9 Production and Cost in the Long Run

Learning Objectives

After reading Chapter 9 and working the problems for Chapter 9 in the textbook and in this Workbook, you should be able to:

- Draw a graph of a typical production isoquant and use the definition of an isoquant to explain why isoquants must be downward sloping.
- Discuss the properties of an isoquant.
- Construct isocost curves for a given level of expenditure on inputs.
- Apply the theory of optimization to find the optimal input combination.
- Show graphically that the conditions for minimizing the total cost of producing a given level of output are the same conditions for maximizing the level of output for a given level of total cost.
- Construct an expansion path.
- Define and illustrate graphically the concept of returns to scale.
- Construct a long-run total cost curve from an expansion path.
- Explain the concept of economies and diseconomies of scale.
- Define economies of scope and explain how to measure economies of scope.
- Show the relation between long-run and short-run cost curves.

Essential Concepts

1. In long-run analysis of production, all inputs are variable and isoquants are used to study production decisions. An *isoquant* is a curve showing all possible input combinations capable of producing a given level of output.

2. Isoquants are downward sloping because if greater amounts of labor are used, then less capital is required to produce a given level of output. The *marginal rate of technical substitution* (*MRTS*) is the slope of an isoquant and measures the rate at which the two inputs can be substituted for one another while maintaining a constant level of output

$$MRTS = -\frac{\Delta K}{\Delta L}$$

The minus sign is added in order to make *MRTS* a positive number since $\Delta K / \Delta L$, the slope of the isoquant, is negative.

3. The marginal rate of technical substitution can be expressed as the ratio of two marginal products:

$$MRTS = \frac{MP_L}{MP_K}$$

As labor is substituted for capital, MP_L declines and MP_K rises causing *MRTS* to diminish.

4. *Isocost curve*s show the various combinations of inputs that may be purchased for a given level of expenditure ($\overline{C}$) at given input prices (*w* and *r*). The equation of an isocost curve is given by

$$K = \frac{\overline{C}}{r} - \frac{w}{r}L$$

The slope of an isocost curve is the negative of the input price ratio ($-w/r$). The *K*-intercept is $\overline{C}/r$, which represents the amount of capital that may be purchased when all $\overline{C}$ dollars are spent on capital (i.e., zero labor is purchased).

5. A manager can minimize the total cost of producing $\overline{Q}$ units of output by choosing the input combination on the isoquant for $\overline{Q}$ which is just tangent to an isocost curve. Since the optimal input combination occurs at the point of tangency between the isoquant and an isocost curve, the two slopes are equal in equilibrium. Mathematically, the equilibrium condition may be expressed as

$$\frac{MP_L}{MP_K} = \frac{w}{r} \quad \text{or} \quad \frac{MP_L}{w} = \frac{MP_K}{r}$$

6. In order to maximize output for a given level of expenditure on inputs, a manager must choose the combination of inputs that equates the marginal rate of technical substitution and the input price ratio, which requires choosing an input combination satisfying exactly the same conditions set forth above for minimizing cost.

7. The *expansion path* is the curve that gives the efficient (least-cost) input combinations for every level of output. The expansion path is derived for a specific set of input prices. Along an expansion path, the input-price ratio is constant and equal to the marginal rate of technical substitution.

8. If all inputs are increased by a factor of *c* and output goes up by a factor of *z*, then in general, a producer experiences:
   a. *increasing returns to scale* if $z > c$, because output goes up proportionately *more* than the increase in input usage.
   b. *decreasing returns to scale* if $z < c$, because output goes up proportionately *less* than the increase in input usage.
   c. *constant returns to scale* if $z = c$, because output goes up by the *same* proportion as the increase in input usage.

9. Long-run total cost (LTC) for a given level of output $\overline{Q}$ is given by

$$LTC = wL^* + rK^*$$

where w and r are the prices of labor and capital, respectively, and L^* and K^* is the input combination on the expansion path that minimizes the total cost of producing $\overline{Q}$ units of output.

10. Long-run average cost (LAC) measures the cost per unit of output when the manager can adjust production so that the optimal amount of each input is employed

$$LAC = \frac{LTC}{Q}$$

LAC is $\cup$-shaped. Falling LAC indicates *economies of scale*, and rising LAC indicates *diseconomies of scale*.

11. Long-run marginal cost (LMC) measures the rate of change in long-run total cost as output changes along the expansion path:

$$LMC = \frac{\Delta LTC}{\Delta Q}$$

LMC is $\cup$-shaped. LMC lies below (above) LAC when LAC is falling (rising). LMC equals LAC at LAC's minimum value.

12. When constant returns to scale occur over the entire range of output, the firm experiences constant costs in the long run and the LAC curve is flat and equal to LMC at all output levels (see Figure 9.12 in the textbook).

13. *Economies of scope* exist for a multiproduct firm when the joint cost of producing two or more goods is less than the sum of the separate costs of producing the goods. In the case of two goods, X and Y, economies of exist when

$$C(X,Y) < C(X) + C(Y)$$

14. The relations between long-run cost and short-run cost can be summarized by the following points:
    a. LMC intersects LAC when the latter is at its minimum point.
    b. At each output where a particular ATC is tangent to LAC, the relevant SMC equals LMC.
    c. For all ATC curves, the point of tangency with LAC is at an output less (greater) than the output of minimum ATC if the tangency is at an output less (greater) than that associated with minimum LAC.

15. Because managers have the greatest flexibility to choose inputs in the long run, costs are lower in the long run than in the short run for all output levels except the output level for which the fixed input is at its optimal level. Thus, the firm's short-run costs can generally be reduced by adjusting the fixed inputs to their optimal long-run levels when the long-run opportunity to adjust fixed inputs arises.

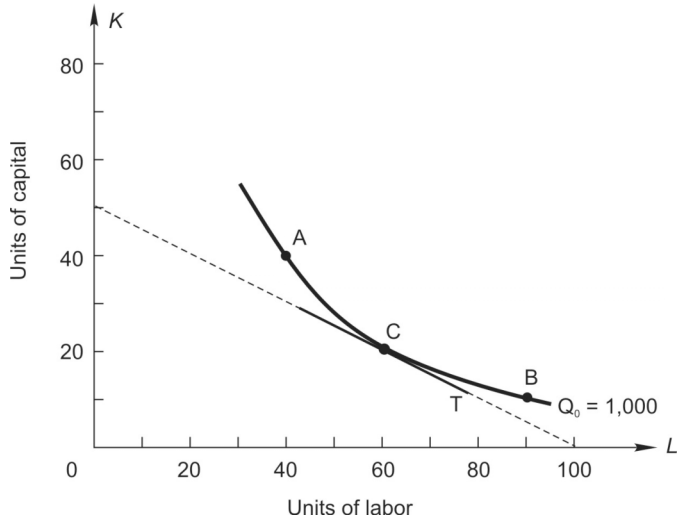
Matching Definitions

constant costs	increasing returns to scale
constant returns to scale	isocost curve
decreasing returns to scale	isoquant
diseconomies of scale	long-run average cost
economies of scale	long-run marginal cost
economies of scope	marginal rate of technical substitution
expansion path	short-run expansion path

1. _____ A curve that displays all the various combinations of inputs that will produce a given amount of output.
2. _____ The rate at which one input is substituted for another along an isoquant.
3. _____ Line that shows all the possible combinations of inputs that can be purchased for a given total cost.
4. _____ A curve showing all of the cost-minimizing levels of input usage for various levels of output.
5. _____ When the usage of all inputs is increased by an equiproportionate amount, output increases by exactly the same proportion.
6. _____ When the usage of all inputs is increased by an equiproportionate amount, output increases by a larger proportionate amount.
7. _____ When the usage of all inputs is increased by an equiproportionate amount, output increases by a smaller proportionate amount.
8. _____ Cost per unit in the long run.
9. _____ The change in long-run total cost per unit change in output.
10. _____ When long-run average cost falls as output increases.
11. _____ When long-run average cost increases with increases in output.
12. _____ Long-run average and marginal costs are equal for all levels of output.
13. _____ The situation in which the joint cost of producing two goods is less than the sum of the separate costs of producing the two goods.
14. _____ Horizontal line showing the cost-minimizing input combinations for various output levels when capital is fixed in the short run.

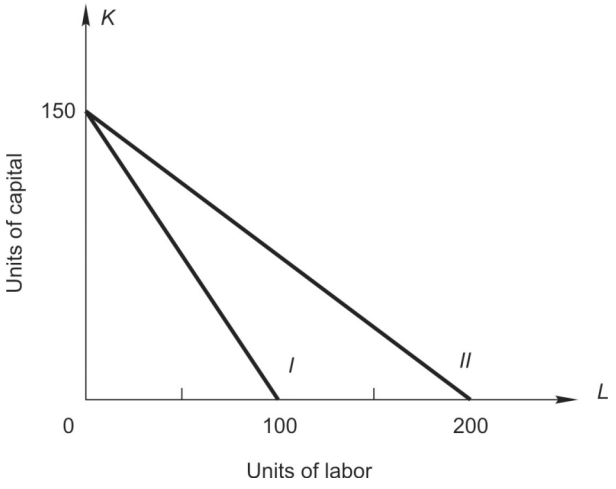
Study Problems

1. In the following figure, isoquant Q_0 is the isoquant for 1,000 units of output.



   a. Marginal rate of technical substitution between points *A* and *C* is _____.
   b. Marginal rate of technical substitution between points *C* and *B* is _____.
   c. Marginal rate of technical substitution at point *C* is _____.

2. The following graph shows two isocost curves. The price of capital is $100.



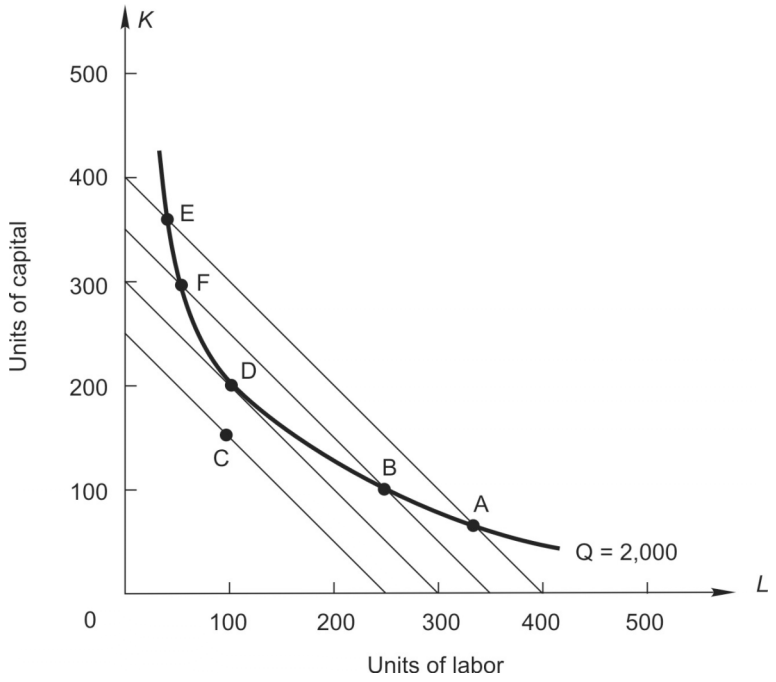
   a. The total cost associated with isocost *I* is $_____, and the price of labor is $_____.

b. The equation for isocost *I* is _____. With isocost *I* the firm must give up _____ units of capital to purchase one more unit of labor in the market.

c. The total cost associated with isocost *II* is $_____, and the price of labor is $_____.

d. The equation for isocost *II* is _____. With isocost *II* the firm must give up _____ units of capital to purchase one more unit of labor in the market.

3. The following figure shows a firm's isoquant for producing 2,000 units of output and four isocost curves. Labor and capital each cost $50 per unit.



a. At point *A*, the *MRTS* is _____ (less than, greater than, equal to) the input price ratio, *w*/*r*. The total cost of producing 2,000 units of output with input combination *A* is $_____.

b. By moving from *A* to *B*, the firm _____ (increases, decreases) labor usage and _____ (increases, decreases) capital usage. At point *B* the *MRTS* is _____ (greater than, less than, equal to) the input price ratio, *w*/*r*. The movement from *A* to *B* _____ (increased, decreased) total cost by $_____.

c. At Point *D* the firm _____ (minimizes, maximizes) the cost of producing 2,000 units of output. The *MRTS* is _____ (greater than, less than, equal to) the input price ratio, *w*/*r*.

d. The optimal input combination is _____ units of labor and _____ units of capital. At this combination, the total cost of producing 2,000 units is $ _____.

e. At point *E*, the *MP* per dollar spent on _____ is less than the *MP* per dollar spent on _____. The total cost of producing 2,000 units of output with input combination *E* is $_____.

f. The movement from *E* to *F* reduces the *MP* per dollar spent on _____ and increases the *MP* per dollar spent on _____. This movement _____ (increased, decreased) total cost by $_____.

g. At input combination *D,* the *MP* per dollar spent on labor is _____ (greater than, less than, equal to) the *MP* per dollar spent on capital.

h. Input combination *C* costs $_____. The firm would not use this combination to produce 2,000 units of output because _____.

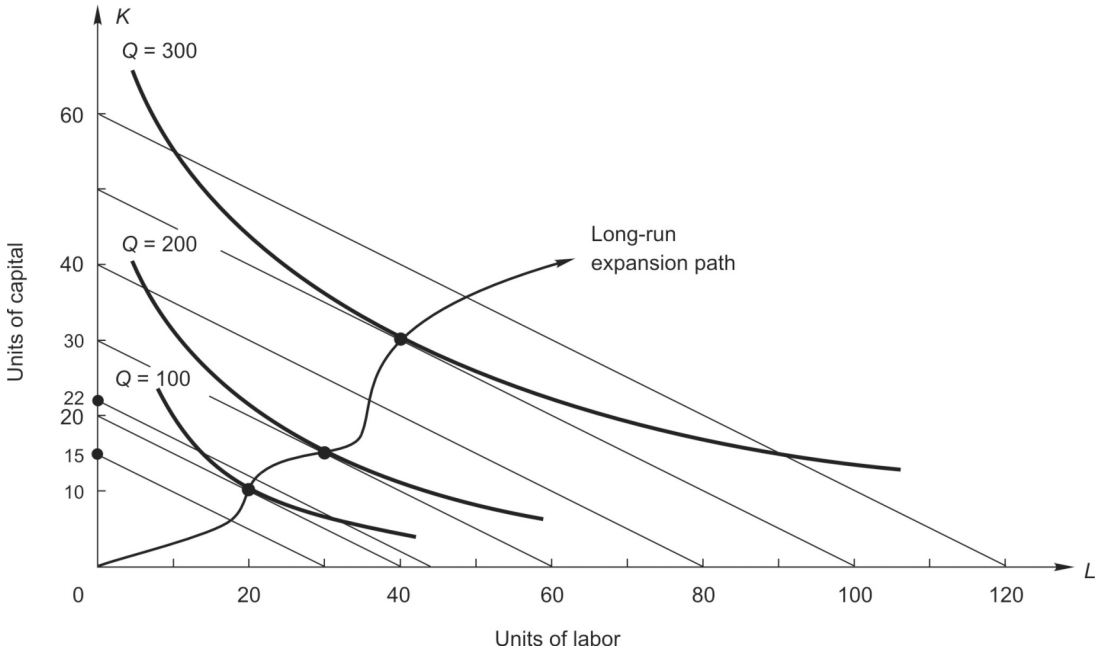
4. Your firm produces clay pots entirely by hand even though a pottery machine exists that can make clay pots faster than a human. Workers cost $100 per day and each additional worker can produce 20 more pots per day (i.e., marginal product is constant and equal to 20). Installation of the first pottery machine would increase output by 300 pots per day. Currently your firm produces 1,200 pots per day.

   a. Your financial analysis department estimates that the price of a pottery machine is $2,000 per day. Can you reduce the cost of producing 1,200 pots per day by adding a pottery machine to your production process and reducing the amount of labor? Explain why or why not.

   b. If a labor union negotiates higher wages so that labor costs rise to $150 per day, does this change your answer to part *a*? Explain.

   c. Suppose your firm wants to expand output to 2,500 pots per day and input prices are $100 and $2,000 per day for labor and capital, respectively. Is it efficient to hire more labor or more capital? Explain using the ratio of marginal products and input prices.

5. The figure below shows a portion of the expansion path for a firm. The price of labor is $75.



a. The price of capital is $_____. Along the expansion path, the marginal rate of technical substitution is equal to _____.

b. To produce 100 units in the long run, a manager would use _____ units of labor and _____ units of capital. The long-run total cost of producing 100 units is $_____.

c. To produce 200 units in the long run, a manager would use _____ units of labor and _____ units of capital. The long-run total cost of producing 200 units is $_____.

d. To produce 300 units in the long run, a manager would use _____ units of labor and _____ units of capital. The long-run total cost of producing 300 units is $_____.

e. The firm currently operates with 15 units of capital equipment. In the figure above, construct the firm's short-run expansion path and label it "Short-run expansion path."

f. To produce 100 units in the short run, a manager would use _____ units of labor and _____ units of capital. The short-run total cost of producing 100 units is $_____, which is _____ (more than, less than, the same as) the long-run total cost of producing 100 units.

g. To produce 200 units in the short run, a manager would use _____ units of labor and _____ units of capital. The short-run total cost of producing 200 units is $_____, which is _____ (more than, less than, the same as) the long-run total cost of producing 200 units.

h. To produce 300 units in the short run, a manager would use _____ units of labor and _____ units of capital. The short-run total cost of producing 300 units is $_____, which is _____ (more than, less than, the same as) the long-run total cost of producing 300 units.

i. If the firm is producing 100 units in the short run, it can restructure its production in the long-run and reduce its costs of producing 100 units by $_____.

j. If the firm is producing 300 units in the short run, it can restructure its production in the long-run and reduce its costs of producing 300 units by $_____.

k. Only when the firm wishes to produce _____ units in the short run will the manager be unable to restructure production in the long run and reduce costs. Explain.

6. Explain carefully each of the following characteristics of an expansion path:

a. Along an expansion path, the input price ratio is constant.

b. Along an expansion path, the marginal rate of technical substitution is constant.

c. An increase in the price of one input always causes a shift in the expansion path.

d. An equiproportionate increase in the price of both labor and capital does not shift the expansion path.

7. You are a management consultant hired by the Rio Loco Vineyards to estimate the costs of raising grapes in an arid region of New Mexico. If labor costs $6,000 per man-year and capital costs $200 per unit annually, you determine that the least-cost input combinations for various levels of grape production are:

Output (bushels/year)	*Labor (man-years)*	*Capital (units/year)*
100,000	30	100
200,000	51	270
300,000	56	420
400,000	60	600
500,000	62	640
600,000	84	1,080

a. Complete the table below:

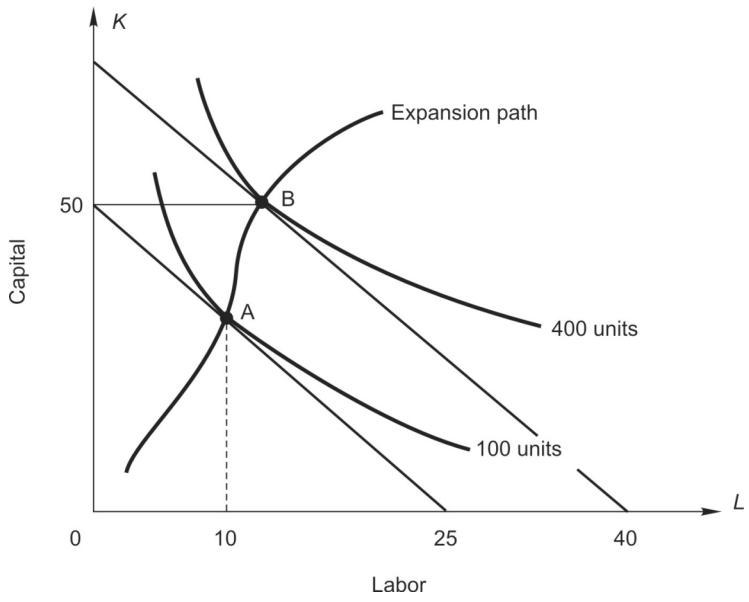
Output	*LTC*	*LAC*	*LMC*
100,000	$_____	$_____	xx
200,000	_____	_____	$_____
300,000	_____	_____	_____
400,000	_____	_____	_____
500,000	_____	_____	_____
600,000	_____	_____	_____

b. Over what range of output do economies of scale exist in the production of grapes?

c. Over what range of output do diseconomies of scale exist in the production of grapes?

Multiple Choice / True-False

For questions 1–5, consider the expansion path illustrated below. The price of capital is $2.



1. What is the price of labor?
   a. $1
   b. $2
   c. $2.50
   d. $3.00
   e. $4

2. The efficient amount of capital for producing 100 units of output is
   a. 10 units of capital.
   b. 20 units of capital.
   c. 30 units of capital.
   d. 40 units of capital.

3. The marginal rate of technical substitution at point B is _____.
   a. 0.5
   b. 0.25
   c. 1
   d. 2
   e. 4

4. The average cost of producing 400 units is
   a. $1.
   b. $0.10.
   c. $4.
   d. $0.40.
   e. $0.50.

5. The efficient amount of labor for producing 400 units of output is
   a. 5.
   b. 10.
   c. 15.
   d. 25.
   e. 50.

6. A ∪-shaped long-run average cost (*LAC*) curve represents
   a. increasing returns and diminishing returns.
   b. fixed costs and variable costs.
   c. economies and diseconomies of scale.
   d. average fixed costs and average variable costs.

7. At any output at which *ATC* is tangent to *LAC*,
   a. *LMC* = *SMC*.
   b. economies of scale must be present.
   c. long-run total cost (*LTC*) equals short-run total cost (*TC*).
   d. both *a* and *c*.
   e. all of the above.

Questions 8–11 refer to the following:

The price of labor is $20 per unit and the price of capital is $40 per unit.

	Optimal input combination				
Output	*L**	*K**	*LTC*	*LAC*	*LMC*
10	20	8	$_____	$_____	xx
20	_____	12	_____	_____	$24
30	32	_____	_____	48	_____
40	50	_____	2,040	_____	_____

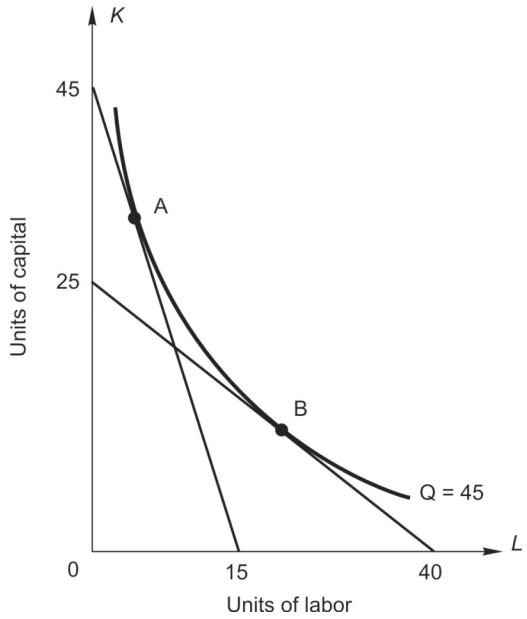
8. When output is 10 units, what is long-run average cost?
   a. $24
   b. $48
   c. $60
   d. $72

9. When output is 20 units, how many units of labor will the firm use?
   a. 22
   b. 24
   c. 30
   d. 50

10. How much does the 30th unit add to long-run total cost?
   a. $24
   b. $48
   c. $60
   d. $72

11. When output is 40 units, how many units of capital will the firm use?
   a. 22
   b. 24
   c. 26
   d. 30

The next three questions refer to the following:



12. What is the marginal rate of technical substitution at point *A?*
   a. 0.3
   b. 1
   c. 1.125
   d. 1.67
   e. none of the above

13. As you move from point *A* to point *B*,
    a. output is unchanged.
    b. cost is unchanged.
    c. the rate at which the firm can substitute labor for capital while holding output constant decreases.
    d. both *a* and *b*.
    e. both *a* and *c*.

14. If the firm continues to produce 45 units of output and moves from the combination at *A* to the combination at *B*, it must be true that
    a. the price of labor decreased relative to the price of capital.
    b. the price of capital decreased relative to the price of labor.
    c. the cost of producing 45 units decreased.
    d. both *b* and *c*.
    e. none of these are true.

15. A sofa manufacturer currently is using 50 workers and 30 machines to produce 5,000 sofas a day. The wage rate is $200 and the rental rate for a machine is $1,000. At these input levels, another worker adds 200 sofas, while another machine adds 500 sofas. If the firm uses 45 workers and 31 machines instead,
    a. then its cost will be unchanged, and its output will decrease by 500 units.
    b. then its cost will be unchanged, and its output will increase by 300 units.
    c. then its cost will be unchanged, and its output will increase by 500 units.
    d. then its output will be unchanged, and its cost will decrease by $800.
    e. none of the above.

16. T F An increase in input prices causes a downward shift in each isoquant.

17. T F When the production function exhibits constant returns to scale, doubling the usage of all inputs doubles the output.

18. T F The expansion path gives the input combinations that minimize the average cost of producing various levels of output.

19. T F The efficient input combination is the one that maximizes output and minimizes total cost.

20. T F Economies of scale occur when input prices fall as output rises.

Answers

MATCHING DEFINITIONS

1. isoquant
2. marginal rate of technical substitution
3. isocost curve
4. expansion path
5. constant returns to scale
6. increasing returns to scale
7. decreasing returns to scale
8. long-run average cost
9. long-run marginal cost
10. economies of scale
11. diseconomies of scale
12. constant costs
13. economies of scope
14. short-run expansion path

STUDY PROBLEMS

1. a. $1 \left(= -\frac{20-40}{60-40}\right)$, which is the slope over the interval from A to C.

   b. $0.33 \left(= -\frac{10-20}{90-60}\right)$, which is the slope over the interval from C to B.

   c. $0.5 \left(= -\frac{-50}{100}\right)$, which is the slope of the tangent line at point C.

2. a. 15,000; 150. The K-intercept is 150, so the isocost curve represents a cost of \$15,000 (= 150×\$100). The L-intercept is 100, to w = \$150 (= 15,000/100).

   b. $K = 150 - 1.5L$ (or $K = 150 - (150/100)L$ or $15{,}000 = 150L + 100K$); 1.5

   c. 15,000; \$75. The price of labor decreases and causes an outward rotation of the isocost curve.

   d. $K = 150 - 0.75L$ (or $K = 150 - (150/200)L$ or $15{,}000 = 75L + 100K$); 0.75

3. a. less than; \$20,000 (= \$50 × 400)

   b. decreases; increases; less than; decreased; \$2,500 [= (400–350) × \$50]. [Note: For the last part of this answer, you must decide visually that the isocost curve passing through point B intersects the L or K-intercepts at 350. Do not panic, your instructor knows this.]

   c. minimizes; equal

   d. 100; 200; \$15,000 (= 300 × \$50)

   e. capital; labor; \$20,000

   f. labor; capital; decreased; \$2,500 (see answer to part *b* above)

   g. equal to

   h. \$12,500 (= 250 × \$50); this combination lies below the 2,000 unit isoquant and so 2,000 units cannot be produced with combination C.

4. a. By purchasing one pottery machine, which would increase output by 300 units, 15 laborers could be fired and output would remain exactly equal to 1,200 units per day. This reduces the cost of labor by 15 × \$100 = \$1,500. The cost of capital increases by \$2,000. Clearly, substituting the machine for an equally productive amount of

labor (i.e., the 15 workers) increases the total cost of producing 1,200 clay pots per day.

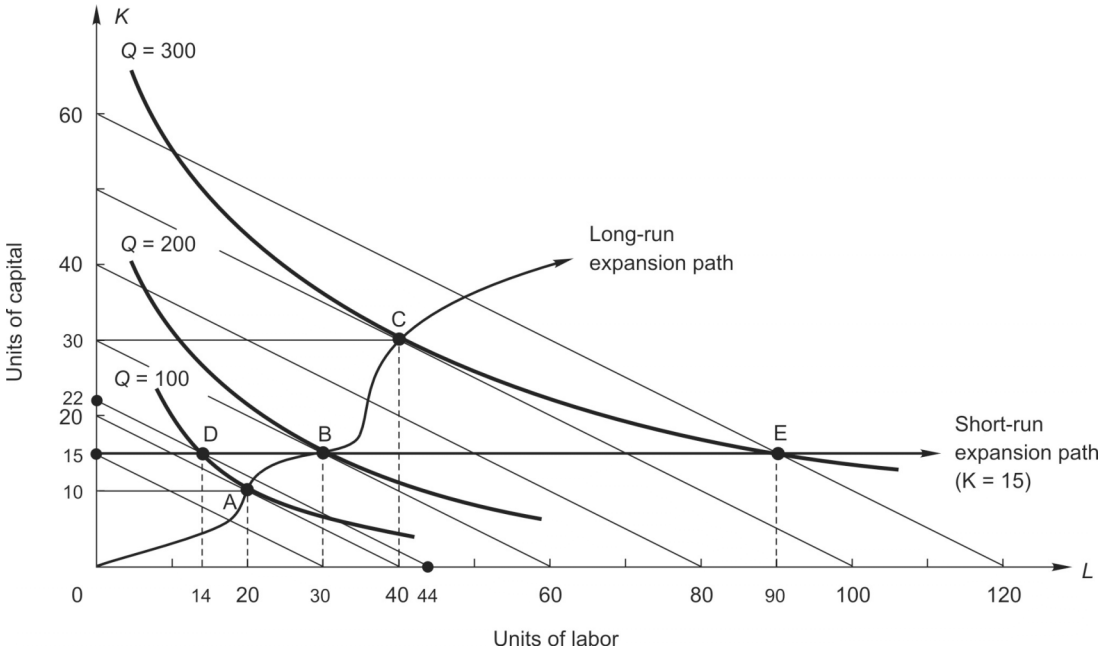
b. Yes, at \$150 per worker, the reduction in wage expense is now $15 \times 150 = \$2{,}250$, which is more than the cost of the machine (\$2,000 per day). Thus, the higher wages make buying a machine efficient.

c. $MP_L/w = 20/100 = 0.2$ additional pots per additional dollar spent on labor

$MP_K/r = 300/2{,}000 = 0.15$ additional pots per extra dollar spent on capital

Since each additional dollar spent on labor increases output by more than an additional dollar spent on capital, it is less costly to expand output by hiring more labor than by buying pottery machines.

5. a. The price of capital is \$150. You can discover this by noting in the figure that the slope of the isocost curves is ½. Since the slope of isocost curves equals w/r and you are told that $r = \$150$, you can see that $75/r = ½$ and thus $r = 150$. At every tangency point along the (long-run) expansion path, the slope of the isoquant equals the slope of the isocost line. Since the isocost lines are always parallel, their slopes are constant along the expansion path and equal to *MRTS*, which must be ½ in this case.



b. 20; 10; \$3,000. At point *A* in the figure above, you can see that the tangency occurs at 20 units of labor and 10 units of capital, which costs \$3,000 ($= \$150 \times 20$ or $\$75 \times 20 + 150 \times 10$).

c. 30; 15; \$4,500. At point *B* in the figure above, you can see that the tangency occurs at 30 units of labor and 15 units of capital, which costs \$4,500 ($= \$150 \times 30$ or $\$75 \times 30 + 150 \times 15$).

d. 40; 30; \$7,500. At point *C* in the figure above, you can see that the tangency occurs at 40 units of labor and 30 units of capital, which costs \$7,500 ($= \$150 \times 50$ or $\$75 \times 40 + 150 \times 30$).

e. The short-run expansion path is a horizontal line at 15 units of capital, which is designated in the figure above as "Short-run expansion path."

f. 14; 15; \$3,300; more than. At point *D* in the figure above, you can see that the 100-

unit isoquant is reached with 15 units of capital by employing 14 units of labor at a cost of \$3,300 (= \$150 × 22 or \$75 × 14 + 150 × 15), which is more than the long-run cost of \$3,000.

g. 30; 15; \$4,500; the same as. At point *B* in the figure above, you can see that the 200-unit isoquant is reached with 15 units of capital by employing 30 units of labor, which costs \$4,500 (= \$150 × 30 or \$75 × 30 + 150 × 15), which is the same as the long-run cost of \$4,500.

h. 90; 15; \$9,000; more than. At point *E* in the figure, you can see that the 300-unit isoquant is reached with 15 units of capital by employing 90 units of labor at a cost of \$9,000 (= \$150 × 60 or \$75 × 90 + \$150 × 15), which is more than the long-run cost of \$7,500.

i. \$300; This is the difference between the short-run and long-run total costs of producing 100 units (= \$3,300 – \$3,000).

j. \$1,500; This is the difference between the short-run and long-run total costs of producing 300 units (= \$9,000 – \$7,500).

k. 200; When 200 units are produced in the short-run, the fixed amount of capital (15 units) happens also to be the long-run optimal level of capital, so the costs are equal in the long-run and short-run for 200 units of output.

6. a. An expansion path is derived for a given set of input prices. Thus the input price ratio is constant for every point on an expansion path.

b. The expansion path is a locus of efficient input combinations for each level of output. The efficient input combinations satisfy the condition that *MRTS* = the input price ratio. Since the input price ratio is constant for all *Q* along an expansion path, then *MRTS* must also be constant.

c. An increase in one input price must alter the input price ratio. Thus a different set of input combinations becomes efficient at every level of output, and the expansion path shifts.

d. An equiproportional increase (or decrease) in input prices leaves the input price ratio unchanged. The same capital-labor combination is efficient for every output level.

7. a. Your table should look like this:

Q	*LTC*	*LAC*	*LMC*
100,000	\$200,000	\$2.00	xx
200,000	360,000	1.80	\$1.60
300,000	420,000	1.40	0.60
400,000	480,000	1.20	0.60
500,000	500,000	1.00	0.20
600,000	720,000	1.20	2.20

b. Economies of scale occur over the output range 100,000 to 500,000 bushels/year.

c. Diseconomies of scale set in at outputs greater than 500,000 bushels/year.

MULTIPLE CHOICE / TRUE-FALSE

1. e From the figure, the isocost curves can be seen to have a slope of 2. Since r is given to be \$2, $w/2 = 2 \Rightarrow w = \$4$.

2. c Input combination A costs \$100 (= \$4 × 25 or \$2 × 50). Since input combination A has 10 units of labor, which cost \$40 to buy, \$60 remains to be spent on capital. Thus, 30 (= \$60/\$2) units of capital are used to produce 100 units of output.

3. d At every point on the expansion path, *MRTS* = the slope of the isocost curve. Since the isocost curves have a slope equal to 2, *MRTS* must also equal 2.

4. d Total cost of 400 units is \$160 (= \$4 × 40), so average cost is \$160/400 = \$0.40.

5. c \$100 is being spent on 50 units of capital, leaving \$60 to purchase labor. Since w = \$4, 15 units of labor can be purchased (input bundle B).

6. c When *LAC* falls, economies of scale exist. If *LAC* rises, diseconomies of scale exist.

7. d When *ATC* = *LAC* at a given Q, *LTC* must equal *TC*. It is also true that *LMC* = *SMC* at the point of tangency between *LAC* and *ATC*.

8. d LAC_{10} = \$720/10 = \$72

9. b Since *MC* = 24 for each of the ten extra units (10 units to 20 units), total cost must rise by \$240 (= \$24 × 10). Thus $TC_{Q=20}$ must equal $TC_{Q=20}$ + \$240 or \$720 + \$240 = \$960. Once 12 units of capital are purchased by the firm, \$480 of the \$960 has been spent on capital, leaving \$480 to spend on labor. Thus the amount of labor is \$480/\$20 = 24 units of labor.

10. b $LMC = \Delta LTC / \Delta Q = (1,440 - 960)/(30 - 20) = \$48$. Each of the units in the interval 20 – 30 cost (on average) an additional \$48 to produce. Thus, the 30th unit adds \$48 to total cost.

11. c 50 units of labor and 26 units of capital cost \$2,040.

12. e *MRTS* at point A = 45/15 = 3.

13. e Moving from point A to B leaves output unchanged and decreases *MRTS*.

14. a To induce managers to move from A to B, labor must become cheaper relative to capital. Note that the slope of the isocost curve (= w/r) is smaller at B than at A.

15. a 45 workers and 31 machines cost the same as 50 workers and 30 machines. Even though cost is the same, output falls since MP_L/w exceeds MP_K/r.

16. F Isoquants do not shift with changes in input prices. Isocost curves do rotate if the relative input price ratio changes, and isocost curves shift parallel if cost changes.

17. T With constant returns to scale, $c = z$, and a doubling of inputs leads to an equiproportionate change in output (a doubling in this case).

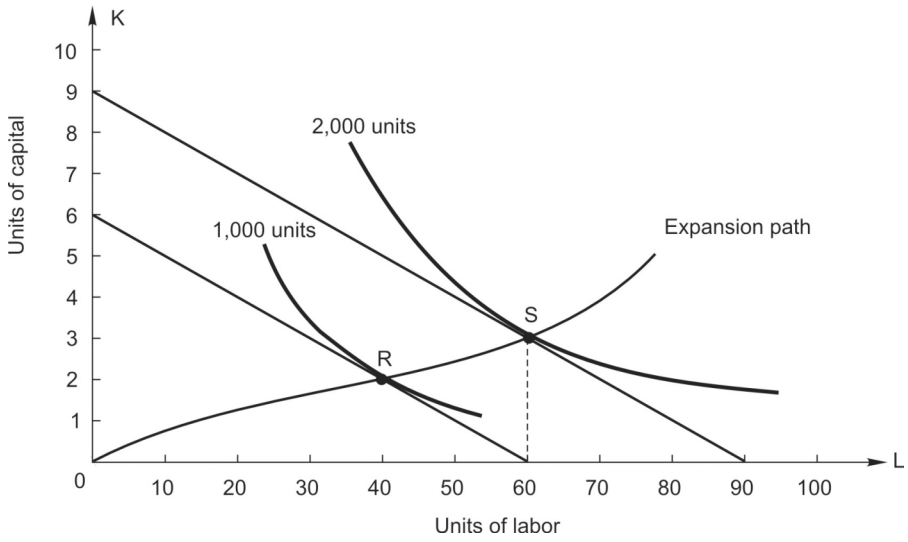
18. F The expansion path is the locus of input combinations that minimize total (not average) cost.

19. F This statement is meaningless. The manager can either minimize total cost for a given output or maximize output for a given total cost.

20. F Input prices are assumed to be constant along the *LAC* curve.

Homework Exercises

1. Answer the following questions using the expansion path illustrated below. The price of labor is \$4 per unit.



a. The price of capital is \$_____.

b. In the long run, 1,000 units of output is produced at the lowest possible total cost by employing _____ units of labor.

c. The marginal rate of technical substitution at point *S* is _____.

d. When producing 2,000 units in the long run, the marginal product of the 60th unit of labor (MP_L) is 5. The marginal product of capital (MP_K) must equal _____.

e. The equation of the isocost curve passing through point *R* is

$K =$ _____

f. In the long run, 2,000 units of output is produced at the lowest possible total cost by employing _____ units of capital.

g. Is input combination *R* technically efficient? Explain.

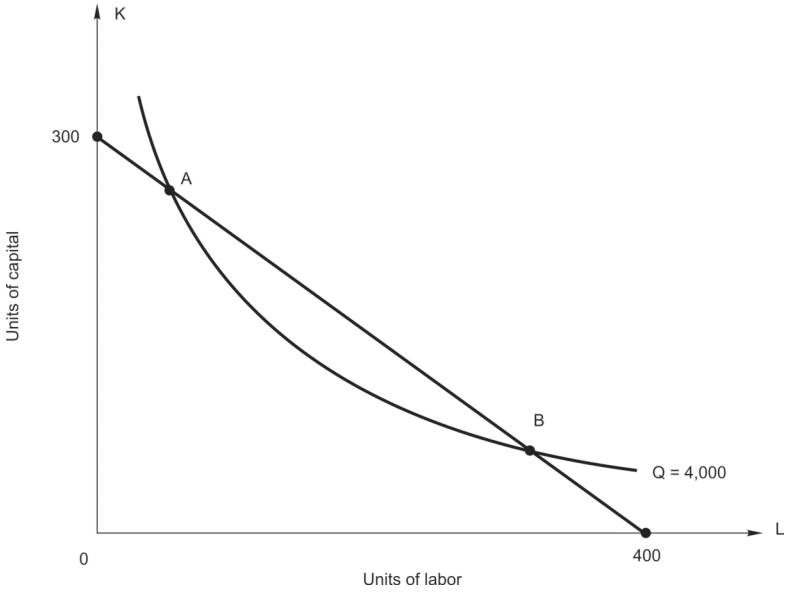
h. Is input combination *R* economically efficient? Explain.

i. Over the range of output from 1,000 units to 2,000 units, does the firm experience economies or diseconomies of scale? Explain.

j. Construct the short-run expansion path when capital is fixed at 2 units.

k. In the short run with capital fixed at 2 units, 2,000 units can be produced by employing _____ units of labor. The short-run total cost of producing 2,000 units is $_____. By restructuring its costs in the long run, the firm can _____ (reduce, increase) its total cost of producing 2,000 by $_____.

2. The following graph shows one of a firm's isocost curves and isoquants:



a. Combination *A* is not an economically efficient method of producing 4,000 units of output because, at *A*, _____ exceeds _____ or in other words, _____ exceeds _____. The firm should increase _____ and decrease _____.

b. Combination *B* is not an economically efficient method of producing 4,000 units of output because, at *B*, _____ exceeds _____, or in other words, _____ exceeds _____. The firm should increase _____ and decrease _____.

c. At the economically efficient method of producing 4,000 units of output the *MRTS* will equal _____.