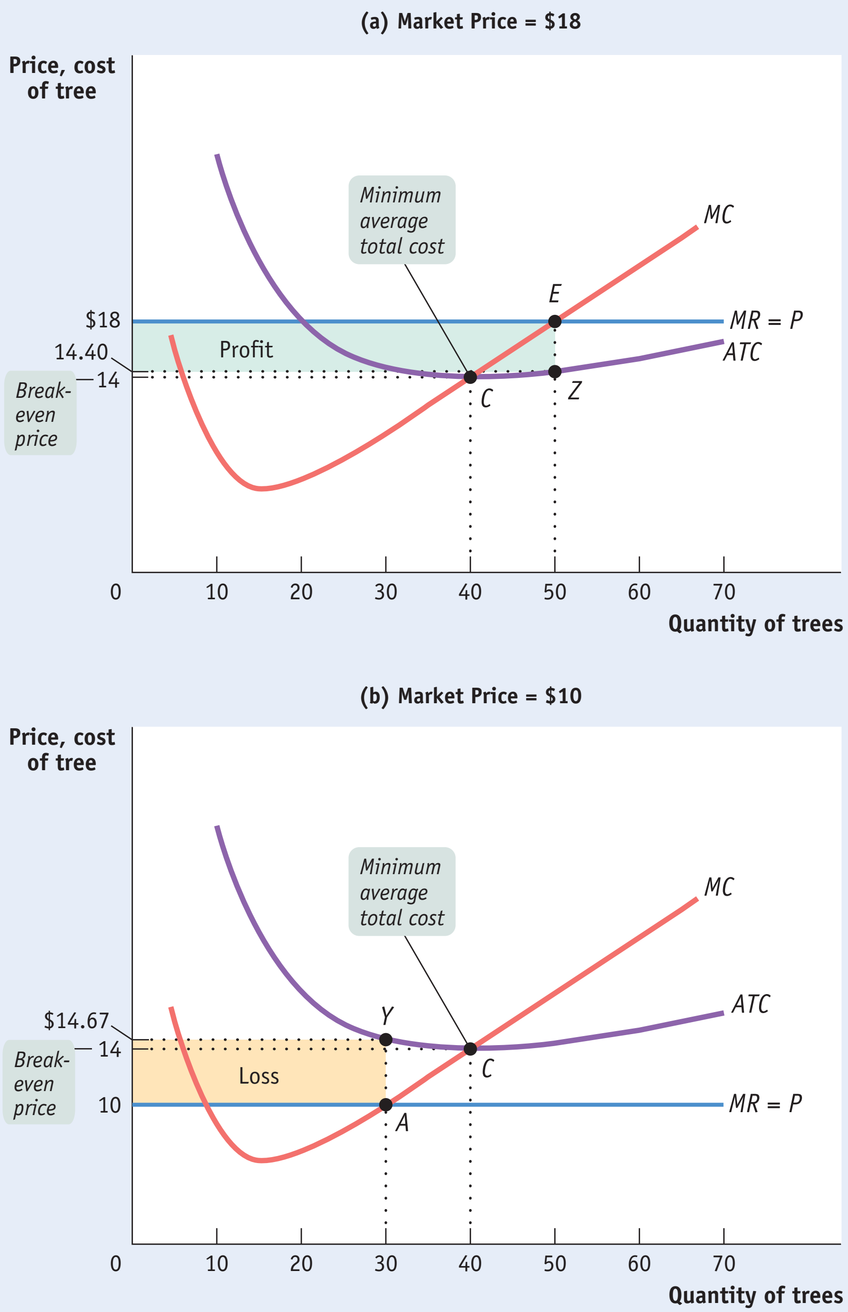
Noelle's total profit when the market price is $18 is represented by the area of the shaded rectangle in panel (a). To see why, notice that total profit can be expressed in terms of profit per unit:

**(12-5)** $\text{Profit} = TR - TC = (TR/Q - TC/Q) \times Q$

or, equivalently,

$$\text{Profit} = (P - ATC) \times Q$$

**FIGURE 12-3 Profitability and the Market Price**




In panel (a) the market price is $18. The farm is profitable because price exceeds minimum average total cost, the break-even price, $14. The farm's optimal output choice is indicated by point *E*, corresponding to an output of 50 trees. The average total cost of producing 50 trees is indicated by point *Z* on the *ATC* curve, corresponding to an amount of $14.40. The vertical distance between *E* and *Z* corresponds to the farm's per-unit profit, $18.00 – $14.40 = $3.60. Total profit is given by the area of the shaded rectangle, 50 × $3.60 = $180.00. In panel (b) the market price is $10; the farm is unprofitable because the price falls below the minimum average total cost, $14. The farm's optimal output choice when producing is indicated by point *A*, corresponding to an output of 30 trees. The farm's per-unit loss, $14.67 – $10.00 = $4.67, is represented by the vertical distance between *A* and *Y*. The farm's total loss is represented by the shaded rectangle, 30 × $4.67 = $140.00 (adjusted for rounding error).

since *P* is equal to *TR*/*Q* and *ATC* is equal to *TC*/*Q*. The height of the shaded rectangle in panel (a) corresponds to the vertical distance between points *E* and *Z*. It is equal to *P* – *ATC* = $18.00 – $14.40 = $3.60 per tree. The shaded rectangle has a width equal to the output: *Q* = 50 trees. So the area of that rectangle is equal to Noelle's profit: 50 trees × $3.60 profit per tree = $180—the same number we calculated in Table 12-1.

What about the situation illustrated in panel (b)? Here the market price of trees is $10 per tree. Setting price equal to marginal cost leads to a profit-maximizing output of 30 trees, indicated by point *A*. At this output, Noelle has an average total cost of \$14.67 per tree, indicated by point *Y*. At the profit-maximizing output quantity—30 trees—average total cost exceeds the market price. This means that Noelle's farm generates a loss, not a profit.

How much does she lose by producing when the market price is \$10? On each tree she loses $ATC - P$ = \$14.67 − \$10.00 = \$4.67, an amount corresponding to the vertical distance between points *A* and *Y*. And she would produce 30 trees, which corresponds to the width of the shaded rectangle. So the total value of the losses is \$4.67 × 30 = \$140.00 (adjusted for rounding error), an amount that corresponds to the area of the shaded rectangle in panel (b).

But how does a producer know, in general, whether or not its business will be profitable? It turns out that the crucial test lies in a comparison of the market price to the producer's *minimum average total cost*. On Noelle's farm, minimum average total cost, which is equal to \$14, occurs at an output quantity of 40 trees, indicated by point *C*.

Whenever the market price exceeds minimum average total cost, the producer can find some output level for which the average total cost is less than the market price. In other words, the producer can find a level of output at which the firm makes a profit. So Noelle's farm will be profitable whenever the market price exceeds \$14. And she will achieve the highest possible profit by producing the quantity at which marginal cost equals the market price.

Conversely, if the market price is less than minimum average total cost, there is no output level at which price exceeds average total cost. As a result, the firm will be unprofitable at any quantity of output. As we saw, at a price of \$10—an amount less than minimum average total cost—Noelle did indeed lose money. By producing the quantity at which marginal cost equals the market price, Noelle did the best she could, but the best that she could do was a loss of \$140. Any other quantity would have increased the size of her loss.

The minimum average total cost of a price-taking firm is called its **break-even price,** the price at which it earns zero profit. (Recall that's *economic profit*.) A firm will earn positive profit when the market price is above the break-even price, and it will suffer losses when the market price is below the break-even price. Noelle's break-even price of \$14 is the price at point *C* in Figures 12-2 and 12-3.

The **break-even price** of a price-taking firm is the market price at which it earns zero profit.

So the rule for determining whether a producer of a good is profitable depends on a comparison of the market price of the good to the producer's break-even price—its minimum average total cost:

- Whenever the market price exceeds minimum average total cost, the producer is profitable.
- Whenever the market price equals minimum average total cost, the producer breaks even.
- Whenever the market price is less than minimum average total cost, the producer is unprofitable.

## The Short-Run Production Decision

You might be tempted to say that if a firm is unprofitable because the market price is below its minimum average total cost, it shouldn't produce any output. In the short run, however, this conclusion isn't right.

In the short run, sometimes the firm should produce even if price falls below minimum average total cost. The reason is that total cost includes *fixed cost*—cost that does not depend on the amount of output produced and can only be altered in the long run.

In the short run, fixed cost must still be paid, regardless of whether or not a firm produces. For example, if Noelle rents a refrigerated truck for the year, she has to pay the rent on the truck regardless of whether she produces any trees. *Since it cannot be changed in the short run, her fixed cost is irrelevant to her decision about whether to produce or shut down in the short run.*

A firm will cease production in the short run if the market price falls below the **shut-down price,** which is equal to minimum average variable cost.

Although fixed cost should play no role in the decision about whether to produce in the short run, other costs—variable costs—do matter. An example of variable costs is the wages of workers who must be hired to help with planting and harvesting. Variable costs can be saved by *not* producing; so they should play a role in determining whether or not to produce in the short run.

Let's turn to Figure 12-4: it shows both the short-run average total cost curve, *ATC,* and the short-run average variable cost curve, *AVC,* drawn from the information in Table 12-3. Recall that the difference between the two curves—the vertical distance between them—represents average fixed cost, the fixed cost per unit of output, *FC/Q*.

Because the marginal cost curve has a "swoosh" shape—falling at first before rising—the short-run average variable cost curve is U-shaped: the initial fall in marginal cost causes average variable cost to fall as well, before rising marginal cost eventually pulls it up again. The short-run average variable cost curve reaches its minimum value of $10 at point *A,* at an output of 30 trees.

We are now prepared to fully analyze the optimal production decision in the short run. We need to consider two cases:

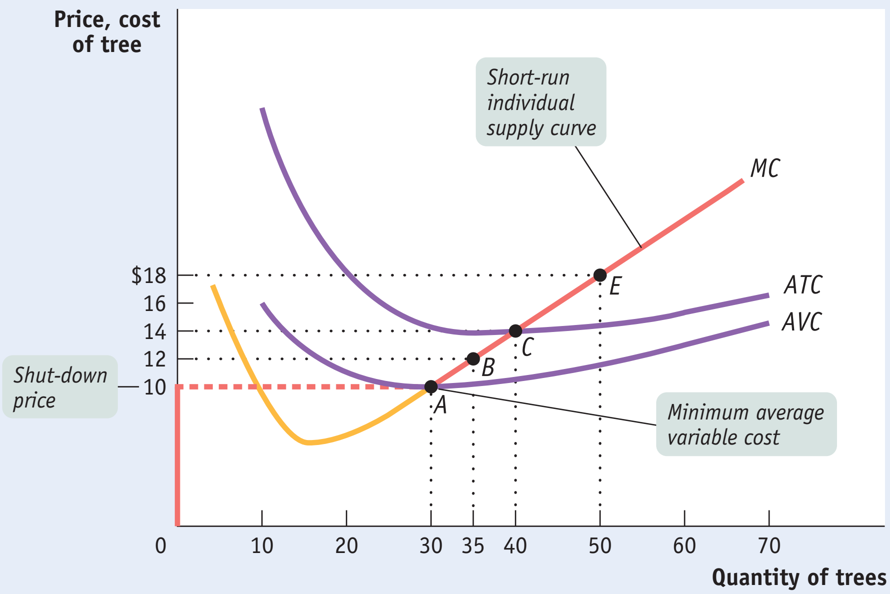
1. When the market price is below minimum average *variable* cost
2. When the market price is greater than or equal to minimum average *variable* cost

When the market price is below minimum average variable cost, the price the firm receives per unit is not covering its variable cost per unit. A firm in this situation should cease production immediately. Why? Because there is no level of output at which the firm's total revenue covers its variable costs—the costs it can avoid by not operating.

In this case the firm maximizes its profits by not producing at all—by, in effect, minimizing its losses. It will still incur a fixed cost in the short run, but it will no longer incur any variable cost. This means that the minimum average variable cost is equal to the **shut-down price,** the price at which the firm ceases production in the short run. In the example of Noelle's tree farm, she will cease production in the short run by laying off workers and halting all planting and harvesting of trees.

**FIGURE 12-4 The Short-Run Individual Supply Curve**

When the market price equals or exceeds Noelle's *shut-down price* of $10, the minimum average variable cost indicated by point *A*, she will produce the output quantity at which marginal cost is equal to price. So at any price equal to or above the minimum average *variable* cost, the short-run individual supply curve is the firm's marginal cost curve; this corresponds to the upward-sloping segment of the individual supply curve. When market price falls below minimum average variable cost, the firm ceases operation in the short run. This corresponds to the vertical segment of the individual supply curve along the vertical axis.



When price is greater than minimum average variable cost, however, the firm should produce in the short run. In this case, the firm maximizes profit—or minimizes loss—by choosing the output quantity at which its marginal cost is equal to the market price. For example, if the market price of each tree is $18, Noelle should produce at point *E* in Figure 12-4, corresponding to an output of 50 trees. Note that point *C* in Figure 12-4 corresponds to the farm's break-even price of $14 per tree. Since *E* lies above *C*, Noelle's farm will be profitable; she will generate a per-tree profit of $18.00 – $14.40 = $3.60 when the market price is $18.

But what if the market price lies between the shut-down price and the break-even price—that is, between minimum average *variable* cost and minimum average *total* cost? In the case of Noelle's farm, this corresponds to prices anywhere between $10 and $14—say, a market price of $12. At $12, Noelle's farm is not profitable; since the market price is below minimum average total cost, the farm is losing the difference between price and average total cost per unit produced.

Yet even if it isn't covering its total cost per unit, it is covering its variable cost per unit and some—but not all—of the fixed cost per unit. If a firm in this situation shuts down, it would incur no variable cost but would incur the *full* fixed cost. As a result, shutting down generates an even greater loss than continuing to operate.

This means that whenever price lies between minimum average total cost and minimum average variable cost, the firm is better off producing some output in the short run. The reason is that by producing, it can cover its variable cost per unit and at least some of its fixed cost, even though it is incurring a loss. In this case, the firm maximizes profit—that is, minimizes loss—by choosing the quantity of output at which its marginal cost is equal to the market price. So if Noelle faces a market price of $12 per tree, her profit-maximizing output is given by point *B* in Figure 12-4, corresponding to an output of 35 trees.

It's worth noting that the decision to produce when the firm is covering its variable costs but not all of its fixed cost is similar to the decision to ignore *sunk costs*. You may recall from Chapter 9 that a sunk cost is a cost that has already been incurred and cannot be recouped; and because it cannot be changed, it should have no effect on any current decision.

In the short-run production decision, fixed cost is, in effect, like a sunk cost—it has been spent, and it can't be recovered in the short run. This comparison also illustrates why variable cost does indeed matter in the short run: it can be avoided by not producing.

And what happens if market price is exactly equal to the shut-down price, minimum average variable cost? In this instance, the firm is indifferent between producing 30 units or 0 units. As we'll see shortly, this is an important point when looking at the behavior of an industry as a whole. For the sake of clarity, we'll assume that the firm, although indifferent, does indeed produce output when price is equal to the shut-down price.

Putting everything together, we can now draw the **short-run individual supply curve** of Noelle's farm, the red line in Figure 12-4; it shows how the profit-maximizing quantity of output in the short run depends on the price. As you can see, the curve is in two segments. The upward-sloping red segment starting at point *A* shows the short-run profit-maximizing output when market price is equal to or above the shut-down price of $10 per tree.

As long as the market price is equal to or above the shut-down price, Noelle produces the quantity of output at which marginal cost is equal to the market price. That is, at market prices equal to or above the shut-down price, the firm's short-run supply curve corresponds to its marginal cost curve. But at any market price below minimum average variable cost—in this case, $10 per tree—the firm shuts down and output drops to zero in the short run. This corresponds to the vertical segment of the curve that lies on top of the vertical axis.

Do firms really shut down temporarily without going out of business? Yes. In fact, in some businesses temporary shut-downs are routine. The most common

The **short-run individual supply curve** shows how an individual producer's profit-maximizing output quantity depends on the market price, taking fixed cost as given.

examples are industries in which demand is highly seasonal, like outdoor amusement parks in climates with cold winters. Such parks would have to offer very low prices to entice customers during the colder months—prices so low that the owners would not cover their variable costs (principally wages and electricity). The wiser choice economically is to shut down until warm weather brings enough customers who are willing to pay a higher price.

## Changing Fixed Cost

istockphoto

Buying or selling equipment allows a firm to change its fixed cost.

Although fixed cost cannot be altered in the short run, in the long run firms can acquire or get rid of machines, buildings, and so on. As we learned in Chapter 11, in the long run the level of fixed cost is a matter of choice. There we saw that a firm will choose the level of fixed cost that minimizes the average total cost for its desired output quantity. Now we will focus on an even bigger question facing a firm when choosing its fixed cost: whether to incur *any* fixed cost at all by remaining in its current business.

In the long run, a producer can always eliminate fixed cost by selling off its plant and equipment. If it does so, of course, it can't ever produce—it has exited the industry. In contrast, a potential producer can take on some fixed cost by acquiring machines and other resources, which puts it in a position to produce—it can enter the industry. In most perfectly competitive industries the set of producers, although fixed in the short run, changes in the long run as firms enter or exit the industry.

Consider Noelle's farm once again. In order to simplify our analysis, we will sidestep the problem of choosing among several possible levels of fixed cost. Instead, we will assume from now on that Noelle has only one possible choice of fixed cost if she operates, the amount of $140, Noelle's minimum average total cost, that was the basis for the calculations in Tables 12-1, 12-2, and 12-3. (With this assumption, Noelle's short-run average total cost curve and long-run average total cost curve are one and the same.) Alternatively, she can choose a fixed cost of zero if she exits the industry.

Suppose that the market price of trees is consistently less than $14 over an extended period of time. In that case, Noelle never fully covers her fixed cost: her business runs at a persistent loss. In the long run, then, she can do better by closing her business and leaving the industry. In other words, *in the long run* firms will exit an industry if the market price is consistently less than their break-even price—their minimum average total cost.

Conversely, suppose that the price of Christmas trees is consistently above the break-even price, $14, for an extended period of time. Because her farm is profitable, Noelle will remain in the industry and continue producing.

But things won't stop there. The Christmas tree industry meets the criterion of *free entry*: there are many potential tree producers because the necessary inputs are easy to obtain. And the cost curves of those potential producers are likely to be similar to those of Noelle, since the technology used by other producers is likely to be very similar to that used by Noelle. If the price is high enough to generate profits for existing producers, it will also attract some of these potential producers into the industry. So *in the long run* a price in excess of $14 should lead to entry: new producers will come into the Christmas tree industry.

As we will see next, exit and entry lead to an important distinction between the *short-run industry supply curve* and the *long-run industry supply curve*.

## Summing Up: The Perfectly Competitive Firm's Profitability and Production Conditions

In this chapter, we've studied where the supply curve for a perfectly competitive, price-taking firm comes from. Every perfectly competitive firm makes its production decisions by maximizing profit, and these decisions determine the supply curve. Table 12-4 summarizes the perfectly competitive firm's profitability and production conditions. It also relates them to entry into and exit from the industry.

**TABLE 12-4 Summary of the Perfectly Competitive Firm's Profitability and Production Conditions**

| **Profitability condition (minimum *ATC* = break-even price)** | **Result** |
|---|---|
| $P >$ minimum *ATC* | Firm profitable. Entry into industry in the long run. |
| $P =$ minimum *ATC* | Firm breaks even. No entry into or exit from industry in the long run. |
| $P <$ minimum *ATC* | Firm unprofitable. Exit from industry in the long run. |
| **Production condition (minimum *AVC* = shut-down price)** | **Result** |
| $P >$ minimum *AVC* | Firm produces in the short run. If $P <$ minimum *ATC*, firm covers variable cost and some but not all of fixed cost. If $P >$ minimum *ATC*, firm covers all variable cost and fixed cost. |
| $P =$ minimum *AVC* | Firm indifferent between producing in the short run or not. Just covers variable cost. |
| $P <$ minimum *AVC* | Firm shuts down in the short run. Does not cover variable cost. |

## ECONOMICS ▶ *in Action*

### Farmers Move Up Their Supply Curves

To reduce gasoline consumption, Congress mandated that increasing amounts of biofuel, mostly corn-based ethanol, be added to the American fuel supply—from 4 billion gallons of ethanol in 2006 to 14 billion gallons in 2013. The unsurprising result of this mandate was that the demand for corn skyrocketed, along with its price. In 2012, farmers received an average price per bushel of about \$7 to \$8, compared to less than \$2 in 2005. Being the smart profit-maximizers that they are, American farmers responded by planting more corn and less of other crops such as cotton. By 2013, U.S. farmers had delivered five straight years of increase in acreage planted in corn.

If this sounds like a sure way to make a profit, think again. Corn farmers were taking a considerable gamble in planting more corn as their costs went up. Consider the cost of fertilizer, an important input. Corn requires more fertilizer than other crops, and with more farmers planting corn, the increased demand for fertilizer led to a price increase. In 2006 and 2007, fertilizer prices surged to five times their 2005 level; by 2013 prices were still twice as high.

The pull of higher corn prices also lifted farmland prices to record levels—levels so high that by 2013 there was talk of a bubble in farmland prices. Remember that even if a farmer owns land outright, that farmer still incurs an opportunity cost when planting rather than leasing the land or selling it to someone else. In 2013, the average price of an acre of farmland was up almost 300% over the past decade, with the price of some land increasing by as much as 1,000%.

Despite the risk and increase in costs, what corn farmers did made complete economic sense. By planting more corn, each farmer moved up his or her individual supply curve. And because the individual supply curve is the marginal cost curve, each farmer's costs also went up because of the need to use more inputs that are now more expensive to obtain.

Dave Reede/All Canada Photos/Superstock

Although farmers were taking a big gamble by cutting the size of their other crops to plant more corn, their decision made good economic sense.

So the moral of the story is that farmers will increase their corn acreage until the marginal cost of producing corn is approximately equal to the market price of corn—which shouldn't come as a surprise, because corn production satisfies all the requirements of a perfectly competitive industry.

**Quick Review**

- A producer chooses output according to the **optimal output rule.** For a price-taking firm, **marginal revenue** is equal to price and it chooses output according to the **price-taking firm's optimal output rule** ***P* = *MC*.**
- A firm is profitable whenever price exceeds its **break-even price,** equal to its minimum average total cost. Below that price it is unprofitable. It breaks even when price is equal to its break-even price.
- Fixed cost is irrelevant to the firm's optimal short-run production decision. When price exceeds its **shut-down price,** minimum average variable cost, the price-taking firm produces the quantity of output at which marginal cost equals price. When price is lower than its shut-down price, it ceases production in the short run. This defines the firm's **short-run individual supply curve.**
- Over time, fixed cost matters. If price consistently falls below minimum average total cost, a firm will exit the industry. If price exceeds minimum average total cost, the firm is profitable and will remain in the industry; other firms will enter the industry in the long run.

**Check Your Understanding 12-2**

1. Draw a short-run diagram showing a U-shaped average total cost curve, a U-shaped average variable cost curve, and a "swoosh"-shaped marginal cost curve. On it, indicate the range of output and the range of price for which the following actions are optimal.
   a. The firm shuts down immediately.
   b. The firm operates in the short run despite sustaining a loss.
   c. The firm operates while making a profit.
2. The state of Maine has a very active lobster industry, which harvests lobsters during the summer months. During the rest of the year, lobsters can be obtained from other parts of the world but at a much higher price. Maine is also full of "lobster shacks," roadside restaurants serving lobster dishes that are open only during the summer. Explain why it is optimal for lobster shacks to operate only during the summer.

Solutions appear at back of book.

# The Industry Supply Curve

Why will an increase in the demand for Christmas trees lead to a large price increase at first but a much smaller increase in the long run? The answer lies in the behavior of the **industry supply curve—**the relationship between the price and the total output of an industry as a whole. The industry supply curve is what we referred to in earlier chapters as *the* supply curve or the market supply curve. But here we take some extra care to distinguish between the *individual supply curve* of a single firm and the supply curve of the industry as a whole.

As you might guess from the previous section, the industry supply curve must be analyzed in somewhat different ways for the short run and the long run. Let's start with the short run.

## The Short-Run Industry Supply Curve

Recall that in the short run the number of producers in an industry is fixed—there is no entry or exit. And you may also remember from Chapter 3 that the market supply curve is the horizontal sum of the individual supply curves of all producers—you find it by summing the total output across all suppliers at every given price. We will do that exercise here under the assumption that all the producers are alike—an assumption that makes the derivation particularly simple. So let's assume that there are 100 Christmas tree farms, each with the same costs as Noelle's farm.

The **industry supply curve** shows the relationship between the price of a good and the total output of the industry as a whole.

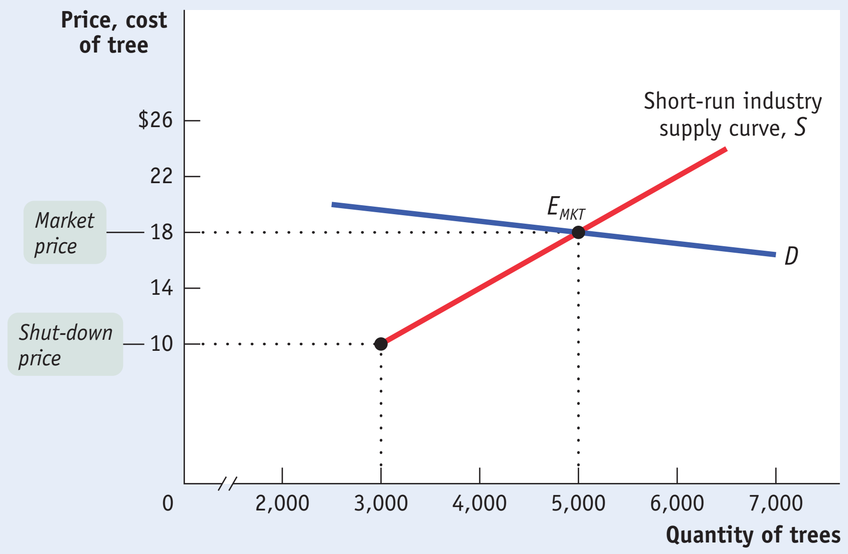
The **short-run industry supply curve** shows how the quantity supplied by an industry depends on the market price given a fixed number of producers.

Each of these 100 farms will have an individual short-run supply curve like the one in Figure 12-4. At a price below \$10, no farms will produce. At a price of \$10 or more, each farm will produce the quantity of output at which its marginal cost is equal to the market price. As you can see from Figure 12-4, this will lead each farm to produce 40 trees if the price is \$14 per tree, 50 trees if the price is \$18, and so on. So if there are 100 tree farms and the price of Christmas trees is \$18 per tree, the industry as a whole will produce 5,000 trees, corresponding to 100 farms × 50 trees per farm, and so on. The result is the **short-run industry supply curve,** shown as *S* in Figure 12-5. This curve shows the quantity that producers will supply at each price, *taking the number of producers as given.*

The demand curve *D* in Figure 12-5 crosses the short-run industry supply curve at $E_{MKT}$, corresponding to a price of \$18 and a quantity of 5,000 trees. Point $E_{MKT}$

**FIGURE 12-5 The Short-Run Market Equilibrium**

The short-run industry supply curve, *S*, is the industry supply curve taking the number of producers—here, 100—as given. It is generated by adding together the individual supply curves of the 100 producers. Below the shut-down price of $10, no producer wants to produce in the short run. Above $10, the short-run industry supply curve slopes upward, as each producer increases output as price increases. It intersects the demand curve, *D*, at point $E_{MKT}$, the point of short-run market equilibrium, corresponding to a market price of $18 and a quantity of 5,000 trees.




is a **short-run market equilibrium:** the quantity supplied equals the quantity demanded, taking the number of producers as given. But the long run may look quite different, because in the long run farms may enter or exit the industry.

There is a **short-run market equilibrium** when the quantity supplied equals the quantity demanded, taking the number of producers as given.

## The Long-Run Industry Supply Curve

Suppose that in addition to the 100 farms currently in the Christmas tree business, there are many other potential producers. Suppose also that each of these potential producers would have the same cost curves as existing producers like Noelle if it entered the industry.

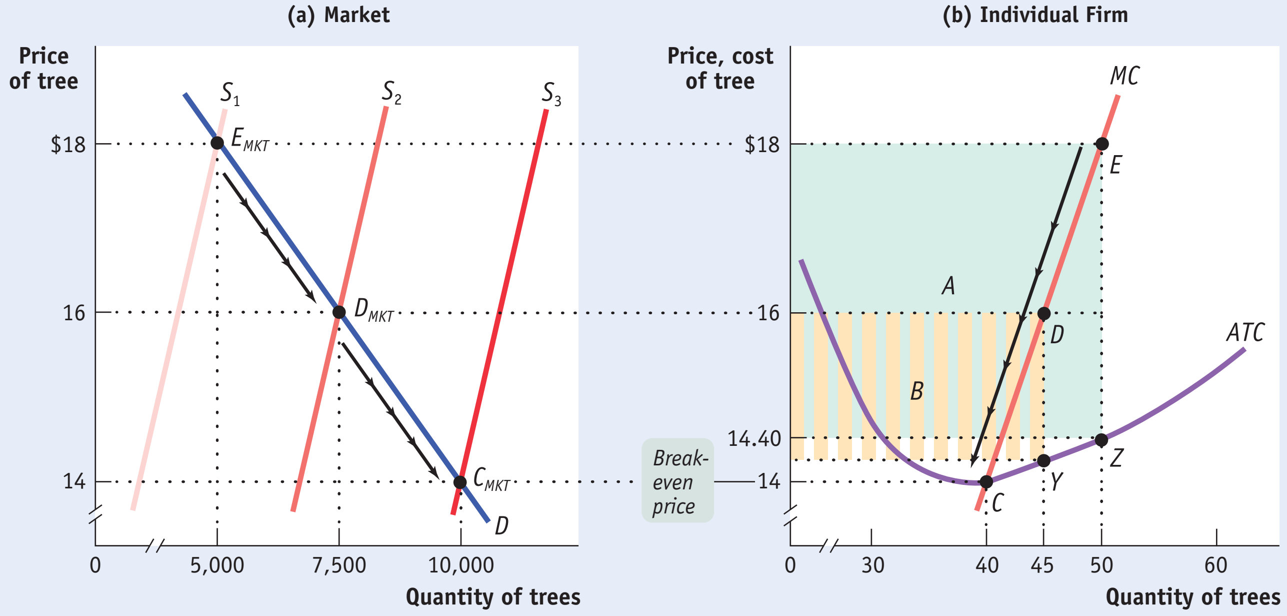
When will additional producers enter the industry? Whenever existing producers are making a profit—that is, whenever the market price is above the break-even price of $14 per tree, the minimum average total cost of production. For example, at a price of $18 per tree, new firms will enter the industry.

What will happen as additional producers enter the industry? Clearly, the quantity supplied at any given price will increase. The short-run industry supply curve will shift to the right. This will, in turn, alter the market equilibrium and result in a lower market price. Existing firms will respond to the lower market price by reducing their output, but the total industry output will increase because of the larger number of firms in the industry.

Figure 12-6 illustrates the effects of this chain of events on an existing firm and on the market; panel (a) shows how the market responds to entry, and panel (b) shows how an individual existing firm responds to entry. (Note that these two graphs have been rescaled in comparison to Figures 12-4 and 12-5 to better illustrate how profit changes in response to price.) In panel (a), $S_1$ is the initial short-run industry supply curve, based on the existence of 100 producers. The initial short-run market equilibrium is at $E_{MKT}$, with an equilibrium market price of $18 and a quantity of 5,000 trees. At this price existing producers are profitable, which is reflected in panel (b): an existing firm makes a total profit represented by the green-shaded rectangle labeled *A* when market price is $18.

These profits will induce new producers to enter the industry, shifting the short-run industry supply curve to the right. For example, the short-run industry supply curve when the number of producers has increased to 167 is $S_2$.

FIGURE 12-6 The Long-Run Market Equilibrium




Point $E_{MKT}$ of panel (a) shows the initial short-run market equilibrium. Each of the 100 existing producers makes an economic profit, illustrated in panel (b) by the green rectangle labeled *A*, the profit of an existing firm. Profits induce entry by additional producers, shifting the short-run industry supply curve outward from $S_1$ to $S_2$ in panel (a), resulting in a new short-run equilibrium at point $D_{MKT}$, at a lower market price of $16 and higher industry output. Existing firms reduce output and profit falls to the area given by the striped rectangle labeled *B* in panel (b). Entry continues to shift out the short-run industry supply curve, as price falls and industry output increases yet again. Entry of new firms ceases at point $C_{MKT}$ on supply curve $S_3$ in panel (a). Here market price is equal to the break-even price; existing producers make zero economic profits, and there is no incentive for entry or exit. So $C_{MKT}$ is also a long-run market equilibrium.

Corresponding to this supply curve is a new short-run market equilibrium labeled $D_{MKT}$, with a market price of $16 and a quantity of 7,500 trees. At $16, each firm produces 45 trees, so that industry output is 167 × 45 = 7,500 trees (rounded).

From panel (b) you can see the effect of the entry of 67 new producers on an existing firm: the fall in price causes it to reduce its output, and its profit falls to the area represented by the striped rectangle labeled *B*.

Although diminished, the profit of existing firms at $D_{MKT}$ means that entry will continue and the number of firms will continue to rise. If the number of producers rises to 250, the short-run industry supply curve shifts out again to $S_3$, and the market equilibrium is at $C_{MKT}$, with a quantity supplied and demanded of 10,000 trees and a market price of $14 per tree.

Like $E_{MKT}$ and $D_{MKT}$, $C_{MKT}$ is a short-run equilibrium. But it is also something more. Because the price of $14 is each firm's break-even price, an existing producer makes zero economic profit—neither a profit nor a loss, earning only the opportunity cost of the resources used in production—when producing its profit-maximizing output of 40 trees. At this price there is no incentive either for potential producers to enter or for existing producers to exit the industry. So $C_{MKT}$ corresponds to a **long-run market equilibrium**—a situation in which the quantity supplied equals the quantity demanded given that sufficient time has elapsed for producers to either enter or exit the industry. In a long-run market equilibrium, all existing and potential producers have fully adjusted to their optimal long-run choices; as a result, no producer has an incentive to either enter or exit the industry.

A market is in **long-run market equilibrium** when the quantity supplied equals the quantity demanded, given that sufficient time has elapsed for entry into and exit from the industry to occur.

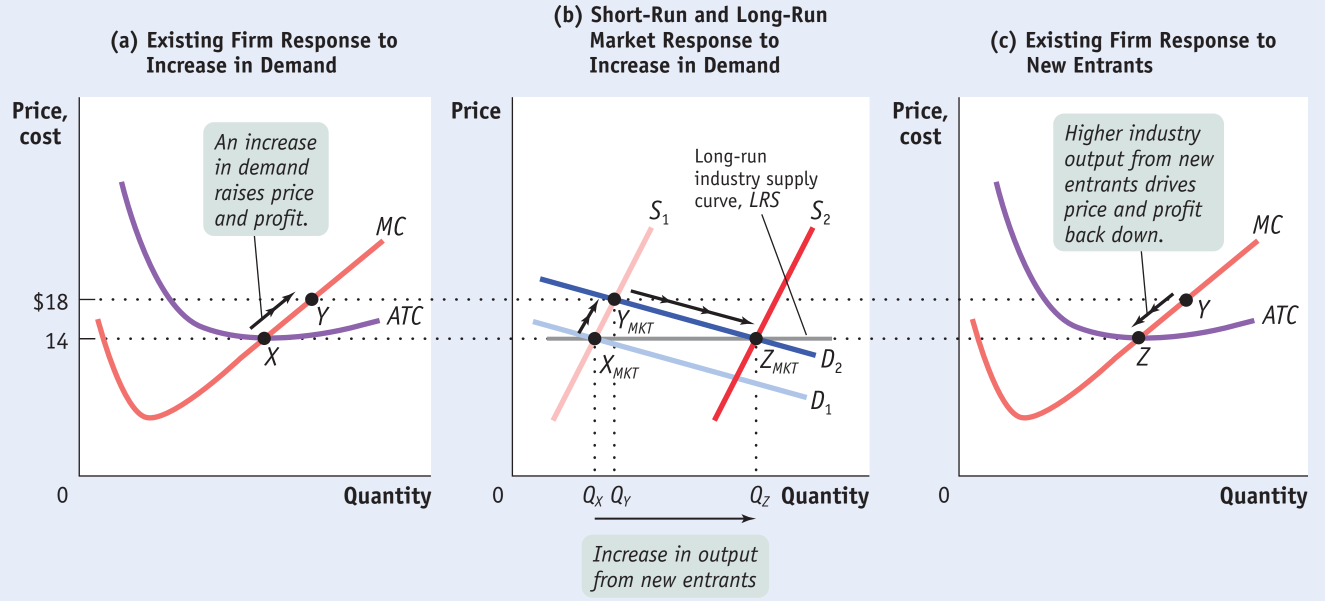
To explore further the significance of the difference between short-run and long-run equilibrium, consider the effect of an increase in demand on an industry with free entry that is initially in long-run equilibrium. Panel (b) in Figure 12-7 shows the market adjustment; panels (a) and (c) show how an existing individual firm behaves during the process.

In panel (b) of Figure 12-7, $D_1$ is the initial demand curve and $S_1$ is the initial short-run industry supply curve. Their intersection at point $X_{MKT}$ is both a short-run and a long-run market equilibrium because the equilibrium price of \$14 leads to zero economic profit—and therefore neither entry nor exit. It corresponds to point $X$ in panel (a), where an individual existing firm is operating at the minimum of its average total cost curve.

Now suppose that the demand curve shifts out for some reason to $D_2$. As shown in panel (b), in the short run, industry output moves along the short-run industry supply curve $S_1$ to the new short-run market equilibrium at $Y_{MKT}$, the intersection of $S_1$ and $D_2$. The market price rises to \$18 per tree, and industry output increases from $Q_X$ to $Q_Y$. This corresponds to an existing firm's movement from $X$ to $Y$ in panel (a) as the firm increases its output in response to the rise in the market price.

But we know that $Y_{MKT}$ is not a long-run equilibrium, because \$18 is higher than minimum average total cost, so existing producers are making economic profits. This will lead additional firms to enter the industry.

**FIGURE 12-7 The Effect of an Increase in Demand in the Short Run and the Long Run**




Panel (b) shows how an industry adjusts in the short and long run to an increase in demand; panels (a) and (c) show the corresponding adjustments by an existing firm. Initially the market is at point $X_{MKT}$ in panel (b), a short-run and long-run equilibrium at a price of \$14 and industry output of $Q_X$. An existing firm makes zero economic profit, operating at point $X$ in panel (a) at minimum average total cost. Demand increases as $D_1$ shifts rightward to $D_2$ in panel (b), raising the market price to \$18. Existing firms increase their output, and industry output moves along the short-run industry supply curve $S_1$ to a short-run equilibrium at $Y_{MKT}$. Correspondingly, the existing firm in panel (a) moves from point $X$ to point $Y$. But at a price of \$18 existing firms are profitable. As shown in panel (b), in the long run new entrants arrive and the short-run industry supply curve shifts rightward, from $S_1$ to $S_2$. There is a new equilibrium at point $Z_{MKT}$, at a lower price of \$14 and higher industry output of $Q_Z$. An existing firm responds by moving from $Y$ to $Z$ in panel (c), returning to its initial output level and zero economic profit. Production by new entrants accounts for the total increase in industry output, $Q_Z - Q_X$. Like $X_{MKT}$, $Z_{MKT}$ is also a short-run and long-run equilibrium: with existing firms earning zero economic profit, there is no incentive for any firms to enter or exit the industry. The horizontal line passing through $X_{MKT}$ and $Z_{MKT}$, $LRS$, is the long-run industry supply curve: at the break-even price of \$14, producers will produce any amount that consumers demand in the long run.

The **long-run industry supply curve** shows how the quantity supplied responds to the price once producers have had time to enter or exit the industry.

Over time entry will cause the short-run industry supply curve to shift to the right. In the long run, the short-run industry supply curve will have shifted out to $S_2$, and the equilibrium will be at $Z_{MKT}$—with the price falling back to $14 per tree and industry output increasing yet again, from $Q_Y$ to $Q_Z$. Like $X_{MKT}$ before the increase in demand, $Z_{MKT}$ is both a short-run and a long-run market equilibrium.

The effect of entry on an existing firm is illustrated in panel (c), in the movement from $Y$ to $Z$ along the firm's individual supply curve. The firm reduces its output in response to the fall in the market price, ultimately arriving back at its original output quantity, corresponding to the minimum of its average total cost curve. In fact, every firm that is now in the industry—the initial set of firms and the new entrants—will operate at the minimum of its average total cost curve, at point $Z$. This means that the entire increase in industry output, from $Q_X$ to $Q_Z$, comes from production by new entrants.

The line *LRS* that passes through $X_{MKT}$ and $Z_{MKT}$ in panel (b) is the **long-run industry supply curve.** It shows how the quantity supplied by an industry responds to the price given that producers have had time to enter or exit the industry.

In this particular case, the long-run industry supply curve is horizontal at $14. In other words, in this industry supply is *perfectly elastic* in the long run: given time to enter or exit, producers will supply any quantity that consumers demand at a price of $14. Perfectly elastic long-run supply is actually a good assumption for many industries. In this case we speak of there being *constant costs across the industry*: each firm, regardless of whether it is an incumbent or a new entrant, faces the same cost structure (that is, they each have the same cost curves). Industries that satisfy this condition are industries in which there is a perfectly elastic supply of inputs—industries like agriculture or bakeries.

In other industries, however, even the long-run industry supply curve slopes upward. The usual reason for this is that producers must use some input that is in limited supply (that is, inelastically supplied). As the industry expands, the price of that input is driven up. Consequently, later entrants in the industry find that they have a higher cost structure than early entrants. An example is beachfront resort hotels, which must compete for a limited quantity of prime beachfront property. Industries that behave like this are said to have *increasing costs across the industry*.

It is possible for the long-run industry supply curve to slope downward. This can occur when an industry faces increasing returns to scale, in which average costs fall as output rises. Notice we said that the *industry* faces increasing returns. However, when increasing returns apply at the level of the individual firm, the industry usually ends up dominated by a small number of firms (an *oligopoly*) or a single firm (a *monopoly*).

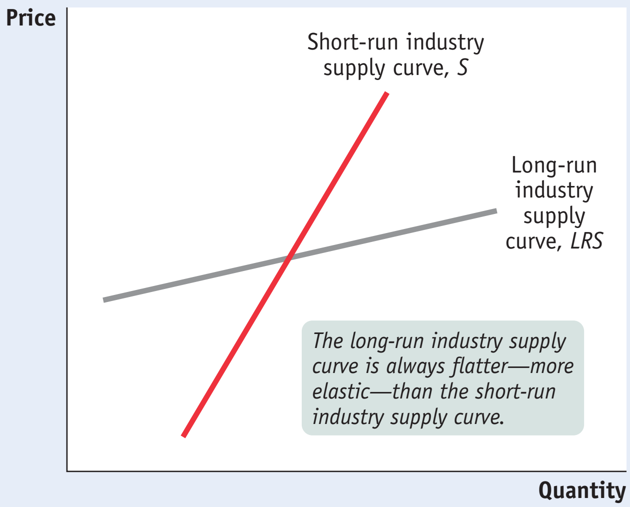
In some cases, the advantages of large scale for an entire industry accrue to all firms in that industry. For example, the costs of new technologies such as solar panels tend to fall as the industry grows because that growth leads to improved knowledge, a larger pool of workers with the right skills, and so on.

Regardless of whether the long-run industry supply curve is horizontal or upward sloping or even downward sloping, the long-run price elasticity of supply is *higher* than the short-run price elasticity whenever there is free entry and exit. As shown in Figure 12-8, the long-run industry supply curve is always flatter than the short-run industry supply curve. The reason is entry and exit: a high price caused by an increase in demand attracts entry by new producers, resulting in a rise in industry output and an eventual fall in price; a low price caused by a decrease in demand induces existing firms to exit, leading to a fall in industry output and an eventual increase in price.

The distinction between the short-run industry supply curve and the long-run industry supply curve is very important in practice. We often see a sequence of events like that shown in Figure 12-7: an increase in demand initially leads to a large price increase, but prices return to their initial level once new firms have entered the industry. Or we see the sequence in reverse: a fall in demand reduces prices in the short run, but they return to their initial level as producers exit the industry.

**FIGURE 12-8 Comparing the Short-Run and Long-Run Industry Supply Curves**

The long-run industry supply curve may slope upward, but it is always flatter—more elastic—than the short-run industry supply curve. This is because of entry and exit: a higher price attracts new entrants in the long run, resulting in a rise in industry output and a fall in price; a lower price induces existing producers to exit in the long run, generating a fall in industry output and an eventual rise in price.




## The Cost of Production and Efficiency in Long-Run Equilibrium

Our analysis leads us to three conclusions about the cost of production and efficiency in the long-run equilibrium of a perfectly competitive industry. These results will be important in our discussion in Chapter 13 of how monopoly gives rise to inefficiency.

First, in a perfectly competitive industry in equilibrium, the value of marginal cost is the same for all firms. That's because all firms produce the quantity of output at which marginal cost equals the market price, and as price-takers they all face the same market price.

Second, in a perfectly competitive industry with free entry and exit, each firm will have zero economic profit in long-run equilibrium. Each firm produces the quantity of output that minimizes its average total cost—corresponding to point *Z* in panel (c) of Figure 12-7. So the total cost of production of the industry's output is minimized in a perfectly competitive industry.

The exception is an industry with increasing costs across the industry. Given a sufficiently high market price, early entrants make positive economic profits, but the last entrants do not as the market price falls. Costs are minimized for later entrants, as the industry reaches long-run equilibrium, but not necessarily for the early ones.

The third and final conclusion is that the long-run market equilibrium of a perfectly competitive industry is efficient: no mutually beneficial transactions go unexploited. To understand this, we need to recall a fundamental requirement for efficiency: all consumers who have a willingness to pay greater than or equal to sellers' costs actually get the good. We also learned that when a market is efficient (except under certain, well-defined conditions), the market price matches all consumers with a willingness to pay greater than or equal to the market price to all sellers who have a cost of producing the good less than or equal to the market price.

So in the long-run equilibrium of a perfectly competitive industry, production is efficient: costs are minimized and no resources are wasted. In addition, the allocation of goods to consumers is efficient: every consumer willing to pay the cost of producing a unit of the good gets it. Indeed, no mutually beneficial transaction is left unexploited. Moreover, this condition tends to persist over time as the environment changes: the force of competition makes producers responsive to changes in consumers' desires and to changes in technology.

**PITFALLS**

**ECONOMIC PROFIT, AGAIN**

Some readers may wonder why a firm would want to enter an industry if the market price is only slightly greater than the break-even price. Wouldn't a firm prefer to go into another business that yields a higher profit?

The answer is that here, as always, when we calculate cost, we mean *opportunity cost*—that is, cost that includes the return a firm could get by using its resources elsewhere. And so the profit that we calculate is *economic profit;* if the market price is above the break-even level, no matter how slightly, the firm can earn more in this industry than they could elsewhere.

## ECONOMICS in Action

### From Global Wine Glut to Shortage

Thinkstock/Getty Images

A wine shortage may soon become a wine glut as growers respond by planting more vineyards.

If you were a wine producer still in business in 2012, you were probably breathing a big sigh of relief. Why? Because that is when the global wine market went from glut to shortage. This was a big change from the years 2004 to 2010, when the wine industry battled with an oversupply of product and plunging prices, driven first by a series of large global harvests and then by declining demand due to the global recession of 2008. After years of losses, many wine producers finally decided to exit the industry.

By 2012, wine production capacity was down significantly in Europe, South America, Africa, and Australia, and inventories were at their lowest point in over a decade. Moreover, 2012 was a year of bad weather for wine producers. And that same year, American wine consumption started growing again, while China's wine consumption was surging, quadrupling over the previous five years. So combine a significant drop in capacity, a weather-induced fall in supply, and an increase in demand and—*voilà!*—a wine shortage appears.

But as industry analysts noted, many vintners are cheering. The lack of production in other parts of the world and surging demand in China have opened opportunities for expansion. As the CEO of Washington State's Chateau Ste. Michelle winery, Ted Bessler, commented, "Right now, we have about 50,000 acres in the state. I can foresee that we could have as much as 150,000 or more."

Hold onto your wine glasses—the present shortage could turn into a glut once again.

#### Quick Review

- The **industry supply curve** corresponds to the supply curve of earlier chapters. In the short run, the time period over which the number of producers is fixed, the **short-run market equilibrium** is given by the intersection of the **short-run industry supply curve** and the demand curve. In the long run, the time period over which producers can enter or exit the industry, the **long-run market equilibrium** is given by the intersection of the **long-run industry supply curve** and the demand curve. In the long-run market equilibrium, no producer has an incentive to enter or exit the industry.
- The long-run industry supply curve is often horizontal, although it may slope upward when a necessary input is in limited supply. It is always more elastic than the short-run industry supply curve.
- In the long-run market equilibrium of a perfectly competitive industry, each firm produces at the same marginal cost, which is equal to the market price, and the total cost of production of the industry's output is minimized. It is also efficient.

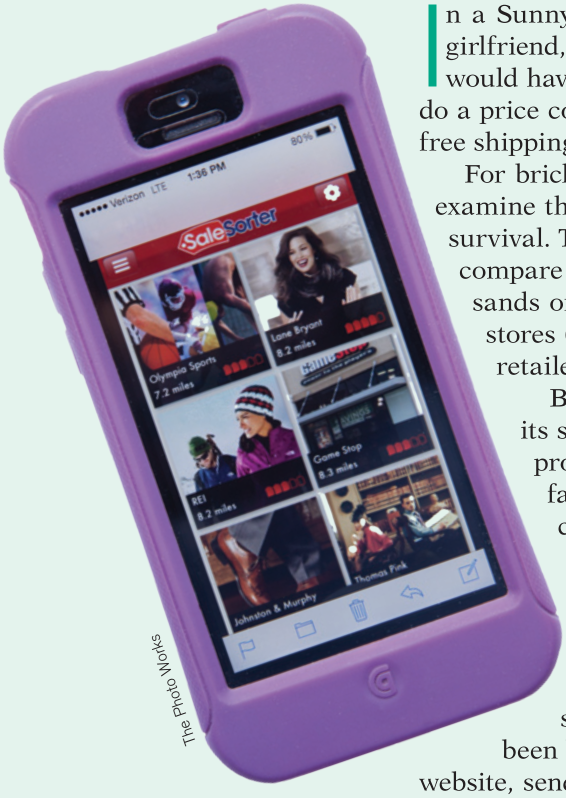
#### Check Your Understanding 12-3

1. Which of the following events will induce firms to enter an industry? Which will induce firms to exit? When will entry or exit cease? Explain your answer.
   a. A technological advance lowers the fixed cost of production of every firm in the industry.
   b. The wages paid to workers in the industry go up for an extended period of time.
   c. A permanent change in consumer tastes increases demand for the good.
   d. The price of a key input rises due to a long-term shortage of that input.
2. Assume that the egg industry is perfectly competitive and is in long-run equilibrium with a perfectly elastic long-run industry supply curve. Health concerns about cholesterol then lead to a decrease in demand. Construct a figure similar to Figure 12-7, showing the short-run behavior of the industry and how long-run equilibrium is reestablished.

Solutions appear at back of book.

BUSINESS CASE

## Shopping Apps, Showrooming, and the Challenges Facing Brick-and-Mortar Retailers




The Photo Works

In a Sunnyvale, California Best Buy, Tri Trang found the perfect gift for his girlfriend, a $184.85 Garmin GPS. Before mobile shopping apps appeared, he would have purchased it there. Instead, Trang whipped out his smartphone to do a price comparison. Finding the same item on Amazon.com for $106.75 with free shipping, he bought it from Amazon on the spot.

For brick-and-mortar retailers like Best Buy, customers who "showroom"—examine the merchandise in-store and then buy it on-line—threaten their very survival. The explosive growth of shopping apps that allow you to immediately compare prices and make a purchase (TheFind), give you access to thousands of coupons (Coupons.com), and alert you to discount sales at nearby stores (SaleSorter), has struck terror in the corporate offices of traditional retailers.

Before shopping apps, a traditional retailer could lure customers into its store with enticing specials and reasonably expect them to buy more profitable items with prompting from a salesperson. But those days are fast disappearing. The consulting firm Accenture found that 73% of customers with mobile devices preferred to shop with their phones rather than talk to a salesperson. In just four years, from 2010 to 2014, the use of mobile coupons has quadrupled from 12.3 million to 53.2 million.

But brick-and-mortar retailers are now fighting back. To combat showrooming, Target stocks products that manufacturers have slightly modified for them alone. Like other retailers, Target has been building its online presence, quadrupling the number of items on its website, sending coupons and discount alerts to customers' mobile phones, and offering loyalty rewards. Walmart now offers free in-store delivery for online purchases so customers can avoid shipping charges. And Staples will give you a discount on a new printer if you trade in your old one.

However, traditional retailers know that their survival rests on pricing. While prices on their websites tend to be lower than in the stores, these retailers are still struggling to compete with online sellers like Amazon.com. A recent study showed Amazon.com's prices were about 9% lower than Walmart.com's and 14% lower than Target.com's. Best Buys now offers to match online prices for its best customers.

It's clearly a race for survival. As one analyst said, "Only a couple of retailers can play the lowest-price game. This is going to accelerate the demise of retailers who do not have either competitive pricing or standout store experience."

### QUESTIONS FOR THOUGHT

1. From the evidence in the case, what can you infer about whether or not the retail market for electronics satisfied the conditions for perfect competition before the advent of mobile-device comparison price shopping? What was the most important impediment to competition?
2. What effect is the introduction of mobile shopping apps having on competition in the retail market for electronics? On the profitability of brick-and-mortar retailers like Best Buy? What, on average, will be the effect on the consumer surplus of purchasers of these items?
3. Why are some retailers responding by having manufacturers make exclusive versions of products for them? Is this trend likely to increase or diminish?

## SUMMARY

1. In a **perfectly competitive market** all producers are **price-taking producers** and all consumers are **price-taking consumers—**no one's actions can influence the market price. Consumers are normally price-takers, but producers often are not. In a **perfectly competitive industry,** all producers are price-takers.
2. There are two necessary conditions for a perfectly competitive industry: there are many producers, none of whom have a large **market share,** and the industry produces a **standardized product** or **commodity—** goods that consumers regard as equivalent. A third condition is often satisfied as well: **free entry and exit** into and from the industry.
3. A producer chooses output according to the **optimal output rule:** produce the quantity at which **marginal revenue** equals marginal cost. For a price-taking firm, marginal revenue is equal to price and its **marginal revenue curve** is a horizontal line at the market price. It chooses output according to the **price-taking firm's optimal output rule:** produce the quantity at which price equals marginal cost. However, a firm that produces the optimal quantity may not be profitable.
4. A firm is profitable if total revenue exceeds total cost or, equivalently, if the market price exceeds its **break-even price—**minimum average total cost. If market price exceeds the break-even price, the firm is profitable; if it is less, the firm is unprofitable; if it is equal, the firm breaks even. When profitable, the firm's per-unit profit is $P - ATC$; when unprofitable, its per-unit loss is $ATC - P$.
5. Fixed cost is irrelevant to the firm's optimal short-run production decision, which depends on its **shut-down price—**its minimum average variable cost—and the market price. When the market price is equal to or exceeds the shut-down price, the firm produces the output quantity where marginal cost equals the market price. When the market price falls below the shut-down price, the firm ceases production in the short run. This generates the firm's **short-run individual supply curve.**
6. Fixed cost matters over time. If the market price is below minimum average total cost for an extended period of time, firms will exit the industry in the long run. If above, existing firms are profitable and new firms will enter the industry in the long run.
7. The **industry supply curve** depends on the time period. The **short-run industry supply curve** is the industry supply curve given that the number of firms is fixed. The **short-run market equilibrium** is given by the intersection of the short-run industry supply curve and the demand curve.
8. The **long-run industry supply curve** is the industry supply curve given sufficient time for entry into and exit from the industry. In the **long-run market equilibrium—**given by the intersection of the long-run industry supply curve and the demand curve—no producer has an incentive to enter or exit. The long-run industry supply curve is often horizontal. It may slope upward if there is limited supply of an input, resulting in increasing costs across the industry. It may even slope downward, the case of decreasing costs across the industry. But it is always more elastic than the short-run industry supply curve.
9. In the long-run market equilibrium of a competitive industry, profit maximization leads each firm to produce at the same marginal cost, which is equal to market price. Free entry and exit means that each firm earns zero economic profit—producing the output corresponding to its minimum average total cost. So the total cost of production of an industry's output is minimized. The outcome is efficient because every consumer with a willingness to pay greater than or equal to marginal cost gets the good.

## KEY TERMS

## PROBLEMS

1. For each of the following, is the business a price-taking producer? Explain your answers.
   **a.** A cappuccino café in a university town where there are dozens of very similar cappuccino cafés
   **b.** The makers of Pepsi-Cola
   **c.** One of many sellers of zucchini at a local farmers' market

2. For each of the following, is the industry perfectly competitive? Referring to market share, standardization of the product, and/or free entry and exit, explain your answers.
   **a.** Aspirin
   **b.** Alicia Keys concerts
   **c.** SUVs

3. Bob produces Blu-ray movies for sale, which requires a building and a machine that copies the original movie onto a Blu-ray. Bob rents a building for $30,000 per month and rents a machine for $20,000 a month. Those are his fixed costs. His variable cost per month is given in the accompanying table.

| Quantity of Blu-rays | *VC* |
|---|---|
| 0 | $0 |
| 1,000 | 5,000 |
| 2,000 | 8,000 |
| 3,000 | 9,000 |
| 4,000 | 14,000 |
| 5,000 | 20,000 |
| 6,000 | 33,000 |
| 7,000 | 49,000 |
| 8,000 | 72,000 |
| 9,000 | 99,000 |
| 10,000 | 150,000 |

   **a.** Calculate Bob's average variable cost, average total cost, and marginal cost for each quantity of output.
   **b.** There is free entry into the industry, and anyone who enters will face the same costs as Bob. Suppose that currently the price of a Blu-ray is $25. What will Bob's profit be? Is this a long-run equilibrium? If not, what will the price of Blu-ray movies be in the long run?

4. Consider Bob's Blu-ray company described in Problem 4. Assume that Blu-ray production is a perfectly competitive industry. For each of the following questions, explain your answers.
   **a.** What is Bob's break-even price? What is his shut-down price?
   **b.** Suppose the price of a Blu-ray is $2. What should Bob do in the short run?
   **c.** Suppose the price of a Blu-ray is $7. What is the profit-maximizing quantity of Blu-rays that Bob should produce? What will his total profit be? Will he produce or shut down in the short run? Will he stay in the industry or exit in the long run?
   **d.** Suppose instead that the price of Blu-rays is $20. Now what is the profit-maximizing quantity of Blu-rays that Bob should produce? What will his total profit be now? Will he produce or shut down in the short run? Will he stay in the industry or exit in the long run?

5. Consider again Bob's Blu-ray company described in Problem 4.
   **a.** Draw Bob's marginal cost curve.
   **b.** Over what range of prices will Bob produce no Blu-rays in the short run?
   **c.** Draw Bob's individual supply curve. In your graph, plot the price range from $0 to $60 in increments of $10.

6. **a.** A profit-maximizing business incurs an economic loss of $10,000 per year. Its fixed cost is $15,000 per year. Should it produce or shut down in the short run? Should it stay in the industry or exit in the long run?
   **b.** Suppose instead that this business has a fixed cost of $6,000 per year. Should it produce or shut down in the short run? Should it stay in the industry or exit in the long run?

7. The first sushi restaurant opens in town. Initially people are very cautious about eating tiny portions of raw fish, as this is a town where large portions of grilled meat have always been popular. Soon, however, an influential health report warns consumers against grilled meat and suggests that they increase their consumption of fish, especially raw fish. The sushi restaurant becomes very popular and its profit increases.
   **a.** What will happen to the short-run profit of the sushi restaurant? What will happen to the number of sushi restaurants in town in the long run? Will the first sushi restaurant be able to sustain its short-run profit over the long run? Explain your answers.
   **b.** Local steakhouses suffer from the popularity of sushi and start incurring losses. What will happen to the number of steakhouses in town in the long run? Explain your answer.

8. A perfectly competitive firm has the following short-run total cost:

| Quantity | *TC* |
|---|---|
| 0 | $5 |
| 1 | 10 |
| 2 | 13 |
| 3 | 18 |
| 4 | 25 |
| 5 | 34 |
| 6 | 45 |

Market demand for the firm's product is given by the following market demand schedule:

| Price | Quantity demanded |
|---|---|
| $12 | 300 |
| 10 | 500 |
| 8 | 800 |
| 6 | 1,200 |
| 4 | 1,800 |

**a.** Calculate this firm's marginal cost and, for all output levels except zero, the firm's average variable cost and average total cost.

**b.** There are 100 firms in this industry that all have costs identical to those of this firm. Draw the short-run industry supply curve. In the same diagram, draw the market demand curve.

**c.** What is the market price, and how much profit will each firm make?

**9.** A new vaccine against a deadly disease has just been discovered. Presently, 55 people die from the disease each year. The new vaccine will save lives, but it is not completely safe. Some recipients of the shots will die from adverse reactions. The projected effects of the inoculation are given in the accompanying table:

| Percent of population inoculated | Total deaths due to disease | Total deaths due to inoculation | Marginal benefit of inoculation | Marginal cost of inoculation | "Profit" of inoculation |
|---|---|---|---|---|---|
| 0 | 55 | 0 | | | |
| | | | — | — | — |
| 10 | 45 | 0 | | | |
| | | | — | — | — |
| 20 | 36 | 1 | | | |
| | | | — | — | — |
| 30 | 28 | 3 | | | |
| | | | — | — | — |
| 40 | 21 | 6 | | | |
| | | | — | — | — |
| 50 | 15 | 10 | | | |
| | | | — | — | — |
| 60 | 10 | 15 | | | |
| | | | — | — | — |
| 70 | 6 | 20 | | | |
| | | | — | — | — |
| 80 | 3 | 25 | | | |
| | | | — | — | — |
| 90 | 1 | 30 | | | |
| | | | — | — | — |
| 100 | 0 | 35 | | | |

**a.** What are the interpretations of "marginal benefit" and "marginal cost" here? Calculate marginal benefit and marginal cost per each 10% increase in the rate of inoculation. Write your answers in the table.

**b.** What proportion of the population should optimally be inoculated?

**c.** What is the interpretation of "profit" here? Calculate the profit for all levels of inoculation.

**10.** Evaluate each of the following statements. If a statement is true, explain why; if it is false, identify the mistake and try to correct it.

**a.** A profit-maximizing firm in a perfectly competitive industry should select the output level at which the difference between the market price and marginal cost is greatest.

**b.** An increase in fixed cost lowers the profit-maximizing quantity of output produced in the short run.

**11.** The production of agricultural products like wheat is one of the few examples of a perfectly competitive industry. In this question, we analyze results from a study released by the U.S. Department of Agriculture about wheat production in the United States back in 2013.

**a.** The average variable cost per acre planted with wheat was $127 per acre. Assuming a yield of 44 bushels per acre, calculate the average variable cost per bushel of wheat.

**b.** The average price of wheat received by a farmer in 2013 was $7.58 per bushel. Do you think the average farm would have exited the industry in the short run? Explain.

**c.** With a yield of 44 bushels of wheat per acre, the average total cost per farm was $4.80 per bushel. The harvested acreage for rye (a type of wheat) in the United States increased from 242,000 in 2010 to 306,000 in 2013. Using the information on prices and costs here and in parts a and b, explain why this might have happened.

**d.** Using the above information, what do you think will happen to wheat production and prices after 2013?

**12.** The accompanying table presents prices for washing and ironing a man's shirt taken from a survey of California dry cleaners.

| Dry Cleaner | City | Price |
|---|---|---|
| A-1 Cleaners | Santa Barbara | $1.50 |
| Regal Cleaners | Santa Barbara | 1.95 |
| St. Paul Cleaners | Santa Barbara | 1.95 |
| Zip Kleen Dry Cleaners | Santa Barbara | 1.95 |
| Effie the Tailor | Santa Barbara | 2.00 |
| Magnolia Too | Goleta | 2.00 |
| Master Cleaners | Santa Barbara | 2.00 |
| Santa Barbara Cleaners | Goleta | 2.00 |
| Sunny Cleaners | Santa Barbara | 2.00 |
| Casitas Cleaners | Carpinteria | 2.10 |
| Rockwell Cleaners | Carpinteria | 2.10 |
| Norvelle Bass Cleaners | Santa Barbara | 2.15 |
| Ablitt's Fine Cleaners | Santa Barbara | 2.25 |
| California Cleaners | Goleta | 2.25 |
| Justo the Tailor | Santa Barbara | 2.25 |
| Pressed 4 Time | Goleta | 2.50 |
| King's Cleaners | Goleta | 2.50 |

**a.** What is the average price per shirt washed and ironed in Goleta? In Santa Barbara?

**b.** Draw typical marginal cost and average total cost curves for California Cleaners in Goleta, assuming it is a perfectly competitive firm but is making a profit on each shirt in the short run. Mark the short-run equilibrium point and shade the area that corresponds to the profit made by the dry cleaner.

**c.** Assume $2.25 is the short-run equilibrium price in Goleta. Draw a typical short-run demand and supply curve for the market. Label the equilibrium point.

**d.** Observing profits in the Goleta area, another dry cleaning service, Diamond Cleaners, enters the market. It charges $1.95 per shirt. What is the new average price of washing and ironing a shirt in Goleta? Illustrate the effect of entry on the average Goleta price by a shift of the short-run supply curve, the demand curve, or both.

**e.** Assume that California Cleaners now charges the new average price and just breaks even (that is, makes zero economic profit) at this price. Show the likely effect of the entry on your diagram in part b.

**f.** If the dry cleaning industry is perfectly competitive, what does the average difference in price between Goleta and Santa Barbara imply about costs in the two areas?

WORK IT OUT

Macmillan Education LaunchPad

**For interactive, step-by-step help in solving the following problem, visit LaunchPad by using the URL on the back cover of this book.**

**13.** Kate's Katering provides catered meals, and the catered meals industry is perfectly competitive. Kate's machinery costs $100 per day and is the only fixed input. Her variable cost consists of the wages paid to the cooks and the food ingredients. The variable cost per day associated with each level of output is given in the accompanying table.

| Quantity of meals | *VC* |
|---|---|
| 0 | 0 |
| 10 | 200 |
| 20 | 300 |
| 30 | 480 |
| 40 | 700 |
| 50 | 1,000 |

**a.** Calculate the total cost, the average variable cost, the average total cost, and the marginal cost for each quantity of output.

**b.** What is the break-even price and quantity? What is the shut-down price and quantity?

**c.** Suppose that the price at which Kate can sell catered meals is $21 per meal. In the short run, will Kate earn a profit? In the short run, should she produce or shut down?

**d.** Suppose that the price at which Kate can sell catered meals is $17 per meal. In the short run, will Kate earn a profit? In the short run, should she produce or shut down?

**e.** Suppose that the price at which Kate can sell catered meals is $13 per meal. In the short run, will Kate earn a profit? In the short run, should she produce or shut down?