CHAPTER 10 Technology, Production, and Costs

Chapter Summary and Learning Objectives

10.1 Technology: An Economic Definition (pages 326–327)

Define technology and give examples of technological change. The basic activity of a firm is to use inputs, such as workers, machines, and natural resources, to produce goods and services. The firm’s technology is the processes it uses to turn inputs into goods and services. Technological change refers to a change in the ability of a firm to produce a given level of output with a given quantity of inputs.

10.2 The Short Run and the Long Run in Economics (pages 327–331)

Distinguish between the economic short run and the economic long run. In the short run, a firm’s technology and the size of its factory, store, or office are fixed. In the long run, a firm is able to adopt new technology and to increase or decrease the size of its physical plant. Total cost is the cost of all the inputs a firm uses in production. Variable costs are costs that change as output changes. Fixed costs are costs that remain constant as output changes. Opportunity cost is the highest-valued alternative that must be given up to engage in an activity. An explicit cost is a cost that involves spending money. An implicit cost is a nonmonetary opportunity cost. The relationship between the inputs employed by a firm and the maximum output it can produce with those inputs is called the firm’s production function.

10.3 The Marginal Product of Labor and the Average Product of Labor (pages 331–335)

Understand the relationship between the marginal product of labor and the average product of labor. The marginal product of labor is the additional output produced by a firm as a result of hiring one more worker. Specialization and division of labor cause the marginal product of labor to rise for the first few workers hired. Eventually, the law of diminishing returns causes the marginal product of labor to decline. The average product of labor is the total amount of output produced by a firm divided by the quantity of workers hired. When the marginal product of labor is greater than the average product of labor, the average product of labor increases. When the marginal product of labor is less than the average product of labor, the average product of labor decreases.

10.4 The Relationship between Short-Run Production and Short-Run Cost (pages 335–337)

Explain and illustrate the relationship between marginal cost and average total cost. The marginal cost of production is the increase in total cost resulting from producing another unit of output. The marginal cost curve has a U shape because when the marginal product of labor is rising, the marginal cost of output is falling. When the marginal product of labor is falling, the marginal cost of output is rising. When marginal cost is less than average total cost, average total cost falls. When marginal cost is greater than average total cost, average total cost rises.

10.5 Graphing Cost Curves (page 338)

Graph average total cost, average variable cost, average fixed cost, and marginal cost. Average fixed cost is equal to fixed cost divided by the level of output. Average variable cost is equal to variable cost divided by the level of output. Figure 10-5 on page 339 in the textbook shows the relationship among marginal cost, average total cost, average variable cost, and average fixed cost. It is one of the most important graphs in microeconomics.
10.6 Costs in the Long Run (pages 338–343)
Understand how firms use the long-run average cost curve in their planning. The long-run average cost curve shows the lowest cost at which a firm is able to produce a given level of output in the long run. For many firms, the long-run average cost curve falls as output expands because of economies of scale. Minimum efficient scale is the level of output at which all economies of scale have been exhausted. After economies of scale have been exhausted, firms experience constant returns to scale, where their long-run average cost curve is flat. At high levels of output, the long-run average cost curve turns up as the firm experiences diseconomies of scale.

Appendix: Using Isoquants and Isocosts to Understand Production and Cost (pages 355–365)
Use isoquants and isocost lines to understand production and cost.

Chapter Review

Chapter Opener: Sony Uses a Cost Curve to Determine the Price of Radios (page 325)
The introduction to the chapter uses a story related by Sony Corporation chairman Akio Morita regarding the behavior of his firm’s average costs of production. Sony’s cost per unit, or average cost, changes as it increases its rate of output. At first, average cost falls as output increases, but eventually increases as output increases further. The U shape of Sony’s average total cost curve is typical of most firms’ average total cost curves.

10.1 Technology: An Economic Definition (pages 326–327)
Learning Objective: Define technology and give examples of technological change.

Technology is the processes a firm uses to turn inputs into outputs of goods and services. Technological change is a change in the ability of a firm to produce a given level of output with a given quantity of inputs. Positive technological change results from changes such as rearranging the layout of a store and purchasing faster or more reliable machinery. Positive technological change causes more output to be produced from the same inputs or the same output from fewer inputs. Negative technological change may result from changes such as hiring less-skilled workers or damage to buildings due to inclement weather. The result is a decline in the quantity of output that can be produced from a given quantity of inputs.

Study Hint
Do not confuse technological change with invention. An invention is the development of a new product or process for making a product. An invention or discovery of new information, such as a chemical formula, is not technological change. Technological change results from the application of new or old knowledge to a production process. Making the Connection “Improving Inventory Control at Wal-Mart” provides an example of technological change in which Wal-Mart uses electronic point-of-sale information and just-in-time (JIT) delivery to manage its inventories and supply chain to fulfill the needs of the customer and grow the business. A number of other firms have followed in Wal-Mart’s footsteps by incorporating JIT and electronic inventory controls into their production process to increase their efficiency.
Extra Solved Problem 10-1

Technological Change: Wright and Wrong

Supports Learning Objective 10.1: Define technology and give examples of technological change.

Decades can pass before a new idea is developed to the point where it can be widely used. For instance, the Wright brothers first achieved self-propelled flight at Kitty Hawk, North Carolina, in 1903. But their plane was very crude, and it wasn’t until the introduction of the DC-3 by Douglas Aircraft in 1936 that regularly scheduled intercity flights became common in the United States. Similarly, the development of the first digital electronic computer—the ENIAC—occurred in 1945, but the first IBM personal computer was not introduced until 1981. It wasn’t until the 1990s that widespread use of computers began to have a significant effect on the productivity of American business.

In 1999, Hershey Foods, manufacturer of Hershey’s bars and Reese’s Peanut Butter Cups, installed a new software program designed by the German company SAP to coordinate almost all of the company’s operations. Unfortunately, it took Hershey many months to get the software to work properly. During the period when the software was not working well, Hershey failed to send out some shipments and other shipments contained less candy than they were supposed to have. Software problems made it difficult for Hershey to keep track of what had been shipped and to whom it had been shipped. The company lost $150 million worth of sales before the problem was corrected and the software began to work as intended.


a. Define technology and technological change.

b. Was the Wright Brothers’ 1903 flight at Kitty Hawk an example of technological change? Was the development of the ENIAC computer an example of technological change?

c. Explain why the widespread use of computers in the 1990s resulted in positive technological change.

d. Did Hershey’s use of a new software program in 1999 result in positive or negative technological change?

SOLVING THE PROBLEM:

Step 1: Review the chapter material.
This problem is about technology and technological change, so you may want to review the section “Technology: An Economic Definition,” which begins on page 326 in the textbook.

Step 2: Define technology and technological change.
A firm’s technology is the process it uses to turn inputs into outputs of goods and services. Technological change is the change in the ability to produce a given level of output with a given quantity of inputs.

Step 3: Was the Wright Brothers’ 1903 flight at Kitty Hawk an example of technological change? Was the development of the ENIAC computer an example of technological change?
Neither the Wright Brothers’ 1903 flight at Kitty Hawk nor the development of ENIAC represents technological change because there was no impact on the ability of firms to produce output with a different quantity of inputs.
Step 4: Explain why the widespread use of computers in the 1990s resulted in positive technological change.
The widespread use of computers led to an improvement in productivity. Many firms were able to produce the same output of goods and services with fewer inputs or more output with the same quantity of inputs.

Step 5: Did Hershey’s use of a new software program in 1999 result in positive or negative technological change?
The initial use of the software produced negative technological change because Hershey’s output was less with the same quantity of inputs. After the “bugs” were eliminated, the use of this software produced positive technological change.

The Short Run and the Long Run in Economics (pages 327–331)
Learning Objective: Distinguish between the economic short run and the economic long run.

The short run is a period of time during which at least one of the firm’s inputs is fixed. The long run is a period of time long enough to allow a firm to vary all of its inputs, to adopt new technology, and to increase or decrease the size of its physical plant. Total cost is the cost of all the inputs a firm uses in production. Variable costs are costs that change as output changes. Fixed costs are costs that remain constant as output changes.

\[
\text{Total Cost (} TC \text{)} = \text{Fixed Cost (} FC \text{)} + \text{Variable Cost (} VC \text{)}
\]

In the long run, all costs are variable because the quantities of all inputs are variable.

Total costs can also be divided into explicit and implicit costs. An explicit cost is a cost that involves spending money. An implicit cost is a nonmonetary opportunity cost. Recall from Chapters 1 and 2 that the opportunity cost of an activity is the highest-valued alternative that must be given up to engage in the activity. Opportunity costs can include both explicit and implicit costs.

The production function is the relationship between the inputs employed by the firm and the maximum output it can produce with those inputs. In the short run, at least one input is fixed, so the short-run production function shows the level of output the firm can produce with different levels of the variable inputs and a constant quantity of the fixed input. The long-run production function shows the maximum quantity of output the firm can produce using various levels of all inputs. Knowing how many inputs are required to produce a given level of output allows you to determine the total cost of production as well. The average total cost is total cost divided by the quantity of output produced. The average total cost curve often has a U shape.
Study Hint
An example may help you to understand the difference between a short-run and a long-run production function. Your hometown probably has a theater, stadium, or auditorium. Various events are held at these venues during the year, some of which may sell out while others do not. In the short run, the size of the facility is a fixed input and variations in crowd size can be accommodated by changes in the use of variable inputs (such as ticket takers, ushers, parking attendants, and food at refreshment stands). It is unlikely that the owners will decide to increase or decrease the capacity of the facility unless they expect a permanent change in average expected attendance. Such a permanent change could be the result of an increase or decrease in the population served by the facility or the acquisition or loss of a permanent tenant; for example, a professional sports franchise or a philharmonic orchestra. Expanding or contracting the size of the facility (usually by tearing down the existing structure and building a new one) is an example of a long-run production decision. See Making the Connection “Fixed Costs in the Publishing Industry” for a discussion of fixed costs in the editing and marketing of books. Because the number of editors, designers, and marketing people does not vary with the number of copies of books that are sold in a given year, publishers treat the salaries and benefits of people in these job categories as fixed costs.

Extra Solved Problem 10-2
Apple Picking
Supports Learning Objective 10.2: Distinguish between the economic short run and the economic long run.

Suppose that you own an apple orchard and the following chart represents the number of apples that can be picked from your orchard on a per-hour basis with a given quantity of capital equipment, such as baskets and ladders.

<table>
<thead>
<tr>
<th>Quantity of Workers</th>
<th>Apples</th>
<th>Fixed Cost</th>
<th>Variable Cost</th>
<th>Total Cost</th>
<th>Cost per Apple (Average Total Cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>$10</td>
<td>$0</td>
<td>$10</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>10</td>
<td>5</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>210</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>290</td>
<td>10</td>
<td>15</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>340</td>
<td>10</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>360</td>
<td>10</td>
<td>25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Complete the table above by calculating the total cost and the average total cost.

b. Does the total cost in the table represent your short-run or long-run total cost?

SOLVING THE PROBLEM
Step 1: Review the chapter material.
This problem is about distinguishing short-run and long-run costs, so you may want to review the section, “The Short Run and the Long Run in Economics,” which begins on page 327 in the textbook.
Step 2: **Answer question (a) by computing the total cost and the average total cost.**

Total cost is calculated by adding the fixed costs to the variable costs. The average total cost is the total cost divided by the quantity. The table below provides the results of the calculations.

<table>
<thead>
<tr>
<th>Quantity of Workers</th>
<th>Apples</th>
<th>Fixed Cost</th>
<th>Variable Cost</th>
<th>Total Cost</th>
<th>Cost per Apple (Average Total Cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>$10</td>
<td>$0</td>
<td>$10</td>
<td>—</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>10</td>
<td>5</td>
<td>15</td>
<td>$0.15</td>
</tr>
<tr>
<td>2</td>
<td>210</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>0.10</td>
</tr>
<tr>
<td>3</td>
<td>290</td>
<td>10</td>
<td>15</td>
<td>25</td>
<td>0.09</td>
</tr>
<tr>
<td>4</td>
<td>340</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>0.09</td>
</tr>
<tr>
<td>5</td>
<td>360</td>
<td>10</td>
<td>25</td>
<td>35</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Step 3: **Answer question (b) by determining whether the costs and production function shown in the table are representative of the short run or the long run.**

To determine whether this is the short run or the long run, we need to determine if all inputs are variable or if at least one input is fixed. In the description of the problem, we see that the number of ladders and baskets is fixed, so we are looking at the short-run condition. This is reinforced by the fact that your orchard is experiencing a positive and constant fixed cost.

### 10.3 The Marginal Product of Labor and the Average Product of Labor (pages 331–335)

**Learning Objective:** Understand the relationship between the marginal product of labor and the average product of labor.

The **marginal product of labor** is the additional output a firm produces as a result of hiring one more worker. The increases in marginal product of labor that occur at low rates of output result from specialization and the division of labor. Consider for instance, a firm that initially employs only one worker. Adding a second or third worker, for example, would typically reduce the time the workers spend moving from one activity to the next and allow them to become more specialized at their tasks. At some point, adding more of a variable input, such as labor, to the same amount of a fixed input, such as capital, will cause the marginal product of the variable input to decline. This principle is called the **law of diminishing returns**. When the marginal product of labor is decreasing, but still positive, total output increases, but at a decreasing rate.

The **average product of labor** is the total output produced by a firm divided by the quantity of workers. When the marginal product of labor is greater than the average product of labor, the average product of labor must be increasing. When the marginal product of labor is less than the average product of labor, the average product of labor must be decreasing. The marginal product of labor equals the average product of labor for the quantity of workers where the average product of labor is at a maximum.
Study Hint
The relationship between the marginal product of labor and average product of labor is similar to many other marginal-average relationships. You will better understand the relationship between the two after reviewing the example of GPAs illustrated in Figure 10-3. Also read Making the Connection “Adam Smith’s Famous Account of the Division of Labor in a Pin Factory” for a discussion of how the division of labor can increase the average output per worker. Smith describes how workers become very specialized in a particular part of the production process with the division of labor and, thus, become more productive.

Extra Solved Problem 10-3
Apple Picking—Continued
Supports Learning Objective 10.3: Understand the relationship between the marginal product of labor and the average product of labor.

Suppose that you own an apple orchard and the following chart represents the number of apples that can be picked from your orchard on a per-hour basis with the given capital equipment, including five baskets.

<table>
<thead>
<tr>
<th>Quantity of Workers</th>
<th>Quantity of Baskets</th>
<th>Apples</th>
<th>Marginal Product of Labor</th>
<th>Average Product of Labor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>100</td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>5</td>
<td>210</td>
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<td>3</td>
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<td>4</td>
<td>5</td>
<td>340</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>360</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Complete the table above by calculating the marginal product of labor and the average product of labor.

b. Describe the relationship between marginal product of labor and the orchard’s total production. Does the law of diminishing returns apply to the orchard’s production?

c. Describe the relationship between the marginal product of labor and the average product of labor.

SOLVING THE PROBLEM
Step 1: Review the chapter material.
This problem is about marginal and average product of labor, so you may want to review the section “The Marginal Product of Labor and the Average Product of Labor,” which begins on page 331 in the textbook.
Step 2: Answer question (a) by computing the marginal product of labor and the average product of labor.

The marginal product of labor is the additional output a firm produces as a result of hiring one more worker. This is calculated by dividing the change in the quantity of apples produced by the change in the quantity of labor used to produce the apples. The average product of labor is the total output produced by a firm divided by the quantity of workers used to produce that output. The results of these calculations are displayed in the table below.

<table>
<thead>
<tr>
<th>Quantity of Workers</th>
<th>Quantity of Baskets</th>
<th>Apples</th>
<th>Marginal Product of Labor</th>
<th>Average Product of Labor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td>5</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>210</td>
<td>110</td>
<td>105</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>290</td>
<td>80</td>
<td>97</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>340</td>
<td>50</td>
<td>85</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>360</td>
<td>20</td>
<td>72</td>
</tr>
</tbody>
</table>

Step 3: Answer question (b) by explaining the relationship between the marginal product and the total output.

When the marginal product is increasing rapidly, the firm’s total output increases rapidly. As the gains from specialization and the division of labor are exhausted, an additional increase in labor causes the marginal product to fall. Total output continues to increase but at a decreasing rate as the marginal product falls. See Figure 10-2 on page 332 in the textbook to see an example of this.

Step 4: Answer question (c) by describing the relationship between the marginal product of labor and the average product of labor.

When the marginal product of labor is greater than the average product of labor, the average product of labor will increase. When the marginal product of labor is lower than the average product of labor, the average product of labor will decrease. The marginal product of the second worker is 110, which is higher than the average product of 100 apples per worker, causing the average product of two workers to rise from 100 to 105. When the third worker is hired, only 80 additional apples are picked, which is less than the average of 105. The addition of the third worker whose marginal product was less productive than average pulls down the average product from 105 to 97. (See the GPA example on page 334 in the textbook for an example of how the marginal value drives the average value.)

10.4 The Relationship between Short-Run Production and Short-Run Cost
(pages 335–337)

Learning Objective: Explain and illustrate the relationship between marginal cost and average total cost.

In the short run, the behavior of the marginal product of the variable factor is represented in the behavior of marginal cost. **Marginal cost** is the change in a firm’s total cost from producing one more unit of a good or service. The U shape of the average total cost curve is determined by the shape of the marginal
cost curve. Marginal cost \((MC)\) can be expressed mathematically as

\[
MC = \frac{\Delta TC}{\Delta Q}
\]

where \(\Delta\) represents “change in,” \(TC\) is total cost, and \(Q\) is output.

The law of diminishing returns explains the behavior of the marginal product of the variable factor in the short run. This is illustrated in the table that is part of Figure 10-4 on page 336 in the textbook. The table in this figure shows how the marginal product of labor rises for the first and second workers, and the marginal cost falls as these first two workers are hired. As diminishing returns set in, the marginal product of labor falls and the marginal cost rises as the last four workers are hired. The marginal cost of production falls and then rises—a U shape—because the marginal product of labor rises and then falls.

**Study Hint**

*Solved Problem 10-4* shows how, as diminishing returns set in, the average and marginal costs of production rise. Work related end-of-chapter problems 4.5 and 4.6 for further help in understanding the law of diminishing returns and its relationship to costs.

### 10.5 Graphing Cost Curves (page 338)

**Learning Objective:** Graph average total cost, average variable cost, average fixed cost, and marginal cost.

Several related average cost measures can be described mathematically.

Remember that average total cost \(\text{(ATC)}\) equals total cost \(\text{(TC)}\) divided by the quantity of output produced.

\[
\text{ATC} = \frac{TC}{Q}
\]

**Average fixed cost** \(\text{(AFC)}\) equals fixed cost divided by the quantity of output produced.

\[
\text{AFC} = \frac{FC}{Q}
\]

**Average variable cost** \(\text{(AVC)}\) equals variable cost divided by the quantity of output produced.

\[
\text{AVC} = \frac{VC}{Q}
\]

Average total cost \(\text{(ATC)}\) can then be calculated as the sum of average fixed cost and average variable cost.

\[
\text{ATC} = \text{AFC} + \text{AVC}
\]
The \( MC \), \( ATC \), and \( AVC \) curves are all U-shaped. Here are key points about these curves:

- The \( MC \) curve intersects the \( AVC \) and \( ATC \) curves at their minimum points.
- When \( MC \) is below \( AVC \) or \( ATC \), it causes them to decrease, and when \( MC \) is above \( AVC \) or \( ATC \), it causes them to increase.
- As output increases, the difference between \( ATC \) and \( AVC \) (this is equal to \( AFC \)) gets smaller because \( AFC \) gets smaller and smaller as output increases.

### Study Hint

To draw the curves accurately, it is best to draw the \( MC \) curve first. Then draw \( ATC \), but start by putting your pencil or pen on the \( MC \) curve and drawing the left half of \( ATC \) so that it curves up and to the left. Go back to the \( MC \) curve and then draw the right half of \( ATC \) so that it curves up and to the right. This ensures that the minimum point of \( ATC \) is where \( ATC \) crosses \( MC \). Follow the same procedure to draw \( AVC \) below \( ATC \). When you draw the left half of \( AVC \), make sure that the difference between \( ATC \) and \( AVC \) becomes greater as output decreases. When you draw the right half of \( AVC \), make the difference between \( ATC \) and \( AVC \) smaller as output increases. Remember that the difference between \( ATC \) and \( AVC \) is \( AFC \) (average fixed cost), which gets smaller as output increases.

### Extra Solved Problem 10-5

**Apple Picking—Continued**

Supports Learning Objective 10.5: Graph average total cost, average variable cost, average fixed cost, and marginal cost.

Suppose that you own an apple orchard and the following chart represents the quantity of apples that can be picked from your orchard per hour with a given quantity of capital equipment, such as baskets and ladders.

<table>
<thead>
<tr>
<th>Quantity of Workers</th>
<th>Apples</th>
<th>Fixed Cost</th>
<th>Variable Cost</th>
<th>Total Cost</th>
<th>Cost per Apple (ATC)</th>
<th>MC</th>
<th>AVC</th>
<th>AFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>10</td>
<td>5</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>210</td>
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<td>10</td>
<td>20</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>3</td>
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<td>25</td>
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<tr>
<td>4</td>
<td>340</td>
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<td>20</td>
<td>30</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>5</td>
<td>360</td>
<td>10</td>
<td>25</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Complete the table above by calculating the average total cost, marginal cost, average variable cost, and the average fixed cost.

b. Graph the marginal cost, average total cost, average variable cost, and average fixed cost curves.

**SOLVING THE PROBLEM**

**Step 1:** Review the chapter material.

To complete this problem you may want to review the section “Graphing Cost Curves” on page 338 in the textbook.
Step 2: Answer question (a) by computing the marginal cost, the average variable cost, and the average fixed cost.

The average total cost is the total cost divided by the quantity of output. The average fixed cost is the fixed cost divided by the quantity of output produced. Average variable cost is calculated by dividing variable cost by the quantity of units produced. The marginal cost is the change in a firm’s total cost from producing one more unit of a good or service. The results of these calculations are presented below. (Hint: Don’t make the mistake of using the quantity of workers in these calculations; use the quantity of apples produced.)

<table>
<thead>
<tr>
<th>Quantity of Workers</th>
<th>Apples</th>
<th>Fixed Cost</th>
<th>Variable Cost</th>
<th>Total Cost</th>
<th>Cost per Apple (ATC)</th>
<th>MC</th>
<th>AVC</th>
<th>AFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>10</td>
<td>$0.15</td>
<td>.05</td>
<td>.050</td>
<td>.100</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>10</td>
<td>5</td>
<td>15</td>
<td>$.05</td>
<td>.05</td>
<td>.047</td>
<td>.048</td>
</tr>
<tr>
<td>2</td>
<td>210</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>.09</td>
<td>.06</td>
<td>.052</td>
<td>.034</td>
</tr>
<tr>
<td>3</td>
<td>290</td>
<td>10</td>
<td>15</td>
<td>25</td>
<td>.09</td>
<td>.10</td>
<td>.059</td>
<td>.029</td>
</tr>
<tr>
<td>4</td>
<td>340</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>.10</td>
<td>.25</td>
<td>.069</td>
<td>.028</td>
</tr>
<tr>
<td>5</td>
<td>360</td>
<td>10</td>
<td>25</td>
<td>35</td>
<td>.10</td>
<td>.25</td>
<td>.069</td>
<td>.028</td>
</tr>
</tbody>
</table>

Step 3: Answer question (b) by graphing the cost curves.

To graph each of the average cost curves and the marginal cost curve, consider what the cost is for each given quantity. The graph of the curves is as follows:
There are no fixed costs in the long run, so total cost equals variable cost. In the short run, managers of firms decide how they will operate their current store, office, or factory. In the long run, managers decide whether the firm would be more profitable if the store, office, or factory were made larger or smaller.

A long-run average cost curve shows the lowest cost at which the firm is able to produce a given quantity of output in the long run, when no inputs are fixed. **Economies of scale** is the situation when a firm’s long-run average total costs fall as it increases output. **Constant returns to scale** is the situation when a firm’s long-run average costs remain unchanged as it increases output. **Minimum efficient scale** is the level of output at which all economies of scale have been exhausted. **Diseconomies of scale** is the situation when a firm’s long-run average costs rise as it increases output.

Economies of scale may result from several factors. The firm’s technology may make it possible to increase production with a smaller than proportional increase in at least one input. As output expands, both workers and managers may become more specialized, enabling them to be more productive. Large firms may be able to purchase inputs at lower costs than smaller competitors. Diseconomies of scale result when managers have difficulty coordinating a firm as it grows in scale.

**Study Hint**

Long-run average cost curves, such as those shown in Solved Problem 10-6, are drawn as smooth U-shaped curves. Do not confuse these curves with short-run average total cost curves. Read *Don’t Let This Happen to YOU!* “Don’t Confuse Diminishing Returns with Diseconomies of Scale,” which explains why there are different explanations for the U shape of the short-run and long-run curves. The smooth long-run average cost curve is similar to the optical illusion of a motion picture. A motion picture is essentially a series of still photographs that when projected sequentially (and rapidly) give the viewer the illusion of live, continuous motion. Similarly, the long-run average cost curve is made up of a series of short-run ATC curves, each of which contributes a small portion (one point) of the long-run average cost curve. As the plant size increases or decrease, the effect of the plant size on the production cost (that is, economies and diseconomies of scale) determines the shape of the long-run average cost curve. The shape of the short-run average cost curve, however, is determined by diminishing returns.

**Appendix**

**Using Isoquants and Isocosts to Understand Production and Cost (pages 355–365)**

Learning Objective: Use isoquants and isocost lines to understand production and cost.

The chapter covers the relationship between a firm’s level of production and its costs. This appendix looks more closely at how firms choose the combination of inputs to produce a given level of output.

**Isoquants**

Firms search for the cost-minimizing combination of inputs that will allow them to produce a given level of output. The cost-minimizing combination of inputs depends on technology and input prices. An
**isoquant** is a curve showing all the combinations of two inputs, such as capital and labor, that will produce the same level of output. The farther an isoquant is from the origin—the farther to the right on the graph—the more output the firm is producing. There are many isoquants, one for every possible level of output.

The **marginal rate of technical substitution (MRTS)** is the rate at which a firm is able to substitute one input for another while keeping the level of output constant. The slope of an isoquant becomes less steep as one moves downward along the isoquant. This is a consequence of diminishing returns.

**Study Hint**

Figure 10A-1 illustrates three isoquants, each of which represents various combinations of capital (measured on the vertical axis) and labor (measured on the horizontal axis) that enable Jill to produce a given number of pizzas per week. Isoquants are similar to indifference curves in several respects. If you understand the analysis of indifference curves in the appendix to Chapter 9, then you should understand isoquants.

**Isocost Lines**

The relationship between the quantity of inputs used and the firm’s total cost can be shown with an **isocost line**. An isocost line shows all the combinations of two inputs, such as capital and labor, that have the same total cost. An isocost line intersects the vertical axis at the maximum amount of an input (for example, capital) that can be purchased with a given budget, or total cost. The same isocost line intersects the horizontal axis at the maximum amount of another input (for example, labor) that can be purchased with the same budget. One input is substituted for another as one moves along an isocost line, but the total expenditure on inputs is the same. The slope of an isocost line is constant and equals the change in the quantity of one input (capital) divided by the change in the quantity of the other input (labor). The slope of an isocost line is equal to the ratio of the price of the input on the horizontal axis divided by the price of the input on the vertical axis, multiplied by negative 1. A change in the price of an input causes the slope to change, which is a rotation of the isocost line. Higher levels of total cost shift the isocost line outward, and lower levels of cost shift the isocost line inward.

**Study Hint**

Figure 10A-2 on page 357 in the textbook illustrates an example of an isocost line. The analysis of isocost lines is similar to the analysis of budget lines in the appendix to Chapter 9.

**Choosing the Cost-Minimizing Combination of Capital and Labor**

If diminishing returns exist, there will be only one combination of inputs that will produce a given amount of output at the lowest total cost. The lowest cost combination of inputs that will produce a given level of output is found at the tangency of an isocost line with the isoquant that represents the given output level. At the point of cost minimization, the MRTS is equal to the price of the input measured on the horizontal axis (for example, the wage rate or price of labor) divided by the price of the input measured on the vertical axis (for example, the rental price of capital).

The cost-minimizing choice of inputs is determined jointly by available production technology and input prices. A change in technology affects the position of isoquants and may affect the choice of inputs. If input prices change, then the position of isocost lines will change and the choice of inputs may also change.
Moving along an isoquant, the output is constant while the amounts of two inputs change. The marginal product of capital \((MP_K)\) equals the change in output from using an additional unit of capital. The marginal product of labor \((MP_L)\) equals the change in output from using an additional unit of labor. Because the loss in output from using lower capital equals the gain in output from using more workers along an isoquant,

\[-\text{Change in the quantity of capital } \times MP_K = \text{Change in the quantity of labor } \times MP_L.\]

Rewriting this equation:

\[\frac{\text{Change in the quantity of capital}}{\text{Change in the quantity of labor}} = \frac{MP_L}{MP_K} = \text{MRTS.}\]

The slope of the isocost line equals the wage rate \((w)\) divided by the rental price of capital \((r)\). At the point of cost minimization, the slope of the isoquant equals the slope of the isocost line. Therefore:

\[\frac{MP_L}{MP_K} = \frac{w}{r}\]

or, after rearranging:

\[\frac{MP_L}{w} = \frac{MP_K}{r}\]

The last equation implies that to minimize cost, a firm should hire inputs up to the point where the last dollar spent on each input results in the same increase in output.

---

**Study Hint**

*Solved Problem 10A-1* explains how Jill can find the cost minimizing combination of inputs to produce pizza. A firm should purchase or hire inputs up to the point where the ratio of the marginal product to the price of the input is the same for every input used. If one input has a higher marginal product for the last dollar spent, then the firm should hire more of that input and less of the other input to minimize the costs of production.

**The Expansion Path**

An expansion path is a curve that shows a firm’s cost-minimizing combination of inputs for every level of output. The expansion path represents the least-cost combination of inputs to produce a given level of output in the long run when the firm is able to vary the levels of all of its inputs. In the short run, at least one of the firm’s inputs is fixed. The expansion of output is possible only by varying the firm’s variable input(s), so the firm’s minimum total costs of production are lower in the long run than in the short run.

**Key Terms**

- **Average fixed cost** Fixed cost divided by the quantity of output produced.
- **Average product of labor** The total output produced by a firm divided by the quantity of workers.
- **Average total cost** Total cost divided by the quantity of output produced.
- **Average variable cost** Variable cost divided by the quantity of output produced.

Constant returns to scale  The situation when a firm’s long-run average costs remain unchanged as it increases output.

Diseconomies of scale  The situation when a firm’s long-run average costs rise as the firm increases output.

Economies of scale  The situation when a firm’s long-run average costs fall as it increases output.

Explicit cost  A cost that involves spending money.

Fixed costs  Costs that remain constant as output changes.

Implicit cost  A nonmonetary opportunity cost.

Law of diminishing returns  The principle that, at some point, adding more of a variable input, such as labor, to the same amount of a fixed input, such as capital, will cause the marginal product of the variable input to decline.

Long run  The period of time in which a firm can vary all its inputs, adopt new technology, and increase or decrease the size of its physical plant.

Long-run average cost curve  A curve showing the lowest cost at which a firm is able to produce a given quantity of output in the long run, when no inputs are fixed.

Marginal cost  The change in a firm’s total cost from producing one more unit of a good or service.

Marginal product of labor  The additional output a firm produces as a result of hiring one more worker.

Minimum efficient scale  The level of output at which all economies of scale are exhausted.

Opportunity cost  The highest-valued alternative that must be given up to engage in an activity.

Production function  The relationship between the inputs employed by a firm and the maximum output it can produce with those inputs.

Short run  The period of time during which at least one of a firm’s inputs is fixed.

Technological change  A change in the ability of a firm to produce a given level of output with a given quantity of inputs.

Technology  The processes a firm uses to turn inputs into outputs of goods and services.

Total cost  The cost of all the inputs a firm uses in production.

Variable costs  Costs that change as output changes.

Expansion path  A curve that shows a firm’s cost-minimizing combination of inputs for every level of output.

Isoquant  A curve that shows all the combinations of two inputs, such as capital and labor, that will produce the same level of output.

Isoquant  A curve that shows all the combinations of two inputs, such as capital and labor, that will produce the same level of output.

Marginal rate of technical substitution (MRTS)  The rate at which a firm is able to substitute one input for another while keeping the level of output constant.
Self-Test

(Answers are provided at the end of the Self-Test.)

Multiple-Choice Questions

1. The processes a firm uses to turn inputs into outputs of goods and services is _________.
   a. technology
   b. technological change
   c. the short run
   d. the production function

2. The term used to describe a change in the ability of a firm to produce a given level of output with a given level of inputs is called _________.
   a. technology
   b. technological change
   c. the long run
   d. the production function

3. What is the short run?
   a. a period of time during which a firm can vary all of its inputs
   b. a period of time during which a firm can adopt a new technology
   c. a period of time during which a firm can increase or decrease the size of its physical plant
   d. a period of time during which at least one of the firm’s inputs is fixed

4. Which costs are affected by the level of output produced?
   a. fixed costs
   b. variable costs
   c. all costs
   d. sunk costs

5. If the number of people in a publishing company does not go up or down with the quantity of books it publishes, then how should we categorize the salaries and benefits paid to these employees?
   a. They are part of fixed cost.
   b. They are part of variable cost.
   c. They are an implicit cost.
   d. They are not considered a part of the cost of production.

6. Which of the following is known as the highest-valued alternative that must be given up in order to engage in an activity?
   a. opportunity cost
   b. explicit cost
   c. total cost
   d. variable cost
7. Refer to the table below. Which of the following costs are implicit costs?

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>$20,000</td>
</tr>
<tr>
<td>Wages</td>
<td>$48,000</td>
</tr>
<tr>
<td>Lease payment for copy machines</td>
<td>$10,000</td>
</tr>
<tr>
<td>Electricity</td>
<td>$6,000</td>
</tr>
<tr>
<td>Lease payment for store</td>
<td>$24,000</td>
</tr>
<tr>
<td>Foregone salary</td>
<td>$30,000</td>
</tr>
<tr>
<td>Foregone interest</td>
<td>$3,000</td>
</tr>
<tr>
<td>Total</td>
<td>$141,000</td>
</tr>
</tbody>
</table>

a. the foregone salary and interest
b. the lease payments
c. the payments for paper, wages, and electricity
d. all of the above

8. Which of the following are sometimes called accounting costs?
   a. economic costs
   b. implicit costs
   c. explicit costs
d. total variable costs

9. What is the production function?
   a. the representation of the firm’s costs
   b. the relationship between the inputs employed by a firm and the maximum output it can produce with those inputs
c. the total cost divided by the quantity of output produced
d. all of the above

10. Fill in the blanks. When graphing a conventional short-run production function, we place ____________ on the horizontal axis and ____________ on the vertical axis.
   a. output; the variable input
   b. the variable input; the fixed input
c. the fixed input; the variable input
d. the variable input; output
11. Refer to the graphs below. Which graph is representative of a typical average total cost curve?

a. A  
b. B  
c. C  
d. D

12. Which of the following is true?
   i. Total cost = fixed cost + variable cost
   ii. Total cost = explicit costs + implicit costs
   iii. Economic cost = accounting cost + implicit costs
   a. i only  
b. ii only  
c. i and ii only  
d. i, ii, and iii

13. What is the additional output that a firm produces as a result of hiring one more worker called?
   a. the production function  
b. average total cost  
c. marginal product of labor  
d. average product of labor

14. Refer to the table below. When do diminishing returns in the production of pizzas start?

<table>
<thead>
<tr>
<th>QUANTITY OF WORKERS</th>
<th>QUANTITY OF PIZZA OVENS</th>
<th>QUANTITY OF PIZZAS</th>
<th>MARGINAL PRODUCT OF LABOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>450</td>
<td>250</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>550</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>600</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>625</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>640</td>
<td>15</td>
</tr>
</tbody>
</table>
a. when the second worker is hired  
b. when the third worker is hired  
c. when the fourth worker is hired  
d. when the fifth worker is hired

15. Refer to the graph below. In moving along the curve from point A to point B, which of the following is more likely to occur?

![Graph Image]

a. specialization  
b. diminishing returns  
c. division of labor  
d. none of the above

16. Refer to the graph below. From the origin up until point A,

![Graph Image]

a. output increases at an increasing rate.  
b. output increases at a decreasing rate.  
c. output increases at a constant rate.  
d. the effect of diminishing returns is greater than the effect of specialization.
17. Which of the following statements about the relationship between marginal product of labor and average product of labor is correct?
   a. Whenever the marginal product of labor is less than the average product of labor, the average product of labor must be increasing.
   b. Whenever the marginal product of labor is greater than the average product of labor, the average product of labor must be increasing.
   c. Whenever the marginal product of labor is greater than the average product of labor, the marginal product of labor must be decreasing.
   d. Whenever the marginal product of labor is less than the average product of labor, the marginal product of labor must be decreasing.

18. Which of the following refers to the total output produced by a firm divided by the quantity of workers?
   a. average total cost
   b. marginal cost
   c. average product of labor
   d. marginal product of labor

19. Refer to the graph below. Based on the relationship between marginal product and average product, which curve appears to be average product?
   a. Curve 1
   b. Curve 2
   c. Both curves appear to be average product curves.
   d. neither curve
20. Refer to the table below. What is the marginal cost of producing the 200th pizza?

<table>
<thead>
<tr>
<th>Quantity of Workers</th>
<th>Quantity of Pizzas</th>
<th>Marginal Product of Labor</th>
<th>Total Cost of Pizzas</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>-</td>
<td>$800</td>
</tr>
<tr>
<td>1</td>
<td>200</td>
<td>200</td>
<td>1450</td>
</tr>
<tr>
<td>2</td>
<td>450</td>
<td>250</td>
<td>2100</td>
</tr>
<tr>
<td>3</td>
<td>550</td>
<td>100</td>
<td>2750</td>
</tr>
<tr>
<td>4</td>
<td>600</td>
<td>50</td>
<td>3400</td>
</tr>
<tr>
<td>5</td>
<td>625</td>
<td>25</td>
<td>4050</td>
</tr>
<tr>
<td>6</td>
<td>640</td>
<td>15</td>
<td>4700</td>
</tr>
</tbody>
</table>

a. $0.00  
b. $2.60  
c. $3.25  
d. $650.00

21. Refer to the graph below. Based on the relationship between average total cost and marginal cost, which of the curves below appears to be average total cost?

a. Curve 1  
b. Curve 2  
c. Both curves appear to be average cost curves.  
d. neither curve
22. Refer to the graph below. For a certain output range (or quantity of pizzas produced per day), marginal cost is greater than average cost. What is this output range?

- a. from zero to about 525 pizzas per day
- b. the output range greater than about 525 pizzas per day
- c. the entire output range, from zero to about 640 pizzas per day
- d. exactly 640 pizzas per day

23. What do we obtain by dividing the fixed cost by the quantity of output produced?
- a. total variable cost
- b. average fixed cost
- c. total cost
- d. average variable cost

24. What cost measure is equal to \( AFC + AVC \)?
- a. total cost
- b. average total cost
- c. marginal cost
- d. total variable cost
25. Refer to the graph below. What does Curve 4 represent?

a. average variable cost  
b. average total cost  
c. average fixed cost  
d. marginal cost
26. Refer to the graph below. At any level of output, what is the vertical distance between Curve 2 and Curve 3 equal to?

![Graph showing four curves: Curve 1, Curve 2, Curve 3, Curve 4.](image)

- a. Curve 1
- b. Curve 4
- c. total cost
- d. marginal cost

27. The following cost measures reach their minimum points when they are equal to the value of marginal cost, except one. Which cost measure is the exception?

- a. average variable cost
- b. average total cost
- c. average fixed cost
- d. There is no exception; all three measures above reach their minimum values when they are equal to the value of marginal cost.

28. What does the term “spreading the overhead” refer to?

- a. reducing average fixed cost by selling more output
- b. reducing average total cost by selling more output.
- c. reducing average variable cost by selling more output
- d. reducing total cost by selling more output
29. Refer to the graph below. How much is the value of total fixed cost?

![Graph showing costs per copy and quantity of copies produced.]

a. $2,400  
b. $3,400  
c. $5,800  
d. None of the above; total fixed cost cannot be computed using this graph.

30. Refer to the table below. What is the marginal cost of producing the 640th pizza?

<table>
<thead>
<tr>
<th>Quantity of Workers</th>
<th>Quantity of Ovens</th>
<th>Quantity of Pizzas</th>
<th>Cost of Ovens (Fixed cost)</th>
<th>Cost of Workers (Variable cost)</th>
<th>Total Cost of Pizzas</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
<td>0</td>
<td>$800</td>
<td>$0</td>
<td>$800</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>200</td>
<td>800</td>
<td>650</td>
<td>1,450</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>450</td>
<td>800</td>
<td>1,300</td>
<td>2,100</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>550</td>
<td>800</td>
<td>1,950</td>
<td>2,750</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>600</td>
<td>800</td>
<td>2,600</td>
<td>3,400</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>625</td>
<td>800</td>
<td>3,250</td>
<td>4,050</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>640</td>
<td>800</td>
<td>3,900</td>
<td>4,700</td>
</tr>
</tbody>
</table>

a. $43.33  
b. $650.00  
c. $4050.00  
d. $4700.00
31. Refer to the table below. What is the average total cost of producing 550 pizzas?

<table>
<thead>
<tr>
<th>Quantity of Workers</th>
<th>Quantity of Ovens</th>
<th>Quantity of Pizzas</th>
<th>Cost of Ovens (Fixed cost)</th>
<th>Cost of Workers (Variable cost)</th>
<th>Total Cost of Pizzas</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
<td>0</td>
<td>$800</td>
<td>$0</td>
<td>$800</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>200</td>
<td>800</td>
<td>650</td>
<td>1,450</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>450</td>
<td>800</td>
<td>1,300</td>
<td>2,100</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>550</td>
<td>800</td>
<td>1,950</td>
<td>2,750</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>600</td>
<td>800</td>
<td>2,600</td>
<td>3,400</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>625</td>
<td>800</td>
<td>3,250</td>
<td>4,050</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>640</td>
<td>800</td>
<td>3,900</td>
<td>4,700</td>
</tr>
</tbody>
</table>

a. $5.00  
b. $6.48  
c. $13.00  
d. $26.00

32. What happens to the difference between average variable cost and average total cost as the level of output increases?
   a. the difference increases
   b. the difference decreases
   c. the difference remains the same
   d. the difference first increases then decreases

33. Which of the following statements is correct?
   a. In the long run, all costs are variable.
   b. In the long run, all costs are fixed.
   c. In the long run, there are no fixed or variable costs.
   d. In the long run, at least one input remains fixed.

34. Which of the following terms refers to the lowest cost at which a firm is able to produce a given level of output in the long run, when no inputs are fixed?
   a. the long-run marginal cost curve
   b. the long-run average cost curve
   c. the variable inputs curve
   d. economies of scale

35. What happens when firms experience economies of scale?
   a. Firms can produce more output in smaller plants.
   b. The firm’s long-run average costs fall as output increases.
   c. The possibility of lowering long-run average costs is exhausted.
   d. Only a single plant size minimizes the long-run average cost of production.
36. Refer to the graph below. Which change in output represents economies of scale in bookselling?

- a. the move from 1,000 to 20,000 books sold per month
- b. the move from 20,000 to 40,000 books sold per month
- c. the move from 40,000 to 80,000 books sold per month
- d. None of the above. Economies of scale cannot be achieved anywhere on the graph.

37. Refer to the graph below. Which level of output represents the minimum efficient scale?

- a. 1,000 books
- b. 20,000 books
- c. 40,000 books
- d. 80,000 books
38. Refer to the graph below. In what output range do we find constant returns to scale?

- a. between 0 and 1,000 books
- b. between 1,000 and 20,000 books
- c. between 20,000 and 40,000 books
- d. between 40,000 and 80,000 books

39. Refer to the graph below. Which bookstore is more likely to experience diseconomies of scale?

- a. a bookstore selling 1,000 books per month
- b. a bookstore selling 20,000 books per month
- c. a bookstore selling 40,000 books per month
- d. a bookstore selling 80,000 books per month
40. When does the law of diminishing returns apply?
   a. when there are diseconomies of scale
   b. in the short run only
   c. in the long run only
   d. in both the short run and the long run

Short Answer Questions

1. You are studying for your economics exam with a friend, and your friend tells you that he thinks that if a firm can spread overhead costs over larger levels of output as output expands, then marginal costs must decline. Explain the flaw in your friend’s reasoning.

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2. What is the difference between a sunk cost and an opportunity cost?

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______________________________________________________________________________
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3. Figure 10-6 on page 340 in the textbook illustrates a bookstore’s long-run average total cost curve. The average total cost of selling 60,000 books per month ($20) is greater than the average total cost of selling 40,000 books per month ($18). If the bookstore sells 60,000 books at a cost of $20 each, is it producing inefficiently?

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4. The last column of Table 10-3 on page 331 in the textbook shows that the marginal product of labor at Jill Johnson’s restaurant changes as additional workers are hired. The marginal product of labor of the second worker (250 pizzas) is greater than the marginal product of labor for any other worker. To make the most profit, should Jill hire two workers?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
5. In his famous account of the division of labor in a pin factory, Adam Smith refers to “…the important business of making a pin…” Even in Smith’s day, the total value of pin production in the United Kingdom was not a large fraction of total output. Why would Smith use the word “important” in referring to the production of a seemingly insignificant product?

True/False Questions

T F 1. In the short run, as the marginal product of labor (the variable factor) rises, marginal cost falls (assuming the wage rate remains constant as the quantity of labor hired changes).
T F 2. The average product of labor equals the total output produced by a firm divided by the change in the quantity of workers.
T F 3. Economies of scale result when the marginal product of labor rises as one more worker is hired in the short run.
T F 4. Average fixed cost is constant in the short run.
T F 5. Explicit costs are opportunity costs; implicit costs are not.
T F 6. When the average product of labor increases, marginal cost decreases.
T F 7. In the short run, the change in total cost is equal to the change in variable cost.
T F 8. Isoquants are curves that represent all the combinations of two inputs that have the same total cost.
T F 9. In the short run, if an increase in output causes average total cost to increase, then marginal cost must be greater than average total cost.
T F 10. The relationship between the inputs employed by a firm and the maximum output it can produce with those inputs is a production function.
T F 11. A technological change always results in the production of more output using the same inputs, or the same output using fewer inputs.
T F 12. In the long run, average fixed cost declines as output increases.
T F 13. According to the law of diminishing returns, as more workers are hired in the short run, the marginal product of labor always decreases.
T F 14. The average product of labor is the average of the marginal products of labor.
T F 15. In the long run, all costs are variable.

Answers to the Self-Test

Multiple-Choice Questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a</td>
<td>See the definition of technology on page 326 in the textbook.</td>
</tr>
<tr>
<td>2</td>
<td>b</td>
<td>See the definition of technological change on page 326 in the textbook.</td>
</tr>
<tr>
<td>3</td>
<td>d</td>
<td>See the definition of short run on page 327 in the textbook.</td>
</tr>
<tr>
<td>4</td>
<td>b</td>
<td>Variable costs are the costs that vary with the amount of output produced.</td>
</tr>
<tr>
<td>5</td>
<td>a</td>
<td>Read Making the Connection “Fixed Costs in the Publishing Industry” on page 328 in the textbook. The company’s output is books published per year. The input in</td>
</tr>
</tbody>
</table>
question is the quantity of labor. Since the quantity of labor does not change when the number of books published changes, labor must be a fixed input in this production process.

6 a See page 328 in the textbook.
7 a Implicit costs are nonmonetary opportunity costs.
8 c Explicit costs are sometimes called accounting costs.
9 b The relationship between the inputs employed by a firm and the maximum output it can produce with those inputs is called the firm’s production function.
10 d The short-run production function shows the quantity of output that can be produced by a variable input (such as labor), while another input (such as capital) remains fixed.

11 b Average total cost is typically U-shaped.
12 d Each of the equations is true.
13 c The additional output produced by a firm as a result of hiring one more worker is called the marginal product of labor.

14 b The marginal product of labor starts to decrease when the third worker is hired.
15 b Because of specialization and the division of labor, output will at first increase at an increasing rate, with each additional worker hired causing production to increase by a greater amount than did the hiring of the previous worker. After point A, hiring more workers while keeping the amount of machinery constant results in diminishing returns. Once point A, or the point of diminishing returns, has been reached, production increases at a decreasing rate.

16 a Because of specialization and the division of labor, output will at first increase at an increasing rate, with each additional worker hired causing production to increase by a greater amount than did the hiring of the previous worker.

17 b When marginal product is greater than average product, average product is rising. When marginal product is less than average product, average product is falling.

18 c The average product of labor is the total output produced divided by the quantity of workers.

19 b When marginal product is greater than average product, average product is rising.
20 c Marginal cost is the change in total cost divided by the change in the level of output produced. The change in total cost from zero to 200 pizzas is $1450 – $800 = $650. The change in output is 200 – 0 = 200. Therefore, marginal cost is $650/200 = $3.25.

21 b When the marginal cost curve is above the average total cost curve, the average total cost curve rises, and when the marginal cost curve is below the average total cost curve, the average total cost curve falls.

22 b Marginal cost is above average total cost when average total cost is rising.
23 b Average fixed cost equals fixed cost divided by the quantity of output produced.
24 b \[ ATC = AFC + AVC. \]
25 c Average fixed cost gets smaller and smaller as output increases.
26 b \[ ATC – AVC = AFC. \] Curve 4 represents AFC, average fixed cost.
27 c When marginal cost equals average variable cost or average total cost, they must be at their minimums, but not average fixed cost, which decreases continuously as output increases.

28 a Firms often refer to lowering average fixed cost by selling more output as “spreading the overhead.” See page 338 in the textbook.
29 a \[ ATC – AVC = AFC, \] or $58 – $34 = $24. Then $AFC \times \text{the quantity of copies produced} = \text{total fixed cost}, \text{or} $24 \times 100 = $2,400.

30 a Marginal cost is the change in total cost divided by the change in output. As output increases from 625 to 640 pizzas, the total cost increases from $4,050 to
$4,700. Marginal cost is therefore $650/15 = $43.33.

31 a Average total cost equals total cost divided by output produced. The total cost of producing 550 pizzas is $2,750, so average total cost is $2,750/550 = $5.00.

32 b As output increases, the difference between average total cost and average variable cost decreases because average fixed cost gets smaller as output increases.

33 a In the long run, all costs are variable. There are no fixed costs in the long run.

34 b The long-run average cost curve shows the lowest cost at which the firm is able to produce a given level of output in the long run, when no inputs are fixed.

35 b Economies of scale means that a firm’s long-run average cost falls as it increases the quantity of output it produces.

36 a For a small bookstore, the average total cost of selling 1,000 books per month would be $22 per book. By moving to a different short-run average total cost curve, the average total cost of selling 20,000 books would be only $18 per book. This decline in average cost represents the economies of scale that exist in bookselling.

37 b The first quantity where economies of scale have been exhausted is 20,000.

38 c A bookstore selling 20,000 books per month and a bookstore selling 40,000 books per month will experience constant returns to scale and have the same average cost.

39 d Very large bookstores will experience diseconomies of scale, and their average costs will rise as sales increase beyond 40,000 books per month.

40 b The law of diminishing returns applies in the short run, when at least one of the firm’s inputs is fixed.

Short Answer Responses

1. Overhead costs are part of the fixed costs of production. Average fixed cost is calculated as fixed cost divided by total output. Marginal cost is calculated as the change in total cost divided by the change in output. Changes in cost reflect variable costs, not fixed costs. Your friend is correct that spreading out overhead costs results in a decrease in average fixed cost, but that is not related to marginal cost.

2. A sunk cost is not an opportunity cost because it has been paid in the past and cannot be avoided.

3. No. $20 is the lowest long-run average total cost of selling 60,000 books. The store can reduce its average total cost only by selling fewer books with a smaller scale (for example, with a smaller size store). As long as the firm is producing output on its long-run average cost curve, it is producing efficiently.

4. One cannot determine Jill’s profit or the optimal number of workers to hire without knowing the selling price of her services and her firm’s costs. In Table 10-3 the marginal product of labor of the sixth worker is only 15 pizzas, but if the revenue Jill earns from selling these pizzas is greater than the wage she pays to this worker, then her profits would increase (assuming that labor is the only variable factor of production in the short run).

5. Smith used the example of how a pin was produced to show how using specialization and a division of labor in production could cause an enormous increase in the productivity of a nation’s scarce resources. The lessons learned from Smith’s example can be applied to many more products with similar effects on productivity. It was the process, not the product, that was important to Smith.

True/False Answers

1. T See the section “Why Are the Marginal and Average Cost Curves U-Shaped?” beginning on page 335 in the textbook.
2. F The average product of labor is the total output produced by a firm divided by the total amount of workers, not the change in the quantity of workers.
3. F Economies of scale refers to changes in the average cost in the long run, not the short run.
4. F Fixed cost, not average fixed cost, is constant in the short run. Average fixed cost decreases as output expands in the short run.
5. F Implicit costs are the nonmonetary opportunity costs.
6. F When the marginal product of labor increases, marginal cost decreases.
7. T The change in total cost is equal to the change in marginal cost due to fixed costs being constant in the short run.
8. F Isocost lines represent all the combinations of two inputs that have the same total cost.
9. T If the quantity of output is such that marginal cost is greater than average total cost, then average total cost increases.
10. T See page 329 in the textbook.
11. F This describes only positive technological change. Technological change may also be negative.
12. F There are no fixed costs in the long run.
13. F In the short run, the marginal product of labor (the variable factor) increases initially but eventually decreases.
14. T See the section entitled “The Relationship between Marginal and Average Product” beginning on page 333 in the textbook.
15. T Because there are no fixed inputs in the long run, there are no fixed costs, and all costs are variable.