Mirror Images: Marginal Product and Marginal Cost

Most of the activities in this unit concern a firm's costs of production. You will learn about a firm's costs of producing a given amount of its product—*total fixed cost (TFC)*, *total variable cost (TVC)*, and *total cost (TC)*. You also will work with the firm's costs of a typical (average) unit of output—*average fixed cost (AFC)*, *average variable cost (AVC)*, and *average total cost (ATC)*. The most important measure of a firm's cost is *marginal cost (MC)* because it shows the change in the firm's total cost when it produces one more unit of output. You will not be surprised to find that the cost of producing output is based on the productivity of the firm. If a firm is highly productive, that means it is producing a lot of output from a given amount of resources, thus reducing its costs of production. Firms that are inefficient will have high production costs and be at a competitive disadvantage. Because high productivity implies low cost, economists treat a firm's cost measures as mirror images of its productivity measures.

A firm makes production decisions in two time horizons. The "short run" is a period of time in which the amount of some key factor of production, often capital, is fixed. Other factors, such as labor, are variable because the firm can increase or decrease the amount of these resources in the short run. In the "long run," all resources are variable and can be increased or decreased by the firm.

There are three measures of the productivity of a firm.

1. The firm's *total physical product* or *total output* (Q) is how many units of its good or service the firm produces in a specified period of time. If a firm produces 100 units per week, we express this as Q = 100.
2. The firm's *average physical product* (*APP*) shows how many units of output are produced by an average unit of labor (the variable resource). If the firm uses five units of labor (L) to produce 100 units of output each week, we say APP = Q/L = 100/5 = 20 units of output.
3. The firm's *marginal physical product* (*MPP*) tells us the change in total product when the firm adds an extra unit of labor to its fixed stock of capital. If, as a result of adding a sixth unit of labor the firm's total output increases from 100 units to 114 units, then the MPP of the sixth labor unit is +14 units: MPP = $\Delta Q/\Delta L$ = +14/+1 = +14.

Student Alert: The terms ***average physical product*** and ***average product*** **mean the same thing. Also,** ***marginal physical product*** **is the same as** ***marginal product.*** **Some textbooks use APP and MPP, while others use AP and MP. But you cannot use "average" terms interchangeably with "marginal" terms!**

The key productivity principle in the short run is the "law of diminishing marginal productivity" (also called the law of diminishing marginal returns). Assume a firm operates in the short run with a fixed amount of capital and with labor as its variable resource. The law of diminishing marginal productivity states that as the firm adds more labor units to its fixed stock of capital, eventually the MPP from an extra unit of labor will diminish.

Part A: The Productivity Measures of a Firm

Table 3-2.1 is a short-run production chart showing how the productivity of the firm changes as it adds additional units of labor to its fixed stock of capital. Assume the data refer to the firm's productivity in a one-week period.

1. Complete Table 3-2.1. Some data are already included in the chart. Put the values of MPP at the new labor level. For example, when the firm increases its labor from one to two units per week, its total output increases by 15 units. Write "+15" at L = 2 in the MPP column.

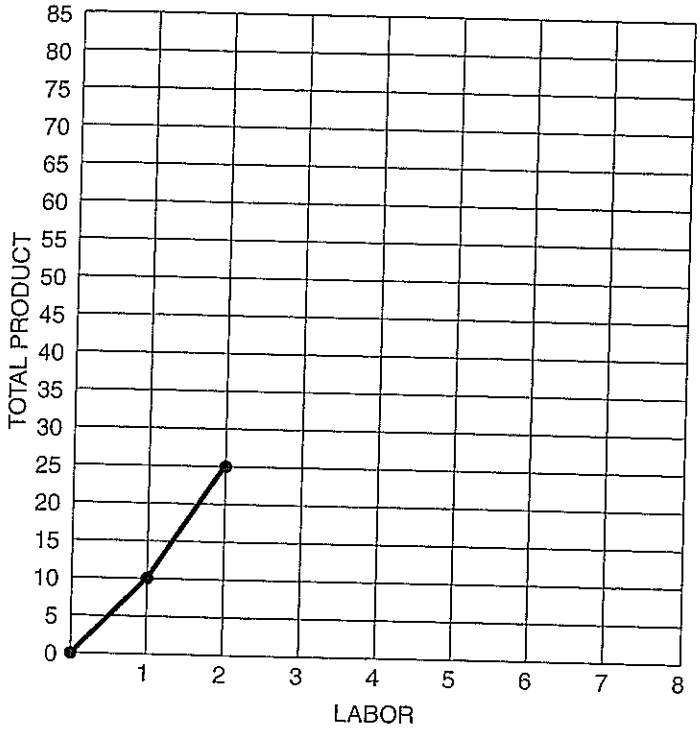
Table 3-2.1

The Three Productivity Measures of a Firm

L	Q	MPP = ΔQ/ΔL	APP = Q/L
0	0	–	–
1	10		10.0
2	25	+15	
3	36		
4	46		11.5
5	55	+9	
6	63		
7	63		9.0
8	60	–3	

2. When you have completed Table 3-2.1, plot the L and Q data in Figure 3-2.1. (The first two combinations are plotted for you already.) This Q curve shows how much total output the firm produces with different amounts of labor. Note that the firm's total product increases as it adds more labor, but eventually the total product declines if the firm adds too many labor units on its limited amount of equipment.

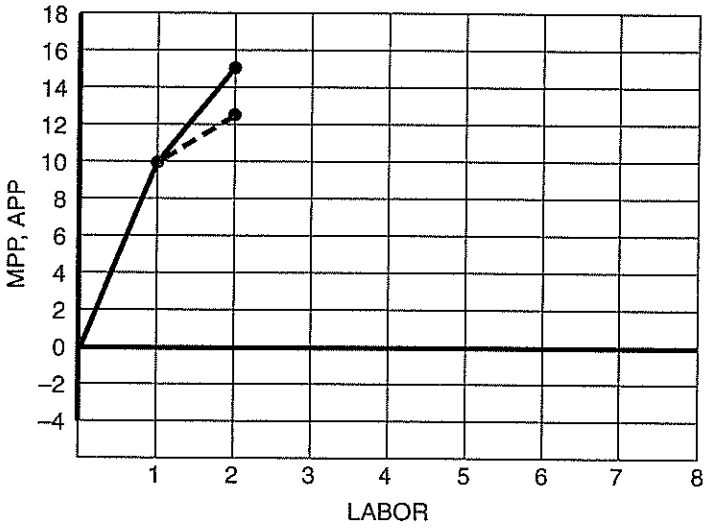
Figure 3-2.1
Total Product



3. Now plot the L, MPP, and APP data in Figure 3-2.2. You can connect the MPP points with a solid line and the APP points with a dotted line. (Some combinations are plotted for you already.) Plot the values of MPP at the new labor level. For example, put a dot on the graph at the combination of L = 2 and MPP = +15 since the MPP resulting from adding the second labor unit is 15 units of output. Note that both MPP and APP increase initially but then decrease as the firm adds more units of labor.

Figure 3-2.2

Marginal Physical Product and Average Physical Product



4. Diminishing marginal productivity sets in with the addition of the _____ labor unit.

5. The average physical product continues to increase as long as the marginal physical product is (*greater than / equal to / less than*) the average physical product.

6. Can the average physical product of labor be negative? Why?

7. Can the marginal physical product of labor be negative? Why?

8. Total product increases as the firm adds units of labor as long as the marginal physical product is (*positive / zero / negative*).

9. Although our graphs have no information about the price of the good or the price of labor, we can conclude that the firm will not want to hire a unit of labor for which marginal physical product is (*diminishing / negative*). Explain your answer.

10. What is the relationship between marginal physical product and total product?

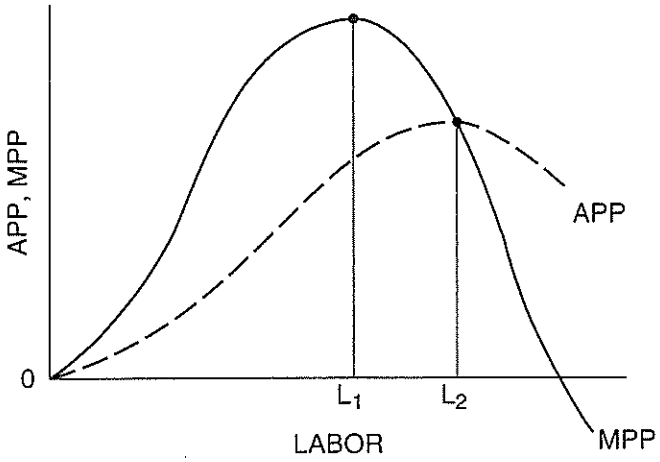
11. What is the relationship between marginal physical product and average physical product?

Part B: Productivity and Cost: A Mirror View of Each Other

As you work with productivity and cost graphs, note how the axes are labeled. The productivity graphs typically have L on the horizontal axis because that is the variable resource that the firm changes in order to alter its level of total output. The vertical axis has some measure of productivity (such as Q or APP). There are no dollar signs on a productivity graph because such graphs are not dealing with revenue or cost. The cost graphs always have total output or total physical product (Q) on the horizontal axis because costs are expressed in relation to the Q of the firm. Cost graphs always have a dollar-measured concept on the vertical axis (such as total cost [TC]or marginal cost [MC]).

Figure 3-2.3 shows the relationship between a firm's MPP and APP. The graph assumes MPP initially increases as the firm adds labor units due to specialization of labor on the firm's equipment. Eventually diminishing marginal productivity sets in, which means that at some point APP also will decline as more labor units are added.

Figure 3-2.3
Marginal Physical Product and Average Physical Product



12. Diminishing marginal productivity sets in at (L_1 / L_2) labor units.

13. APP increases as long as MPP is (*greater than / equal to / less than*) APP.

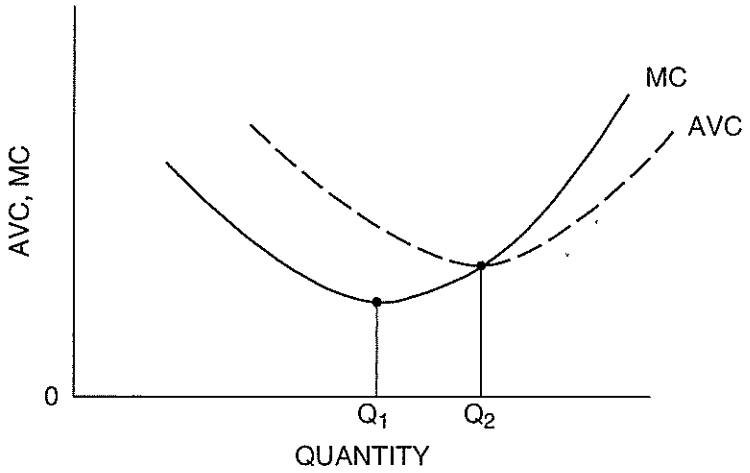
14. APP decreases as long as MPP is (*greater than / equal to / less than*) APP.

15. Why is APP maximized at L_2 labor units?

16. "If MPP is diminishing, then APP must also be diminishing." Is this a correct statement? Why?

Figure 3-2.4 shows the relationship between a firm's MC and AVC: AVC = TVC/Q. If the firm has L as its only variable resource, then AVC represents the labor cost per unit of output. Suppose a firm pays each of its 10 workers a daily wage of \$80 and produces a Q of 400 units. Its TVC is \$800 = (10)(\$80), and its AVC is \$2 = \$800/400. Each of its 400 units has a labor cost component of \$2.

Figure 3-2.4
Marginal Cost and Average Variable Cost



17. AVC decreases as long as MC is (*greater than / equal to / less than*) AVC.

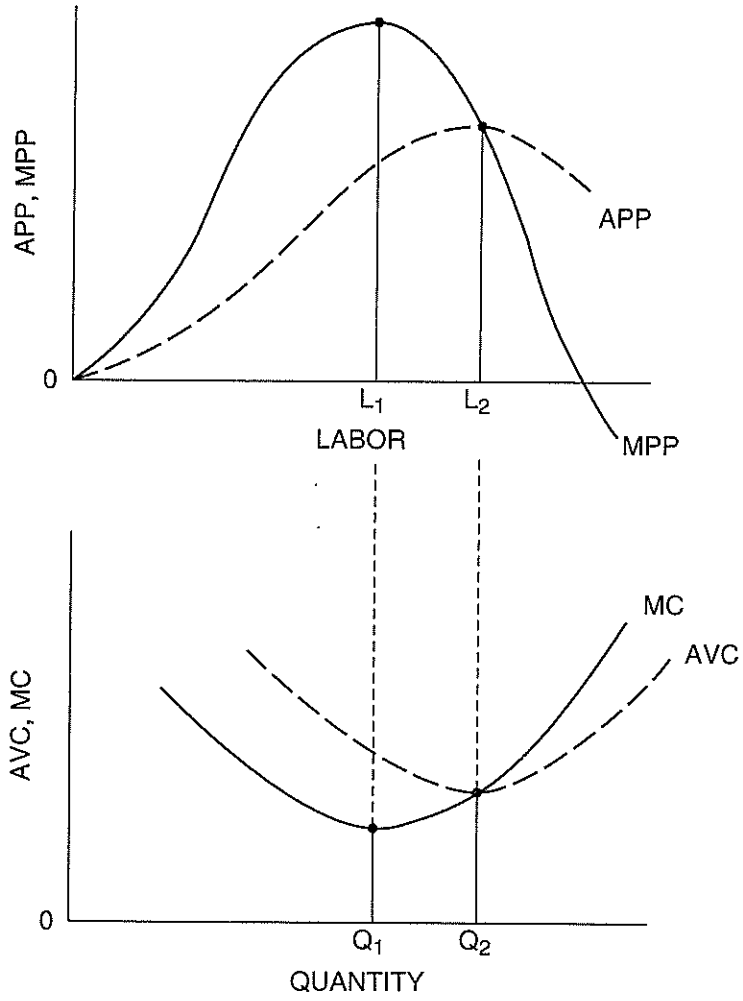
18. AVC increases as long as MC is (*greater than / equal to / less than*) AVC.

19. Why is AVC minimized at Q_2 units of output?

20. "If MC is increasing, then AVC must also be increasing." Is this a correct statement? Why?

Figure 3-2.5

Mirror Image of Productivity and Cost Measures



The productivity of a firm is the basis of its cost. A firm wants to be highly productive in order to keep its costs low. Refer to Figure 3-2.5 to answer the following questions based on a firm's productivity and cost measures. Assume outputs Q_1 and Q_2 are produced by this firm when it uses L_1 and L_2 labor units, respectively.

21. As long as the MPP of labor is increasing, the MC of producing extra units of output will (*increase / not change / decrease*).

22. As long as the MPP of labor is decreasing, the MC of producing extra units of output will (*increase / not change / decrease*).

23. The MC of producing extra units of output will be minimized when the MPP of labor is _____.

24. As long as the APP of labor is increasing, the AVC of producing output will (*increase / not change / decrease*).

25. As long as the APP of labor is decreasing, the AVC of producing output will (*increase / not change / decrease*).

26. The AVC of producing output will be minimized when the APP of labor is _____.

Understanding the Different Cost Measures of a Firm

Part A: Different Meanings of the Word "Profit"

Economists assume the goal of a firm is to maximize its total profit. This sounds like an easy goal to understand, but the economist's view of profit is different from that of an accountant. Let's use a short story about Pat to illustrate the differences. First, we must define two categories of cost. An *explicit cost* is an expenditure by the firm; it could be a payment for items such as wages, rent, or advertising. An *implicit cost* is the opportunity cost of an entrepreneur using his/her own resource in the company.

An economic short story: Pat is a banker who earned an annual salary of $50,000 last year. She invested a total of $100,000 of her own money in various savings assets, which gave her interest income of $6,000. Pat also owns a small building, which she leased to someone last year for $14,000. But now Pat decides she wants to leave banking and set up her own landscaping company. Rather than borrowing money to buy new equipment, she uses her $100,000 in savings to buy it. She also decides to stop leasing her building so she can use it for her new enterprise. In her first year of landscaping, Pat brings in total revenue of $300,000. She spends $220,000 for such things as her equipment, workers, supplies, and insurance.

1. An accountant defines total profit to be total revenue minus explicit costs. Pat's *accounting profit* from her landscaping company is $_____ this year.

2. In addition to explicit costs, an economist considers implicit costs as well. This year, Pat's *economic profit* from her landscaping business is $_____.

3. Another type of profit is called *normal profit*. It recognizes that Pat should "pay herself" for using her resources in her own company. Her normal profit, which is equal to her implicit costs, indicates the income Pat's resources would have earned had they been used in their best alternative occupations. Pat's normal profit is $_____.

4. If Pat's total revenue from her landscaping business is only $280,000, what would be the values of the different measures of profit?

   (A) Accounting profit = $_____

   (B) Economic profit = $_____

   (C) Normal profit = $_____

Part B: The Seven Measures of a Firm's Short-Run Costs

The Morton Boat Company produces the very popular Jazzy Johnboat, which is desired by many fishermen and fisherwomen. Assume the firm operates in the short run with a fixed amount of equipment (capital) and views labor as its only variable resource. If it wants to produce more output, it will add more units of labor to its stock of equipment. Of course, the firm will have to pay its workers and also the owners of its capital, which means its total cost will increase as it produces more boats. Table 3-3.1 defines the seven cost measures the Morton Boat Company must consider.

Table 3-3.1

The Seven Short-Run Cost Measures of a Firm

Cost measure	What it means	How to calculate it
Total fixed cost (TFC)	All costs that do not change when output changes. TFC is a constant amount at all Q levels.	TFC = total cost of all fixed factors of production TFC = Q × AFC
Total variable cost (TVC)	All costs that do change when output changes. TVC gets bigger as Q increases because the firm needs more labor to make more output.	TVC = total cost of all variable factors of production TVC = Q × AVC
Total cost (TC)	All costs at a given output level. TC is the sum of TFC and TVC. TC increases as the level of output increases.	TC = TFC + TVC TC = Q × ATC
Average fixed cost (AFC)	Fixed cost (capital cost) per unit of output. AFC always falls as Q rises since TFC is a constant value.	AFC = TFC/Q
Average variable cost (AVC)	Variable cost (labor cost) per unit of output. AVC falls at first, and then rises as Q increases.	AVC = TVC/Q
Average total cost (ATC)	Total cost per unit of output. It is the sum of AFC and AVC. ATC falls at first, and then rises as Q increases.	ATC = TC/Q ATC = AFC + AVC
Marginal cost (MC)	Change in the firm's TC when it produces another unit of output. Also shows change in TVC from an extra unit of output. MC falls at first, and then rises as Q increases.	MC = ΔTC/ΔQ MC = ΔTVC/ΔQ because the only part of TC that changes when more Q is produced is TVC.