

Chapter 6

Inputs and Production Functions

in the Short Run:

A Quick Review

1

Key Concepts

The **production function** tells us the *maximum* possible output that can be attained by the firm for any given quantity of inputs.

Production Function:

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

- Q = output
- K = Capital
- L = Labor

The **production set** is a set of technically feasible combinations of inputs and outputs.

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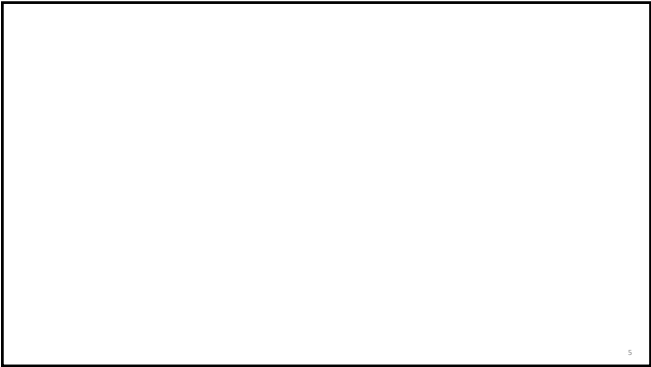
The Production Function & Technical Efficiency



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Total Product (TP), Average Product (AP), and Marginal Product (MP)

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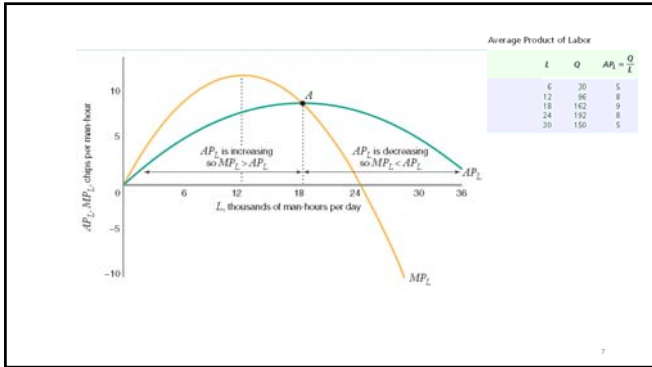
FIGURE 6.2 Total Product Function

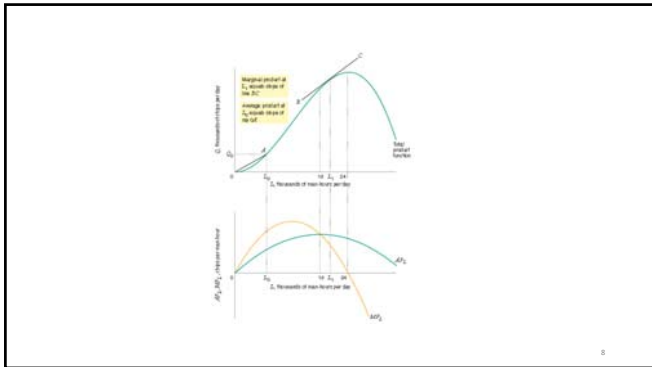
TABLE 6.1 Total Product Function

L*	Q
0	0
6	30
12	96
18	162
24	192
30	150

*L is expressed in thousands of man-hours per day, and Q is expressed in thousands of ships per day.

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Relationship between TP, AP, MP

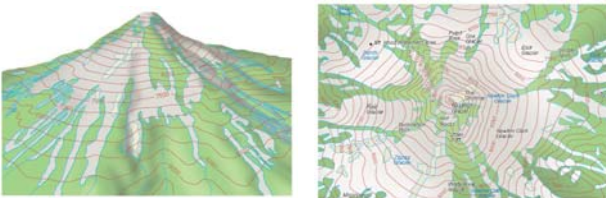
Law of Diminishing Marginal Product of Labor

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Chapter 6 Inputs and Production Functions in the Long Run

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Product Mountain



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TABLE 6.3 Production Function for Semiconductors*

	L**	K**					
		0	6	12	18	24	30
	0	0	0	0	0	0	0
	6	0	5	15	25	30	23
	12	0	15	48	81	96	75
	18	0	25	81	137	162	127
	24	0	30	96	162	192	150
	30	0	23	75	127	150	117

*Numbers in table equal the output that can be produced with various combinations of labor and capital.

**L is expressed in thousands of man-hours per day, K is expressed in thousands of machine-hours per day, and Q is expressed in thousands of semiconductor chips per day.

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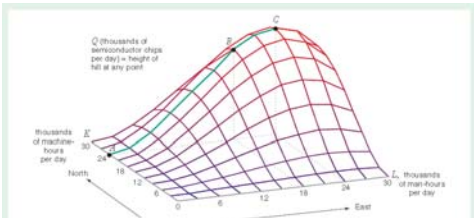
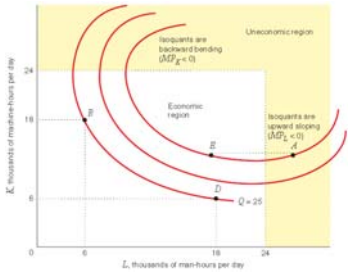


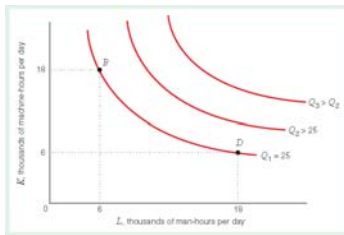
FIGURE 6.5 Total Product Hill
The height of the hill at any point is equal to the quantity of output Q attainable from the quantities of labor L and capital K corresponding to that point.

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Economic and Uneconomic Regions of Production



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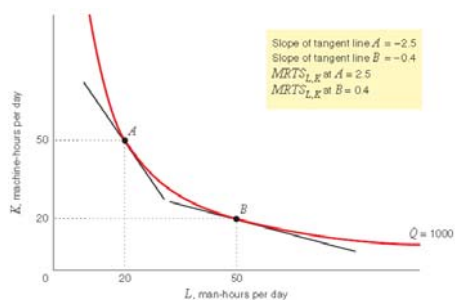
MARGINAL RATE OF TECHNICAL SUBSTITUTION

marginal rate of technical substitution of labor for capital: The rate at which the quantity of capital can be reduced for every one-unit increase in the quantity of labor, holding the quantity of output constant.

- The rate at which the quantity of capital can be *decreased* for every one-unit *increase* in the quantity of labor, holding the quantity of output constant, or
- The rate at which the quantity of capital must be *increased* for every one-unit *decrease* in the quantity of labor, holding the quantity of output constant.

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MARGINAL RATE OF TECHNICAL SUBSTITUTION IS DIMINISHING.

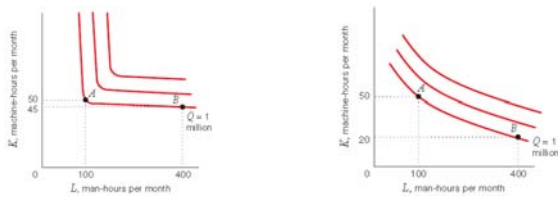


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MARGINAL RATE OF TECHNICAL SUBSTITUTION

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we explore how to describe the ease or difficulty with which a firm can substitute between different inputs



Input Substitution Opportunities and the Shape of Isoquants

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The ease or difficulty with which a firm can substitute among inputs depends on the curvature of its isoquants

- When the production function offers limited input substitution opportunities, the $MRTS_L$ changes **substantially** as we move along an isoquant. In this case, the isoquants are nearly L-shaped, as in Figure a
- When the production function offers abundant input substitution opportunities, the $MRTS_L$ changes **gradually** as we move along an isoquant. In this case, the isoquants are nearly straight lines, as in Figure b

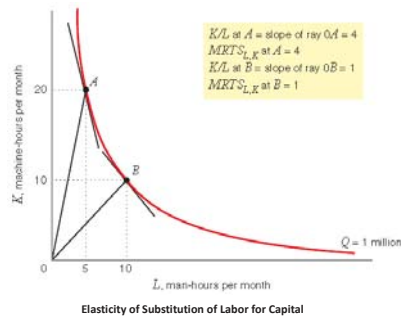
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Elasticity of Substitution can help us describe the firm's input substitution opportunities

Elasticity of substitution: A measure of how easy it is for a firm to substitute labor for capital. It is equal to the percentage change in the capital-labor ratio for every 1 percent change in the marginal rate of technical substitution of labor for capital as we move along an isoquant

$$\sigma = \frac{\text{percentage change in capital-labor ratio}}{\text{percentage change in } MRTS_{L,K}}$$
$$= \frac{\% \Delta \left(\frac{K}{L} \right)}{\% \Delta MRTS_{L,K}}$$

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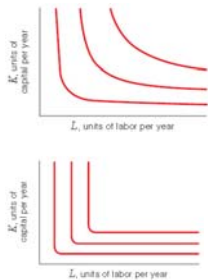
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Elasticities of Substitution in German Industries¹¹

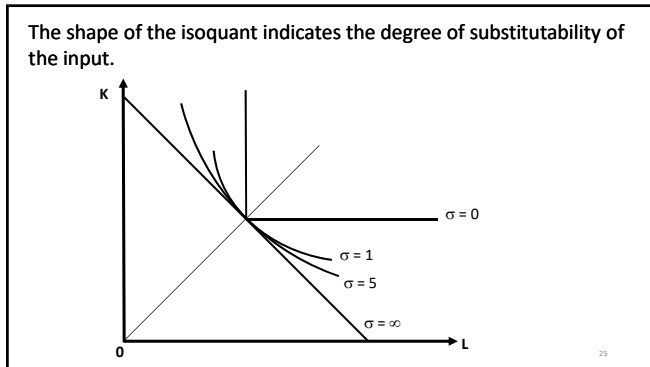
TABLE 6.5 Elasticities of Substitution in German Manufacturing Industries, 1970–1988

Industry	Elasticity of Substitution
Chemicals	0.37
Stone and earth	0.21
Iron	0.50
Motor vehicles	0.10
Paper	0.35
Food	0.66

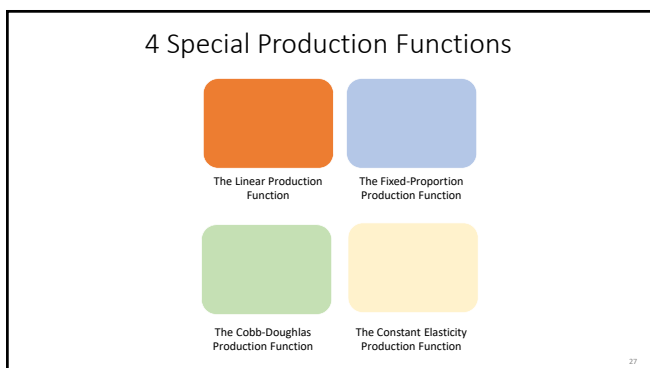
¹¹This example is based on "Estimated Substitution Elasticities of a Nested CES Production Function Approach for Germany," *Energy Economics* 20 (1998): 249–264.



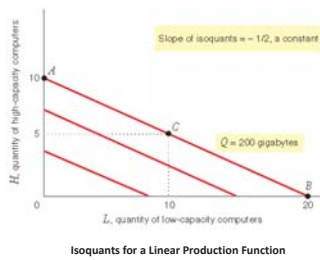
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- #### 4 Special Production Functions
- The linear production function
 - The fixed-proportions production function
 - The Cobb–Douglas production function
 - The constant elasticity of substitution production function
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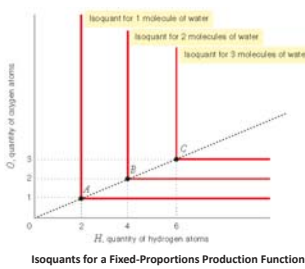


Linear Production Function (Perfect Substitutes)



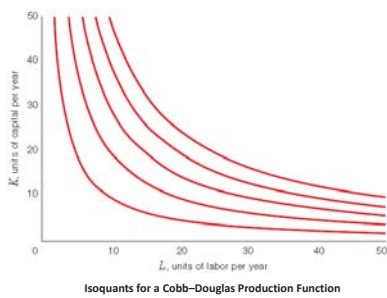
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Fixed-Proportions Production Function (Perfect Complements)



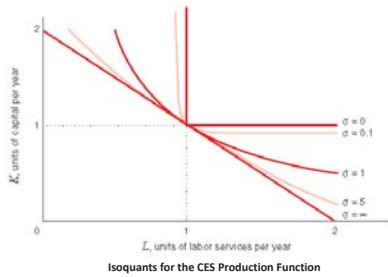
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Cobb–Douglas Production Function



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Constant Elasticity of Substitution Production Function



$$Q = [aL^{\frac{\sigma-1}{\sigma}} + bK^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}}$$

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Characteristics of Production Functions: A Summary

Production Function	Elasticity of Substitution (σ)	Other Characteristics
Linear production function	$\sigma = \infty$	Inputs are perfect substitutes Isoquants are straight lines
Fixed proportions production function	$\sigma = 0$	Inputs are perfect complements Isoquants are L shaped
Cobb–Douglas production function	$\sigma = 1$	Isoquants are curves
CES production function	$0 \leq \sigma \leq \infty$	Includes other three production functions as special cases Shape of isoquants varie

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APPLICATION 6.6

Estimating a CES Production Function for U.S. Industries

Using data from the Bureau of Economic Analysis for 1947–1998, economists Edward Balistreri, Christine McDaniel, and Eina Vivian Wong (BMW) estimated the constant σ in a CES production function relating the quantity of output to the quantities of labor and capital in each of 28 U.S. industries.¹⁴ Because, as discussed in the text, σ represents the elasticity of substitution, BMW's estimates provide insight into the opportunities for substituting between labor and capital in these industries.

Table 6.7 shows the estimates of σ for a subset of the 28 industries BMW studied. The table shows two types of estimates for each industry: a long-run elasticity of substitution and a short-run elasticity of

TABLE 6.7 Estimates of σ for Selected U.S. Industries

Industry	Estimated Value of σ	
	Short Run	Long Run
Agricultural services, forestry, and fishing	0.23	0.36
Coal mining	0.10	1.27
Furniture and fixtures	0.10	1.01
Fabricated metal products	0.11	1.39
Industrial machinery and equipment	0.23	0.82
Motor vehicles and equipment	0.05	0.40
Textile mill products	0.05	1.14
Apparel and other textile products	0.13	2.05

¹⁴Edward Balistreri, Christine McDaniel, and Eina Vivian Wong, "An Estimation of US Industry-Level Capital–Labor Substitution Elasticities: Support for Cobb–Douglas," *North American Journal of Economics and Finance* 14 (2003): 343–356.

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Returns to Scale

Question: By how much would a semiconductor firm be able to increase its output if it doubled its man-hours of labor and its machine-hours of robots?

Returns to scale The concept that tells us the percentage by which output will increase when all inputs are increased by a given percentage.



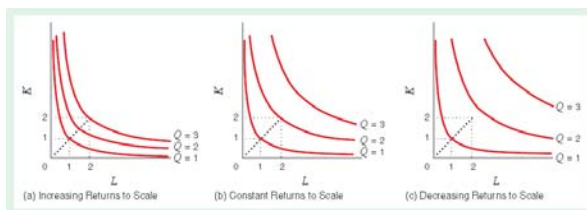
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3 Types of Returns to Scale

- **increasing returns to scale:** proportionate increase in all input quantities resulting in a greater than proportionate increase in output.
- **constant returns to scale:** A proportionate increase in all input quantities simultaneously that results in the same percentage increase in output.
- **decreasing returns to scale** A proportionate increase in all input quantities resulting in a less than proportionate increase in output.

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Increasing, Constant, and Decreasing Returns to Scale



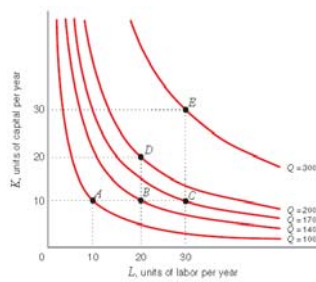
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Learning-by-Doing: Returns to Scale for a Cobb–Douglas Production Function

- Does a Cobb–Douglas production function, $Q = AL^{\alpha}K^{\beta}$ exhibit increasing, decreasing, or constant returns to scale?

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Returns to Scale Versus Diminishing Marginal Returns



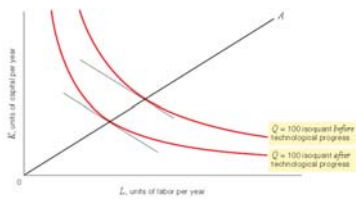
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Technological progress

technological progress : A change in a production process that enables a firm to achieve more output from a given combination of inputs or, equivalently, the same amount of output from less inputs.

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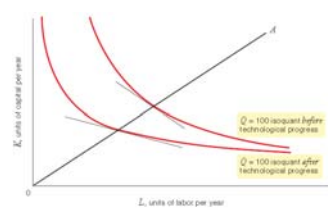
Neutral Technological Progress ($MRTSL,K$ Remains the Same)



neutral technological progress
Technological progress that decreases the amounts of labor and capital needed to produce a given output, without affecting the marginal rate of technical substitution of labor for capital.

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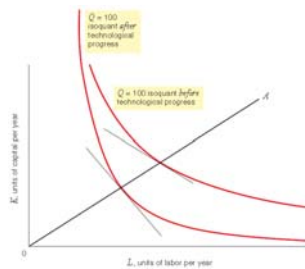
Labor-Saving Technological Progress ($MRTSL,K$ Decreases)



labor-saving technological progress
Technological progress that causes the marginal product of capital to increase relative to the marginal product of labor.

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Capital-Saving Technological Progress ($MRTSL,K$ Increases)



capital-saving technological progress
Technological progress that causes the marginal product of labor to increase relative to the marginal product of capital.

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Learning-by-Doing: Technological Progress

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