

# Production and Cost in the Short Run

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## Learning Objectives

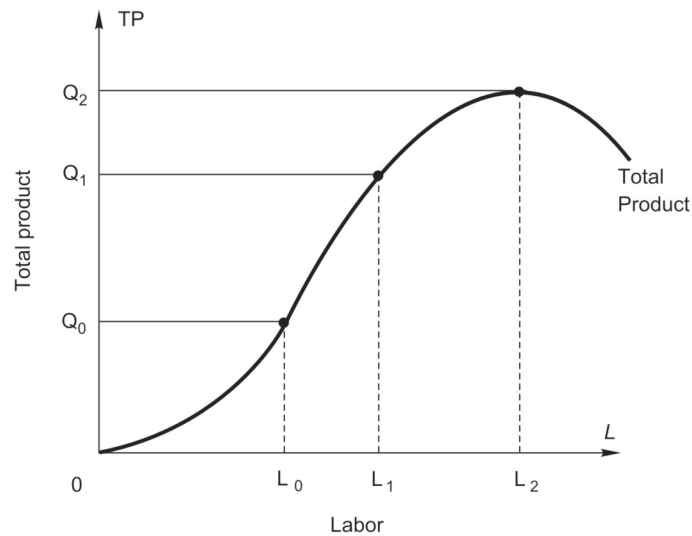
After reading Chapter 8 and working the problems for Chapter 8 in the textbook and in this Student Workbook, you should be able to:

- Understand the information given by a production function.
- Compare and contrast technical efficiency and economic efficiency.
- Explain the difference between long-run and short-run production time periods.
- Compute average product ( $AP$ ) and marginal product ( $MP$ ) and explain the relation among total, average, and marginal products.
- Define and explain the law of diminishing marginal product.
- Explain the difference between fixed costs and variable costs.
- Define and draw graphs of total fixed cost ( $TFC$ ), total variable cost ( $TVC$ ), total cost ( $TC$ ), and short-run marginal cost ( $SMC$ ).
- Define and draw graphs of average fixed cost ( $AFC$ ), average variable cost ( $AVC$ ), and average total cost ( $ATC$ ).
- Relate short-run costs to the production function using the relations between (i) average variable cost and average product, and (ii) short-run marginal cost and marginal product.

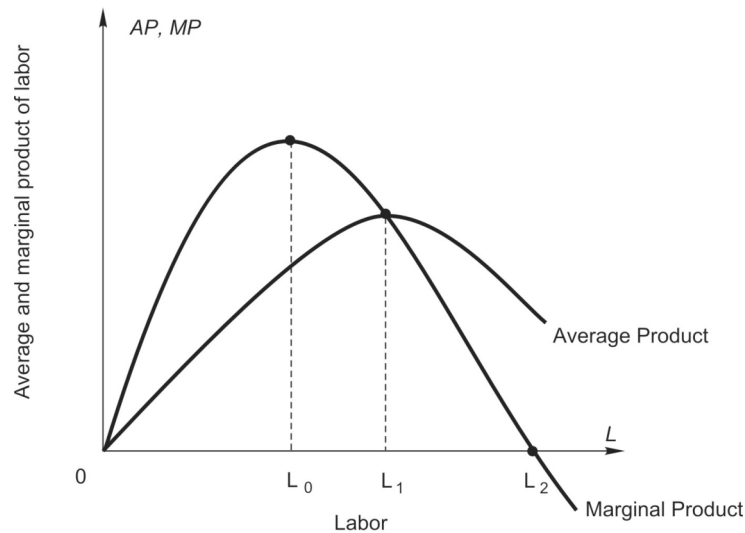
## Essential Concepts

1. A *production function* shows the maximum amount of output that can be produced from any specified set of inputs, given the existing technology.
2. *Technical efficiency* is achieved when the maximum possible amount of output is being produced with a given combination of inputs.
3. *Economic efficiency* is achieved when the firm is producing a given amount of output at the lowest possible total cost.
4. Inputs are classified as either *variable* or *fixed*:
  - (a) variable input: an input for which the level of usage may be changed quite readily in accordance with desired changes in output.

- (b) fixed input: an input for which the level of usage cannot be readily changed and which must be paid even if no output is produced.
  - (c) quasi-fixed input: a special kind of fixed input that, like other fixed inputs, does not vary with the level of output but, unlike other fixed inputs, need not be paid when output is zero.
5. In the short run, at least one input is a fixed input and all changes in the level of output are accomplished by changing the usage of the variable inputs. In the long run, all inputs are variable, and output can be changed by varying the usage of all inputs.
6. In the short run, capital is fixed so that the short-run production function may be written as
- $$Q = f(L, \bar{K})$$
- which indicates that only changes in the variable input  $L$  can change the level of output in the short run.
7. Average product of labor (  $AP = Q/L$  ) and marginal product of labor (  $MP = \Delta Q / \Delta L$  ) are related in the following way:
- When  $AP$  is rising (falling),  $MP$  is greater (less) than  $AP$ . When  $AP$  reaches its maximum value,  $AP = MP$ .
8. The *law of diminishing marginal product* states that as the usage of a variable input increases, a point is reached beyond which its marginal product decreases.



**Panel A**



**Panel B**

9. Panel A in the preceding figure shows the typical total product curve ( $TP$ ) when production occurs with only one variable input. The total product curve reflects the following relations:
- No output can be produced with zero workers.
  - Output increases at an increasing rate until  $L_0$  workers are employed producing  $Q_0$  units of output. Over this range marginal product is increasing.
  - Total product then increases but at a decreasing rate when the firm hires between  $L_0$  and  $L_2$  workers. Over this range  $MP$  is decreasing.
  - Average product reaches its maximum value at  $L_1$ , where  $AP$  equals  $MP$ .
  - Finally a point will be reached beyond which output will decline, indicating a negative marginal product. In Panel A, this occurs for employment levels greater than  $L_2$ . The maximum possible total product is thus  $Q_2$ .

10. Panel *B* in the figure shows the *AP* and *MP* curves that correspond to *TP* in Panel *A*. Notice that
- both curves first rise, reach a maximum, then decline.
  - marginal product attains a maximum (at  $L_0$ ) at a lower input level than the level at which average product attains its maximum (at  $L_1$ ).
  - while *AP* is always positive, *MP* is zero at  $L_2$  units of labor and is negative thereafter.
11. Short-run total cost (*TC*) is the sum of total variable cost (*TVC*) and total fixed cost (*TFC*):

$$TC = TVC + TFC$$

12. Average fixed cost (*AFC*) is equal to total fixed cost divided by output:

$$AFC = \frac{TFC}{Q}$$

13. Average variable cost (*AVC*) is equal to total variable cost divided by output:

$$AVC = \frac{TVC}{Q}$$

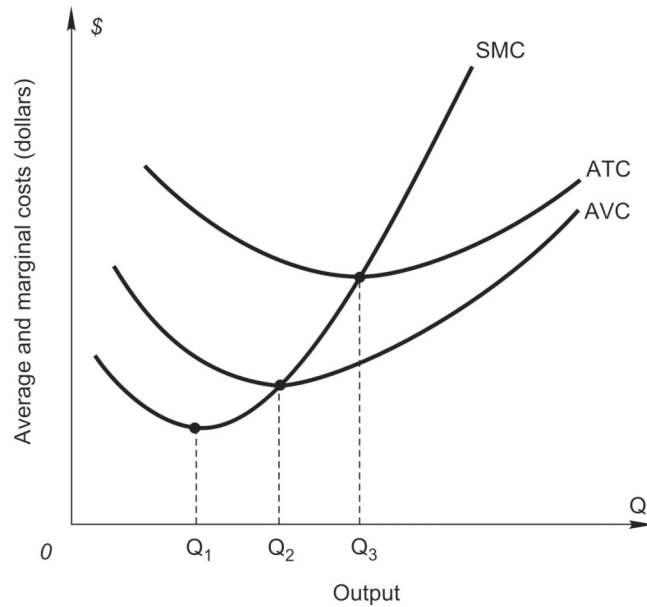
14. Average total cost is equal to total cost divided by output or the sum of average variable and average fixed cost:

$$ATC = \frac{TC}{Q} = AVC + AFC$$

15. Short-run marginal cost (*SMC*) measures the rate of change in *TC* as output varies:

$$SMC = \frac{\Delta TC}{\Delta Q} = \frac{\Delta TVC}{\Delta Q}$$

16. The following figure shows the typical set of short-run average and marginal cost curves. Note the following relations:
- AFC* decreases continuously as output increases (*AFC* is not shown in the figure above, but it is equal to vertical distance between *ATC* and *AVC*).
  - AVC* is U-shaped and *AVC* equals *SMC* at *AVC*'s minimum.
  - ATC* is U-shaped and *ATC* equals *SMC* at *ATC*'s minimum.
  - SMC* is U-shaped and intersects *AVC* and *ATC* at their minimum points. *SMC* lies below (above) *ATC* and *AVC* when *ATC* and *AVC* are falling (rising).



17. In the case of a single variable input, short-run costs are related to the production function by the two relations:

$$AVC = \frac{w}{AP} \quad \text{and} \quad SMC = \frac{w}{MP}$$

where  $w$  is the price of the variable input. Since  $AP$  and  $MP$  first increase, reach a peak and then decrease,  $AVC$  and  $SMC$  first fall, reach a minimum value and then rise.

## Matching Definitions

|                                     |                                 |
|-------------------------------------|---------------------------------|
| average fixed cost                  | production function             |
| average product of labor            | quasi-fixed input               |
| average total cost                  | short run                       |
| average variable cost               | short-run marginal cost         |
| economic efficiency                 | technical efficiency            |
| fixed input                         | total cost                      |
| fixed proportions production        | total fixed cost                |
| law of diminishing marginal product | total variable cost             |
| long run                            | variable input                  |
| marginal product of labor           | variable proportions production |
| production                          |                                 |

1. \_\_\_\_\_ The creation of goods and services from inputs or resources.
2. \_\_\_\_\_ A table or mathematical equation showing the maximum amount of output that can be produced from any specified set of inputs, given the existing technology.
3. \_\_\_\_\_ Production of the maximum level of output that can be obtained from a given combination of inputs.
4. \_\_\_\_\_ Production of a given amount of output at the lowest possible total cost.
5. \_\_\_\_\_ An input for which the level of usage cannot readily be changed.
6. \_\_\_\_\_ An input for which the level of usage may be changed quite readily.
7. \_\_\_\_\_ A fixed input that need not be paid when output is zero.
8. \_\_\_\_\_ That period of time in which the level of usage of one or more inputs is fixed.
9. \_\_\_\_\_ That period of time in which all inputs are variable, which is sometimes called the *planning horizon*.
10. \_\_\_\_\_ Production in which a given level of output can be produced with more than one combination of inputs.
11. \_\_\_\_\_ Production in which one, and only one, ratio or mix of inputs can be used to produce a good.
12. \_\_\_\_\_ Total product divided by the number of units of labor employed.
13. \_\_\_\_\_ Additional output attributable to using one more worker holding the use of all other inputs constant.
14. \_\_\_\_\_ As the level of usage of the variable input increases, other inputs held constant, a point will be reached beyond which the marginal product decreases.
15. \_\_\_\_\_ Total amount paid for fixed inputs.
16. \_\_\_\_\_ Total amount paid for variable inputs.

17. \_\_\_\_\_ The sum of total fixed and total variable costs.
18. \_\_\_\_\_ Fixed cost per unit of output (i.e., total fixed cost divided by output).
19. \_\_\_\_\_ Variable cost per unit of output (i.e., total variable cost divided by output).
20. \_\_\_\_\_ Total cost per unit of output (i.e., total cost divided by output).
21. \_\_\_\_\_ The change in either total cost or total variable cost per unit change in output.

## Study Problems

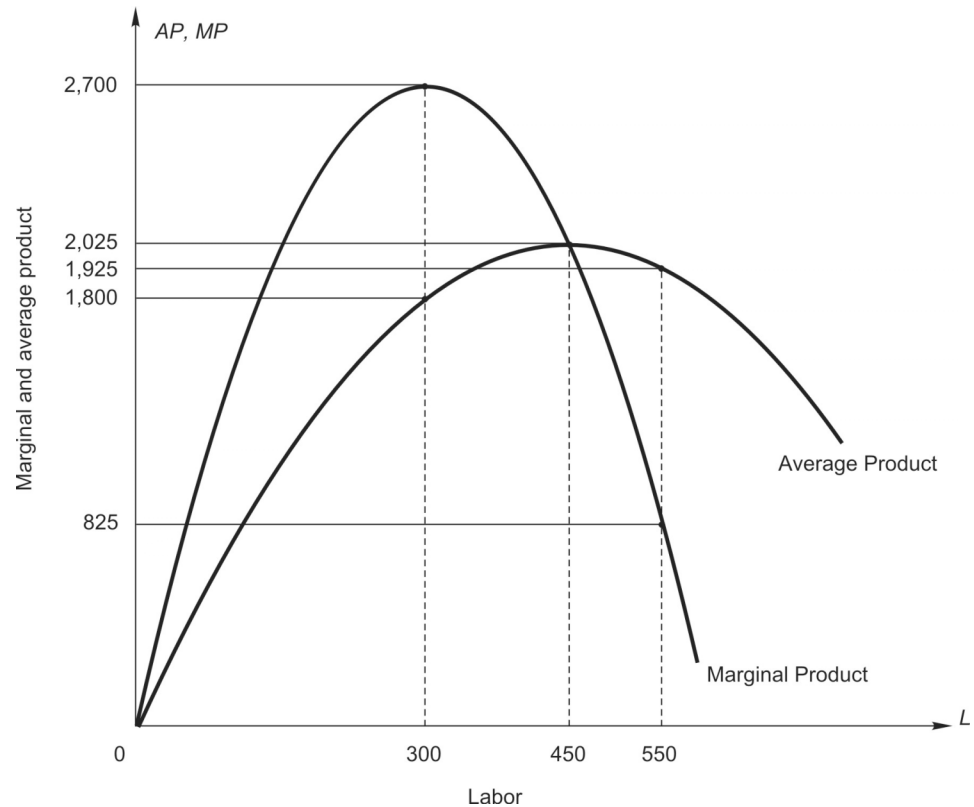
1. For each of the firm's decisions, determine whether the manager is making a decision in the short run or the long run.
  - \_\_\_\_\_ a. Eckerd's decides to stay open 24 hours a day rather than 16 hours a day.
  - \_\_\_\_\_ b. Harley Davidson builds another production facility.
  - \_\_\_\_\_ c. American Airlines restructures its flight schedules to increase the percentage of seats filled on each of its flights.
  - \_\_\_\_\_ d. Dell Computer adds more workers in its shipping department to speed delivery of new PC orders.
2. Fill in the blanks in the following table:

| <i>Usage of<br/>Variable Input</i> | <i>Total<br/>Product</i> | <i>Marginal<br/>Product</i> | <i>Average<br/>Product</i> |
|------------------------------------|--------------------------|-----------------------------|----------------------------|
| 1 .....                            | _____                    | _____                       | 4                          |
| 2 .....                            | _____                    | 8                           | _____                      |
| 3 .....                            | 18                       | _____                       | _____                      |
| 4 .....                            | _____                    | _____                       | 5                          |
| 5 .....                            | _____                    | -5                          | _____                      |

The wage rate is \$12 per unit of labor. After completing the table, answer the following questions:

- a. After \_\_\_\_\_ units of labor usage, the firm experiences diminishing returns.
- b. At \_\_\_\_\_ units of labor,  $SMC = AVC$ .
- c. The level of output at which  $SMC = AVC$  is \_\_\_\_\_ units of output.
- d. Minimum average variable cost = \$\_\_\_\_\_.
- e. At the level of labor usage and associated output for which  $SMC = AVC$ , marginal cost = \$\_\_\_\_\_.

3. Consider a firm using a single variable input and a single fixed input, capital. When the amount of capital is increased:
  - a. the total product curve will \_\_\_\_\_.
  - b. the average product curve will \_\_\_\_\_.
  - c. the marginal product curve will \_\_\_\_\_.
4. Assume labor—the only variable input of a firm—has average and marginal product curves shown in the following figure. The price of labor is \$1,000 per unit (i.e.,  $w = \$1,000$ ).



- a. At minimum average variable cost, the firm employs \_\_\_\_\_ units of labor.
- b. Minimum average variable cost is reached at \_\_\_\_\_ units of output.
- c. At its minimum value, average variable cost is \$\_\_\_\_\_.
- d. Marginal cost reaches its minimum value at \_\_\_\_\_ units of labor usage, which corresponds to \_\_\_\_\_ units of output.
- e. At its minimum value, marginal cost is \$\_\_\_\_\_.
- f. The average variable cost when 550 units of labor are employed is \$\_\_\_\_\_.
- g. The marginal cost when 550 units of labor are employed is \$\_\_\_\_\_.



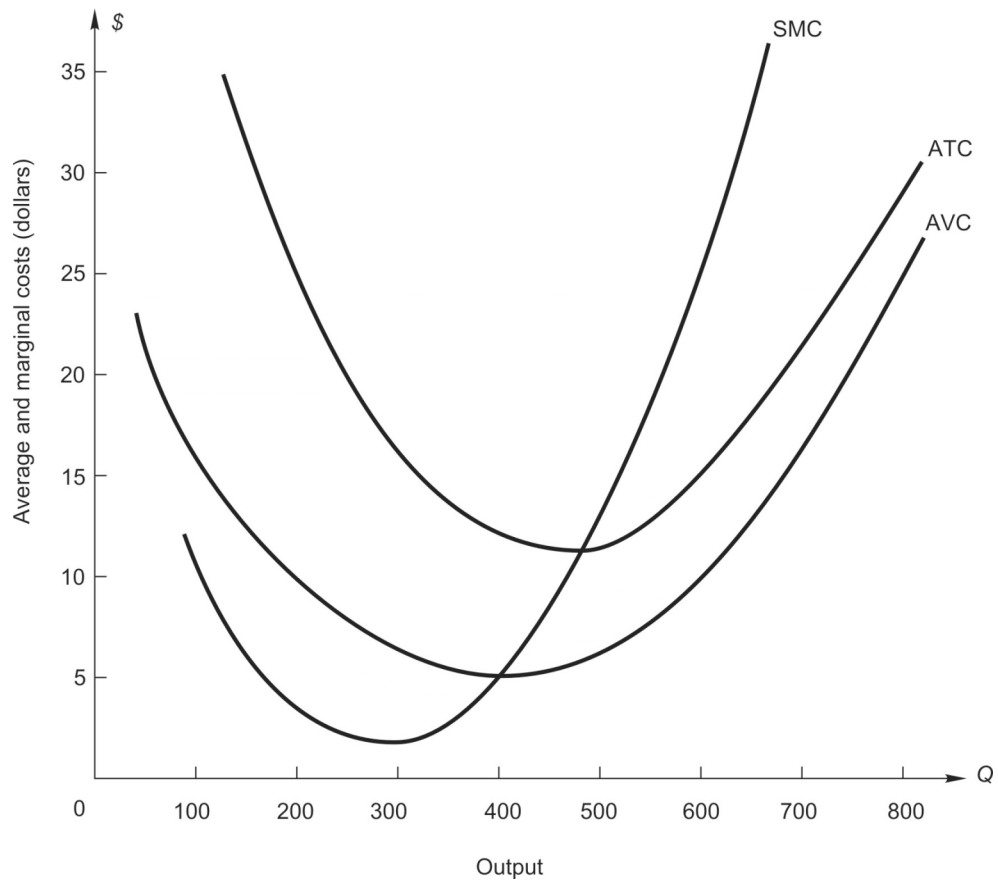
5. Use the figure below to answer these questions:

At 200 units of output, find the following costs:

- |                  |                  |
|------------------|------------------|
| a. $AFC$ = _____ | e. $TVC$ = _____ |
| b. $AVC$ = _____ | f. $TC$ = _____  |
| c. $ATC$ = _____ | g. $SMC$ = _____ |
| d. $TFC$ = _____ |                  |

At 600 units of output, find the following costs:

- |                  |                  |
|------------------|------------------|
| h. $AFC$ = _____ | l. $TVC$ = _____ |
| i. $AVC$ = _____ | m. $TC$ = _____  |
| j. $ATC$ = _____ | n. $SMC$ = _____ |
| k. $TFC$ = _____ |                  |



6. Total fixed cost is \$150 per week and the price per week of labor is \$500 per worker. Fill in the blanks in the table below:

| <i>Labor</i> | <i>Product</i> |                |                 | <i>Total Cost</i> |                 |              | <i>Average Cost</i> |                 |              | <i>Marginal Cost</i> |
|--------------|----------------|----------------|-----------------|-------------------|-----------------|--------------|---------------------|-----------------|--------------|----------------------|
|              | <i>Total</i>   | <i>Average</i> | <i>Marginal</i> | <i>Fixed</i>      | <i>Variable</i> | <i>Total</i> | <i>Fixed</i>        | <i>Variable</i> | <i>Total</i> |                      |
| 0            | 0              | xx             | xx              | _____             | _____           | _____        | xx                  | xx              | xx           | xx                   |
| 1            | 2              | _____          | _____           | _____             | _____           | _____        | _____               | _____           | _____        | _____                |
| 2            | 5              | _____          | _____           | _____             | _____           | _____        | _____               | _____           | _____        | _____                |
| 3            | 10             | _____          | _____           | _____             | _____           | _____        | _____               | _____           | _____        | _____                |
| 4            | 16             | _____          | _____           | _____             | _____           | _____        | _____               | _____           | _____        | _____                |
| 5            | 25             | _____          | _____           | _____             | _____           | _____        | _____               | _____           | _____        | _____                |
| 6            | 30             | _____          | _____           | _____             | _____           | _____        | _____               | _____           | _____        | _____                |
| 7            | 34             | _____          | _____           | _____             | _____           | _____        | _____               | _____           | _____        | _____                |
| 8            | 37             | _____          | _____           | _____             | _____           | _____        | _____               | _____           | _____        | _____                |
| 9            | 39             | _____          | _____           | _____             | _____           | _____        | _____               | _____           | _____        | _____                |
| 10           | 40             | _____          | _____           | _____             | _____           | _____        | _____               | _____           | _____        | _____                |

### Multiple Choice / True-False

- Marginal product equals average product
  - when marginal product equals zero.
  - when average product equals zero.
  - at the inflection point of the total product curve.
  - at the maximum value of marginal product.
  - at the maximum value of average product.
- The economically efficient input combination for producing a given level of output
  - minimizes the average cost of producing the given level of output.
  - occurs at the maximum value of the total product curve.
  - can produce that level of output at the lowest possible total cost.
  - is determined entirely by the production function.
- If average product is rising, then marginal product
  - cannot be falling.
  - can be either rising or falling, but it must lie above average product.
  - must lie below average product.
  - must be rising.

In questions 4–7, suppose that the short-run production function is given by:

| <i>Labor</i> | <i>Quantity</i> |
|--------------|-----------------|
| 0            | 0               |
| 1            | 3               |
| 2            | 10              |
| 3            | 21              |
| 4            | 24              |
| 5            | 25              |
| 6            | 24              |
| 7            | 14              |

4. The average product of labor when 3 units of labor are employed is
  - a. 3.
  - b. 5.
  - c. 7.
  - d. 11.
  - e. -1.
5. The marginal product of the 6<sup>th</sup> laborer is
  - a. 3.
  - b. 5.
  - c. 7.
  - d. 11.
  - e. -1.
6. Diminishing marginal returns begin with the
  - a. 2<sup>nd</sup> unit of labor.
  - b. 4<sup>th</sup> unit of labor.
  - c. 5<sup>th</sup> unit of labor.
  - d. 6<sup>th</sup> unit of labor.
7. Marginal product is negative when more than
  - a. 3 units of labor are employed.
  - b. 4 units of labor are employed.
  - c. 5 units of labor are employed.
  - d. 6 units of labor are employed.
8. Fixed costs
  - a. must be considered in any decision-making process.
  - b. do not exist in the long run.
  - c. decrease as output rises.
  - d. *a* and *b*.
  - e. *b* and *c*.

Fill in the missing values and answer questions 9–13.

| Q      | Total<br>Cost | Fixed<br>Cost | Variable<br>Cost | Average       |                  | Total<br>Cost | Marginal<br>Cost |
|--------|---------------|---------------|------------------|---------------|------------------|---------------|------------------|
|        |               |               |                  | Fixed<br>Cost | Variable<br>Cost |               |                  |
| 0..... | 20            | _____         | _____            | xx            | xx               | xx            | xx               |
| 1..... | _____         | _____         | _____            | _____         | _____            | _____         | 20               |
| 2..... | _____         | _____         | _____            | _____         | 15               | _____         | _____            |
| 3..... | _____         | _____         | _____            | _____         | _____            | 19            | _____            |
| 4..... | _____         | _____         | 48               | _____         | _____            | _____         | _____            |

9. What is total fixed cost?
- 10
  - 15
  - 20
  - cannot be determined
  - none of the above
10. What is total cost when  $Q = 1$ ?
- 30
  - 35
  - 40
  - 20
  - none of the above
11. What is average total cost when  $Q = 2$ ?
- 10
  - 20
  - 30
  - 40
  - none of the above
12. What is marginal cost when  $Q = 3$ ?
- 7
  - 8
  - 9
  - 10
13. What is marginal cost when  $Q = 4$ ?
- 5
  - 10
  - 11
  - 15
  - 20
14. When the average product of the variable input is equal to the marginal product,
- marginal cost reaches its minimum value.
  - average variable cost reaches its minimum value.
  - marginal cost is rising.
  - both  $a$  and  $c$ .
  - both  $b$  and  $c$ .
15. If a firm is producing 5 units of output and the marginal cost for the fifth unit is \$7 and the average variable cost for the fifth unit is \$3, then the average variable cost for the fourth unit is \_\_\_\_\_.
- 1
  - 2
  - 4
  - 8
  - none of the above

16. If short-run marginal cost is U-shaped, then
  - a. total cost increases at an increasing rate, then increases at a decreasing rate.
  - b. total variable cost increases at a decreasing rate then increases at an increasing rate.
  - c. total variable cost must be S-shaped.
  - d. all of the above.
  - e. both *b* and *c*.
17. Average total cost
  - a. increases as output increases.
  - b. decreases as output increases.
  - c. increases if marginal cost is increasing.
  - d. increases if marginal cost is greater than average total cost.
  - e. both *c* and *d*.
18. Average fixed cost
  - a. increases as output increases.
  - b. decreases as output increases.
  - c. increases if marginal cost is increasing.
  - d. increases if marginal cost is greater than average fixed cost.
19. T F A firm that operates in an economically efficient way is also operating in a technically efficient way.
20. T F Average fixed cost is not usually graphed with the other average cost curves because average fixed cost can be obtained from average total cost and average variable cost.
21. T F If average variable cost is rising, marginal cost must be rising.
22. T F Marginal cost measures the change in total variable cost as output changes.

# Answers

## **MATCHING DEFINITIONS**

1. production
2. production function
3. technical efficiency
4. economic efficiency
5. fixed input
6. variable input
7. quasi-fixed input
8. short run
9. long run
10. variable proportions production
11. fixed proportions production
12. average product of labor
13. marginal product of labor
14. law of diminishing marginal product
15. total fixed cost
16. total variable cost
17. total cost
18. average fixed cost
19. average variable cost
20. average total cost
21. short-run marginal cost

## **STUDY PROBLEMS**

1.
  - a. short run; This decision involves increasing the usage of a fixed input, the store.
  - b. long run; A new plant allows increased usage of capital inputs that are fixed in the short run.
  - c. short run; American Airlines is still using the same number of planes (presumably a fixed input in the short run), but using the planes more intensively.
  - d. short run; Dell did not increase the capital resources employed by the shipping department; it is just using more of the variable input labor.
2. The table should look like this:

| <i>Usage of<br/>Variable Input</i> | <i>Total<br/>Product</i> | <i>Marginal<br/>Product</i> | <i>Average<br/>Product</i> |
|------------------------------------|--------------------------|-----------------------------|----------------------------|
| 1.....                             | 4                        | 4                           | 4                          |
| 2.....                             | 12                       | 8                           | 6                          |
| 3.....                             | 18                       | 6                           | 6                          |
| 4.....                             | 20                       | 2                           | 5                          |
| 5.....                             | 15                       | -5                          | 3                          |

- a. 2;  $MP$  begins to fall after 2 units of labor are employed.
  - b. 3;  $SMC$  will equal  $AVC$  when  $MP = AP$ .
  - c. 18;  $TP$  is 18 at  $L = 3$
  - d. \$2;  $AVC = w/AP = 12/6$
  - e. \$2;  $SMC = w/MP = 12/6$
- 3.
- a. increase (shift upward)
  - b. increase (shift upward)
  - c. increase (shift upward)
- 4.
- a. 450;  $AVC$  is minimized when  $AP$  is maximized.
  - b. 911,250; Since  $AP = Q/L$ ,  $2,025 = Q/450 \Rightarrow Q = 911,250$ .
  - c. \$0.49;  $AVC = w/AP \Rightarrow \$1,000/2,025$ .
  - d. 300; 540,000;  $SMC$  is minimized at the level of labor usage where  $MP$  is maximized. Since  $AP = Q/L$  and  $AP = 1,800$  at  $L = 300$ , then  $1,800 = Q/300 \Rightarrow Q = 540,000$ .
  - e. \$0.37;  $SMC = w/MP = \$1,000/2,700$
  - f. \$0.52;  $AVC = w/AP = \$1,000/1,925$
  - g. \$1.21;  $SMC = w/MP = \$1,000/825$
- 5.
- a. \$15; the vertical distance between  $ATC$  and  $AVC$  at  $Q = 200$ .
  - b. \$10; read this off the  $AVC$  curve at  $Q = 200$
  - c. \$25; read this off the  $ATC$  curve at  $Q = 200$
  - d. \$3,000;  $TFC = AFC \times Q = 15 \times 200$
  - e. \$2,000;  $TVC = AVC \times Q = 10 \times 200$
  - f. \$5,000;  $TC = ATC \times Q = 25 \times 200$  or  $TC = TVC + TFC = 3,000 + 2,000$
  - g. about \$4; read this off the  $SMC$  curve at  $Q = 200$
  - h. \$5; the vertical distance between  $ATC$  and  $AVC$  at  $Q = 600$
  - i. \$10; read this off the  $AVC$  curve at  $Q = 600$
  - j. \$15; read this off the  $ATC$  curve at  $Q = 600$
  - k. \$3,000;  $TFC = AFC \times Q = 5 \times 600$
  - l. \$6,000;  $TVC = AVC \times Q = 10 \times 600$
  - m. \$9,000;  $TC = ATC \times Q = 15 \times 600$  or  $TC = TVC + TFC = 3,000 + 6,000$
  - n. \$25; read this off the  $SMC$  curve at  $Q = 600$

6. Your table should look like this:

| <i>Labor</i> | <i>Product</i> |                |                 | <i>Total Cost</i> |                 |              | <i>Average Cost</i> |                 |              |                      |
|--------------|----------------|----------------|-----------------|-------------------|-----------------|--------------|---------------------|-----------------|--------------|----------------------|
|              | <i>Total</i>   | <i>Average</i> | <i>Marginal</i> | <i>Fixed</i>      | <i>Variable</i> | <i>Total</i> | <i>Fixed</i>        | <i>Variable</i> | <i>Total</i> | <i>Marginal Cost</i> |
| 0            | 0              | 0              | xx              | 150               | 0               | 150          | xx                  | xx              | xx           | xx                   |
| 1            | 2              | 2              | 2               | 150               | 500             | 650          | 75                  | 250             | 325          | 250                  |
| 2            | 5              | 2.5            | 3               | 150               | 1,000           | 1,150        | 30                  | 200             | 230          | 166.67               |
| 3            | 10             | 3.3            | 5               | 150               | 1,500           | 1,650        | 15                  | 150             | 165          | 100                  |
| 4            | 16             | 4              | 6               | 150               | 2,000           | 2,150        | 9.37                | 125             | 134.37       | 83.33                |
| 5            | 25             | 5              | 9               | 150               | 2,500           | 2,650        | 6                   | 100             | 106          | 55.55                |
| 6            | 30             | 5              | 5               | 150               | 3,000           | 3,150        | 5                   | 100             | 105          | 100                  |
| 7            | 34             | 4.85           | 4               | 150               | 3,500           | 3,650        | 4.41                | 102.94          | 107.35       | 125                  |
| 8            | 37             | 4.62           | 3               | 150               | 4,000           | 4,150        | 4.05                | 108.11          | 112.16       | 166.67               |
| 9            | 39             | 4.33           | 2               | 150               | 4,500           | 4,650        | 3.85                | 115.38          | 119.23       | 250                  |
| 10           | 40             | 4              | 1               | 150               | 5,000           | 5,150        | 3.75                | 125             | 128.75       | 500                  |

### **MULTIPLE CHOICE / TRUE-FALSE**

- e  $MP = AP$  at  $AP$ 's maximum point. Note that answer  $c$  is wrong because the inflection point on  $TP$  is where  $MP$  (not  $AP$ ) reaches its maximum.
- c The efficient input combination is the one that minimizes *total*, not average, cost.
- b  $MP$  both rises and falls over the range of labor usage for which  $AP$  is rising.
- c  $AP_3 = 21/3 = 7$
- e  $TP_5 = 25$  and  $TP_6 = 24 \Rightarrow TP$  falls by one unit.  $MP$  for the sixth unit of labor is 11.
- b  $MP$  is smaller for the fourth unit of labor than it is for the third unit of labor.
- c  $MP < 0$  after 5 units of labor are employed.
- b Fixed costs are the payment to the fixed inputs. Since all inputs are variable in the long run, there are no fixed costs in the long run.
- c You can see that fixed cost is \$20 by noting that when  $Q = 0$ ,  $TC = \$20$ .
- c Since  $SMC$  for unit 1 is \$20,  $TC$  for the first unit must be \$20 greater than  $TC$  when  $Q = 0$ . Therefore,  $TC = 20 + 20 = 40$ .
- e Since  $AVC = \$15$ ,  $TVC = \$30 (= 2 \times 15)$ .  $TC = TVC + TFC = 30 + 20 = 50$ . Therefore,  $ATC = TC/Q = 50/2 = \$25$ .
- a  $ATC = \$19$  and  $TC = \$57 (= 3 \times 19)$ . Since  $TC$  is \$50 for 2 units, and  $TC$  is \$57 for 3 units, the marginal cost of the 3<sup>rd</sup> unit must be \$7.
- c  $TC_{Q=4} = TVC + TFC = 48 + 20 = 68$ . Since  $TC_{Q=3} = \$57$ , the marginal cost of the 4<sup>th</sup> unit must be \$11.
- e When  $AP = MP$ ,  $AP$  is at its maximum value.  $MP$  is *falling* when  $AP = MP$ , and thus  $SMC (= w/MP)$  is rising.

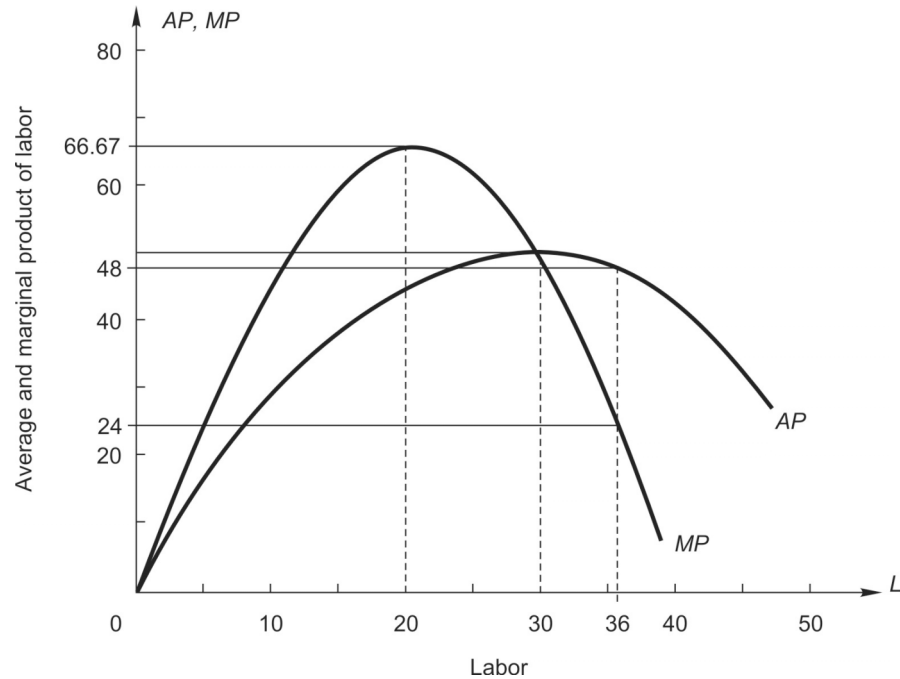


15. b Since  $AVC_5 = \$3$ ,  $TVC_5 = \$15$ . Given marginal cost of the 5<sup>th</sup> unit is \$7, the total variable cost of 4 units must be \$8. Thus  $AVC_4 = \$8/4 = \$2$ .
16. e If  $SMC$  is U-shaped, then the slope of  $TVC$  first falls, then rises. The only way this can occur is if  $TVC$  is S-shaped (i.e.,  $TVC$  first increases at a decreasing rate, then increases at an increasing rate).
17. d If marginal exceeds average, then average rises.
18. b While  $TFC$  is constant,  $AFC$  declines as  $Q$  gets larger.
19. T All economically efficient firms are technically efficient. The converse is *not* true.
20. T  $AFC = ATC - AVC$
21. T When  $AVC$  is rising,  $SMC$  exceeds  $AVC$  and is rising.
22. T  $SMC = \Delta TC / \Delta Q$ . Since  $\Delta TC = \Delta TVC$  (only  $TVC$  varies as  $Q$  changes),  $SMC = \Delta TVC / \Delta Q$ .



## Homework Exercises

- The following figure shows a firm's marginal and average product curves for labor, the only variable input employed by the firm. The wage rate of labor is \$200 and the fixed cost is \$6,000.



When average variable cost reaches its minimum:

- Output is \_\_\_\_\_ units.
- $AVC$  is \$\_\_\_\_\_ and  $SMC$  is \$\_\_\_\_\_.
- $ATC$  is \$\_\_\_\_\_.

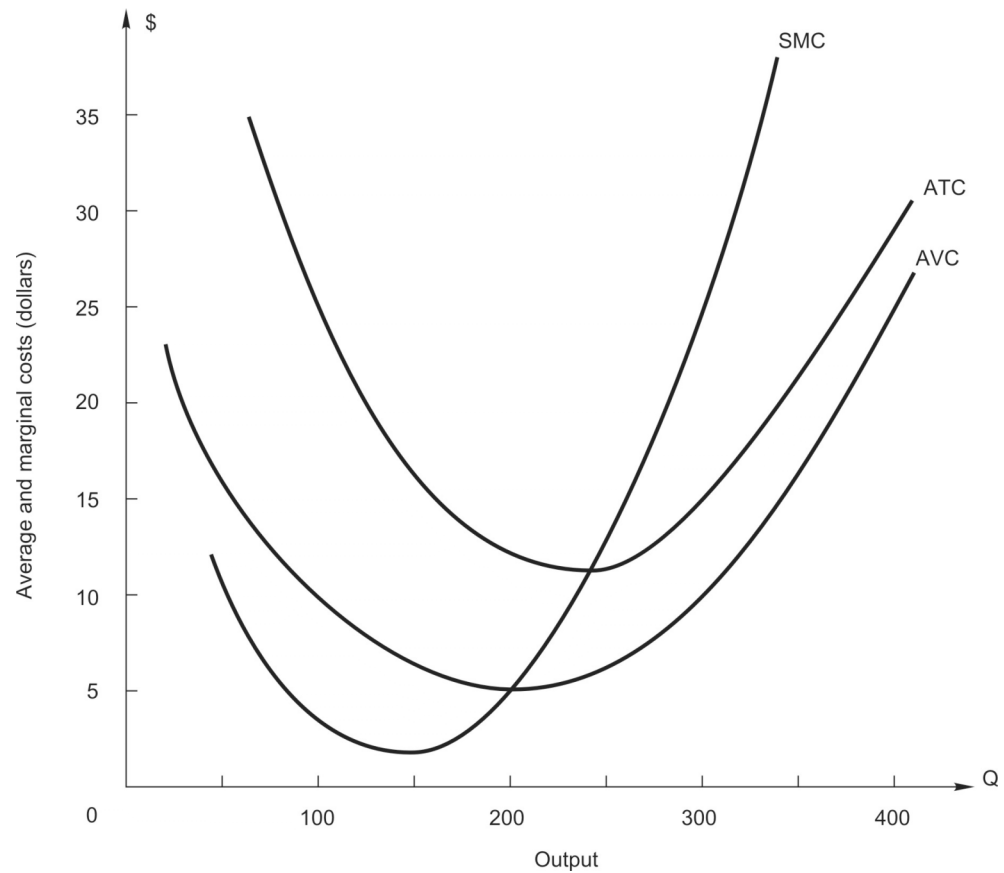
When 36 workers are hired:

- Output is \_\_\_\_\_ units.
- $AVC$  is \$\_\_\_\_\_ and  $SMC$  is \$\_\_\_\_\_ at this output.
- At the level of output associated with 36 workers,  $AVC$  is \_\_\_\_\_ (increasing, decreasing) and  $SMC$  is \_\_\_\_\_ (increasing, decreasing).

2. Fill in the blanks in the table below:

| Output | TC    | TFC   | TVC   | AFC   | AVC   | ATC   | SMC   |
|--------|-------|-------|-------|-------|-------|-------|-------|
| 0      | _____ | _____ | _____ | xx    | xx    | xx    | xx    |
| 10     | _____ | _____ | _____ | _____ | _____ | _____ | 8.0   |
| 20     | _____ | _____ | _____ | _____ | 4.50  | _____ | _____ |
| 30     | 215   | _____ | _____ | 2.00  | _____ | _____ | _____ |
| 40     | _____ | _____ | _____ | _____ | _____ | _____ | 7.2   |
| 50     | _____ | _____ | _____ | _____ | 6.14  | _____ | 8.0   |
| 60     | 452   | _____ | _____ | _____ | _____ | _____ | _____ |
| 70     | _____ | _____ | _____ | _____ | _____ | _____ | 9.0   |
| 80     | _____ | _____ | 582   | _____ | _____ | _____ | _____ |

3. Use the figure below to answer the questions on the next page.



At 100 units of output, find the following costs:

- |                  |                  |
|------------------|------------------|
| a. $AFC$ = _____ | e. $TVC$ = _____ |
| b. $AVC$ = _____ | f. $TC$ = _____  |
| c. $ATC$ = _____ | g. $SMC$ = _____ |
| d. $TFC$ = _____ |                  |

At 300 units of output, find the following costs:

- |                  |                  |
|------------------|------------------|
| h. $AFC$ = _____ | l. $TVC$ = _____ |
| i. $AVC$ = _____ | m. $TC$ = _____  |
| j. $ATC$ = _____ | n. $SMC$ = _____ |
| k. $TFC$ = _____ |                  |

