The Cost of Production

- The economy is made up of thousands of firms that produce the goods and services we enjoy every day.
- Some firms are large; like, Car industry, Cereal industry etc. they employ thousands of workers and have thousands of stockholders who share in the firms' profits.
- Other firms, such as the local barbershop or candy store, are small; they employ only a few workers and are owned by a single person or family.
- Previously, we used the supply curve to summarize firms' production decisions. According to the law of supply, firms are willing to produce and sell a greater quantity of a good when the price of the good is higher, and this response leads to a supply curve that slopes upward.
- For analyzing many questions, the law of supply is all you need to know about firm behavior.
- In this chapter and the ones that follow, we examine firm behavior in more detail.
- This topic will give you a better understanding of the decisions behind the supply curve. In addition, it will introduce you to a part of economics called *industrial organization*—the study of how firms' decisions about prices and quantities depend on the market conditions they face.
- This raises a key question: How does the number of firms affect the prices in a market and the efficiency of the market outcome? The field of industrial organization addresses exactly this question.

➢ WHAT ARE COSTS?

- We begin our discussion of costs at Caroline's Cookie Factory. Caroline, the owner of the firm, buys flour, sugar, chocolate chips, and other cookie ingredients. She also buys the mixers and ovens and hires workers to run this equipment. She then sells the cookies to consumers. By examining some of the issues that Caroline faces in her business, we can learn some lessons about costs that apply to all firms in an economy.

➢ TOTAL REVENUE, TOTAL COST, AND PROFIT:

- We begin with the firm's objective. It is conceivable that Caroline started her business to make money. Economists normally assume that the goal of a firm is to maximize profit, and they find that this assumption works well in most cases.
- What is a firm's profit? The amount that the firm receives for the sale of its output (cookies) is called its total revenue. The amount that the firm pays to buy inputs (flour, sugar, workers, ovens, and so forth) is called its total cost. Caroline gets to keep any revenue that is not needed to cover costs. Profit is a firm's total revenue minus its total cost:

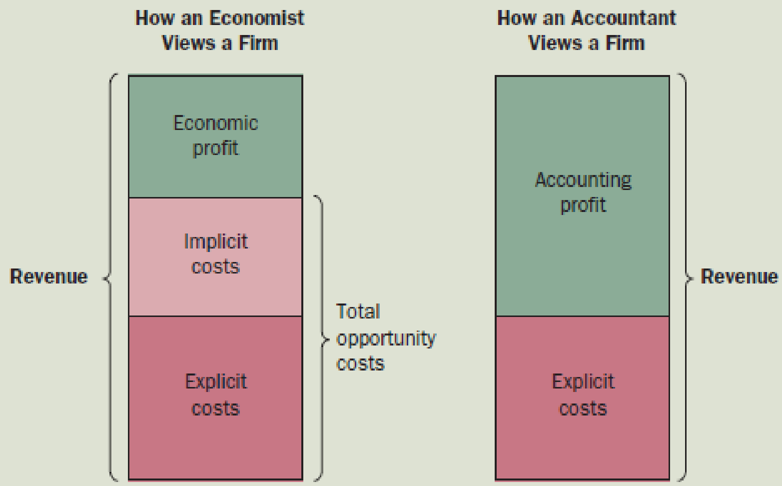
$$\text{Profit} = \text{Total revenue} - \text{Total cost.}$$

- Caroline's objective is to make her firm's profit as large as possible.
- To see how a firm goes about maximizing profit, we must consider fully how to measure its total revenue and its total cost. Total revenue is the easy part: It equals the quantity of output the firm produces times the price at which it sells its output.

- If Caroline produces 10,000 cookies and sells them at $2 a cookie, her total revenue is $20,000. By contrast, the measurement of a firm's total cost is more subtle.

1 FIGURE

Economists versus Accountants
Economists include all opportunity costs when analyzing a firm, whereas accountants measure only explicit costs. Therefore, economic profit is smaller than accounting profit.



➢ <u>Production and Costs:</u>

- In the analysis that follows, we make an important simplifying assumption:
- We assume that the size of Caroline's factory is fixed and that Caroline can vary the quantity of cookies produced only by changing the number of workers she employs. This assumption is realistic in the short run but not in the long run. That is, Caroline cannot build a larger factory overnight, but she can do so over the next year or two. This analysis, therefore, describes the production decisions that Caroline faces in the short run.

THE PRODUCTION FUNCTION

TABLE 1

A Production Function and Total Cost: Caroline's Cookie Factory

Number of Workers	Output (quantity of cookies produced per hour)	Marginal Product of Labor	Cost of Factory	Cost of Workers	Total Cost of Inputs (cost of factory + cost of workers)
0	0		$30	$0	$30
		50			
1	50		30	10	40
		40			
2	90		30	20	50
		30			
3	120		30	30	60
		20			
4	140		30	40	70
		10			
5	150		30	50	80
		5			
6	155		30	60	90

- Table 1 shows how the quantity of cookies produced per hour at Caroline's factory depends on the number of workers. As you can see in the first two columns, if there are no workers in the factory, Caroline produces no cookies.
- When there is 1 worker, she produces 50 cookies. When there are 2 workers, she produces 90 cookies and so on.
- Panel (a) of Figure 2 presents a graph of these two columns of numbers. The number of workers is on the horizontal axis, and the number of cookies produced is on the vertical axis.
- This relationship between the quantity of inputs (workers) and quantity of output (cookies) is called the production function.
- One of the Ten Principles of Economics introduced in Chapter 1 is that rational people think at the margin.
- To take a step toward understanding these decisions, the third column in the table gives the marginal product of a worker.

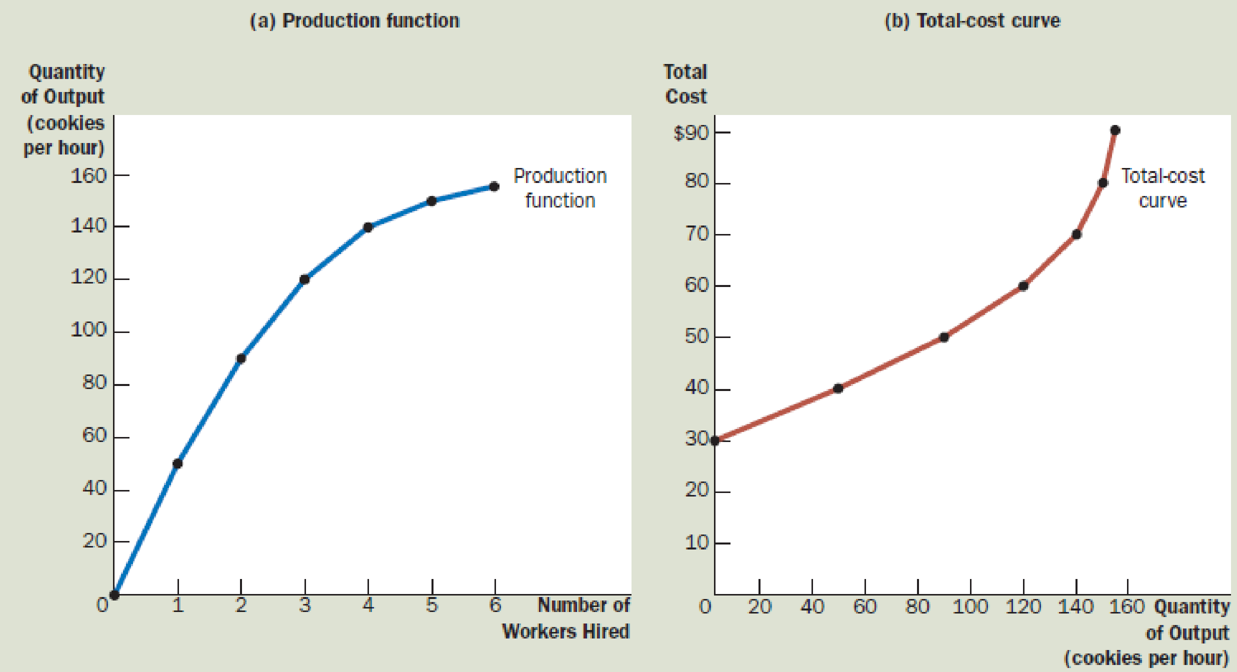
- The marginal product of any input in the production process is the increase in the quantity of output obtained from one additional unit of that input. When the number of workers goes from 1 to 2, cookie production increases from 50 to 90, so the marginal product of the second worker is 40 cookies. And when the number of workers goes from 2 to 3, cookie production increases from 90 to 120, so the marginal product of the third worker is 30 cookies.
- In the table, the marginal product is shown halfway between two rows because it represents the change in output as the number of workers increases from one level to another.
- Notice that as the number of workers increases, the marginal product declines.
- The second worker has a marginal product of 40 cookies, the third worker has a marginal product of 30 cookies, and the fourth worker has a marginal product of 20 cookies.
- This property is called diminishing marginal product.
- At first, when only a few workers are hired, they have easy access to Caroline's kitchen equipment. As the number of workers increases, additional workers have to share equipment and work in more crowded conditions. Eventually, the kitchen is so crowded that the workers start getting in each other's way. Hence, as more and more workers are hired, each additional worker contributes fewer additional cookies to total production.
- Diminishing marginal product is also apparent in Figure 2. The production function's slope ("rise over run") tells us the change in Caroline's output of cookies ("rise") for each additional input of labor ("run"). That is, the slope

of the production function measures the marginal product of a worker. As the number of workers increases, the marginal product declines (even negative after certain point of time), and the production function becomes flatter.

2 FIGURE

Caroline's Production Function and Total-Cost Curve

The production function in panel (a) shows the relationship between the number of workers hired and the quantity of output produced. Here the number of workers hired (on the horizontal axis) is from the first column in Table 1, and the quantity of output produced (on the vertical axis) is from the second column. The production function gets flatter as the number of workers increases, which reflects diminishing marginal product. The total-cost curve in panel (b) shows the relationship between the quantity of output produced and total cost of production. Here the quantity of output produced (on the horizontal axis) is from the second column in Table 1, and the total cost (on the vertical axis) is from the sixth column. The total-cost curve gets steeper as the quantity of output increases because of diminishing marginal product.



➢ FROM THE PRODUCTION FUNCTION TO THE TOTAL-COST CURVE:

- The last three columns of Table 1 show Caroline's cost of producing cookies.
- In this example, the cost of Caroline's factory is $30 per hour, and the cost of a worker is $10 per hour. If she hires 1 worker, her total cost is $40 per hour. If she hires 2 workers, her total cost is $50 per hour, and so on.
- With this information, the table now shows how the number of workers Caroline hires is related to the quantity of cookies she produces and to her total cost of production.
- Panel (b) of Figure 2 graphs these two columns of data with the quantity produced on the horizontal axis and total cost on the vertical axis. This graph is called the total-cost curve.
- Now compare the total-cost curve in panel (b) with the production function in panel (a).
- These two curves are opposite sides of the same coin.
- The total-cost curve gets steeper as the amount produced rises, whereas the production function gets flatter as production rises. These changes in slope occur for the same reason.
- High production of cookies means that Caroline's kitchen is crowded with many workers. Because the kitchen is crowded, each additional worker adds less to production, reflecting diminishing marginal product. Therefore, the production function is relatively flat.
- But now turn this logic around: When the kitchen is crowded, producing an additional cookie requires a lot of additional labor and is thus very costly.

Therefore, when the quantity produced is large, the total-cost curve is relatively steep.

➢ THE VARIOUS MEASURES OF COST

- Our analysis of Caroline's Cookie Factory demonstrated how a firm's total cost reflects its production function.
- From data on a firm's total cost, we can derive several related measures of cost, which will turn out to be useful when we analyze production and pricing decisions in future chapters.
- To see how these related measures are derived, we consider the example in Table 2. This table presents cost data on Caroline's neighbor—Conrad's Coffee Shop.

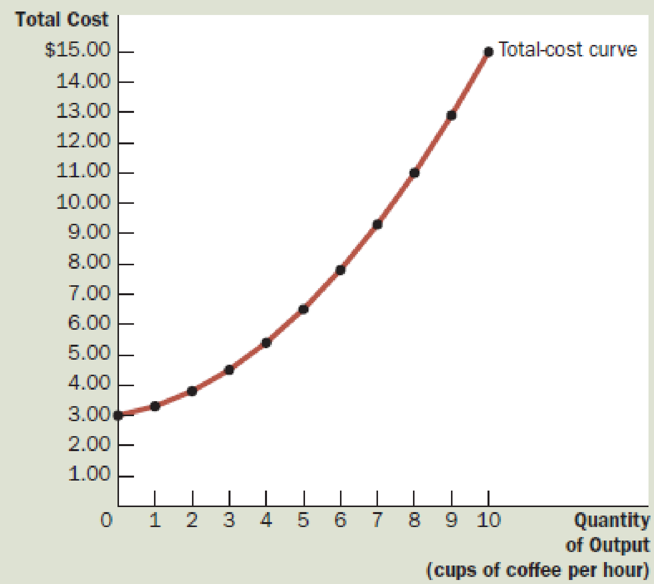
2 TABLE

The Various Measures of Cost: Conrad's Coffee Shop

Quantity of Coffee (cups per hour)	Total Cost	Fixed Cost	Variable Cost	Average Fixed Cost	Average Variable Cost	Average Total Cost	Marginal Cost
0	$ 3.00	$3.00	$ 0.00	—	—	—	
1	3.30	3.00	0.30	$3.00	$0.30	$3.30	$0.30
2	3.80	3.00	0.80	1.50	0.40	1.90	0.50
3	4.50	3.00	1.50	1.00	0.50	1.50	0.70
4	5.40	3.00	2.40	0.75	0.60	1.35	0.90
5	6.50	3.00	3.50	0.60	0.70	1.30	1.10
6	7.80	3.00	4.80	0.50	0.80	1.30	1.30
7	9.30	3.00	6.30	0.43	0.90	1.33	1.50
8	11.00	3.00	8.00	0.38	1.00	1.38	1.70
9	12.90	3.00	9.90	0.33	1.10	1.43	1.90
10	15.00	3.00	12.00	0.30	1.20	1.50	2.10

- The first column of the table shows the number of cups of coffee that Conrad might produce, ranging from 0 to 10 cups per hour. The second column shows Conrad's total cost of producing coffee. Figure 3 plots Conrad's total-cost curve.

FIGURE 3



Conrad's Total-Cost Curve
Here the quantity of output produced (on the horizontal axis) is from the first column in Table 2, and the total cost (on the vertical axis) is from the second column. As in Figure 2, the total-cost curve gets steeper as the quantity of output increases because of diminishing marginal product.

- The quantity of coffee (from the first column) is on the horizontal axis, and total cost (from the second column) is on the vertical axis. Conrad's total-cost curve has a shape similar to Caroline's. In particular, it becomes steeper as the quantity produced rises, which (as we have discussed) reflects diminishing marginal product.

➢ FIXED AND VARIABLE COSTS

- Conrad's total cost can be divided into two types.
- Some costs, called fixed costs, do not vary with the quantity of output produced. They are incurred even if the firm produces nothing at all. Conrad's fixed costs include any rent he pays because this cost is the same regardless of how much coffee he produces. Similarly, if Conrad needs to

hire a full-time bookkeeper to pay bills, regardless of the quantity of coffee produced, the bookkeeper's salary is a fixed cost. The third column in Table 2 shows Conrad's fixed cost, which in this example is $3.00.

- Some of the firm's costs, called variable costs, change as the firm alters the quantity of output produced. Conrad's variable costs include the cost of coffee beans, milk, sugar, and paper cups: The more cups of coffee Conrad makes, the more of these items he needs to buy. Similarly, if Conrad has to hire more workers to make more cups of coffee, the salaries of these workers are variable costs.
- The fourth column of the table shows Conrad's variable cost. The variable cost is 0 if he produces nothing, $0.30 if he produces 1 cup of coffee, $0.80 if he produces 2 cups, and so on.
- A firm's total cost is the sum of fixed and variable costs. In Table 2, total cost in the second column equals fixed cost in the third column plus variable cost in the fourth column.

➢ AVERAGE AND MARGINAL COST

- As the owner of his firm, Conrad has to decide how much to produce. In making this decision, Conrad might ask his production supervisor the following two questions about the cost of producing coffee:
  - How much does it cost to make the typical cup of coffee?
  - How much does it cost to increase production of coffee by 1 cup?
- Although at first these two questions might seem to have the same answer, they do not. Both answers will turn out to be important for understanding how firms make production decisions.

- To find the cost of the typical unit produced, we would divide the firm's costs by the quantity of output it produces. For example, if the firm produces 2 cups of coffee per hour, its total cost is \$3.80, and the cost of the typical cup is \$3.80/2, or \$1.90. Total cost divided by the quantity of output is called average total cost.
- Because total cost is the sum of fixed and variable costs, average total cost can be expressed as the sum of average fixed cost and average variable cost. Average fixed cost is the fixed cost divided by the quantity of output, and average variable cost is the variable cost divided by the quantity of output.
- Although average total cost tells us the cost of the typical unit, it does not tell us how much total cost will change as the firm alters its level of production.
- The last column in Table 2 shows the amount that total cost rises when the firm increases production by 1 unit of output. This number is called marginal cost.
- For example, if Conrad increases production from 2 to 3 cups, total cost raises from \$3.80 to \$4.50, so the marginal cost of the third cup of coffee is \$4.50 minus \$3.80, or \$0.70. In the table, the marginal cost appears halfway between two rows because it represents the change in total cost as quantity of output increases from one level to another.
- It may be helpful to express these definitions mathematically:

$$\text{Average total cost} = \text{Total cost}/\text{Quantity}$$

$$ATC = TC/Q \text{ and}$$

$$\text{Marginal cost} = \text{Change in total cost}/\text{Change in quantity}$$

$$MC = \Delta TC/\Delta Q$$

➢ COST CURVES AND THEIR SHAPES

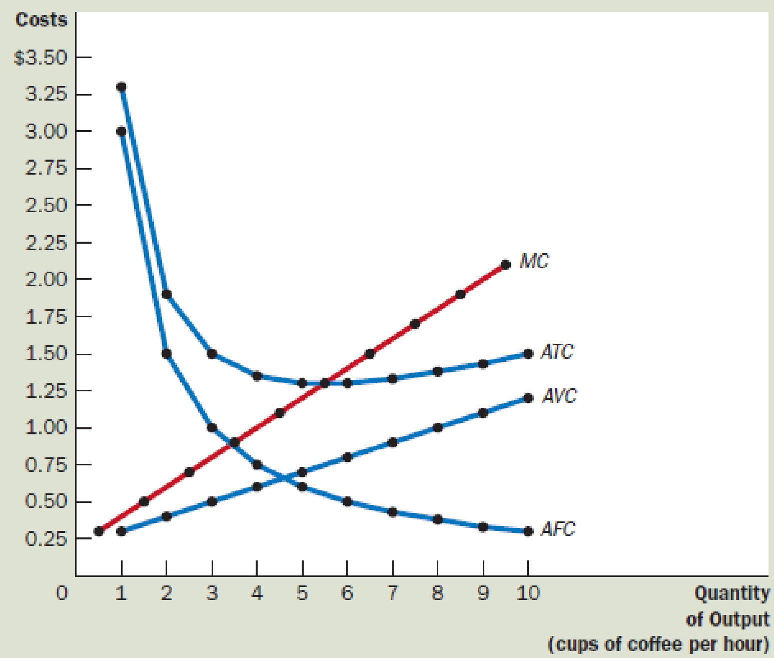


FIGURE 4

Conrad's Average-Cost and Marginal-Cost Curves
This figure shows the average total cost (*ATC*), average fixed cost (*AFC*), average variable cost (*AVC*), and marginal cost (*MC*) for Conrad's Coffee Shop. All of these curves are obtained by graphing the data in Table 2. These cost curves show three features that are typical of many firms: (1) Marginal cost rises with the quantity of output. (2) The average-total-cost curve is U-shaped. (3) The marginal-cost curve crosses the average-total-cost curve at the minimum of average total cost.

- Figure 4 graphs Conrad's costs using the data from Table 2. The horizontal axis measures the quantity the firm produces, and the vertical axis measures marginal and average costs. The graph shows four curves: average total cost (ATC), average fixed cost (AFC), average variable cost (AVC), and marginal cost (MC).
- Let's examine three features in particular: the shape of the marginal-cost curve, the shape of the average-total-cost curve, and the relationship between marginal and average total cost.
- Rising Marginal Cost Conrad's marginal cost rises with the quantity of output produced. This reflects the property of diminishing marginal product. When Conrad produces a small quantity of coffee; he has few workers, and much of his equipment is not used. Because he can easily put these idle

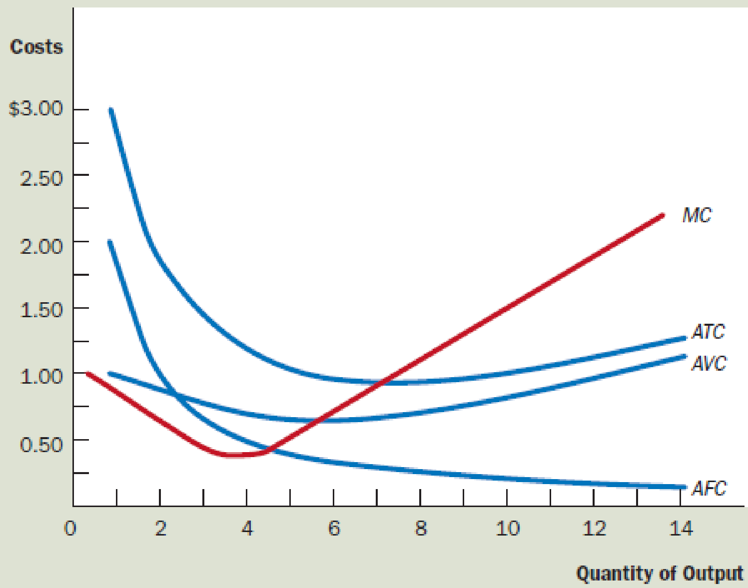
resources to use, the marginal product of an extra worker is large, and the marginal cost of an extra cup of coffee is small. By contrast, when Conrad produces a large quantity of coffee, his shop is crowded with workers, and most of his equipment is fully utilized.

- Conrad can produce more coffee by adding workers, but these new workers have to work in crowded conditions and may have to wait to use the equipment. Therefore, when the quantity of coffee produced is already high, the marginal product of an extra worker is low, and the marginal cost of an extra cup of coffee is large.
- Conrad’s average-total-cost curve is U-shaped, as shown in Figure 4. To understand why, remember that average total cost is the sum of average fixed cost and average variable cost. Average fixed cost always declines as output rises because the fixed cost is spread over a larger number of units. Average variable cost typically rises as output increases because of diminishing marginal product.
- Average total cost reflects the shapes of both average fixed cost and average variable cost. At very low levels of output, such as 1 or 2 cups per hour, average total cost is very high. Even though average variable cost is low, average fixed cost is high because the fixed cost is spread over only a few units. As output increases, the fixed cost is spread more widely. Average fixed cost declines, rapidly at first and then more slowly. As a result, average total cost also declines until the firm’s output reaches 5 cups of coffee per hour, when average total cost is $1.30 per cup.
- When the firm produces more than 6 cups per hour, however, the increase in average variable cost becomes the dominant force, and average total cost starts rising.

- The tug of war between average fixed cost and average variable cost generates the U-shape in average total cost.
- The bottom of the U-shape occurs at the quantity that minimizes average total cost. This quantity is sometimes called the efficient scale of the firm. For Conrad, the efficient scale is 5 or 6 cups of coffee per hour. If he produces more or less than this amount, his average total cost rises above the minimum of $1.30.
- At the efficient scale, these two forces are balanced to yield the lowest average total cost.
- The Relationship between Marginal Cost and Average Total Cost If you look at Figure 4 (or at Table 2), we will see something that may be surprising at first. Whenever marginal cost is less than average total cost, average total cost is falling.
- Whenever marginal cost is greater than average total cost, average total cost is rising. This feature of Conrad's cost curves is not a coincidence from the particular numbers used in the example: It is true for all firms.
- This relationship between average total cost and marginal cost has an important corollary: The marginal-cost curve crosses the average-total-cost curve at its minimum.
- Why? At low levels of output, marginal cost is below average total cost, so average total cost is falling. But after the two curves cross, marginal cost rises above average total cost. For the reason we have just discussed, average total cost must start to rise at this level of output. Hence, this point of intersection is the minimum of average total cost.

➢ TYPICAL COST CURVES

FIGURE 5



Cost Curves for a Typical Firm
Many firms experience increasing marginal product before diminishing marginal product. As a result, they have cost curves shaped like those in this figure. Notice that marginal cost and average variable cost fall for a while before starting to rise.

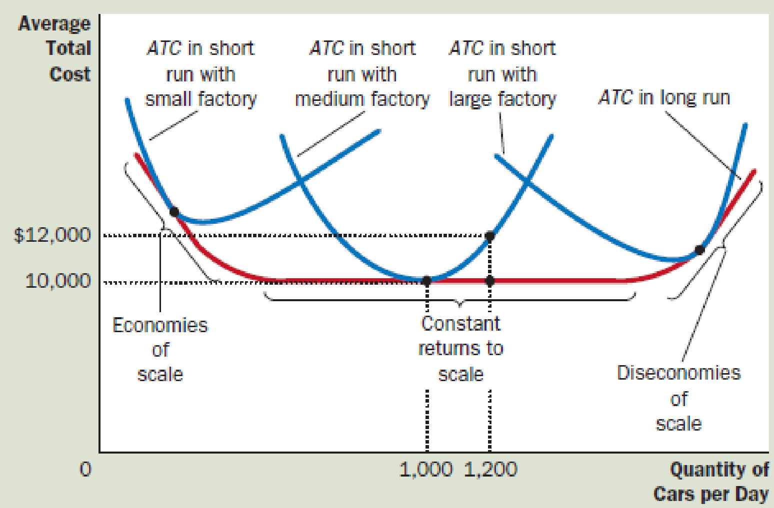
- Figure 5 shows the cost curves for such a firm, including average total cost (ATC), average fixed cost (AFC), average variable cost (AVC), and marginal cost (MC). At low levels of output, the firm experiences increasing marginal product, and the marginal-cost curve falls. Eventually, the firm starts to experience diminishing marginal product, and the marginal-cost curve starts to rise. This combination of increasing then diminishing marginal product also makes the average-variable-cost curve U-shaped.
- The cost curves showed here share the three properties:
  - Marginal cost eventually rises with the quantity of output.
  - The average-total-cost curve is U-shaped.
  - The marginal cost curve crosses both average variable cost and average total cost curve at their minimum point but the minimum point of average total cost curve is situated slightly right hand side compared to the minimum point of average variable cost.

THE RELATIONSHIP BETWEEN SHORT-RUN AND LONG-RUN AVERAGE TOTAL COST

- For many firms, the division of total costs between fixed and variable costs depend on the time horizon.
- Consider, for instance, a car manufacturer such as Ford Motor Company. Over a period of only a few months, Ford cannot adjust the number or sizes of its car factories. The only way it can produce additional cars is to hire more workers at the factories it already has. The cost of these factories is, therefore, a fixed cost in the short run.
- By contrast, over a period of several years, Ford can expand the size of its factories, build new factories, or close old ones. Thus, the cost of its factories is a variable cost in the long run. Because many decisions are fixed in the short run but variable in the long run, a firm's long-run cost curves differ from its short-run cost curves. Figure 6 shows an example.

6 FIGURE

Average Total Cost in the Short and Long Runs
Because fixed costs are variable in the long run, the average-total-cost curve in the short run differs from the average-total-cost curve in the long run.



- The figure presents three short-run average-total-cost curves—for a small, medium, and large factory. It also presents the long-run average-total-cost curve.
- As the firm moves along the long-run curve, it is adjusting the size of the factory to the quantity of production. The long-run average-total-cost curve is a much flatter U-shape than the short-run average total- cost curve. In addition, all the short-run curves lie on or above the long-run curve. These properties arise because firms have greater flexibility in the long run. In essence, in the long run, the firm gets to choose which short-run curve it wants to use. But in the short run, it has to use whatever short-run curve it has chosen in the past.
- The figure shows an example of how a change in production alters costs over different time horizons. When Ford wants to increase production from 1,000 to 1,200 cars per day, it has no choice in the short run but to hire more workers at its existing medium-sized factory. Because of diminishing marginal product, average total cost rises from $10,000 to $12,000 per car. In the long run, however, Ford can expand both the size of the factory and its workforce, and average total cost returns to $10,000.
- How long does it take a firm to get to the long run? The answer depends on the firm. It can take a year or longer for a major manufacturing firm, such as a car company, to build a larger factory. By contrast, a person running a coffee shop can buy another coffee maker within a few hours. There is, therefore, no single answer to how long it takes a firm to adjust its production facilities.

ECONOMIES AND DISECONOMIES OF SCALE

- The shape of the long-run average-total-cost curve conveys important information about the production processes that a firm has available for manufacturing a good. In particular, it tells us how costs vary with the scale—that is, the size—of a firm's operations.
- When long-run average total cost declines as output increases, there are said to be economies of scale. When long-run average total cost rises as output increases, there are said to be diseconomies of scale. When long-run average total cost does not vary with the level of output, there are said to be constant returns to scale.
- In this example, Ford has economies of scale at low levels of output, constant returns to scale at intermediate levels of output, and diseconomies of scale at high levels of output.
- What might cause economies or diseconomies of scale? Economies of scale often arise because higher production levels allow specialization among workers, which permits each worker to become better at a specific task. For instance, if
- Ford hires a large number of workers and produces a large number of cars; it can reduce costs with modern assembly-line production. Diseconomies of scale can arise because of coordination problems that are inherent in any large organization. The more cars Ford produces, the more stretched the management team becomes, and the less effective the managers become at keeping costs down.
- This analysis shows why long-run average-total-cost curves are often U-shaped.

- At low levels of production, the firm benefits from increased size because it can take advantage of greater specialization. Coordination problems, meanwhile, are not yet acute. By contrast, at high levels of production, the benefits of specialization have already been realized, and coordination problems become more severe as the firm grows larger. Thus, long-run average total cost is falling at low levels of production because of increasing specialization and rising at high levels of production because of increasing coordination problems.