Chapter 6

Firms and Production

Key issues

1. ownership and management of firms
2. production (using existing technologies)
3. short-run production: one variable and one fixed input
4. long-run production: two variable inputs
5. returns to scale
6. productivity and technical change

Firm

an organization that converts inputs (labor, materials, and capital) into outputs (goods and services)

Sources of production: U.S.

- firms: 84% of U.S. national production
- government: 12%
- nonprofit institutions: 4%
- private households: 0.2%

Government's share of production

- United States: 12%
- Ghana 37%
- Zambia 38%
- Sudan 40%
- Algeria 90%
- Bangladesh, Paraguay, and Nepal 3%

Legal forms of for-profit firms

- *sole proprietorships*: owned and run by a single individual
- *partnerships*: jointly owned and controlled by two or more people
- *corporations*: owned by shareholders in proportion to the numbers of shares of stock they hold

Corporations

- shareholders elect a board of directors who run the firm
- board of directors usually hire managers

Liability

- sole proprietors and partners liable:
  - personally liable for debts of their firms
  - to the extent of all their personal wealth - not just their investments
- owners of corporations have limited liability:
  - cannot lose personal assets
  - liability limited to their investment (value of stock)

	Business Sales	*Number of Firms*
Sole proprietorships	6%	75%
Partnerships	5%	7%
Corporations	90%	<20%

Management of Firms

- small firm owner usually manages
- corporations and larger partnerships use managers

Objectives

- conflicting objectives between owners, managers, and other employees
- employees want to maximize their earnings or utility
- owners want to maximize profit:

$$\pi = R - C$$

  - R = revenue = pq = price x quantity
  - C = cost

Production efficiency

given current knowledge about technology and organization:

- current level of output cannot be produced with fewer inputs
- given quantity of inputs used, no more output could be produced

Production efficiency and profit

production efficiency is

- a necessary condition to maximize profit
- not a sufficient condition to maximize profit (must produce optimal output level)

Production

- production process: transform inputs or factors of production into outputs
- common types of inputs:
  - capital (K): buildings and equipment
  - labor services (L)
  - materials (M): raw goods and processed products

Production function

relationship between quantities of inputs used and maximum quantity of output that can be produced, given current knowledge about technology and organization

Production function with 2 inputs

a production function that uses only labor and capital:

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

to produce the maximum amount of output given efficient production

Variability of inputs over time

- firm can more easily adjust its inputs in the long run (LR) than in the short run (SR)
- *short run*: a period of time so brief that at least one factor of production is fixed
- *fixed input*: a factor that cannot be varied practically in the SR
- *variable input*: a factor whose quantity can be changed readily during the relevant time period
- *long run*: lengthy enough period of time that all inputs can be varied

Short-run production

- one variable input: Labor (L)
- one fixed input: Capital (K)
- thus, firm can increase output only by using more labor

Example

- service firm assembles computers for a manufacturing firm
- manufacturing firm supplies it with the necessary parts, such as computer chips and disk drives
- assembly firm's capital is fixed: eight workbenches fully equipped with tools, electronic probes, and other equipment for testing computers can vary labor

Table 6.1 Total Product, Marginal Product, and Average Product of Labor with Fixed Capital

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

Marginal product of labor (MP_L)

- should firm hire another worker?
- want to know marginal product of labor:
  - change in total output, Δq, resulting from using an extra unit of labor, $\Delta L = 1$, holding the other factor (K) constant
  - $MP_L = \Delta q/\Delta L$

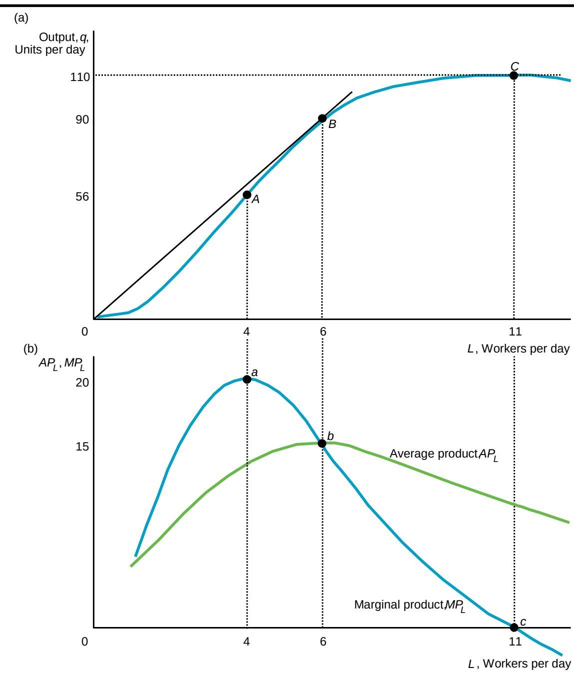
Average product of labor (AP_L)

- does output rise in proportion to this extra labor?
- want to know average product of labor:
  - ratio of output to the number of workers used to produce that output
  - $AP_L = q/L$

Graphical relationships

- total product: q
- marginal product of labor: $MP_L = \Delta q/\Delta L$
- average product of labor: $AP_L = q/L$
- smooth curves because firm can hire a "fraction of a worker" (works part of a day)

Figure 6.1
Production Relationships with Variable Labor



Effect of extra labor

- AP_L
  - rises and then falls with labor
  - slope of line from the origin to point on total product curve
- MP_L
  - first rises and then falls
  - cuts the AP_L curve at its peak
  - is the slope of the total product curve

Solved problem

if each extra worker produces an extra unit of output, how do the total product of labor, average product of labor, and marginal product of labor vary with labor?

Answer

1. *determine how the total product of labor varies with the number of workers*:

   since n workers produce n units of output, the total product of labor equals the number of workers: $q = L$

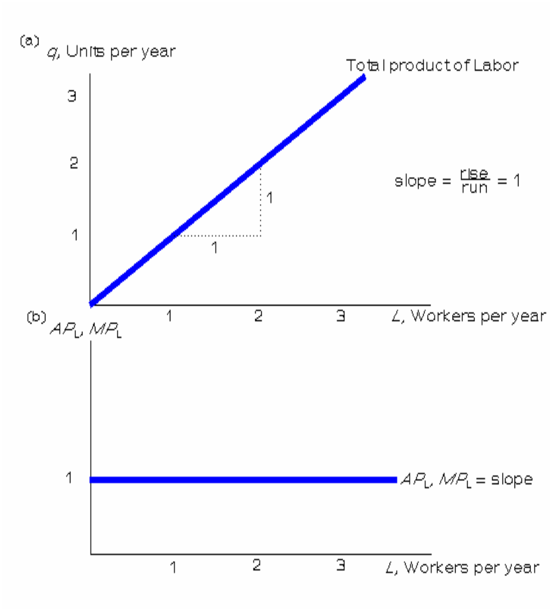
2. *show how MP_L varies with labor*:

   because each extra worker produces one more units of output, $MP_L = \Delta q/\Delta L = 1$

Answer (continued)

3. *show how AP_L varies with labor*:

   dividing both sides of the production function, $q = L$, by L, we find that $AP_L = q/L = 1$



Law of diminishing marginal returns (product)

as a firm increases an input, holding all other inputs and technology constant,

- the corresponding increases in output will become smaller eventually
- that is, the marginal product of that input will diminish eventually
- see Table 6.1 and Figure 6.1b

Mistake 1

- many people overstate this empirical regularity: talk about "diminishing returns" rather than "diminishing marginal returns"
  - "diminishing returns" extra labor causes output to fall: could produce more output with less labor
  - "diminishing marginal returns": MP_L curve is falling but may be positive
- firms may produce where there are diminishing marginal returns to labor but not diminishing returns

Mistake 2 ("Dismal Science")

- many people falsely claim that marginal products must fall as an input rises without requiring that technology and other inputs stay constant
- attributed to Malthus

Long-run production: Two variable inputs

- both capital and labor are variable
- firm can substitute freely between *L* and *K*
- many combinations of *L* and *K* produce a given level of output:
- $q = f(L, K)$

Isoquant

- curve that shows efficient combinations of labor and capital that can produce a single (iso) level of output (*quant*ity):

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

- Examples:
  - 10-unit isoquant for a Norwegian printing firm

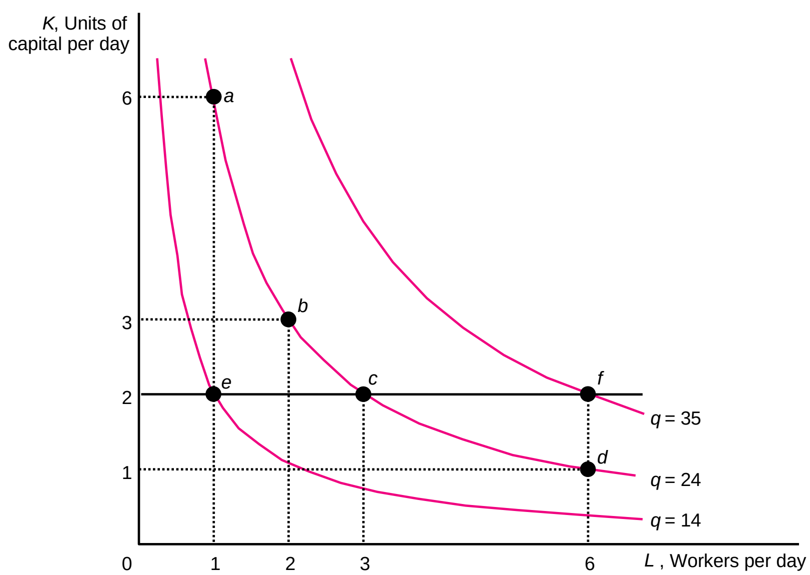
$$10 = 1.52\, L^{0.6} K^{0.4}$$

  - Table 6.2 shows four (L, K) pairs that produce $q = 24$

Table 6.2 Output Produced with Two Variable Inputs

Capital, *K*	Labor, *L* 1	2	3	4	5	6
1	10	14	17	20	22	**24**
2	14	20	**24**	28	32	35
3	17	**24**	30	35	39	42
4	20	28	35	40	45	49
5	22	32	39	45	50	55
6	**24**	35	42	49	55	60

Figure 6.2 Family of Isoquants



Isoquants and indifference curves

- have most of the same properties
- biggest difference:
  - isoquant holds something measurable, quantity, constant
  - indifference curve holds something that is unmeasurable, utility, constant

3 major properties of isoquants

follow from the assumption that production is efficient:

1. further an isoquant is from the origin, the greater is the level of output
2. isoquants do not cross
3. isoquants slope down

Shape of isoquants

- curvature of isoquant shows how readily a firm can substitute one input for another
- extreme cases:
  - perfect substitutes: $q = x + y$
  - perfect complements: $q = \min(x, y)$
- usual case: bowed away from the origin

Figure 6.3a Perfect Substitutes: Fixed Proportions

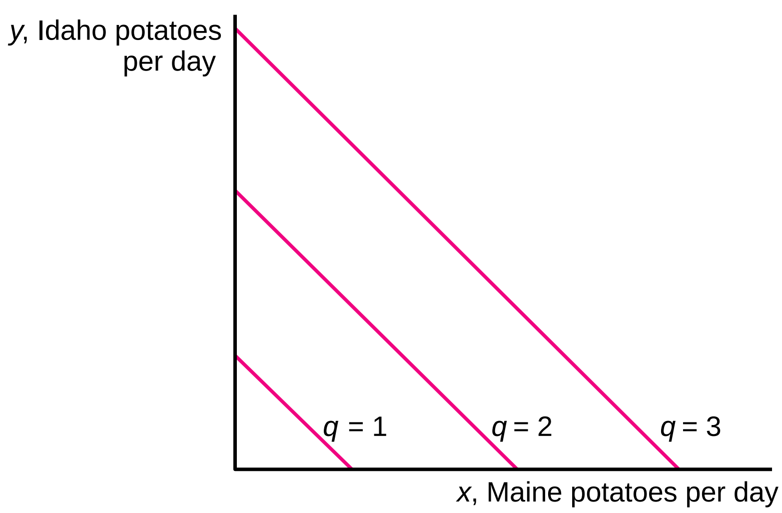


Figure 6.3b Perfect Complements

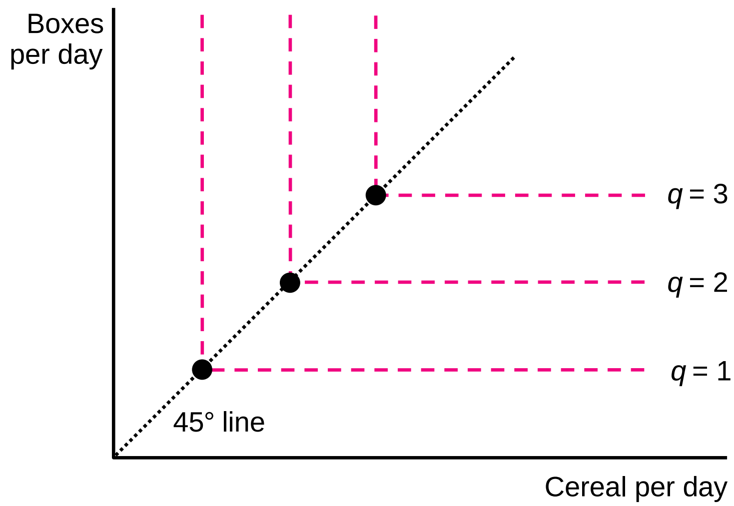
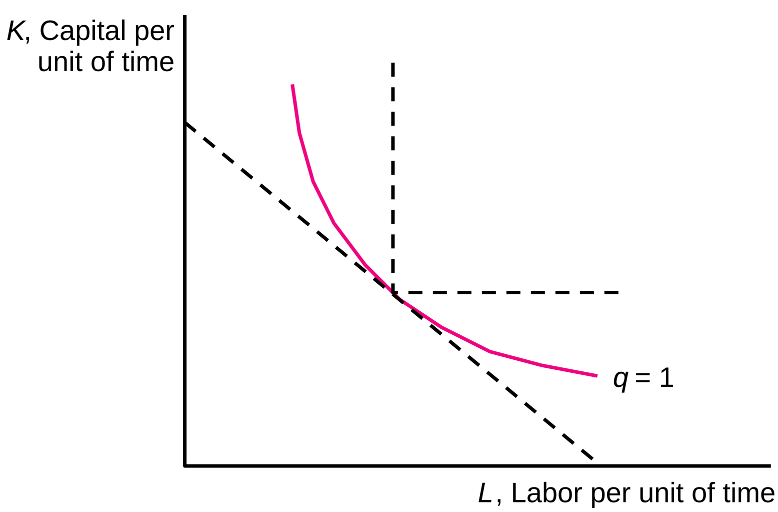
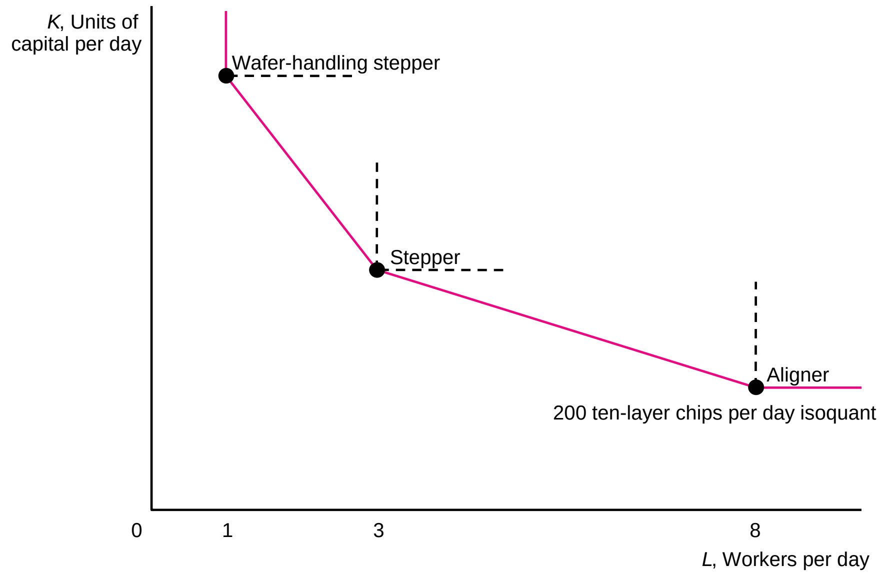


Figure 6.3c Substitutability of Inputs



Application A Semiconductor Integrated Circuit Isoquant



Substituting inputs

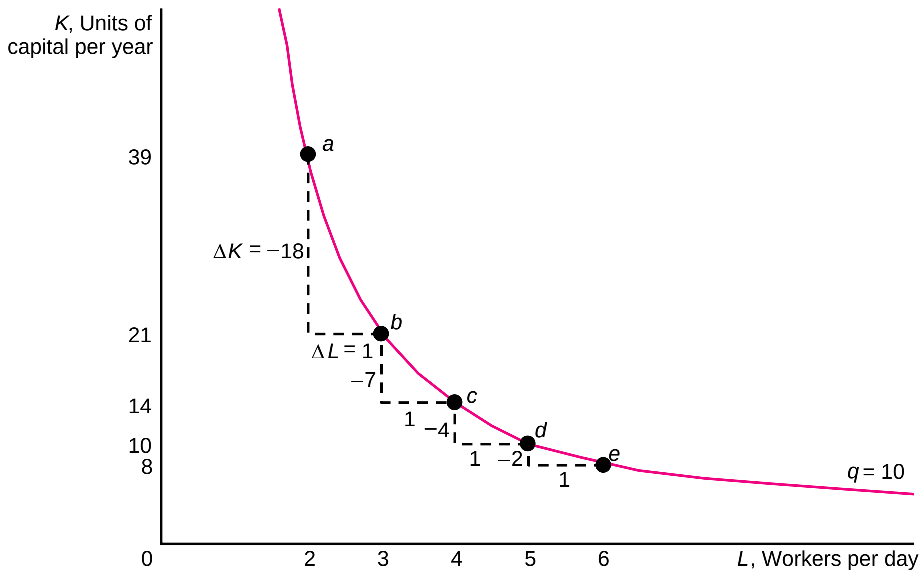
slope of an isoquant shows the ability of a firm to substitute one input for another while holding output constant

Marginal rate of technical substitution (*MRTS*)

- tells how much a firm can increase one input and lower the other so as to stay on an isoquant
- The slope of an isoquant =

  slope of straight line tangent to isoquant
- tells us how many units of *K* firm can replace with an extra unit of *L*, holding output constant
- varies along a curved isoquant

Figure 6.4 How the Marginal Rate of Technical Substitution Varies Along an Isoquant



Meaning of MRTS

- Convention: K in the y-axis and L in the x-axis. Refer to figure 6.4 (previous slide)
- MRTS is the slope of an isoquant at a given point. If the slope is -18 at the point a = (2,39), it means that if we increase the labor input by one unit, how much less capital can we use (negative change in capital)?
- Similar is the interpretation of MRTS at point b = (3,21). But note that the absolute value of MRTS is decreases as we substitute more and more capital with labor.

Returns to scale

how output changes if all inputs are increased by equal proportions

- how much does output change if a firm increases all its inputs proportionately?
- answer to this question helps a firm to determine its scale or size in LR

Constant returns to scale (CRS)

- when all inputs are doubled, output doubles

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

- potato-salad production function is CRS

Increasing returns to scale (IRS)

- when all inputs are doubled, output more than doubles

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

- increasing the size of a cubic storage tank: outside surface (two-dimensional) rises less than in proportion to the inside capacity (three-dimensional)

Decreasing returns to scale (DRS)

- when all inputs are doubled, output rises less than proportionally

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

- decreasing returns to scale because
  - difficulty organizing, coordinating, and integrating activities rises with firm size
  - large teams of workers may not function as well as small teams

Cobb-Douglas

- one of the most widely estimated production functions is the Cobb-Douglas:

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

- A, α, β are positive constants

Solved problem

Under what conditions does a Cobb-Douglas production function exhibit decreasing, constant, or increasing returns to scale?

Answer

1. *show how output changes if both inputs are doubled*:

$$q_1 = AL^{\alpha} K^{\beta}$$

$$q_2 = A(2L)^{\alpha} (2K)^{\beta} = 2^{\alpha+\beta} AL^{\alpha} K^{\beta}$$

2. *Thus, output increases by*

$$\frac{q_2}{q_1} = \frac{2^{\alpha+\beta} AL^{\alpha} K^{\beta}}{AL^{\alpha} K^{\beta}} = 2^{\alpha+\beta} \equiv 2^{\gamma},$$

where $\gamma \equiv \alpha+\beta$

Table 6.3 Returns to Scale in Canadian Manufacturing

	Labor, α	Capital, β	Scale, $\gamma = \alpha + \beta$
Decreasing Returns to Scale			
Thread mill	0.64	0.18	0.82
Knitted fabrics	0.55	0.36	0.90
Lime manufacturers	0.60	0.25	0.84
Constant Returns to Scale			
Shoe factories	0.82	0.18	1.00
Hosiery mills	0.55	0.46	1.01
Jewelry and silverware	0.60	0.41	1.01
Increasing Returns to Scale			
Concrete blocks and bricks	0.93	0.40	1.33
Paint	0.71	0.61	1.32
Orthopedic and surgical appliances	0.30	0.99	1.30

Varying returns to scale

many production functions have:

- increasing returns to scale for small amounts of output (returns to specialization)
- constant returns for moderate amounts of output
- decreasing returns for large amounts of output

Technical progress

- an advance in knowledge that allows more output to be produced with the same level of inputs
- *nonneutral technical change*: innovation that increases output by altering proportion in which inputs are used
- *neutral technical change*: produce more with same bundle of inputs

Neutral technical change

- last year a firm produced

$$q_1 = f(L, K)$$

- due to a new invention, this year the firm produces 10% more output with the same inputs:

$$q_2 = 1.1f(L, K)$$

Labor saving or labor augmenting technological change

- Keeping capital fixed a unit of labor produces more output after labor augmenting technological change than before.
- If the production function before technical change is Yb =F(K,L), after labor augmenting technical change it is given by Ya = F(K,bL), where b = 1.1 for instance. What it means is that a unit of labor after the labor augmenting technological change is equivalent to 1.1 units of labor before the technological change. In this numerical example, labor productivity went up by 10% because of the labor augmenting technological change.
- What causes such technological change? Education, on-the-job-training.
- The concept of capital saving or capital augmenting technological change is analogous.

Organizational change

- may change the production function
- same effect as technological change

Application: Just-in-time delivery

- Japanese auto manufacturers have parts delivered just-in-time for use so they can reduce inventories
- Dell Computer
  - suppliers deliver parts as needed
  - newest factory has no room for inventory storage
  - redesigned its computers to use many of the same parts
  - computers built only after order is placed