QUICK REVIEW 8.1

- Explicit costs are money payments a firm makes to outside suppliers of resources; implicit costs are the opportunity costs associated with a firm's use of resources it owns.
- Normal profit is the implicit cost of entrepreneurship. Economic profit is total revenue less all explicit and implicit costs, including normal profit.
- In the short run, a firm's plant capacity is fixed; in the long run, a firm can vary its plant size and firms can enter or leave the industry.

Short-Run Production Relationships

A firm's costs of producing a specific output depend on the prices of the needed resources and the quantities of resources (inputs) needed to produce that output. Resource supply and demand determine resource prices. The technological aspects of production, specifically the relationships between inputs and output, determine the quantities of resources needed. Our focus will be on the *labor*-output relationship, given a fixed plant capacity. But before examining that relationship, we need to define three terms:

- **Total product (TP)** is the total quantity, or total output, of a particular good or service produced.
- **Marginal product (MP)** is the extra output or added product associated with adding a unit of a variable resource, in this case labor, to the production process. Thus,

$$\text{Marginal product} = \frac{\text{change in total product}}{\text{change in labor input}}$$

- **Average product (AP)**, also called labor productivity, is output per unit of labor input:

$$\text{Average product} = \frac{\text{total product}}{\text{units of labor}}$$

In the short run, a firm can for a time increase its output by adding units of labor to its fixed plant. But by how much will output rise when it adds more labor? Why do we say "for a time"?

Law of Diminishing Returns

The answers are provided in general terms by the **law of diminishing returns.** This law assumes that technology is fixed and thus the techniques of production do not change. It states that as successive units of a variable resource (say, labor) are added to a fixed resource (say, capital or land), beyond some point the extra, or marginal, product that can be attributed to each additional unit of the variable resource will decline. For example, if additional workers are hired to work with a constant amount of capital equipment, output will eventually rise by smaller and smaller amounts as more workers are hired.

ORIGIN OF THE IDEA

O 8.1

Law of diminishing returns

CONSIDER THIS . . .

Diminishing Returns from Study

Here is a noneconomic example of a relationship between "inputs" and "output" that may help you better understand the idea of diminishing returns. Suppose for an individual that

> Total course learning = *f* (intelligence, quality of course materials, instructor effectiveness, class time, and study time)

where *f* means "function of" or "depends on." So this relationship supposes that total course learning depends on intelligence (however defined), quality of course materials such as the textbook, the effectiveness of the instructor, the amount of class time, and the amount of personal study time outside the class.

For analytical purposes, let's assume that one's intelligence, the quality of course materials, the effectiveness of the instructor, and the amount of class time are *fixed*—meaning they do not change over the length of the course. Now let's add units of study time per day over the length of the course to "produce" greater course learning. The first hour of study time per day increases total course learning. Will the second hour enhance course learning by as much as the first? By how much will the third, fourth, fifth, . . . fifteenth hour of study per day contribute to total course learning relative to the *immediate previous hour*?

We think you will agree that eventually diminishing returns to course learning will set in as successive hours of study are added each day. At some point the marginal product of an extra hour of study time will decline and, at some further point, become zero.

This is also true of production relationships within firms. As successive units of a variable input (say, labor) are added to a fixed input (say, capital), the marginal product of the variable input eventually declines. In short, diminishing returns will occur sooner or later. Total product eventually will rise at a diminishing rate, reach a maximum, and then decline.

Rationale Suppose a farmer has a fixed resource—80 acres of land—planted in corn. If the farmer does not cultivate the cornfields (clear the weeds) at all, the yield will be 40 bushels per acre. If he cultivates the land once, output may rise to 50 bushels per acre. A second cultivation may increase output to 57 bushels per acre, a third to 61, and a fourth to 63. Succeeding cultivations will add less and less to the land's yield. If this were not so, the world's needs for corn could be fulfilled by extremely intense cultivation of this single 80-acre plot of land. Indeed, if diminishing returns did not occur, the world could be fed out of a flowerpot. Why not? Just keep adding more seed, fertilizer, and harvesters!

The law of diminishing returns also holds true in nonagricultural industries. Assume a wood shop is manufacturing furniture frames. It has a specific amount of equipment such as lathes, planes, saws, and sanders. If this shop hired just one or two workers, total output and productivity (output per worker) would be very low. The workers would have to perform many different jobs, and the advantages of specialization would not be realized. Time would be lost in switching from one job to another, and machines would stand idle much of the time. In short, the plant would be understaffed, and production would be inefficient because there would be too much capital relative to the amount of labor.

The shop could eliminate those difficulties by hiring more workers. Then the equipment would be more fully used, and workers could specialize on doing a single job. Time would no longer be lost switching from job to job. As more workers were added, production would become more efficient and the marginal product of each succeeding worker would rise.

But the rise could not go on indefinitely. If still more workers were added, beyond a certain point, overcrowding would set in. Since workers would then have to wait in line to use the machinery, they would be underused. Total output would increase at a diminishing rate because, given the fixed size of the plant, each worker would have less capital equipment to work with as more and more labor was hired. The marginal product of additional workers would decline because there would be more labor in proportion to the fixed amount of capital. Eventually, adding still more workers would cause so much congestion that marginal product would become negative and total product would decline. At the extreme, the addition of more and more labor would exhaust all the standing room, and total product would fall to zero.

Note that the law of diminishing returns assumes that all units of labor are of equal quality. Each successive worker is presumed to have the same innate ability, motor coordination, education, training, and work experience. Marginal product ultimately diminishes, not because successive workers are less skilled or less energetic but because more workers are being used relative to the amount of plant and equipment available.

Tabular Example Table 8.1 is a numerical illustration of the law of diminishing returns. Column 2 shows the total product, or total output, resulting from combining each level of a variable input (labor) in column 1 with a fixed amount of capital.

TABLE 8.1 **Total, Marginal, and Average Product: The Law of Diminishing Returns**

(1) Units of the Variable Resource (Labor)	(2) Total Product (TP)	(3) Marginal Product (MP), Change in (2)/ Change in (1)		(4) Average Product (AP), (2)/(1)
0	0			—
		10	Increasing marginal returns	
1	10			10.00
		15		
2	25			12.50
		20		
3	45			15.00
		15	Diminishing marginal returns	
4	60			15.00
		10		
5	70			14.00
		5		
6	75			12.50
		0	Negative marginal returns	
7	75			10.71
		−5		
8	70			8.75

Column 3 shows the marginal product (MP), the change in total product associated with each additional unit of labor. Note that with no labor input, total product is zero; a plant with no workers will produce no output. The first three units of labor reflect increasing marginal returns, with marginal products of 10, 15, and 20 units, respectively. But beginning with the fourth unit of labor, marginal product diminishes continuously, becoming zero with the seventh unit of labor and negative with the eighth.

WORKED PROBLEMS
W 8.2
Total, marginal, and average product

Average product, or output per labor unit, is shown in column 4. It is calculated by dividing total product (column 2) by the number of labor units needed to produce it (column 1). At 5 units of labor, for example, AP is 14 (= 70/5).

Graphical Portrayal **Figure 8.2 (Key Graph)** shows the diminishing-returns data in Table 8.1 graphically and further clarifies the relationships between total, marginal, and average products. (Marginal product in Figure 8.2b is plotted halfway between the units of labor since it applies to the addition of each labor unit.)

Note first in Figure 8.2a that total product, TP, goes through three phases: It rises initially at an increasing rate; then it increases, but at a diminishing rate; finally, after reaching a maximum, it declines.

Geometrically, marginal product—shown by the MP curve in Figure 8.2b—is the slope of the total-product curve. Marginal product measures the change in total product associated with each succeeding unit of labor. Thus, the three phases of total product are also reflected in marginal product. Where total product is increasing at an increasing rate, marginal product is rising. Here, extra units of labor are adding larger and larger amounts to total product. Similarly, where total product is increasing but at a decreasing rate, marginal product is positive but falling. Each additional unit of labor adds less to total product than did the previous unit. When total product is at a maximum, marginal product is zero. When total product declines, marginal product becomes negative.

Average product, AP (Figure 8.2b), displays the same tendencies as marginal product. It increases, reaches a maximum, and then decreases as more and more units of labor are added to the fixed plant. But note the relationship between marginal product and average product: Where marginal product exceeds average product, average product rises. And where marginal product is less than average product, average product declines. It follows that marginal product intersects average product where average product is at a maximum.

This relationship is a mathematical necessity. If you add a larger number to a total than the current average of that total, the average must rise. And if you add a smaller number to a total than the current average of that total, the average must fall. You raise your average examination grade only when your score on an additional (marginal) examination is greater than the average of all your past scores. You lower your average when your grade on an additional exam is below your current average. In our production example, when the amount an extra worker adds to total product exceeds the average product of all workers currently employed, average product will rise. Conversely, when an extra worker adds to total product an amount that is less than the current average product, then average product will decrease.

ORIGIN OF THE IDEA
O 8.2
Production relationship

The law of diminishing returns is embodied in the shapes of all three curves. But, as our definition of the law of diminishing returns indicates, economists are most concerned with its effects on marginal product. The regions of increasing, diminishing, and negative marginal product (returns) are shown in Figure 8.2b. **(Key Question 4)**

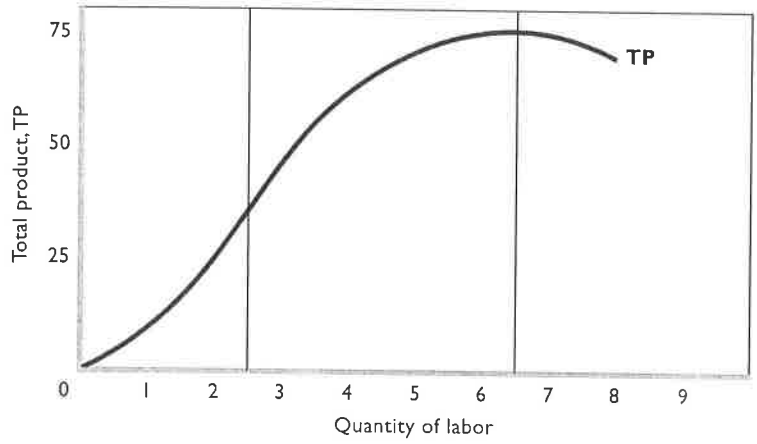
Short-Run Production Costs

Production information such as that provided in Table 8.1 and Figure 8.2a and 8.2b must be coupled with resource prices to determine the total and per-unit costs of producing various levels of output. We know that in the short run some resources, those associated with the firm's plant, are fixed. Other resources, however, are variable. So short-run costs are either fixed or variable.

Fixed, Variable, and Total Costs

Let's see what distinguishes fixed costs, variable costs, and total costs from one another.

Fixed Costs **Fixed costs** are those costs that in total do not vary with changes in output. Fixed costs are associated with the very existence of a firm's plant and therefore must be paid even if its output is zero. Such costs as rental payments, interest on a firm's debts, a portion of depreciation on equipment and buildings, and insurance premiums are generally fixed costs; they do not increase even if a firm produces more. In column 2 of Table 8.2 we assume that the firm's total fixed cost is $100. By definition, this fixed cost is incurred at all levels of output, including zero. The firm cannot avoid paying fixed costs in the short run.



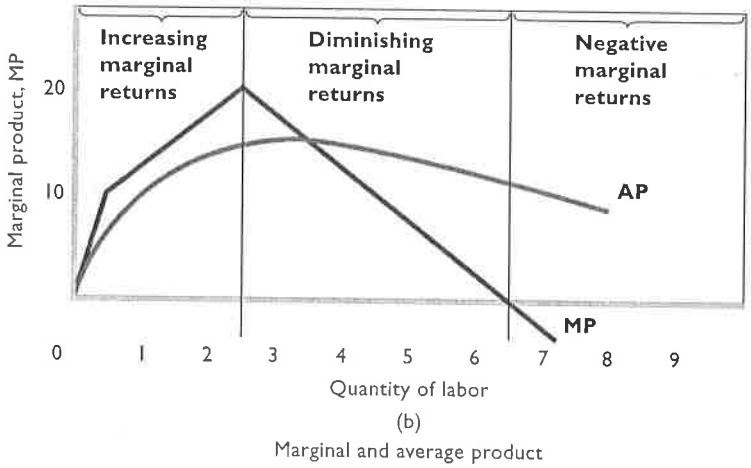


FIGURE 8.2 **The law of diminishing returns.** (a) As a variable resource (labor) is added to fixed amounts of other resources (land or capital), the total product that results will eventually increase by diminishing amounts, reach a maximum, and then decline. (b) Marginal product is the change in total product associated with each new unit of labor. Average product is simply output per labor unit. Note that marginal product intersects average product at the maximum average product.

QUICK QUIZ FOR FIGURE 8.2

1. Which of the following is an assumption underlying these figures?
   a. Firms first hire "better" workers and then hire "poorer" workers.
   b. Capital and labor are both variable, but labor increases more rapidly than capital.
   c. Consumers will buy all the output (total product) produced.
   d. Workers are of equal quality.
2. Marginal product is:
   a. the change in total product divided by the change in the quantity of labor.
   b. total product divided by the quantity of labor.
   c. always positive.
   d. unrelated to total product.
3. Marginal product in graph (b) is zero when:
   a. average product in graph (b) stops rising.
   b. the slope of the marginal-product curve in graph (b) is zero.
   c. total product in graph (a) begins to rise at a diminishing rate.
   d. the slope of the total-product curve in graph (a) is zero.
4. Average product in graph (b):
   a. rises when it is less than marginal product.
   b. is the change in total product divided by the change in the quantity of labor.
   c. can never exceed marginal product.
   d. falls whenever total product in graph (a) rises at a diminishing rate.

Answers: 1. d; 2. a; 3. d; 4. a