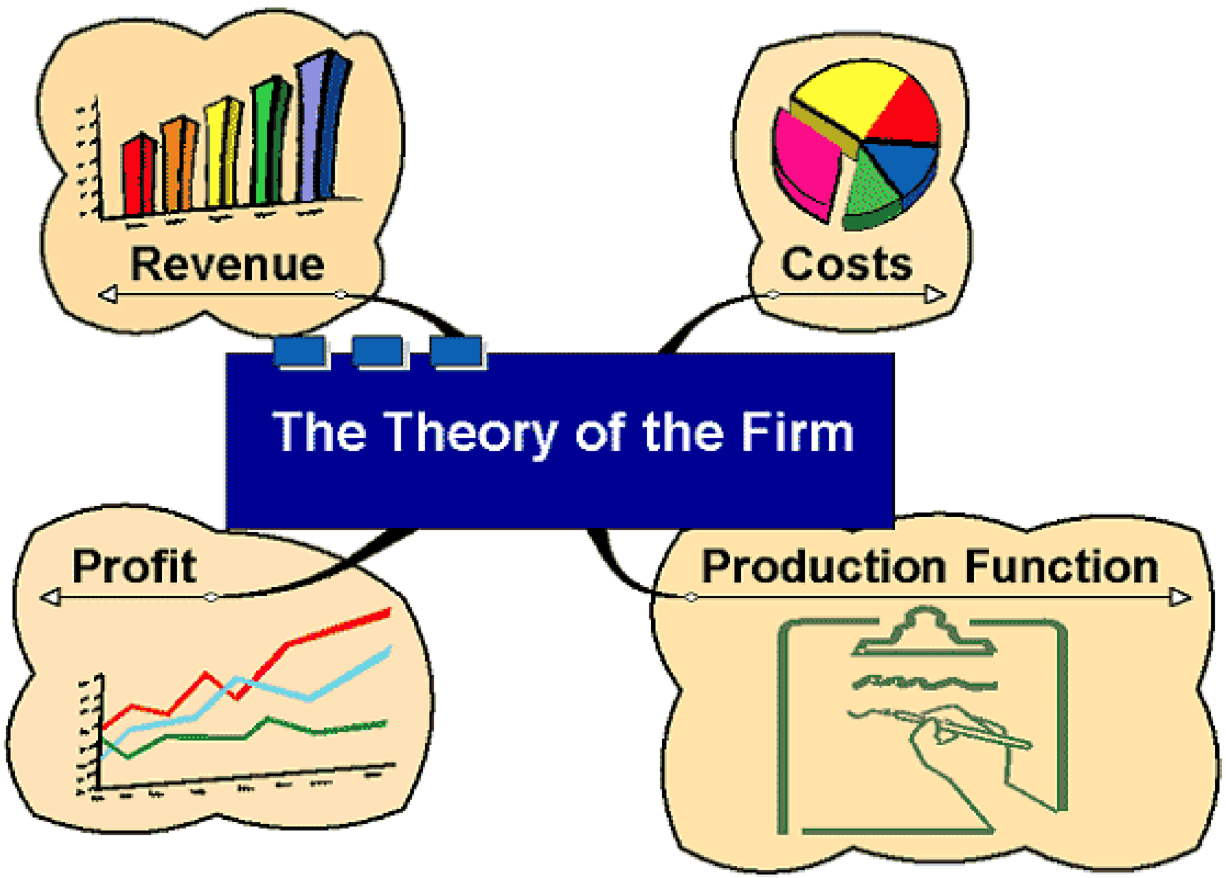
The Theory of the Firm



Production and Costs in the short run

Production and Costs in the short run

- Q= F(K,L)
- Total product (TP), Average product (AP), and Marginal product (MP)
- Law of diminishing marginal returns
- TC, FC, VC
- AC, AFC, AVC
- MC

The short run production function

- Q = F(K,L)
- Where Q is amount of output, K is amount of capital, and L is amount of labor

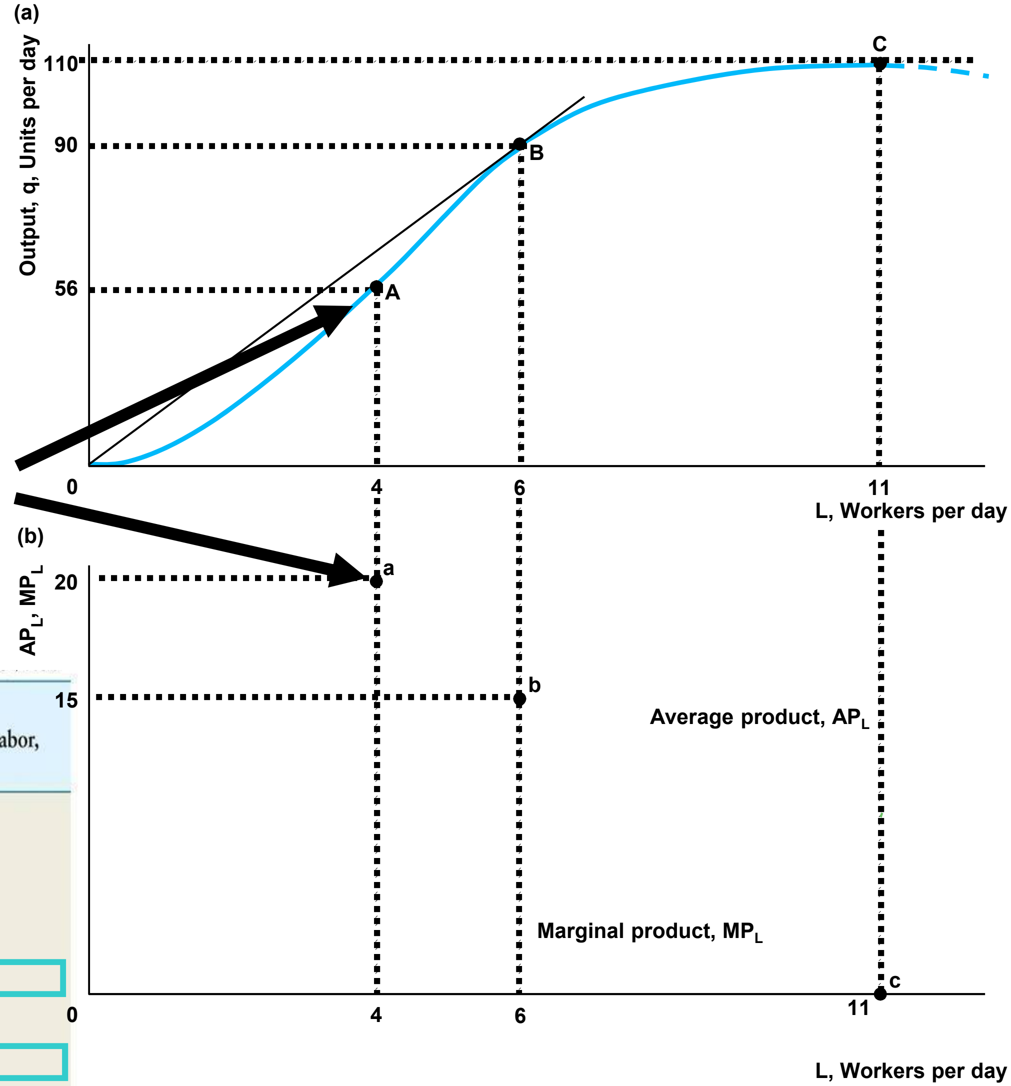
Total product (TP), Average product (AP), and Marginal product (MP) -Table

Capital, $\bar{K}$	Labor, L	Output, Total Product of Labor, Q	Marginal Product of Labor, $MP_L = \Delta Q/\Delta L$	Average Product of Labor, $AP_L = Q/L$
8	0	0		
8	1	5	5	5
8	2	18	13	9
8	3	36	18	12
8	4	56	20	14
8	5	75	19	15
8	6	90	15	15
8	7	98	8	14
8	8	104	6	13
8	9	108	4	12
8	10	110	2	11
8	11	110	0	10
8	12	108	–2	9
8	13	104	–4	8

Production Relationships with Variable Labor

Diminishing Marginal Returns sets in!

Capital, $\bar{K}$	Labor, L	Output, Total Product of Labor, Q	Marginal Product of Labor, $MP_L = \Delta Q/\Delta L$	Average Product of Labor, $AP_L = Q/L$
8	0	0		
8	1	5	5	5
8	2	18	13	9
8	3	36	18	12
8	4	56	20	14
8	5	75	19	15
8	6	90	15	15
8	7	98	8	14
8	8	104	6	13
8	9	108	4	12
8	10	110	2	11
8	11	110	0	10



Law of diminishing marginal product

- As more of the variable input is used with a fixed input, the marginal product first increases, reaches a maximum, then diminishes and even becomes negative.

AP & MP Relationship

Costs in the short run

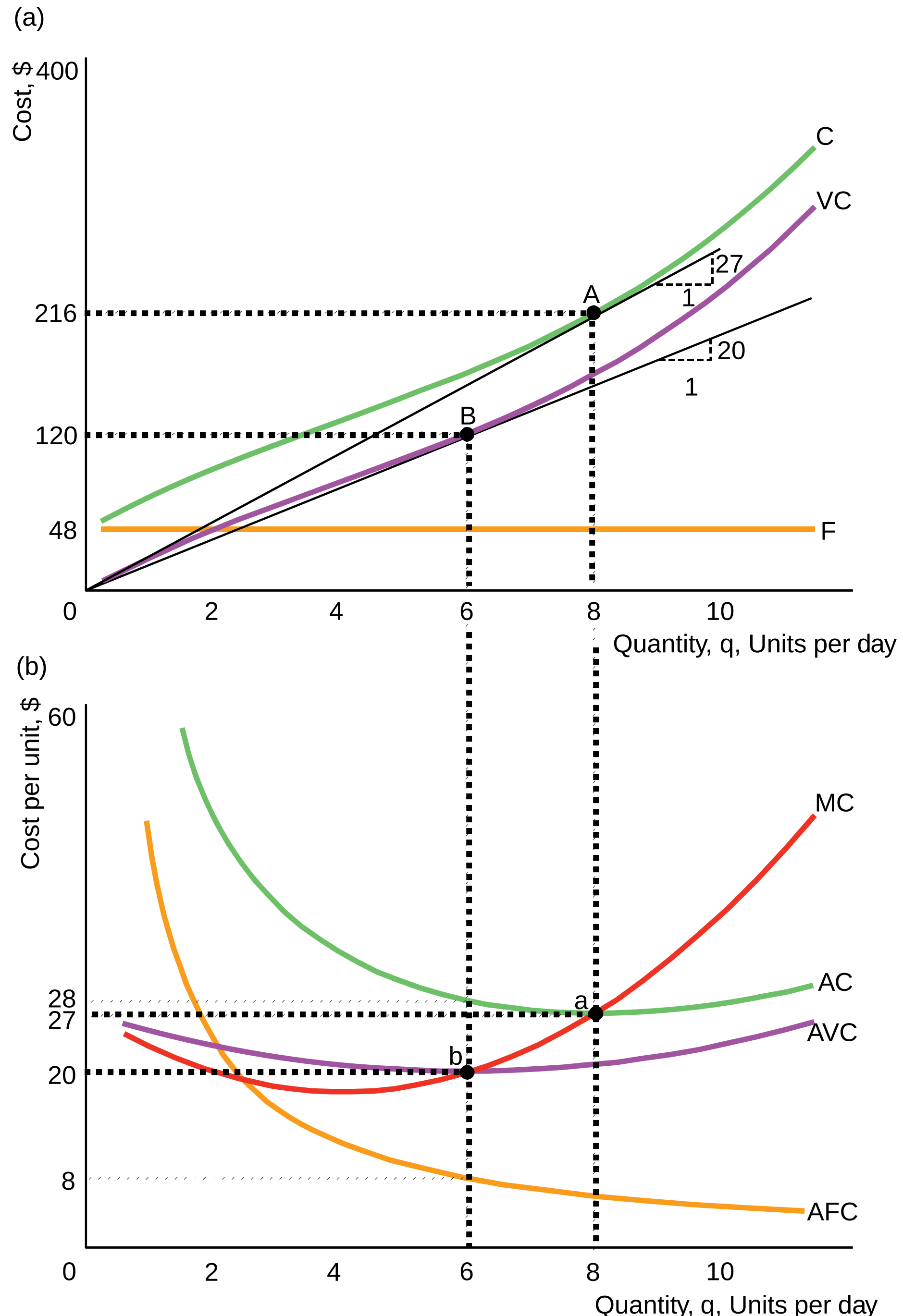
- Total Cost (TC) = Total Fixed Cost (FC) + Total Variable cost (VC)
  - **Fixed costs** – costs that are not related directly to production – rent, rates, insurance costs, admin costs. They can change but not in relation to output.
  - **Variable Costs** – costs directly related to variations in output. Raw materials primarily.

- **Total Cost** - the sum of all costs incurred in production
    - **TC = FC + VC**
- **Average Cost** – the cost per unit of output
    - **AC = TC/Output**
- **Marginal Cost** – the cost of one more or one fewer units of production
    - **$MC = TC_n – TC_{n-1}$ units**

Output, q	Fixed Cost, F	Variable Cost, VC	Total Cost, C	Marginal Cost, MC	Average Fixed Cost, $AFC = F/q$	Average Variable Cost, $AVC = VC/q$	Average Cost, $AC = C/q$
0	48	0	48				
1	48	25	73	25	48	25	73
2	48	46	94	21	24	23	47
3	48	66	114	20	16	22	38
4	48	82	130	16	12	20.5	32.5
5	48	100	148	18	9.6	20	29.6
6	48	120	168	**20**	8	**20**	28
7	48	141	189	21	6.9	20.1	27
8	48	168	216	**27**	6	21	**27**
9	48	198	246	30	5.3	22	27.3
10	48	230	278	32	4.8	23	27.8
11	48	272	320	42	4.4	24.7	29.1
12	48	321	369	49	4.0	26.8	30.8

Short-Run Cost Curves

Output, q	Fixed Cost, F	Variable Cost, VC	Total Cost, C
0	48	0	48
1	48	25	73
2	48	46	94
3	48	66	114
4	48	82	130
5	48	100	148
6	48	120	168
7	48	141	189
8	48	168	216
9	48	198	246
10	48	230	278
11	48	272	320
12	48	321	369



Costs and Production

- **AVC & AP Relationship**

  AVC = w*L/Q

or AVC = w/(Q/L) = w/AP_L

- **MC & MP Relationship**

$$MC = \frac{\Delta VC}{\Delta Q} = \frac{w \bullet \Delta L}{\Delta L \bullet MP_L} = \frac{w}{MP_L}$$

Production and Costs in the long run

Production and costs in the long run

- Isoquant and MTRS
- Isocost
- Least cost combination
- Elasticity of Substitution
- Returns to scale
- Economies of scale
- Homogenous degree one

Isoquants

- **Isoquant -** a curve that shows the efficient combinations of labor and capital that can produce a single (*iso*) level of output (*quant*ity).
- Equation for an Isoquant:

$$\bar{q} = f(L, K).$$

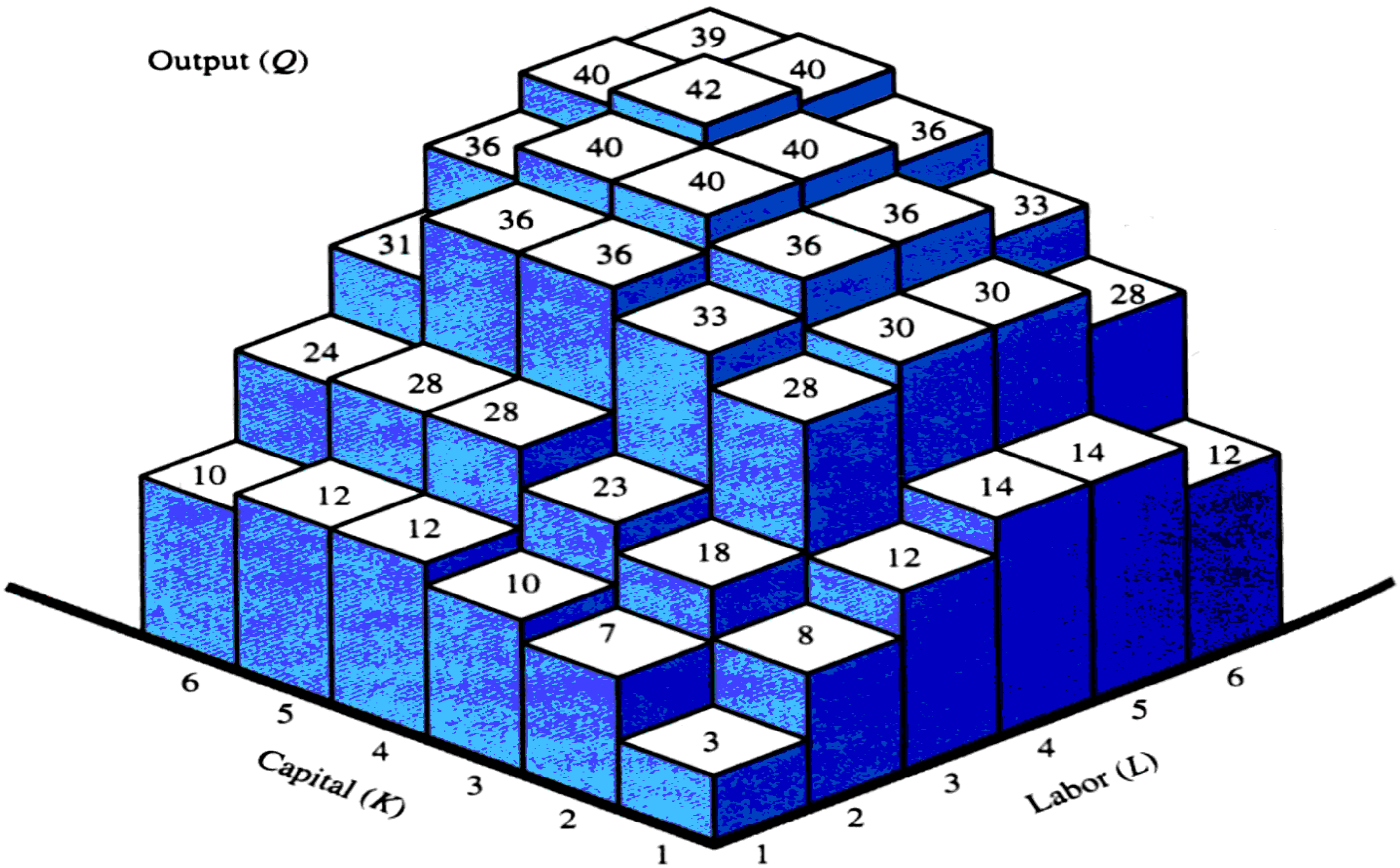
Production Function With Two Inputs

$$Q = f(L, K)$$

K							Q
6	10	24	31	36	40	39	
5	12	28	36	40	42	40	
4	12	28	36	40	40	36	
3	10	23	33	36	36	33	
2	7	18	28	30	30	28	
1	3	8	12	14	14	12	
	1	2	3	4	5	6	L

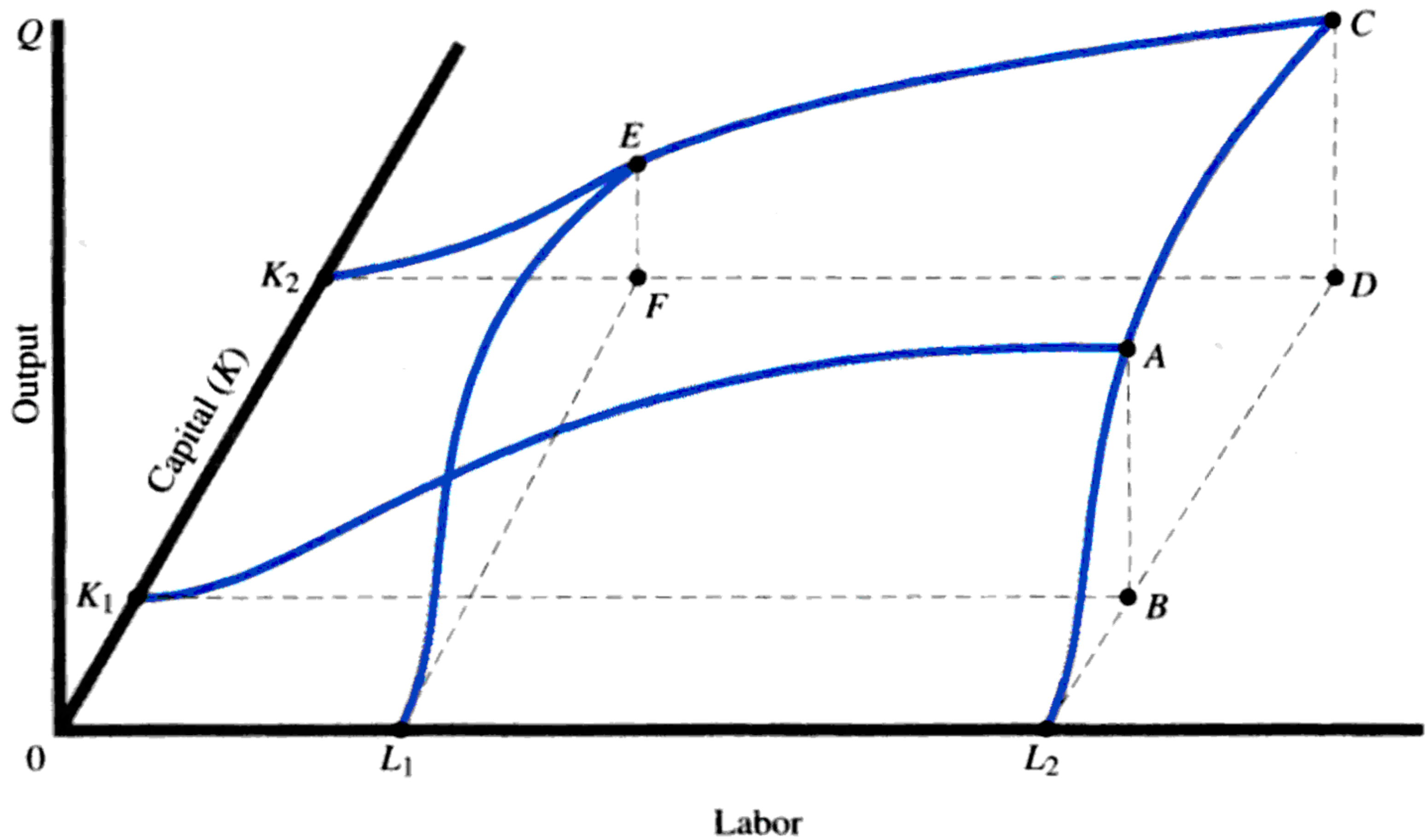
Production Function With Two Inputs

Discrete Production Surface



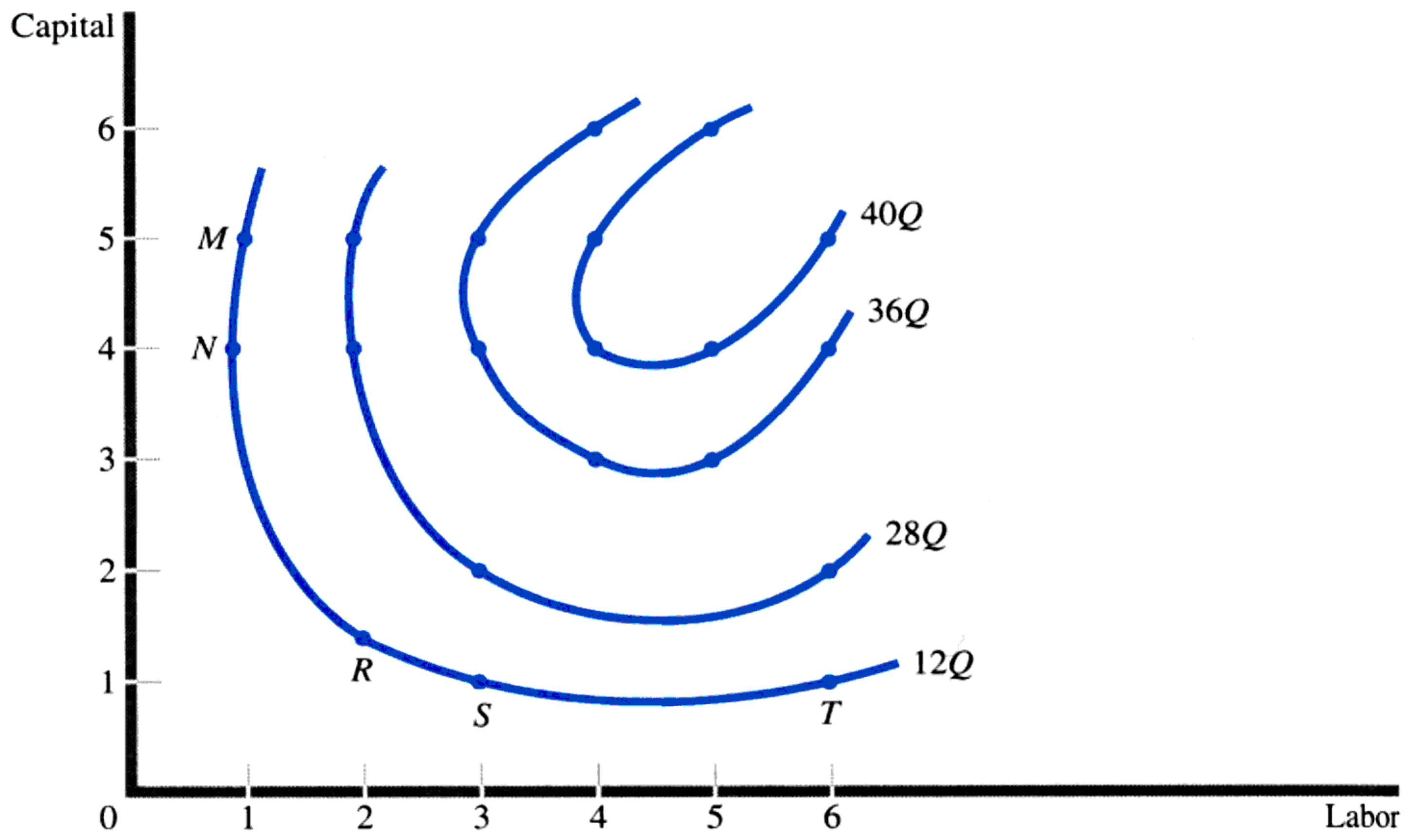
Production Function With Two Inputs

Continuous Production Surface



Production With Two Variable Inputs

Isoquants

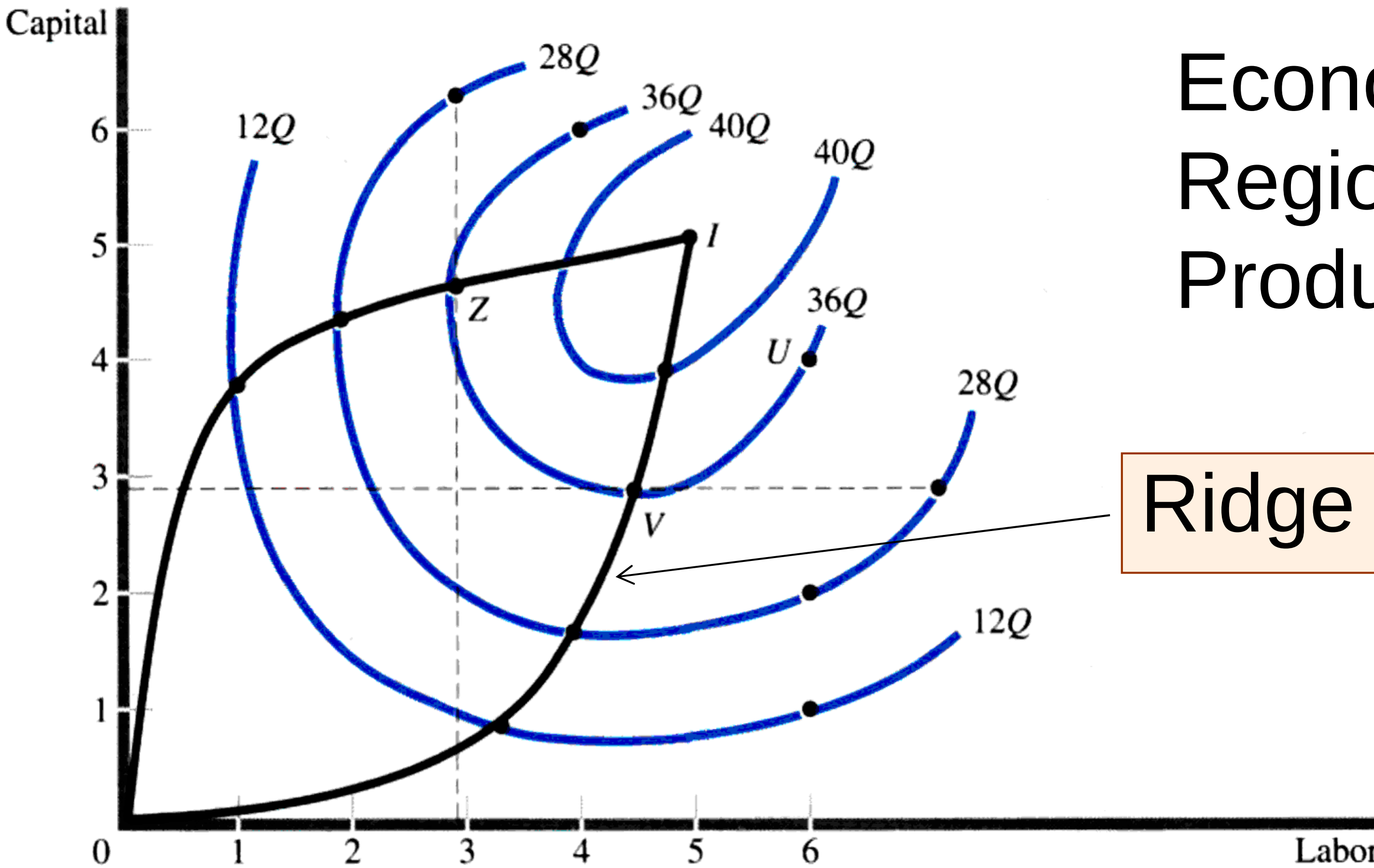


Production With Two Variable Inputs

Isoquants show combinations of two inputs that can produce the same level of output.

Firms will only use combinations of two inputs that are in the economic region of production, which is defined by the portion of each isoquant that is negatively sloped.

Production With Two Variable Inputs



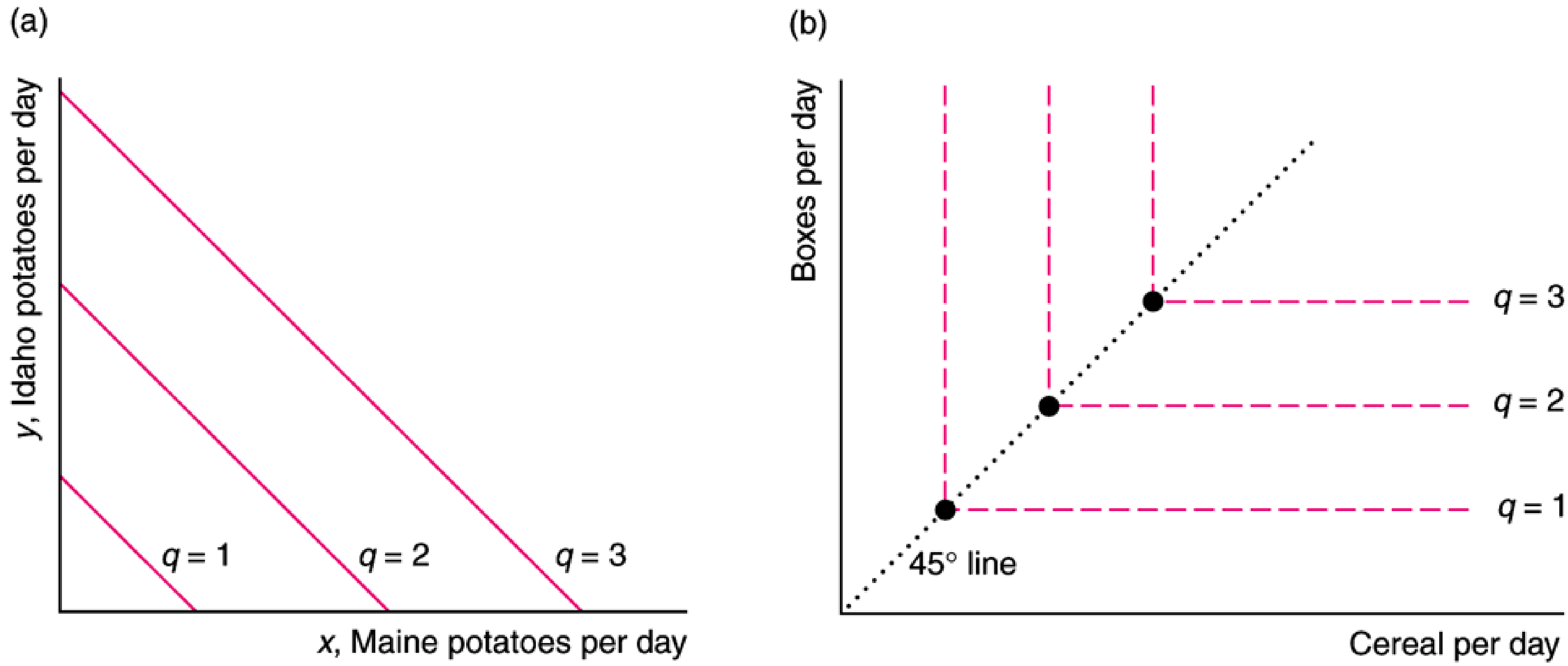
Economic Region of Production

Ridge line

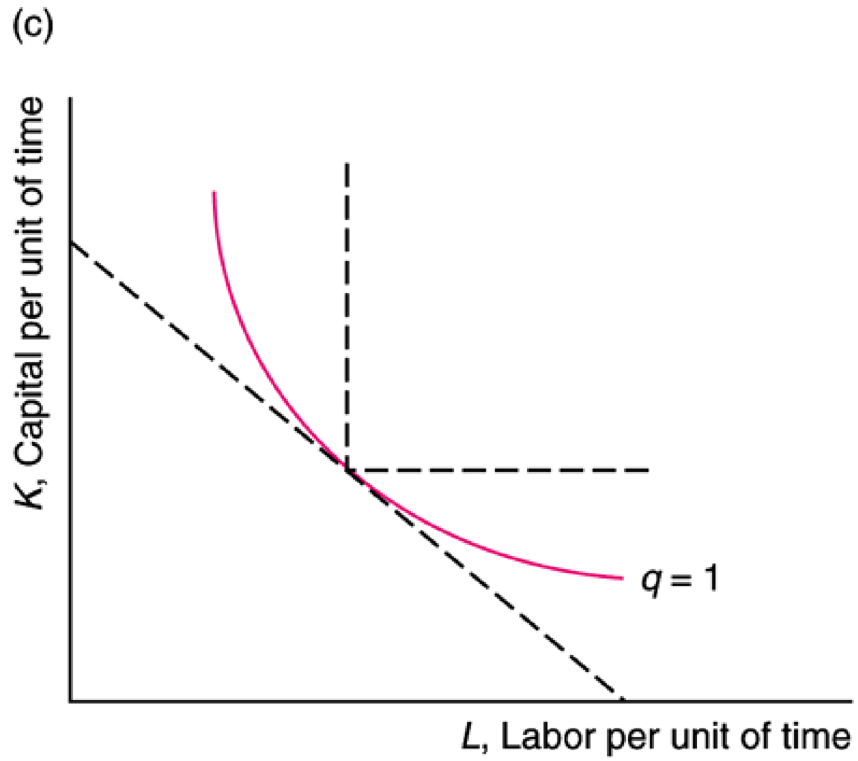
Properties of Isoquants.

1. *The farther an isoquant is from the origin, the greater the level of output*.
2. *Isoquants do not cross.*
3. *Isoquants slope downward*

Substitutability of Inputs

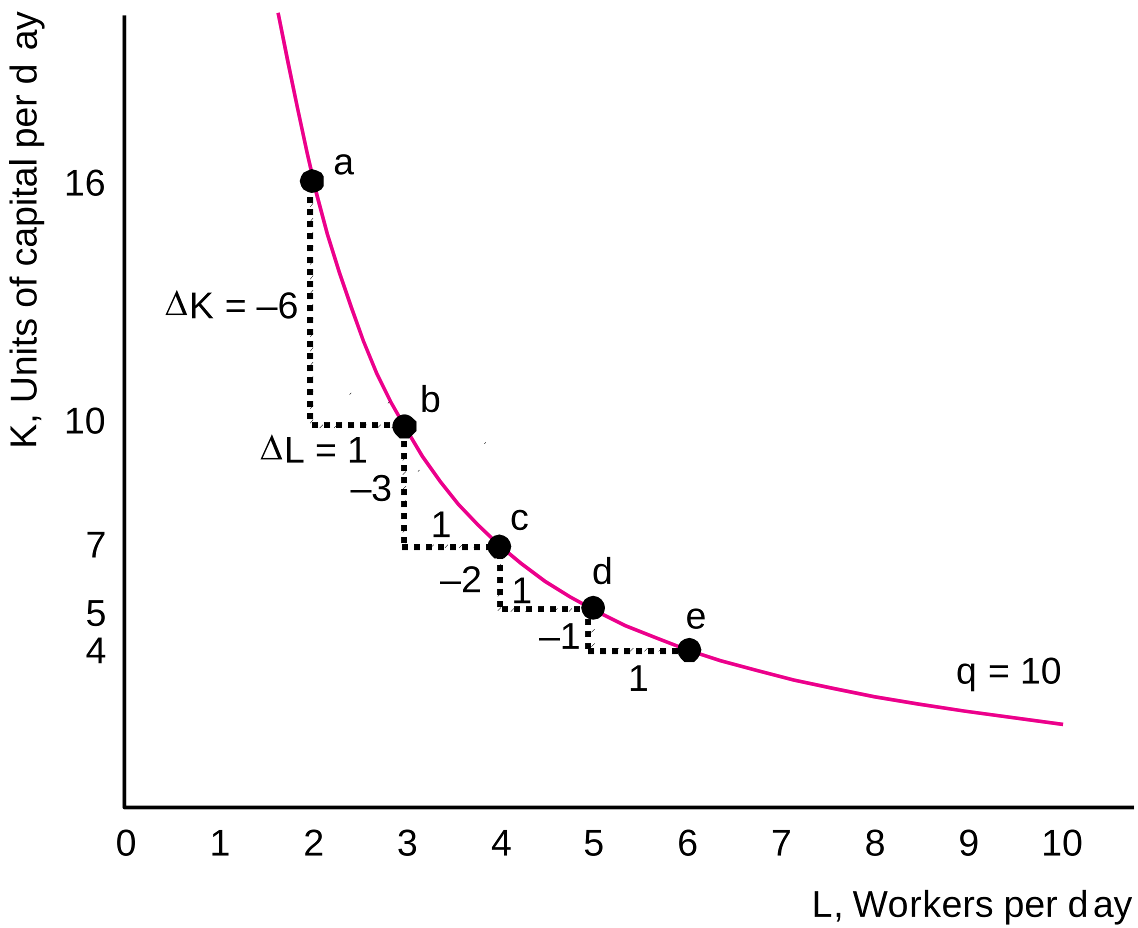


Substitutability of Inputs



How the Marginal Rate of Technical Substitution Varies Along an Isoquant

MRTS in a Printing and Pu blishing U.S. Firm



Returns to Scale

- **Constant returns to scale (*CRS*) -** property of a production function whereby when all inputs are increased by a certain percentage, output increases by that same percentage.

$$f(2L, 2K) = 2f(L, K).$$

Returns to Scale (cont).

- **Increasing returns to scale (*IRS*) -** property of a production function whereby output rises more than in proportion to an equal increase in all inputs

$$f(2L, 2K) > 2f(L, K).$$

Returns to Scale (cont).

- **Decreasing returns to scale (*DRS*) -** property of a production function whereby output increases less than in proportion to an equal percentage increase in all inputs

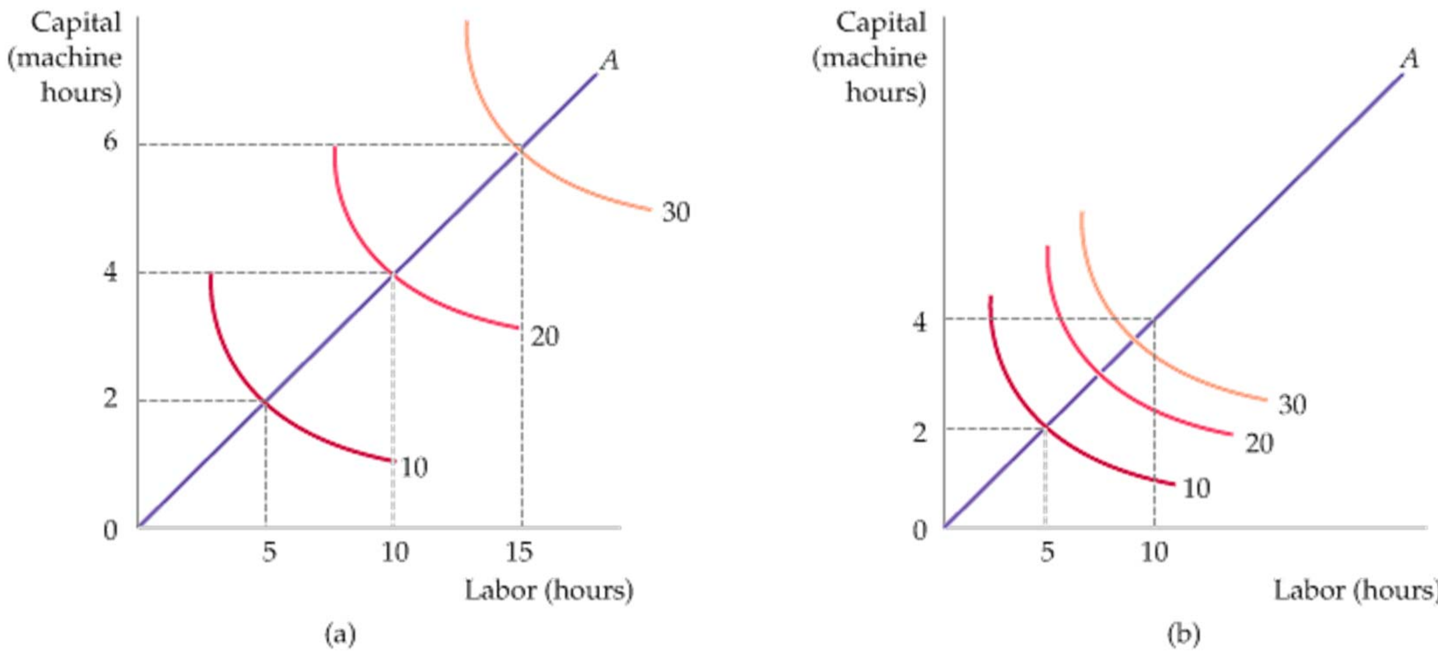
$$f(2L, 2K) < 2f(L, K).$$

RETURNS TO SCALE

- Describing Returns to Scale

Figure 6.9

Returns to Scale



When a firm's production process exhibits constant returns to scale as shown by a movement along line 0*A* in part (a), the isoquants are equally spaced as output increases proportionally.

However, when there are increasing returns to scale as shown in (b), the isoquants move closer together as inputs are increased along the line.

The Cobb-Douglas Production Function

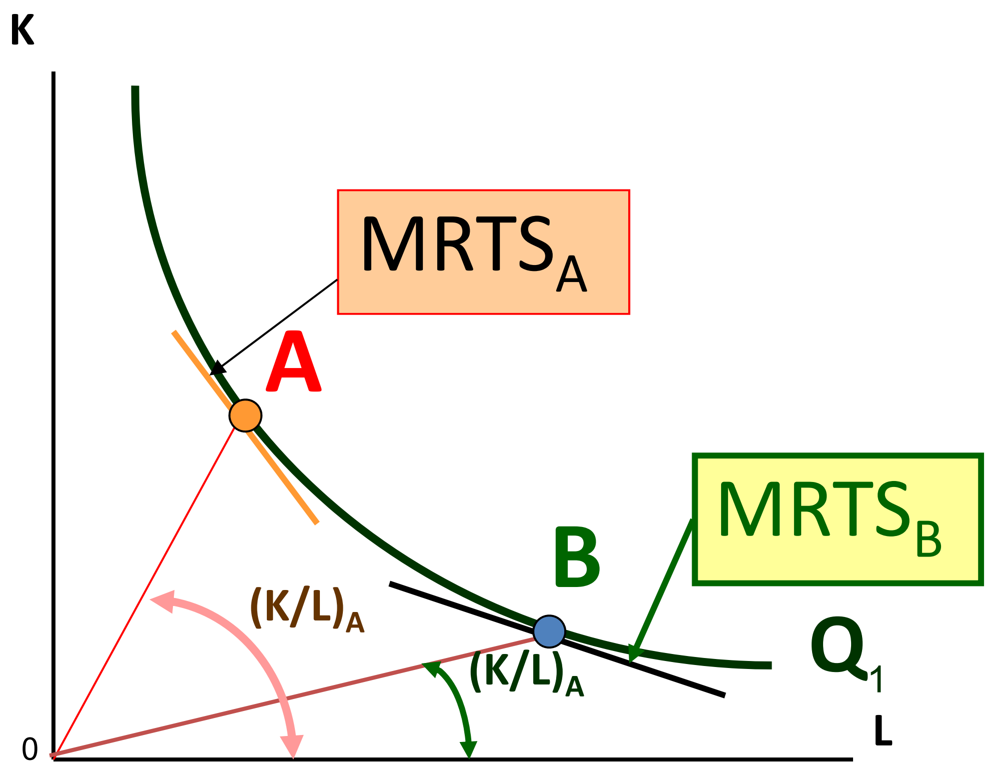
- It one is the most popular estimated functions.

$$q = AL^{\alpha}K^{\beta}$$

Elasticity of Substitution

$$\text{Elasticity of Substitution } (\sigma) = \frac{\text{percent}\,\Delta(K/L)}{\text{percent}\,\Delta MRTS}$$

$$= \frac{d(K/L)}{dMRTS} \bullet \frac{MRTS}{K/L}$$



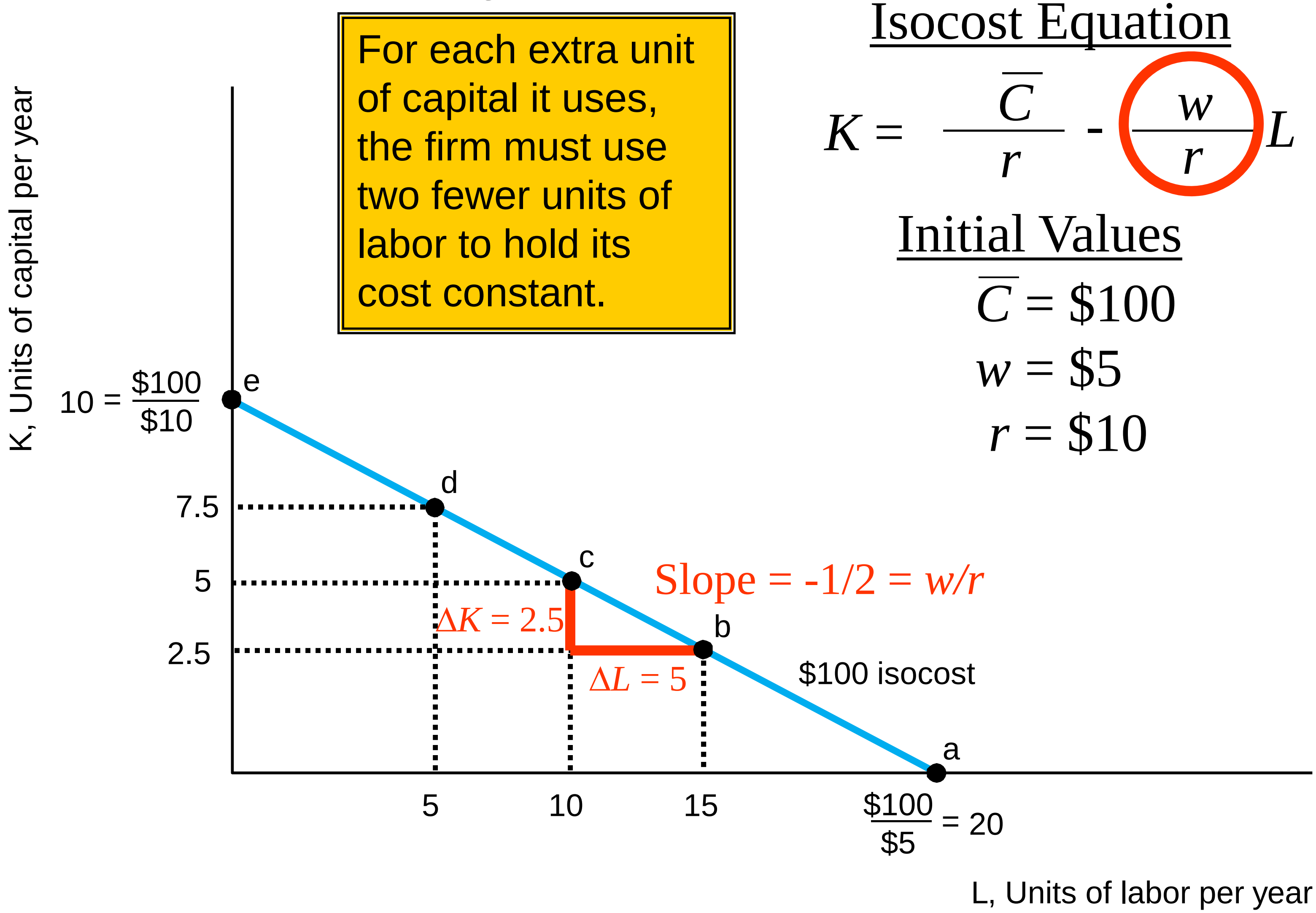
Elasticity of Substitution

$(\sigma = \infty)$ $(\infty \succ \sigma \succ 0)$ $(\sigma = 0)$

Bundles of Labor and Capital That Cost the Firm $100

Bundle	Labor, L	Capital, K	Labor Cost, $wL = \$5L$	Capital Cost, $rK = \$10K$	Total Cost, $wL + rK$
a	20	0	$100	$0	$100
b	14	3	$70	$30	$100
c	10	5	$50	$50	$100
d	6	7	$30	$70	$100
e	0	10	$0	$100	$100

A Family of Isocost Lines



Isocost Equation

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

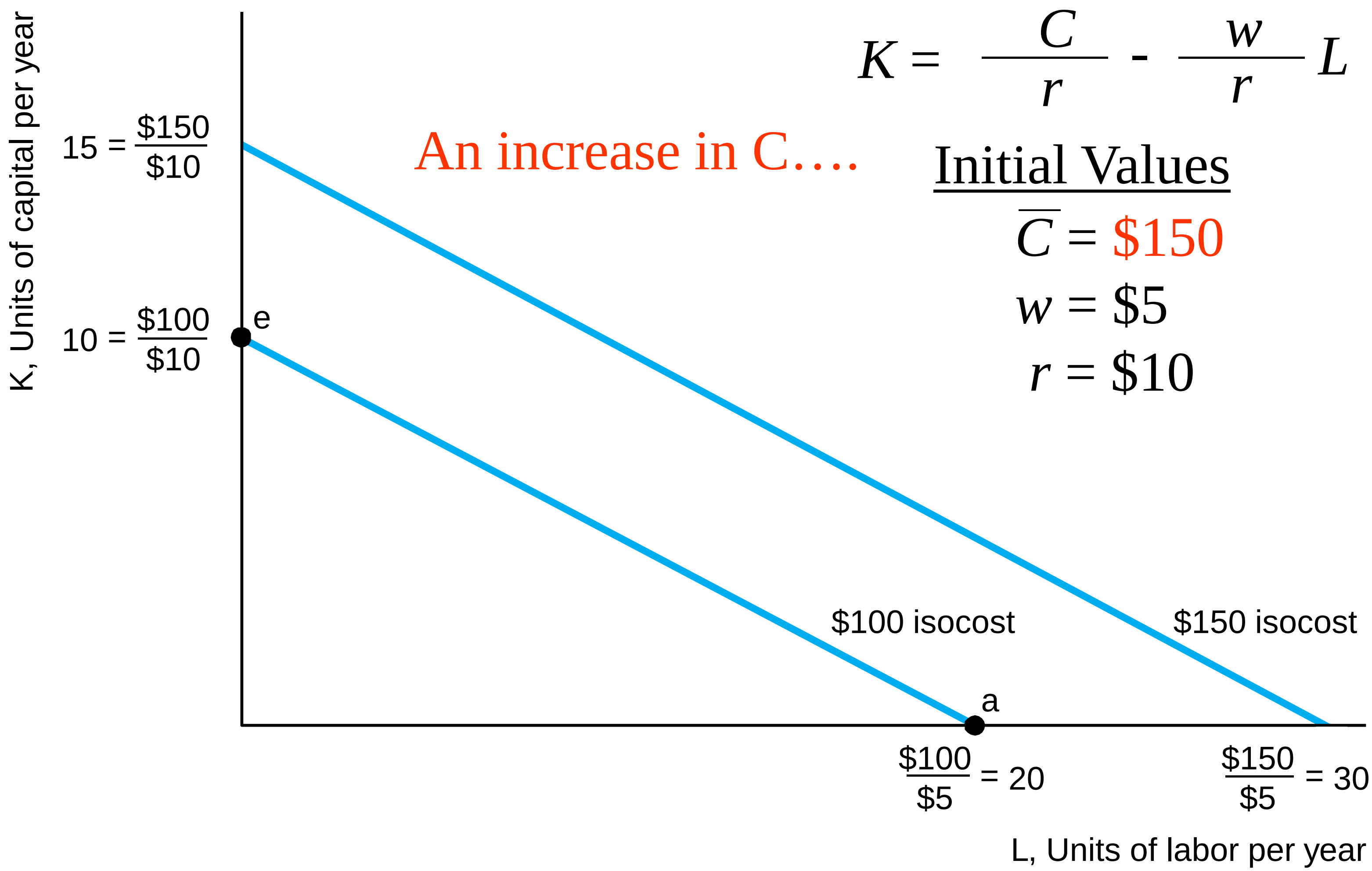
Initial Values

$\bar{C} = \$100$

$w = \$5$

$r = \$10$

A Family of Isocost Lines



Isocost Equation

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

Initial Values

$\bar{C}$ = $150

w = $5

r = $10

A Family of Isocost Lines

<u>Isocost Equation</u>

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

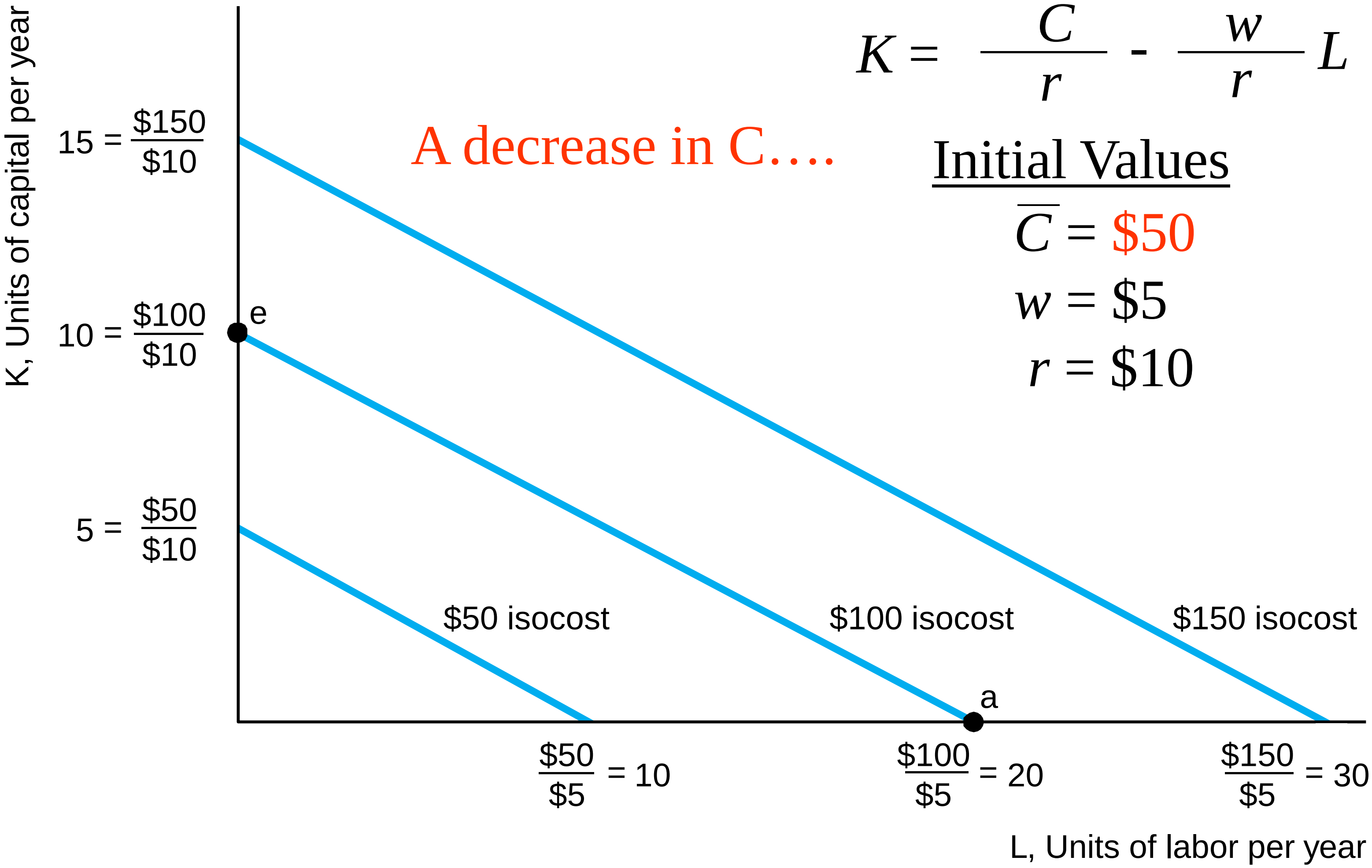
<u>Initial Values</u>

$\bar{C}$ = $50

w = $5

r = $10

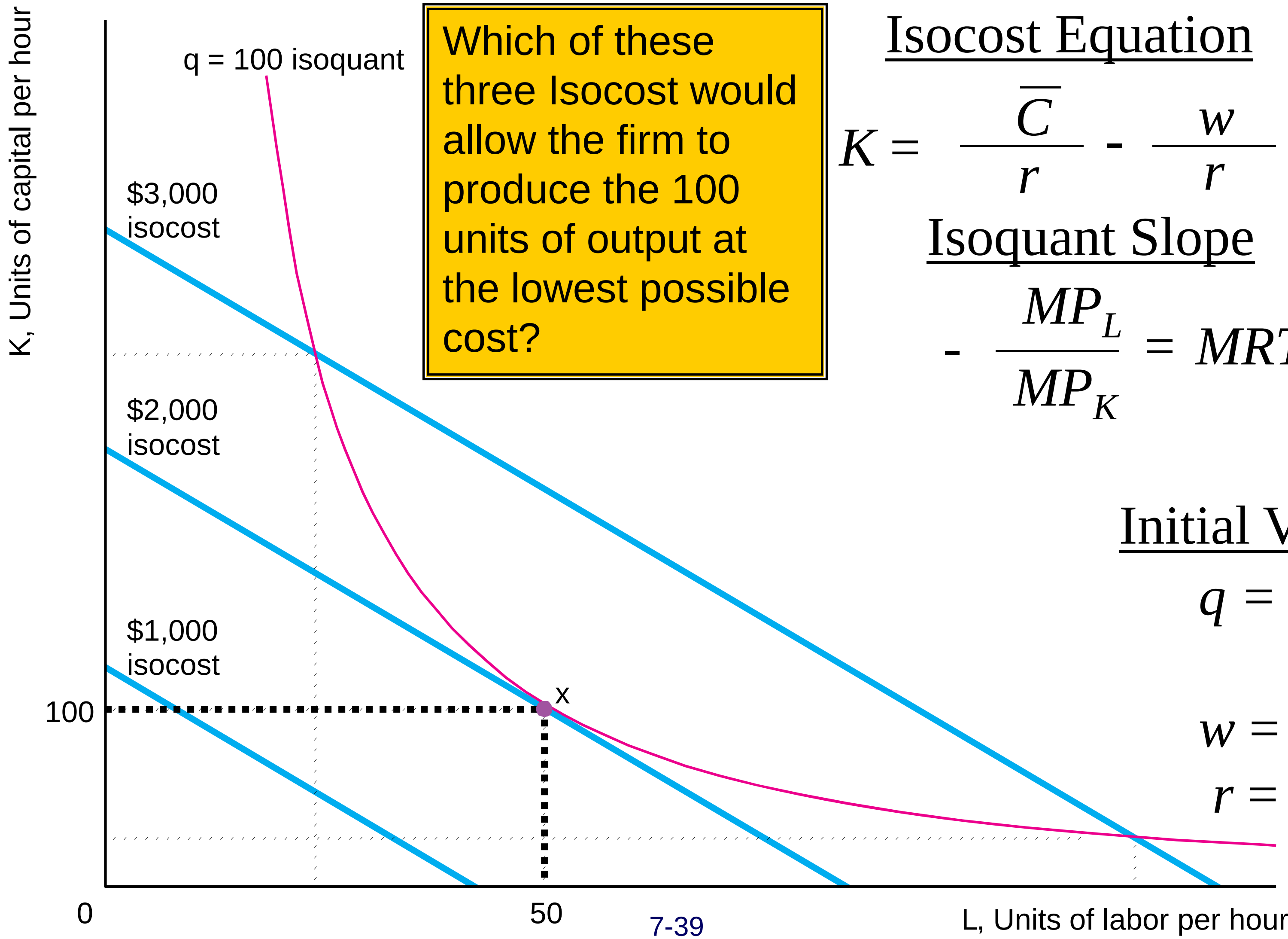
A decrease in C….



Combining Cost and Production Information.

- The firm can choose any of three equivalent approaches to minimize its cost:
  - **Lowest-isocost rule -** pick the bundle of inputs where the lowest isocost line touches the isoquant.
  - **Tangency rule -** pick the bundle of inputs where the isoquant is tangent to the isocost line.
  - **Last-dollar rule -** pick the bundle of inputs where the last dollar spent on one input gives as much extra output as the last dollar spent on any other input.

Cost Minimization



Which of these three Isocost would allow the firm to produce the 100 units of output at the lowest possible cost?

Isocost Equation

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

Isoquant Slope

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

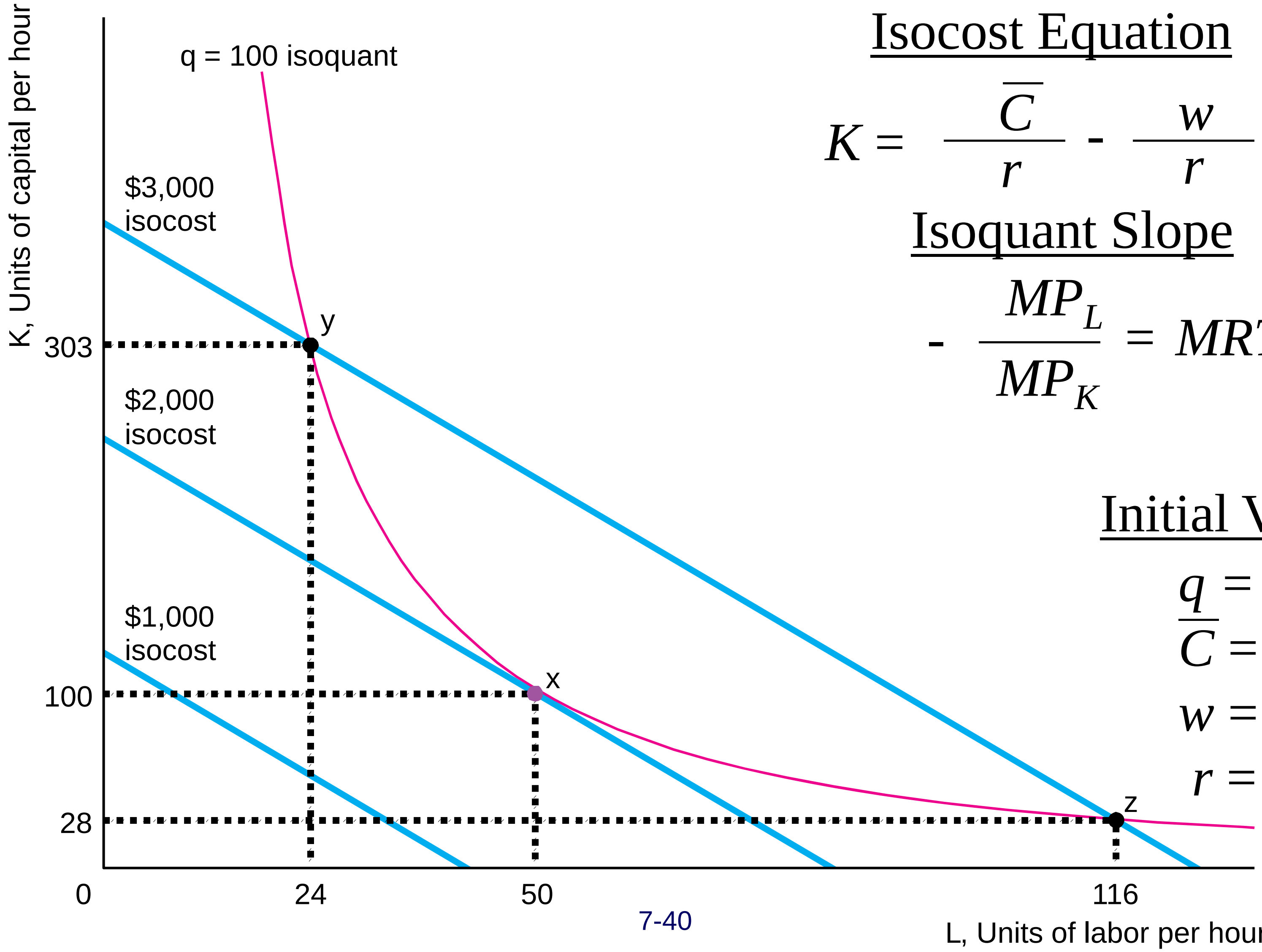
Initial Values

$q = 100$

$w = \$24$

$r = \$8$

Cost Minimization



Isocost Equation

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

Isoquant Slope

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

Initial Values

$q = 100$

$\bar{C} = \$2,000$

$w = \$24$

$r = \$8$

Cost Minimization

- At the point of tangency, the slope of the isoquant equals the slope of the isocost. Therefore,

$$MRTS = -\frac{w}{r}$$

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

$$\frac{MP_L}{MP_K} = \frac{w}{r}$$

$$\frac{MP_L}{w} = \frac{MP_K}{r}$$

last-dollar rule: cost is minimized if inputs are chosen so that the last dollar spent on labor adds as much extra output as the last dollar spent on capital.

Cost Minimization

Initial Values

$q = 100$

$\bar{C} = \$2{,}000$

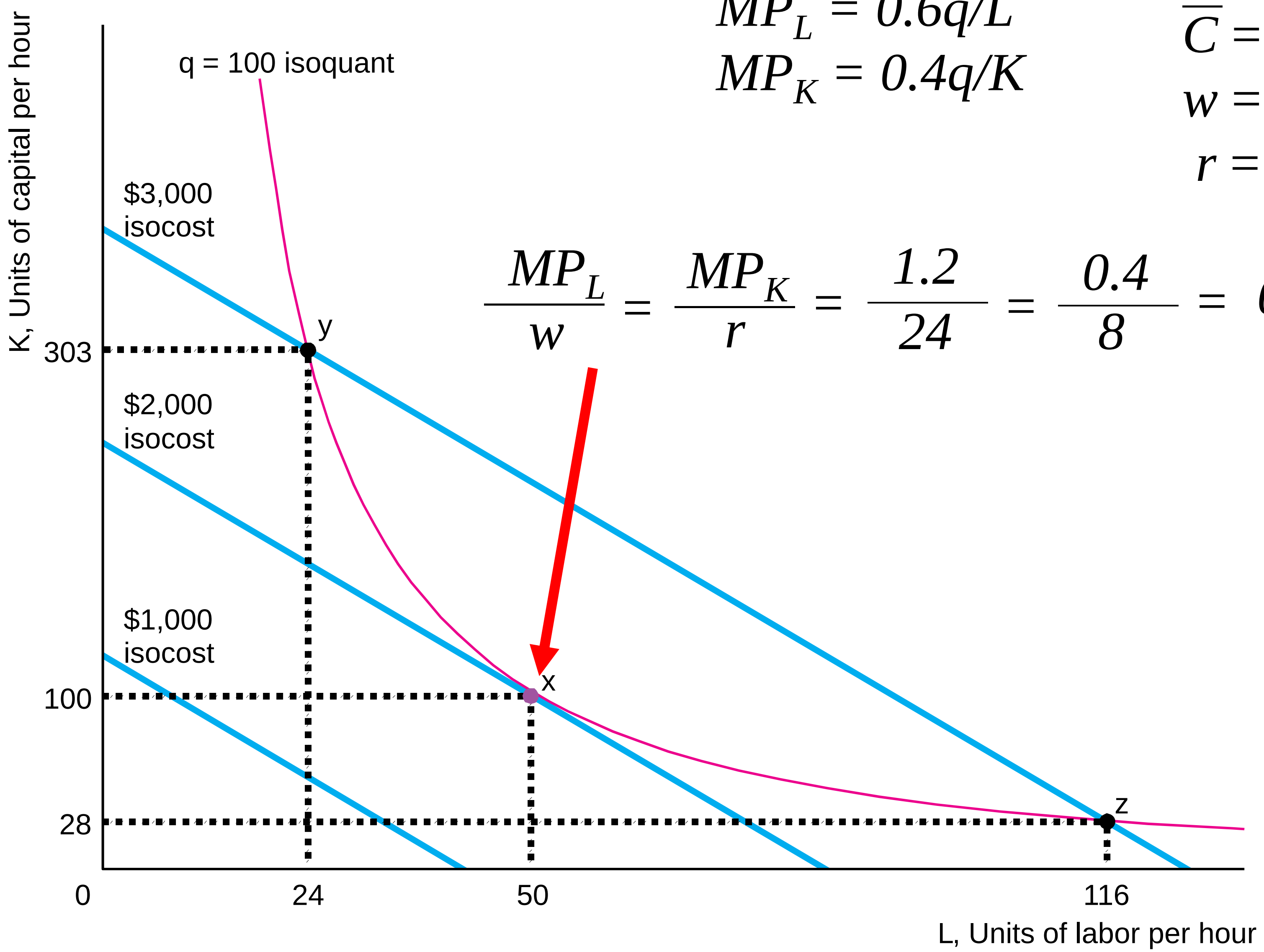
$w = \$24$

$r = \$8$

$MP_L = 0.6q/L$

$MP_K = 0.4q/K$

$$\frac{MP_L}{w} = \frac{MP_K}{r} = \frac{1.2}{24} = \frac{0.4}{8} = 0.05$$



Cost Minimization

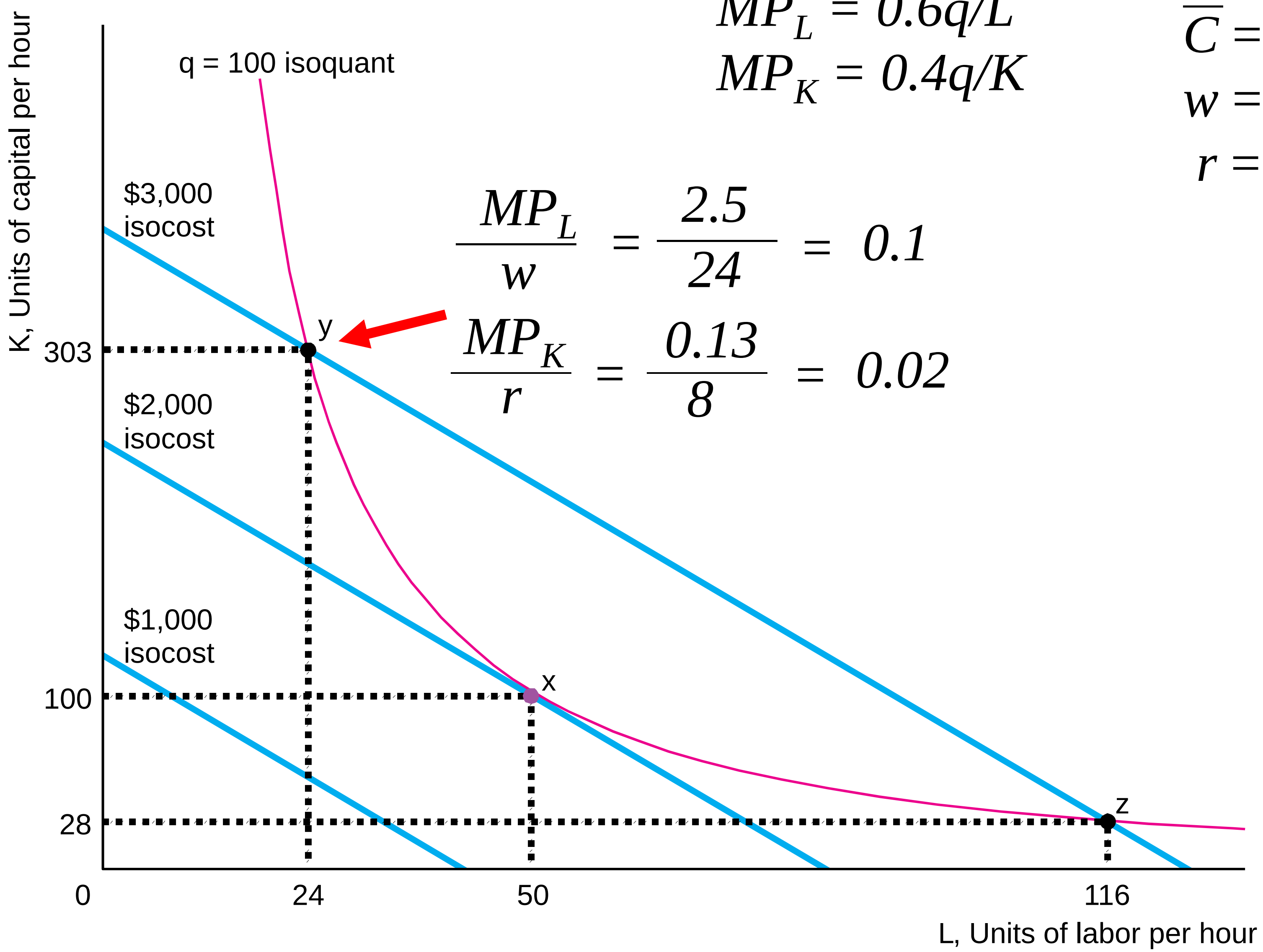
$$MP_L = 0.6q/L$$
$$MP_K = 0.4q/K$$

Initial Values

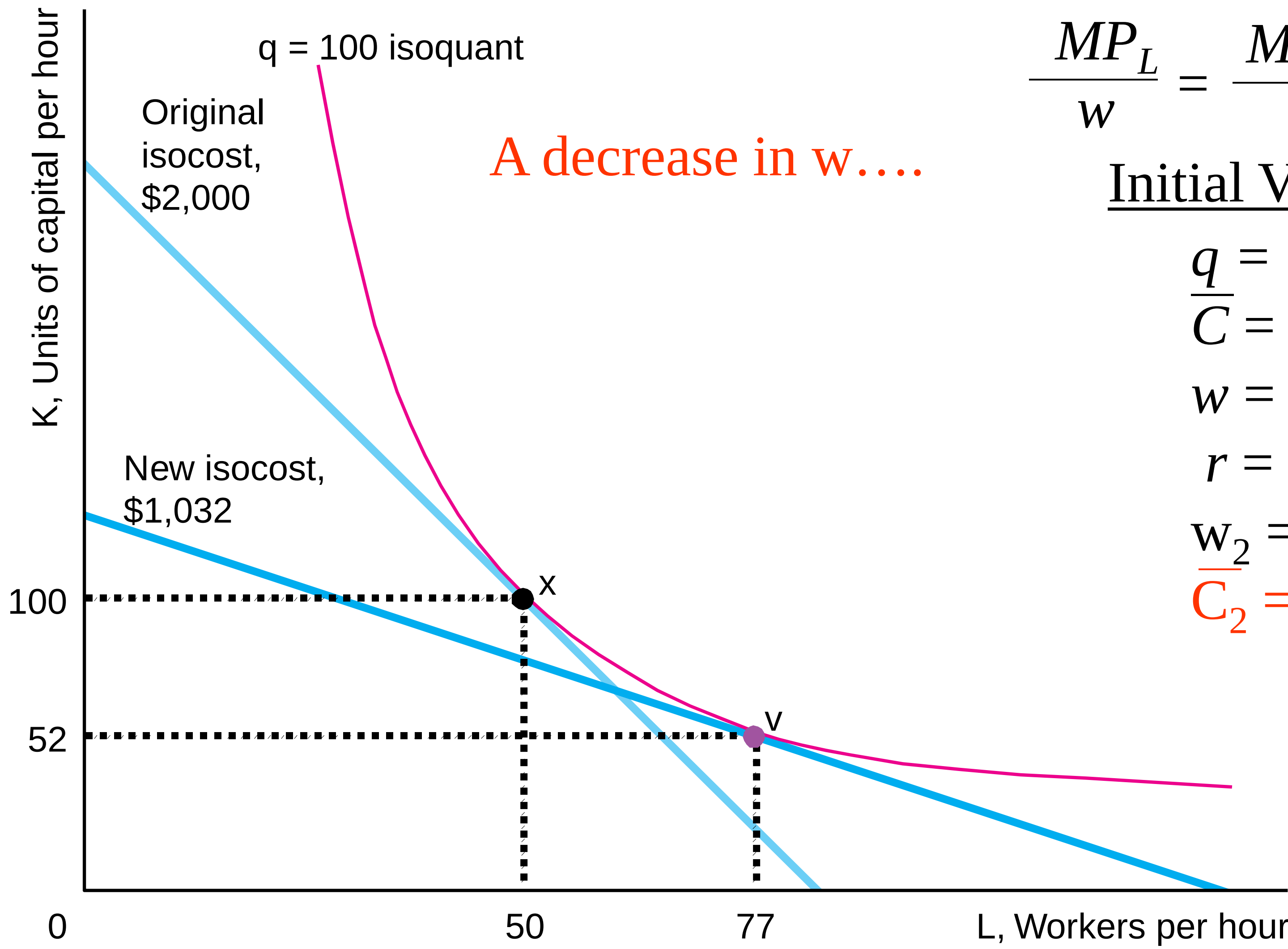
$q = 100$
$C = \$2{,}000$
$w = \$24$
$r = \$8$

$$\frac{MP_L}{w} = \frac{2.5}{24} = 0.1$$

$$\frac{MP_K}{r} = \frac{0.13}{8} = 0.02$$



Change in Factor Price



Minimizing Cost Rule

$$\frac{MP_L}{w} = \frac{MP_K}{r}$$

Initial Values

$q = 100$

$\bar{C}$ = \$2,000

w = \$24

r = \$8

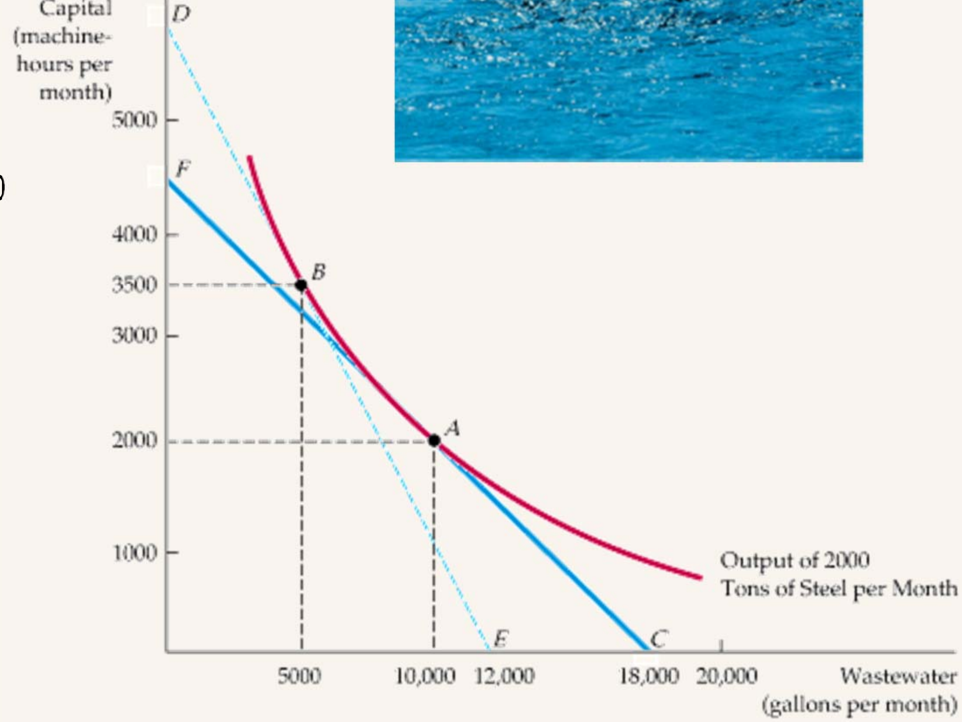
w_2 = \$8

$\bar{C}_2$ = \$1,032

EXAMPLE 7.4 The Effect of Effluent Fees on Input Choices

Figure 7.5

The Cost-Minimizing Response to an Effluent Fee



When the firm is not charged for dumping its wastewater in a river, it chooses to produce a given output using 10,000 gallons of wastewater and 2000 machine-hours of capital at *A*.

However, an effluent fee raises the cost of wastewater, shifts the isocost curve from *FC* to *DE*, and causes the firm to produce at *B*—a process that results in much less effluent.

How Long-Run Cost Varies with Output

- **expansion path -** the cost-minimizing combination of labor and capital for each output level

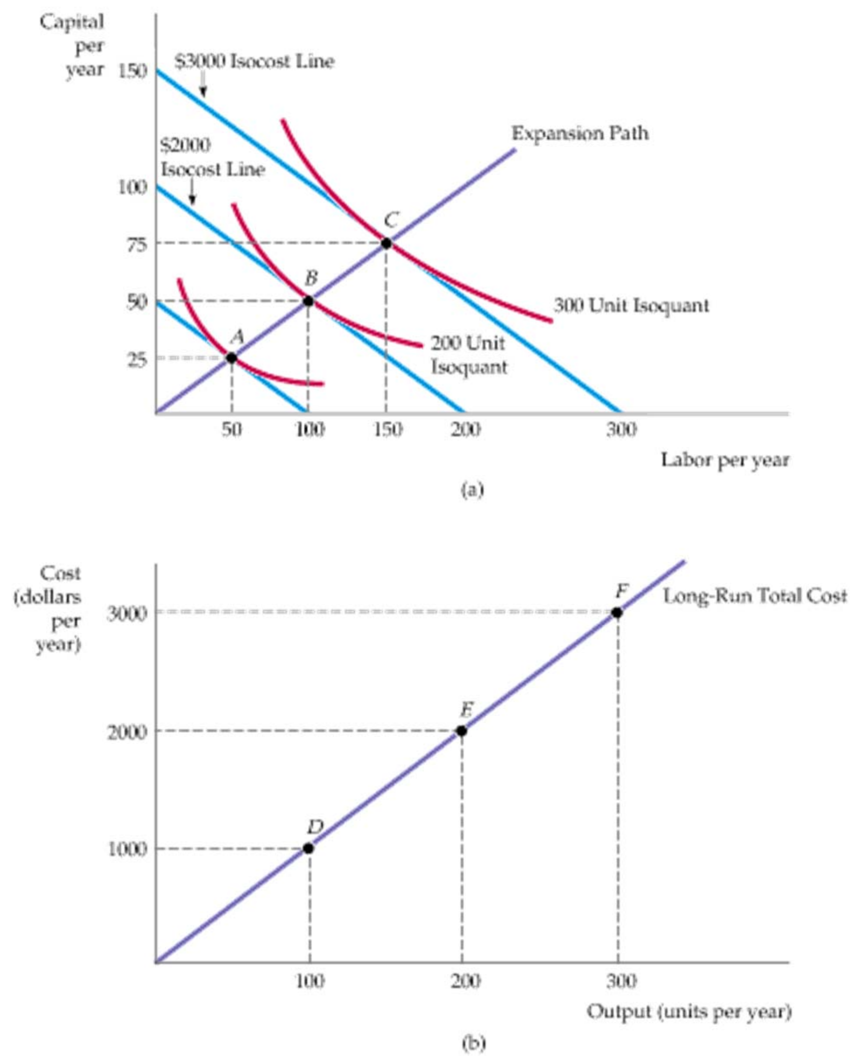
Cost Minimization with Varying Output Levels

Figure 7.6

A Firm's Expansion Path and Long-Run Total Cost Curve

In **(a)**, the expansion path (from the origin through points *A*, *B*, and *C*) illustrates the lowest-cost combinations of labor and capital that can be used to produce each level of output in the long run—i.e., when both inputs to production can be varied.

In **(b)**, the corresponding long-run total cost curve (from the origin through points *D*, *E*, and *F*) measures the least cost of producing each level of output.



The Inflexibility of Short-Run Production

Figure 7.7

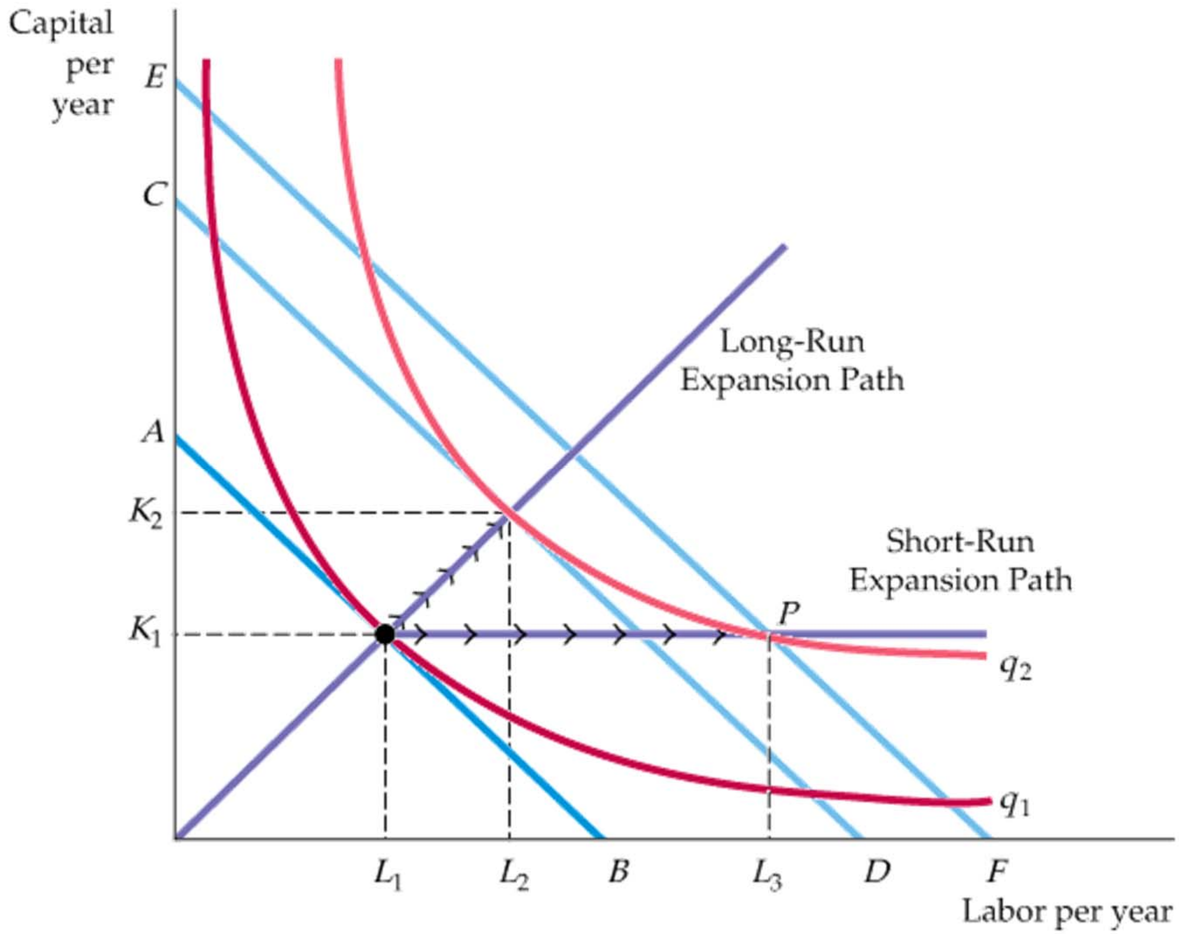
The Inflexibility of Short-Run Production

When a firm operates in the short run, its cost of production may not be minimized because of inflexibility in the use of capital inputs.

Output is initially at level q_1.

In the short run, output q_2 can be produced only by increasing labor from L_1 to L_3 because capital is fixed at K_1.

In the long run, the same output can be produced more cheaply by increasing labor from L_1 to L_2 and capital from K_1 to K_2.



Economies of Scale

- **economies of scale -** property of a cost function whereby the average cost of production _____ as output expands.
- **diseconomies of scale -** property of a cost function whereby the average cost of production _____when output increases.

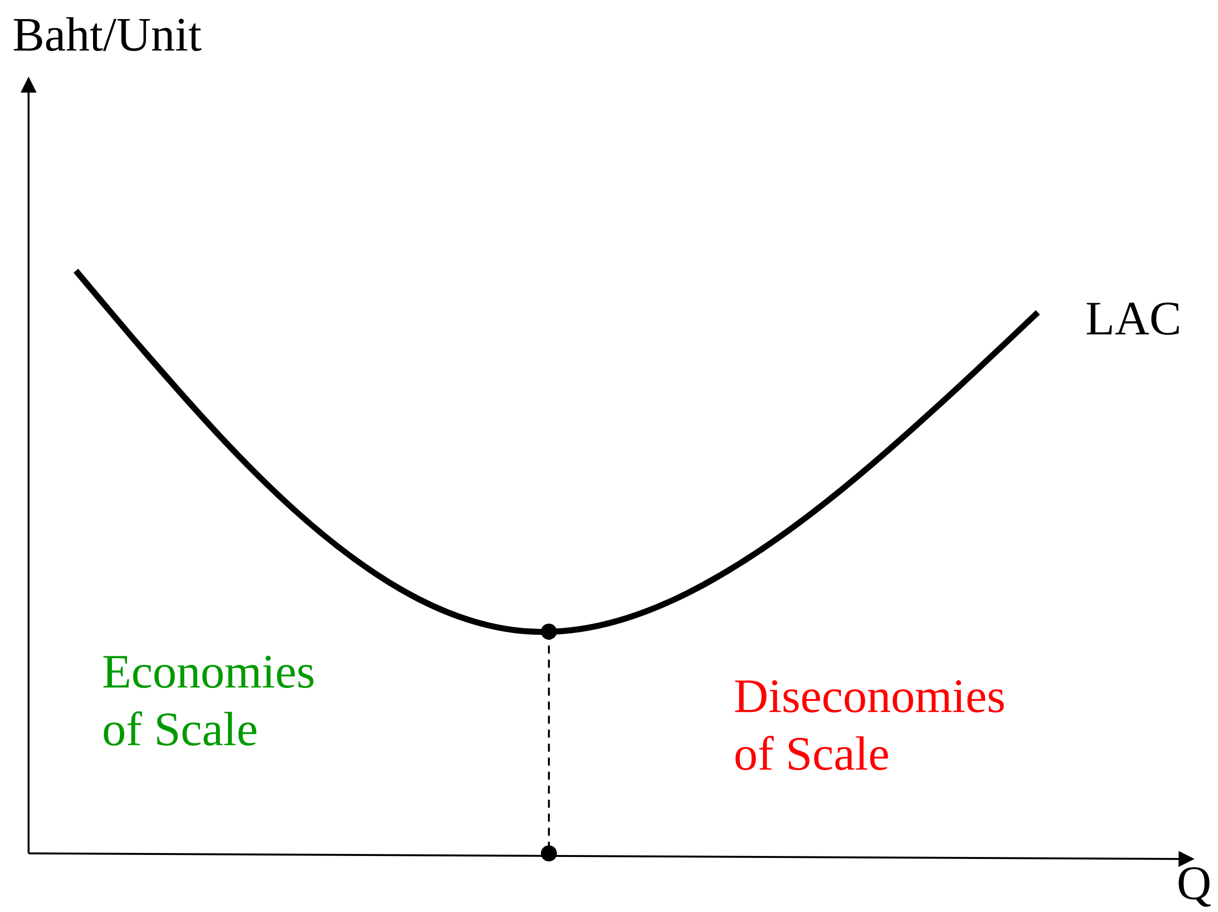
7.4 LONG-RUN VERSUS SHORT-RUN COST CURVES

Economies and Diseconomies of Scale

Economies of scale are often measured in terms of a cost-output elasticity, E_C. E_C is the percentage change in the cost of production resulting from a 1-percent increase in output:

To see how EC relates to our traditional measures of cost, rewrite the equation as follows:

Economies of Scale



Economies and Diseconomies of Scale

As output increases, the firm’s average cost of producing that output is likely to decline, at least to a point.

This can happen for the following reasons:

1. If the firm operates on a larger scale, workers can specialize in the activities at which they are most productive.
2. Scale can provide flexibility. By varying the combination of inputs utilized to produce the firm’s output, managers can organize the production process more effectively.
3. The firm may be able to acquire some production inputs at lower cost because it is buying them in large quantities and can therefore negotiate better prices. The mix of inputs might change with the scale of the firm’s operation if managers take advantage of lower-cost inputs.

7.4 LONG-RUN VERSUS SHORT-RUN COST CURVES

Economies and Diseconomies of Scale

At some point, however, it is likely that the average cost of production will begin to increase with output.

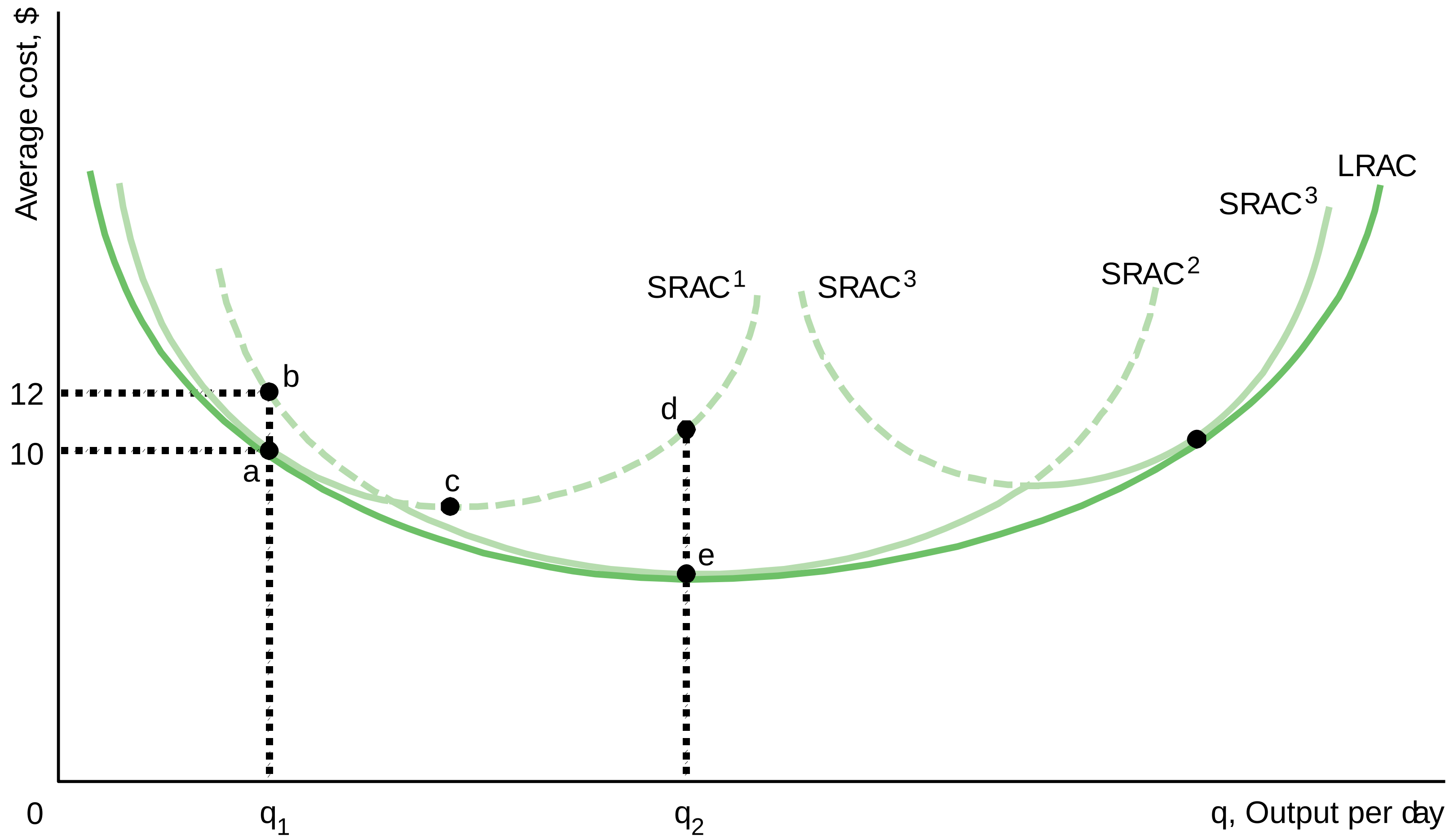
There are three reasons for this shift:

1. At least in the short run, factory space and machinery may make it more difficult for workers to do their jobs effectively.
2. Managing a larger firm may become more complex and inefficient as the number of tasks increases.
3. The advantages of buying in bulk may have disappeared once certain quantities are reached. At some point, available supplies of key inputs may be limited, pushing their costs up.

Long-Run Average Cost

- In its long-run planning, a firm chooses a plant size and makes other investments so as to minimize its long-run cost on the basis of how many units it produces.
  - Once it chooses its plant size and equipment, these inputs are fixed in the short run.
    - Thus, the firm's long-run decision determines its short-run cost.

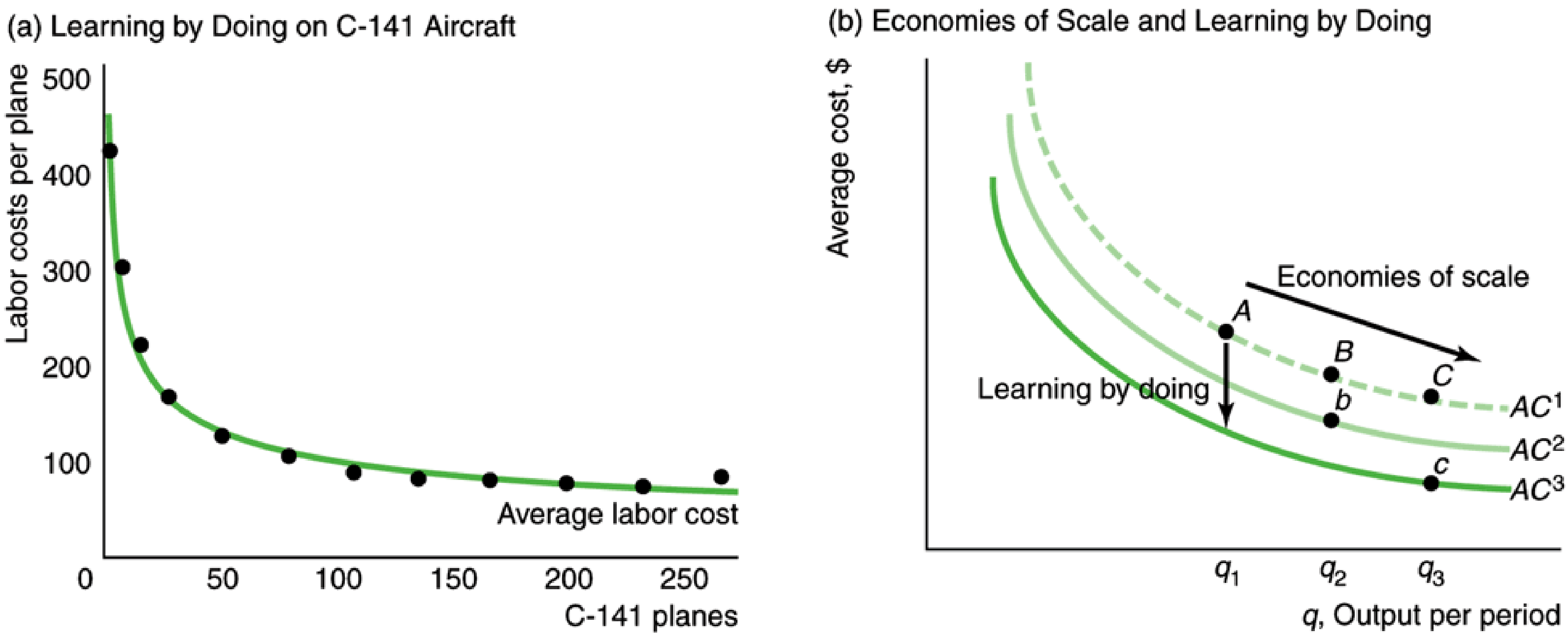
Long-Run Average Cost as the Envelope of Short-Run Average Cost Curves



How Learning by Doing Lowers Costs

- **learning by doing -** the productive skills and knowledge that workers and managers gain from experience

Figure 7.11 Learning by Doing



PRODUCTION WITH TWO OUTPUTS—ECONOMIES OF SCOPE

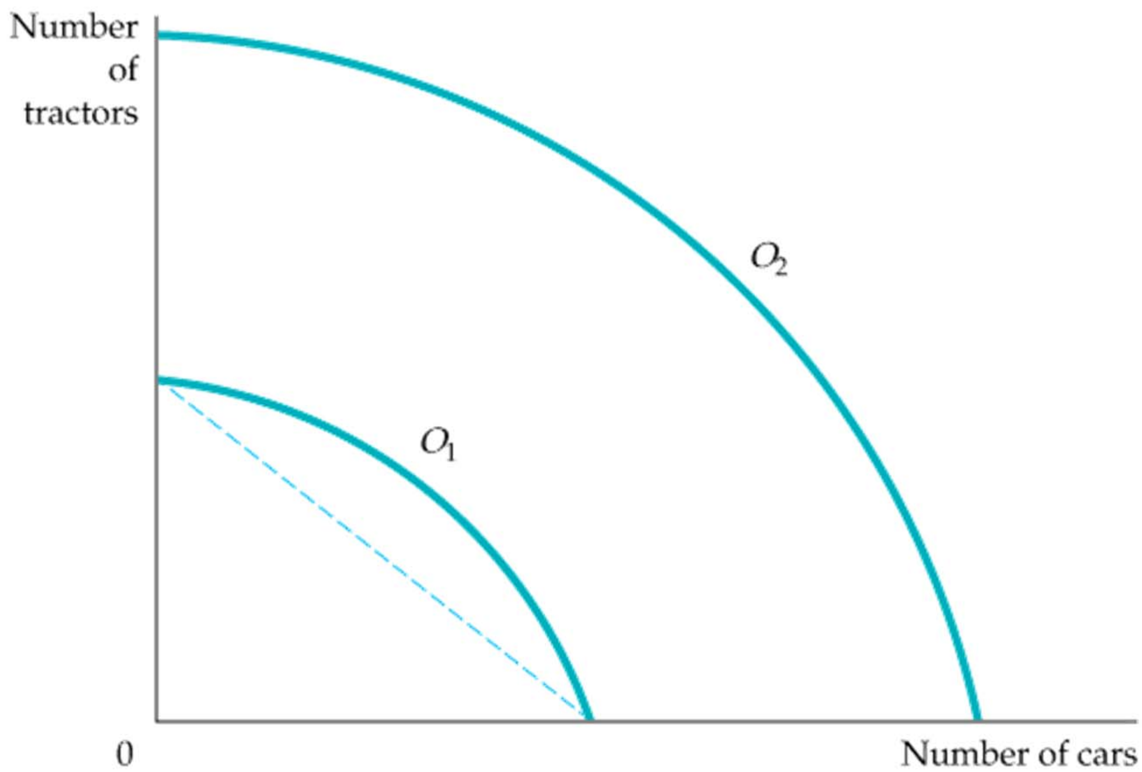
Product Transformation Curves

Figure 7.10

Product Transformation Curve

The product transformation curve describes the different combinations of two outputs that can be produced with a fixed amount of production inputs.

The product transformation curves O_1 and O_2 are bowed out (or concave) because there are economies of scope in production.



- **product transformation curve** Curve showing the various combinations of two different outputs (products) that can be produced with a given set of inputs.

7.5 PRODUCTION WITH TWO OUTPUTS—ECONOMIES OF SCOPE

Economies and Diseconomies of Scope

- **economies of scope** Situation in which joint output of a single firm is greater than output that could be achieved by two different firms when each produces a single product.

- **diseconomies of scope** Situation in which joint output of a single firm is less than could be achieved by separate firms when each produces a single product.

The Degree of Economies of Scope

To measure the *degree* to which there are economies of scope, we should ask what percentage of the cost of production is saved when two (or more) products are produced jointly rather than individually.

$$SC = \frac{C(q_1) + C(q_2) - C(q_1, q_2)}{C(q_1, q_2)} \qquad (7.7)$$

- **degree of economies of scope (SC)** Percentage of cost savings resulting when two or more products are produced jointly rather than Individually.

*7.6

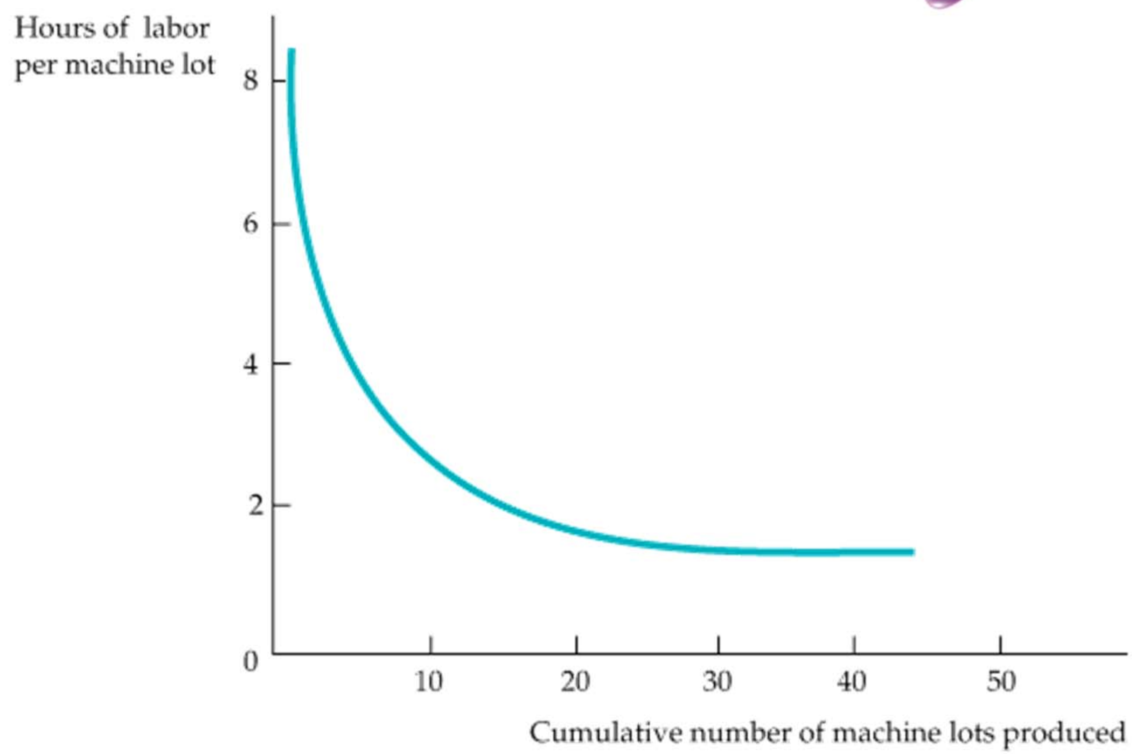
DYNAMIC CHANGES IN COSTS—THE LEARNING CURVE

Figure 7.11

The Learning Curve

A firm's production cost may fall over time as managers and workers become more experienced and more effective at using the available plant and equipment.

The learning curve shows the extent to which hours of labor needed per unit of output fall as the cumulative output increases.



- **learning curve** Graph relating amount of inputs needed by a firm to produce each unit of output to its cumulative output.

*7.6

DYNAMIC CHANGES IN COSTS—THE LEARNING CURVE

Graphing the Learning Curve

The learning curve is based on the relationship

$$L = A + BN^{-\beta} \tag{7.8}$$

Learning versus Economies of Scale

Figure 7.12

Economies of Scale versus Learning

A firm's average cost of production can decline over time because of growth of sales when increasing returns are present (a move from *A* to *B* on curve AC_1),

or it can decline because there is a learning curve (a move from *A* on curve AC_1 to *C* on curve AC_2).