Key Concepts

Decision Time Frames
Firms have two decision time frames:
♦ Short run is the time frame in which the quantities of some resources are fixed.
♦ Long run is the time frame in which the quantities of all resources can be varied.
A sunk cost is a past cost. Sunk costs do not affect a firm’s decisions.

Short-Run Technology Constraint
A firm’s short-run technology constraint is described by its:
♦ Total product (TP) is the total output produced. The total product schedule shows the maximum attainable output with a fixed quantity of capital as the quantity of labor is varied.
♦ Marginal product of labor (MP) is the change in the total product resulting from a one-unit change in the quantity of labor.
♦ Average product of labor (AP) — the total product per worker.
Figure 10.1 illustrates the MP and AP curves for labor. The product curves have the shapes shown because production initially has increasing marginal returns, another worker’s marginal product is higher than the previous worker’s, followed by diminishing marginal returns, another worker’s marginal product is less than the previous worker. The law of diminishing returns states that as a firm uses more of a variable input, with a given quantity of fixed inputs, the marginal product of the variable input eventually diminishes. This figure also shows the (general) relationship between the marginal product and average product:
♦ When the MP > AP, the AP rises.
♦ When the MP < AP, the AP falls.
♦ When MP = AP, the AP is at its maximum.

Short-Run Cost
Several important cost concepts are
♦ Total cost (TC): cost of all resources used, including the normal profit. Average total cost (ATC) is \( TC/q \).
♦ Total fixed cost (TFC): cost of the firm’s fixed inputs. Average fixed cost (AFC) is \( TFC/q \).
Total variable cost (TVC): cost of the firm’s variable inputs. Average variable cost (AVC) is \( \frac{TVC}{q} \).

Marginal cost (MC): the increase in total cost resulting from one-unit increase in output or, in terms of a formula, \( MC = \frac{\Delta TC}{\Delta q} \).

Two relationships between these costs are:
\[ TC = TFC + TVC \quad \text{and} \quad ATC = AFC + AVC. \]

Figure 10.2 shows typical AVC, ATC, and MC curves. The AVC, ATC, and MC curves are U-shaped. The MC crosses the AVC and ATC curves where the AVC and ATC are at their minimums.

- As output initially increases, both AFC and AVC fall, so ATC falls.
- As output increases still more, returns will diminish. AVC increases as output increases, so eventually ATC rises when output increases.

The MC and MP curves are related.
- Over the range of output where the MP curve slopes upward, the MC curve slopes downward.
- At the level of output where the MP curve is at its maximum, the MC curve is at its minimum.
- Over the range of output where the MP curve slopes downward, the MC curve slopes upward.

The AP and ATC curves are similarly related.

An increase in technology shifts the firm’s product curves upward and shifts its cost curves downward. A rise in resource prices shifts the firm’s cost curves upward when both the plant size and labor are varied. The long-run average cost curve is derived from the many different (short-run) average total cost curves that reflect different quantities of capital. The long-run average cost shows the lowest average cost to produce any quantity of output.

The ranges of the LRAC are:
- Economies of scale — the range of output over which the LRAC falls as output increases. With input prices not changing, economies of scale occur if a change in all inputs leads to a larger percentage change in output.
- Diseconomies of scale — the range of output over which the LRAC rises as output increases. With input prices not changing, diseconomies of scale occur if a change in all inputs leads to a smaller change in output.

Constant returns to scale occur when the long-run average cost is constant as output increases. This can occur when a change in all inputs leads to an equal percentage change in the firm’s output. When a firm has constant returns to scale, the long-run average cost curve is horizontal.

The minimum efficient scale is the smallest quantity of output at which the long-run average cost is at its lowest level.
1. **THE MOST IMPORTANT COST CONCEPTS**: Be sure you understand Figure 10.3 thoroughly. Not only is it the most important graph in the chapter, it is one of the most important graphs in all of microeconomics. You will see it repeatedly in the next several chapters.

You need to know three important points about Figure 10.3. First, both the **ATC** and **AVC** curves are U-shaped. The **MC** curve also is U-shaped, but the portion that slopes upward is the most important. Second, the **MC** curve intersects the **ATC** and **AVC** curves at their minimum points. In other words, when the **MC** equals the **ATC**, the **ATC** is at its minimum. Third, following the relationship between a marginal and an average, when the **MC** curve is below the **ATC** or **AVC** curves, the **ATC** or **AVC** slope downward. Similarly, when the **MC** curve is above the **ATC** or **AVC** curves, the **ATC** or **AVC** curves slope upward.

2. **MEANING OF THE WORD “MARGINAL”**: Be certain that you understand the difference between “marginal cost” and “average cost.” These are very different concepts. One way to remember that they are different is to keep in mind that the word “marginal” always means “additional.” Economists use the word marginal this way a lot. In this chapter, you already have seen it used in “marginal product” and “marginal cost.” You might also have seen it in Chapter 7 in the discussion of “marginal utility”, the additional utility from consuming another unit of a product. In the next few chapters you will encounter the term “marginal revenue,” which means additional revenue when output is increased by one unit. In all these examples, the word marginal means “additional”!

3. **THE DIFFERENCE BETWEEN ECONOMIES OF SCALE AND DIMINISHING RETURNS**: The later sections of the chapter explain the long-run production function and cost function when the plant size — that is, the capital stock — varies. As the law of diminishing returns is the key to understanding short-run costs, the concept of economies and diseconomies of scale is the key to understanding long-run costs. In the long run, we explore the increase in output relative to the increase in inputs when all inputs are increased by the same percentage; diminishing returns are what happens when only one resource is changed, with the rest of the inputs being kept constant.

### Questions

**True/False and Explain**

**Decision Time Frames**

1. The short run is the period of time over which only one resource is variable.
2. In the long run, all resources are variable.

**Short-Run Technology Constraint**

3. If the marginal product of another worker exceeds the marginal product of the previous worker hired, the firm is experiencing economies of scale.
4. The law of diminishing returns implies that the marginal product of an input eventually falls as more of the input is used.
5. If the marginal product of labor exceeds the average product of labor, the average product of labor rises when more workers are hired.

**Short-Run Cost**

6. Total cost equals fixed cost plus variable cost.
7. Total costs first fall and then, as diminishing returns sets in, total costs rise as the firm expands its output.
8. Total variable costs are always greater than total fixed costs.

9. Marginal cost equals total cost divided by total output.

10. Marginal cost is always greater than average total cost.

11. The average total cost curve, like the average product of labor curve, has an upside-down U-shape.

12. The ATC curve always passes through the minimum point of the MC curve.

**Long-Run Cost**

13. In the long run, all costs are variable costs and no costs are fixed cost.

14. No part of any short-run average total cost curve lies below the long-run average total cost curve.

15. Economies of scale occur when an increase in the number of workers employed increases total output.

16. When the long-run average cost (LRAC) curve slopes upward, the firm is experiencing economies of scale.

**Multiple Choice**

**Decision Time Frames**

1. The short run is a time period in which
   a. one year or less elapses.
   b. all inputs are variable.
   c. all inputs are fixed.
   d. there is at least one fixed input and the other inputs can be varied.

2. In the long run,
   a. only the amount of capital the firm uses is fixed.
   b. all inputs are variable.
   c. all inputs are fixed.
   d. a firm must experience diseconomies of scale.

3. Total product divided by the total quantity of labor employed equals the
   a. average product of labor.
   b. marginal product of labor.
   c. average total cost.
   d. average variable cost.

4. Diminishing returns occurs when
   a. all inputs are increased, output decreases.
   b. all inputs are increased, output increases by a smaller proportion.
   c. a variable input is increased, output decreases.
   d. a variable unit is increased, its marginal product falls.

5. The marginal product of labor equals the average product of labor when
   a. the average product of labor is at its maximum.
   b. the average product of labor is at its minimum.
   c. the marginal product of labor is at its maximum.
   d. None of the above answers are correct because the marginal product of labor never equals the average product of labor.

6. When the marginal product of labor curve is below the average product of labor curve,
   a. the average product of labor curve has a positive slope.
   b. the average product of labor curve has a negative slope.
   c. the total product curve has a negative slope.
   d. the firm experiences diseconomies of scale.

7. Pat’s Catering finds that when it caters 10 meals a week, its total cost is $3,000. If, at this level of output, Pat has a total variable cost of $2,500, what is Pat’s fixed cost?
   a. $250
   b. $300
   c. $500
   d. $3,000
Use Table 10.1 for the next three questions.

<table>
<thead>
<tr>
<th>Output</th>
<th>Total variable cost</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>$15</td>
<td>$21</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>24</td>
</tr>
</tbody>
</table>

8. The marginal cost of producing the fourth unit is
   a. $6.
   b. $5.
   c. $3.
   d. $2.

9. The average total cost of the fourth unit is
   a. $6.
   b. $5.
   c. $3.
   d. $2.

10. The average fixed cost of the third unit is
    a. $6.
    b. $5.
    c. $3.
    d. $2.

11. If the company produces no output, it must pay
    a. no costs.
    b. a small amount of variable cost.
    c. its fixed cost.
    d. its owners a normal profit.

12. The change in total cost from producing another unit of output equals the
    a. average total cost.
    b. variable cost.
    c. average variable cost.
    d. marginal cost.

13. A farmer discovers that the total cost of growing 50 acres of eggplant is $50,000 and that the total cost of growing 51 acres of eggplant is $52,000. The marginal cost of the 51st acre of eggplant is
    a. $52,000.
    b. $50,000.
    c. $2,000.
    d. $1,000.

Use Figure 10.4 for the next four questions.

14. In Figure 10.4 the $MC$ curve is curve
    a. $a$.
    b. $b$.
    c. $c$.
    d. None of the curves is the $MC$ curve.

15. In Figure 10.4 the $ATC$ curve is curve
    a. $a$.
    b. $b$.
    c. $c$.
    d. None of the curves is the $ATC$ curve.

16. In Figure 10.4 the $AVC$ curve is curve
    a. $a$.
    b. $b$.
    c. $c$.
    d. None of the curves is the $AVC$ curve.

17. In Figure 10.4 the $AFC$ is curve
    a. $a$.
    b. $b$.
    c. $c$.
    d. None of the curves is the $AFC$ curve.
18. Which curve intersects the minimum point of the average total cost curve, that is, minimum point of the $ATC$ curve?
   a. The marginal cost ($MC$) curve
   b. The average variable cost ($AVC$) curve
   c. The average fixed cost ($AFC$) curve
   d. The marginal product ($MP$) curve

19. If the average total cost ($ATC$) curve slopes downward, then at that level of output the marginal cost ($MC$) curve must be
   a. sloping upward.
   b. sloping downward.
   c. above the $ATC$ curve.
   d. below the $ATC$ curve.

20. Over the range of output where the $MP$ curve slopes upward, the
   a. $MC$ curve slopes downward.
   b. $AFC$ curve slopes upward.
   c. firm is experiencing economies of scale.
   d. total cost curve slopes downward.

21. A technological advance
   a. shifts the firm’s total product curve upward.
   b. does not shift the firm’s total product curve.
   c. shifts the firm’s total product curve downward.
   d. cannot occur without raising the firm’s average total costs and hence shifts the average total cost curve upward.

22. The cost of a variable input, such as the wage paid to workers, rises. This change shifts the
   a. total fixed cost curve upward.
   b. marginal product of labor curve downward.
   c. average variable cost curve upward.
   d. marginal product of labor curve upward.

Long-Run Cost

23. The concept of diminishing returns
   a. applies to both labor and capital.
   b. applies to labor but does not apply to capital.
   c. applies to capital but does not apply to labor.
   d. does not apply to either labor or capital.

24. The $LRAC$ curve
   a. equals the minimum points on all the short-run $ATC$ curves.
   b. equals the lowest possible marginal cost of producing the different levels of output.
   c. equals the lowest attainable average total cost for all levels of output when all inputs can be varied.
   d. generally lies above the short-run $ATC$ curves.

25. The $LRAC$ curve generally is
   a. shaped as an upside-down U.
   b. U-shaped.
   c. upward sloping.
   d. downward sloping.

26. When a firm is experiencing economies of scale,
   a. the $MP$ curve slopes upward.
   b. the $LRAC$ curve slopes downward.
   c. diminishing returns to labor have been suspended.
   d. the $MC$ curve slopes downward.

27. Constant returns to scale means that as all inputs are increased,
   a. total output remains constant.
   b. average total cost rises.
   c. average total cost rises at the same rate as do the inputs.
   d. total output increases in the same proportion as do the inputs.

Short Answer Problems

1. Where does the marginal product curve intersect the average product curve? Why?

2. a. Table 10.2 (on the next page) gives the total weekly output of turkeys at Al’s Turkey Town. Complete this table. (The marginal product is entered midway between rows to emphasize that it is the result of changing inputs — moving from one row to the next. Average product corresponds to a fixed quantity of labor and so is entered on the appropriate row.)
   b. In Figure 10.5 (on the next page) label the axes and draw a graph of the total product curve ($TP$).
   c. In Figure 10.6 (on the next page) label the axes and draw a graph of the marginal product ($MP$) and the average product ($AP$). (As in Table 10.2,
Output and Costs

Table 10.2
Short Answer Problem 2 (a)

<table>
<thead>
<tr>
<th>Labor (turkeys per week)</th>
<th>Quantity (turkeys per week)</th>
<th>Average product of labor (AP)</th>
<th>Marginal product of labor (MP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>XX</td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>450</td>
<td></td>
<td>110</td>
</tr>
<tr>
<td>4</td>
<td>630</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>110</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 10.5
Short Answer Problem 2 (b)

Short Answer Problem 2 (b)

FIGURE 10.6
Short Answer Problem 2 (c)

3. a. Now let’s examine Al’s short-run cost of growing turkeys. The first two columns of Table 10.2 are reproduced in the first two columns of Table 10.3. The cost of 1 worker (the only variable input) is $2,000 per month. Total fixed cost is $4,000 per month. Complete Table 10.3 by using your answers from Table 10.2 and by computing total variable cost and total cost.

Table 10.3
Total Cost of Growing Turkeys

<table>
<thead>
<tr>
<th>Labor (turkeys per week)</th>
<th>Quantity (turkeys per week)</th>
<th>Total variable cost (TVC)</th>
<th>Total cost (TC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>$4,000</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>450</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>630</td>
<td></td>
<td>12,000</td>
</tr>
<tr>
<td>5</td>
<td>12,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

plot the marginal products midway between the units of labor and the average products directly above the units of labor.) Where do the $AP$ and $MP$ curves cross?
b. In Figure 10.7 label the axes and draw the $TC$ and $TVC$ curves. What is the relationship between these two curves?

c. Table 10.4 contains spaces for some of Al’s other costs, the average total cost ($ATC$), average variable cost ($AVC$), and marginal cost ($MC$). Complete this table by using your answers from Table 10.3 and calculating the new costs called for in Table 10.4.

d. In Figure 10.8 label the axes and draw the $ATC$, $AVC$, and $MC$ curves. Be sure to plot the values for the $MC$ between the relevant levels of output. What is the relationship between the $ATC$ and $AVC$ curves? Between the $MC$ and $AVC$ curves?

4. a. Suppose Al discovers new technology that boosts the productivity of his workers so that more turkeys can be grown than before. Complete Table 10.5, which presents production data with the new technology.

<table>
<thead>
<tr>
<th>Quantity (turkeys per week)</th>
<th>Average variable cost ($AVC$)</th>
<th>Average total cost ($ATC$)</th>
<th>Marginal cost ($MC$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>XX</td>
<td>XX</td>
<td>$20.00</td>
</tr>
<tr>
<td>100</td>
<td>$20.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>450</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>630</td>
<td></td>
<td>21.43</td>
<td></td>
</tr>
<tr>
<td>66.67</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quantity (turkeys per week)</th>
<th>Average product of labor ($AP$)</th>
<th>Marginal product of labor ($MP$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$XX$</td>
<td>120</td>
</tr>
<tr>
<td>1</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>360</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>540</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>672</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>756</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>792</td>
<td></td>
</tr>
</tbody>
</table>
b. Al’s fixed cost remains at $4,000 and he can continue to hire workers at a wage rate of $2,000. Use the new technology production data to complete Table 10.6, which has the total cost, and Table 10.7, which has (some of) the average costs and the marginal cost.

**TABLE 10.6**
New Technology and Total Costs

<table>
<thead>
<tr>
<th>Labor (turkeys per week)</th>
<th>Quantity</th>
<th>Total variable cost (TVC)</th>
<th>Total cost (TC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>360</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>540</td>
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<td></td>
</tr>
<tr>
<td>4</td>
<td>672</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>756</td>
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<td></td>
</tr>
<tr>
<td>6</td>
<td>792</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 10.7**
New Technology and Other Costs

<table>
<thead>
<tr>
<th>Quantity (turkeys per week)</th>
<th>Average variable cost (AVC)</th>
<th>Average total cost (ATC)</th>
<th>Marginal cost (MC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>XX</td>
<td>XX</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>360</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>540</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>672</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>756</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>792</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

c. In Figure 10.9, plot the ATC and MC curves you have just entered in Table 10.7. Also draw the ATC and MC curves you have already plotted in Figure 10.8 (before the technology changed). Label the old ATC curve ATC₁ and the old MC curve MC₁; label the new ATC curve ATC₂ and the new MC curve MC₂. How do the old and new ATC curves compare? The old and new MC curves?

5. a. Return to the old technology for growing turkeys, which you studied and worked out in problems 2 and 3. Suppose that the cost of Al’s fixed inputs remain at $4,000. Now the cost of his variable input, labor, rises. Specifically, suppose that a worker now receives $3,000 per month. Complete Table 10.8. For the two missing quantities, copy your answers from Table 10.2.

**TABLE 10.8**
A Change in Variable Costs

<table>
<thead>
<tr>
<th>Labor (turkeys per week)</th>
<th>Quantity</th>
<th>Total variable cost (TVC)</th>
<th>Total cost (TC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td></td>
<td>$4,000</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>450</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>630</td>
<td></td>
<td>16,000</td>
</tr>
<tr>
<td>5</td>
<td>630</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>18,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 10.9
Comparison of Costs

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Before increase</th>
<th>After increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average total cost (ATC)</td>
<td>Marginal cost (MC)</td>
</tr>
<tr>
<td>0</td>
<td>XX</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>450</td>
<td></td>
<td></td>
</tr>
<tr>
<td>630</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. To compare the effect of the rise in the variable cost on the average total cost and marginal cost, complete Table 10.9. (Hint: As before, copy the “before increase” ATC and MC values from Table 10.8.) From Table 10.9, how did the rise in variable costs affect the average total cost? The marginal cost?

6. What is the difference between diminishing returns and diseconomies of scale?

### You’re the Teacher

1. “This chapter has a lot to say about firms: production, costs, and stuff like that. But I don’t really see the purpose. In real life, businesses are a lot more complicated than this chapter says. Workers are different, different companies make different goods, Intel’s factory sure isn’t the same as what we see at Krispy Kreme and what have you. What’s the use of this chapter?” This student is missing an essential point about economic theories. Can you help straighten out the student?

2. “I get the idea that marginal cost is important, but I don’t know why. You have any ideas about it?” Your friend is asking you for your ideas; you have a chance to help your friend, so explain why you think marginal cost is important.
Answers

True/False Answers

Decision Time Frames
1. F In the short run, at least one input is fixed.
2. T The question presents the definition of the long run.

Short-Run Technology Constraint
3. F The firm has increasing marginal returns because only one input has been changed.
4. T The question presents the definition of diminishing returns.
5. T This result is a reflection of the relationship between marginals and averages.

Short-Run Cost
6. T Total cost is the sum of fixed cost and variable cost.
7. F As output increases, total cost always rises.
8. F The amount of variable cost and the amount of fixed cost are not necessarily related, except that in the long run all costs are variable costs.
9. F Marginal cost equals the additional total cost divided by the additional output.
10. F Marginal cost usually starts below the average total cost and then rises above it.
11. F The average total cost curve has a “right-side-up” U shape.
12. F The MC curve always passes through the minimum point of the ATC curve.

Long-Run Cost
13. T In the long run, all inputs can be varied so all costs are variable costs.
14. T The long-run average cost curve shows the least possible cost to produce any level of output.
15. F Economies of scale occur when an increase in all inputs increases output by a larger proportion.
16. F When the LRAC curve slopes upward, average cost increases when output increases, so over this range of output the firm is experiencing diseconomies of scale.

Multiple Choice Answers

Decision Time Frames
1. d This is the definition of the short run.
2. b The long run is the amount of time until all inputs become variable.

Short-Run Technology Constraint
3. a The average product of labor is total product (output) per worker.
4. d Answer (d) is the definition of diminishing returns.
5. a When MP > AP, the average product rises when employment increases; when MP < AP, the average product falls; and when MP = AP, the average product is at its maximum.
6. b This answer reflects the average/marginal relationship that when the marginal is below the average, the average falls.

Short-Run Cost
7. c Total cost equals fixed cost plus variable cost, so fixed cost equals total cost minus variable cost.
8. c The marginal cost equals the difference in total cost ($24 – $21 = $3) divided by the change in output (4 – 3 = 1), so the marginal cost is $3.
9. a Average total cost equals total cost divided by total output, that is, $24/4 or $6.
10. d Because total cost equals total fixed cost plus total variable cost, total fixed cost equals $6. Then, average fixed cost is total fixed cost divided by total output, so average fixed cost equals $6/3 = $2.
11. c Fixed cost remains the same regardless of the level of output, that is, whether the firm produces a million units of output or no units of output.
12. d Marginal cost shows the added cost from producing an added unit of output.
13. c The marginal cost equals the change in total cost ($52,000 – $50,000, or $2,000) divided by the change in output (51 acres of eggplant – 50 acres of eggplant, or 1 acre of eggplant). Therefore the marginal cost equals $2,000 per acre of eggplant.
14. **c** Figure 10.10 identifies the MC curve. Note that it goes through the minimum points of both the ATC and AVC curves.

15. **b** Again, Figure 10.10 identifies the ATC curve.

16. **a** Figure 10.10 shows that the AVC curve is the U-shaped curve that lies below the U-shaped ATC curve.

17. **d** None of the curves in the original figure was the AFC curve, but Figure 10.10 shows the AFC curve.

18. **a** The MC curve intersects both the ATC and the AVC curves at their minimums.

19. **d** When the marginal cost is less than the average cost, the average cost falls as output expands.

20. **a** When the MP curve slopes upward, each additional variable input produces more additional output than the previous unit of the input. So the added cost of producing the added units falls — that is, the MC curve slopes downward — because each variable unit has the same additional cost as the previous unit, but each produces more additional output.

21. **a** By shifting the total product curve upward, the technological advance generally shifts the average total cost curve downward.

22. **c** Wages are a variable cost, so a rise in the wage rate shifts the average variable cost curve upward.

### Long-Run Cost

23. **a** All inputs are subject to diminishing returns.

24. **c** The long-run average cost curve, or LRAC curve, shows the lowest possible average total cost for producing any level of output.

25. **b** The LRAC curve has a U shape: When output increases, at first the LRAC falls but as output increases still more, the LRAC rises.

26. **b** Economies of scale means that increases in output lower the firm’s long-run average costs.

27. **d** This is the definition of constant returns to scale.

### Answers to Short Answer Problems

#### FIGURE 10.11

**Short Answer Problem 1**

1. The marginal product curve intersects the average product curve where the average product is at its maximum. To understand why, look at Figure 10.11. To the left of the maximum point, MP > AP. That means that an additional worker produces more additional output than the average of the previously employed workers. As a result, the average product increases. So, as long as the MP exceeds the AP, the average product must be increasing. Now look to the right of the maximum point. Here MP < AP. Each new worker produces less additional output than the average of the previously employed workers, so the average product falls. As long as the MP is less than the AP, the average product must decrease. That means that whenever the marginal product exceeds the average product, which is the
case at any point left of the intersection point, the average product increases with output; whenever the marginal product is less than the average product, which is true for any point right of the intersection point, the average product falls. Hence when the marginal product equals the average product, the average product does not change. Left of this point the average product is rising and right it is falling. Therefore at this point the average product is at its maximum.

2. a. Table 10.10 completes Table 10.2. The average product of labor column is calculated by dividing the total product by the total amount of labor; that is, $APL = \text{Quantity} / L$. So, the $AP$ when 2 workers are employed is \( \frac{300}{2} \), or 150. The marginal product of labor is the extra output produced by an extra worker. In terms of a formula, the $MP$ equals the change in quantity divided by the change in labor, so that $MP = (\Delta \text{Quantity}) / \Delta L$. So, between 2 and 1 workers the $MP$ is \( \frac{(300 - 100)}{(2 - 1)} = 200 \). Because the $MP$ equals the additional output when another unit of labor is employed, the quantity of output produced when 4 workers are employed equals the total quantity produced when 3 workers are employed (450) plus the additional amount the 4th worker produces, 110, or 560.

<table>
<thead>
<tr>
<th>Labor (workers per week)</th>
<th>Quantity (turkeys per week)</th>
<th>Average product of labor (AP)</th>
<th>Marginal product of labor (MP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>XX</td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>450</td>
<td>150</td>
<td>110</td>
</tr>
<tr>
<td>4</td>
<td>560</td>
<td>140</td>
<td>70</td>
</tr>
<tr>
<td>5</td>
<td>630</td>
<td>126</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>660</td>
<td>110</td>
<td></td>
</tr>
</tbody>
</table>

Finally, for the total quantity when 6 workers are used, multiply the average product of labor, 110, by the total number of workers employed, 6, to get the total product of 660.

b. Figure 10.12 shows the graph of the firm’s total product curve.

c. Figure 10.13 shows the firm’s $AP$ and $MP$ curves. The $MP$ curve crosses the $AP$ curve when the $AP$ is at its maximum.
3. a. Table 10.11 shows the total cost for each quantity of labor. Total variable cost equals the number of workers (the variable input) multiplied by $2,000 per worker. Total cost then equals the total variable cost plus the total fixed cost, which is given in the problem as $4,000.

**TABLE 10.11**  
Short Answer Problem 3 (a)

<table>
<thead>
<tr>
<th>Labor (turkeys per week)</th>
<th>Total variable cost (TVC)</th>
<th>Total cost (TC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$0</td>
<td>$4,000</td>
</tr>
<tr>
<td>1</td>
<td>2,000</td>
<td>6,000</td>
</tr>
<tr>
<td>2</td>
<td>4,000</td>
<td>8,000</td>
</tr>
<tr>
<td>3</td>
<td>6,000</td>
<td>10,000</td>
</tr>
<tr>
<td>4</td>
<td>8,000</td>
<td>12,000</td>
</tr>
<tr>
<td>5</td>
<td>10,000</td>
<td>14,000</td>
</tr>
<tr>
<td>6</td>
<td>12,000</td>
<td>16,000</td>
</tr>
</tbody>
</table>

b. Figure 10.14 shows the firm’s total cost (TC) and total variable cost (TVC) curves. The TC curve always lies $4,000 above the TVC curve.

**FIGURE 10.14**  
Short Answer Problem 3 (b)

![Total Cost (TC) and Total Variable Cost (TVC)](image)


c. Table 10.12 completes Table 10.4. In Table 10.12 the average variable cost column was calculated by dividing total variable cost by the total quantity produced. So the AFC when 300 turkeys are produced is $4,000/300 = $13.33. Similarly, the average total cost column is calculated by dividing total cost by the total quantity produced. Finally, marginal cost equals the change in total cost divided by the change in quantity, that is, $MC = (\Delta TC)/\Delta q$. Hence the $MC$ between 300 and 100 turkeys per week is $(8,000 – 6,000)/(300 – 100)$, or $10.00.

**TABLE 10.12**  
Short Answer Problem 3 (c)

<table>
<thead>
<tr>
<th>Quantity (turkeys per week)</th>
<th>Average variable cost (AVC)</th>
<th>Average total cost (ATC)</th>
<th>Marginal cost (MC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>XX</td>
<td>XX</td>
<td>$20.00</td>
</tr>
<tr>
<td>100</td>
<td>$20.00</td>
<td>$60.00</td>
<td>10.00</td>
</tr>
<tr>
<td>300</td>
<td>13.33</td>
<td>26.67</td>
<td>13.33</td>
</tr>
<tr>
<td>450</td>
<td>13.33</td>
<td>22.22</td>
<td>18.18</td>
</tr>
<tr>
<td>560</td>
<td>14.29</td>
<td>21.43</td>
<td>20.57</td>
</tr>
<tr>
<td>630</td>
<td>15.87</td>
<td>22.22</td>
<td>66.67</td>
</tr>
<tr>
<td>660</td>
<td>18.18</td>
<td>24.24</td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 10.15**  
Short Answer Problem 3 (d)

![Average Variable Cost (AVC), Average Total Cost (ATC), and Marginal Cost (MC)](image)

d. Figure 10.15 shows the ATC, AVC, and MC curves. The AVC curve lies below the ATC curve, but the vertical distance between the two (which equals AFC) shrinks as output expands. The MC curve crosses the AVC curve where the
AVC is at its minimum. (It also crosses the ATC curve where the ATC is at its minimum.)

4. a. Table 10.13 shows the new APs and MPs. These answers were calculated in the same way as the answers for short answer problem 2 (a).

<table>
<thead>
<tr>
<th>TABLE 10.13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Answer Problem 4 (a)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Labor</th>
<th>Quantity (turkeys per week)</th>
<th>Average product of labor (AP)</th>
<th>Marginal product of labor (MP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>XX</td>
<td>120</td>
</tr>
<tr>
<td>1</td>
<td>120</td>
<td>120</td>
<td>240</td>
</tr>
<tr>
<td>2</td>
<td>360</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>3</td>
<td>540</td>
<td>180</td>
<td>132</td>
</tr>
<tr>
<td>4</td>
<td>672</td>
<td>168</td>
<td>84</td>
</tr>
<tr>
<td>5</td>
<td>756</td>
<td>151.2</td>
<td>36</td>
</tr>
<tr>
<td>6</td>
<td>792</td>
<td>132</td>
<td>115.15</td>
</tr>
</tbody>
</table>

b. Tables 10.14 and 10.15 show the firm’s new costs after the advance in technology. The answers in Table 10.16 are calculated similarly to those in Table 10.13 for short answer problem 3 (a); the answers in Table 10.17 correspond to those in Table 10.14 for short answer problem 3 (c).

<table>
<thead>
<tr>
<th>TABLE 10.14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Answer Problem 5 (b)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Labor</th>
<th>Quantity (turkeys per week)</th>
<th>Total variable cost (TVC)</th>
<th>Total cost (TC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>$4,000</td>
</tr>
<tr>
<td>1</td>
<td>120</td>
<td>2,000</td>
<td>6,000</td>
</tr>
<tr>
<td>2</td>
<td>360</td>
<td>4,000</td>
<td>8,000</td>
</tr>
<tr>
<td>3</td>
<td>540</td>
<td>6,000</td>
<td>10,000</td>
</tr>
<tr>
<td>4</td>
<td>672</td>
<td>8,000</td>
<td>12,000</td>
</tr>
<tr>
<td>5</td>
<td>756</td>
<td>10,000</td>
<td>14,000</td>
</tr>
<tr>
<td>6</td>
<td>792</td>
<td>12,000</td>
<td>16,000</td>
</tr>
</tbody>
</table>

c. Figure 10.16 shows the old and new ATC and MC curves. The new ATC curve appears generally to lie beneath the old ATC curve. Actually, the new curve always lies below the old curve, but the large discrete changes in output that are plotted make the new ATC curve appear to lie a little above the old ATC curve at low levels of output. The new MC curve is below the old MC curve. Technological advances shift the firm’s average and marginal cost curves downward.
TABLE 10.16
Short Answer Problem 5 (a)

<table>
<thead>
<tr>
<th>Labor (turkeys per week)</th>
<th>Total variable cost (TVC)</th>
<th>Total cost (TC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>$4,000</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>7,000</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>10,000</td>
</tr>
<tr>
<td>3</td>
<td>450</td>
<td>13,000</td>
</tr>
<tr>
<td>4</td>
<td>560</td>
<td>16,000</td>
</tr>
<tr>
<td>5</td>
<td>630</td>
<td>19,000</td>
</tr>
<tr>
<td>6</td>
<td>660</td>
<td>22,000</td>
</tr>
</tbody>
</table>

5. a. Table 10.16 completes Table 10.10 and shows Al’s total variable cost and total cost after the variable input, labor, and rises in cost. The rise in the cost of the variable input raises both the total variable cost and the total cost.

TABLE 10.17
Short Answer Problem 5 (b)

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Before increase</th>
<th>After increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average total cost (ATC)</td>
<td>Marginal cost (MC)</td>
</tr>
<tr>
<td>0</td>
<td>XX</td>
<td>$20.00</td>
</tr>
<tr>
<td>100</td>
<td>$60.00</td>
<td>10.00</td>
</tr>
<tr>
<td>300</td>
<td>26.67</td>
<td>13.33</td>
</tr>
<tr>
<td>450</td>
<td>22.22</td>
<td>18.18</td>
</tr>
<tr>
<td>560</td>
<td>21.43</td>
<td>28.57</td>
</tr>
<tr>
<td>630</td>
<td>22.22</td>
<td>66.67</td>
</tr>
<tr>
<td>660</td>
<td>24.24</td>
<td>33.33</td>
</tr>
</tbody>
</table>

b. Table 10.17 shows the firm’s average total cost and marginal cost after the variable cost has risen. The rise in variable cost raises both the average total cost and the marginal cost. In other words, at any level of output, both the average total cost and marginal cost are greater after the rise in variable cost than before. In a diagram, the rise in Al’s variable cost would shift both the firm’s ATC and MC curves upward.

6. The law of diminishing returns states that as a firm uses additional units of a variable input, while holding constant the quantity of fixed inputs, the marginal product of the variable input will eventually diminish. Diseconomies of scale occur when a firm increases all of its inputs by an equal percentage, and this increase results in a smaller percentage increase in output so that the long-run average cost rises. Diminishing (marginal) returns is a short-run concept because there is a fixed input. Diseconomies of scale is a long run concept because all inputs must be variable.

You’re the Teacher

1. “Look, we’ve talked about this before. Economic theories are abstract on purpose; that is, they deliberately do not include all the nitty-gritty detail of the real world. Instead they focus only on the most important issues. Sure, all companies employ lots of different types of labor — skilled labor, unskilled labor, blue collar workers, white collar workers, sales representatives, and so on. So what? Including this fact in a theory would just give us a bunch more details that don’t tell us anything.”

“You know, consumers are different too. That didn’t stop us from developing useful theories about the factors that affect their demand curves.

“The whole idea is that economic theory looks for qualities that are the same. That is what we’re doing with firms. For instance, all firms hire labor and use capital. And these resources are different when we think about how rapidly the firm can change the amounts that it uses. So all firms have to face the difference between fixed and variable resources. I don’t care if you’re talking about Intel building chips or that Krispy Kreme store we both like. The point is that the theory we’re learning can be applied to all types of firms, which gives the theory its power.”

2. “You’re lucky because I’ve been reading ahead in the book. Remember the discussion of marginal analysis in one of the earlier chapters? You know, where people looked at the effects from making small changes and then compared the additional costs from the change to the additional benefits? Well, that’s what we’ll be using marginal cost for.
When we want to know how much a firm will produce, we can ask whether it wants to increase its production. By increasing its production, the firm will incur some additional costs — its marginal cost. We’ll then compare this cost to the added benefit from increasing production. So you’re right: Marginal cost really is important because it’s basically half the marginal analysis we’ll be doing in the chapters ahead.”
1. In the short run,
   a. at least one input is fixed.
   b. all inputs are fixed.
   c. at least one input is variable.
   d. all inputs are variable.

2. In the long run,
   a. at least one input is fixed.
   b. all inputs are fixed.
   c. at least one input is variable.
   d. all inputs are variable.

3. The marginal product of labor is the
   a. inverse of the marginal product of capital when
      the firm is in the long run.
   b. slope of the curve showing the average product of
      labor.
   c. change in total product divided by the change in
      labor.
   d. total product divided by total labor.

4. The average product of labor curve is at its maxi-
   mum when
   a. the marginal product of labor curve is below it.
   b. the marginal product of labor curve crosses it.
   c. the marginal product of labor curve is above it.
   d. the level of output is at its maximum.

5. The more shallow the total product curve,
   a. the greater is the marginal product of labor.
   b. the smaller is the marginal product of labor.
   c. the lower is the total cost curve.
   d. the lower is the variable cost curve.

6. Variable cost is sum of all
   a. the costs associated with variable inputs.
   b. the costs associated with the production of the
      product.
   c. the explicit costs but not all the implicit costs.
   d. the costs that do not change when the amount
      produced increases.

7. A firm’s average variable cost is $10, its total fixed
   costs are $50 and the firm produces 25 units of out-
   put. Hence its average total cost is
   a. more than $50.
   b. $12.
   c. $4.
   d. $2.

8. When producing 99 units, the total cost is $595. The
   marginal cost of the 100th unit is $5. Hence
   the total cost of producing 100 units
   a. is $600.
   b. is $590.
   c. is $6.
   d. cannot be calculated without additional infor-
      mation.

9. The average total cost curve is lowest when
   a. the marginal cost curve is below it.
   b. the marginal cost curve crosses it.
   c. the marginal cost curve is above it.
   d. the level of output is at its maximum.

10. When long-run average costs increase when output
    increases, there definitely are
     a. economies of scale.
     b. diseconomies of scale.
     c. diminishing returns.
     d. constant returns to scale.

The answers for this Chapter Quiz are on page 367