Part 3

BUSINESS BEHAVIOR AND MARKET EQUILIBRIUM

Chapter 6

Introduction to Production and Resource Use

Maximum economic production does not lead necessarily to maximum economic satisfaction.

Sir Josiah Stamp (1880–1941)

Chapter Outline

Businesses employ a wide variety of resources during the process of producing a particular good or service. A wheat farm, for example, uses a different combination of resources than does a cotton gin or a meat packing firm. Some businesses use labor on a more seasonal basis than others do. And some businesses require more land when producing their product than others do.

Despite the major differences in resources used by certain types of businesses involved in the nation's food and fiber industry, there are a number of features associated with the use of resources by these businesses that can be generalized. First, inputs can be grouped into several specific categories that facilitate their description and analysis. All these firms also share specific production and cost relationships that provide the foundation for the economic decisions made by a business, including the level of output to produce and the level of variable inputs to employ as it utilizes its current productive capacity.

In this chapter, we will assume the existence of **perfect competition**. The farm sector comes closer than any other sector of the economy to satisfying the conditions of perfect competition. We will also focus initially on understanding the effect that varying the use of a single input has upon the production of a *single product*. Both of these assumptions will be reviewed in later chapters when we examine multiple input choices, multiple product choices, and the nature of decisions under **imperfect competition**, which exists in several sectors of the food and fiber industry.

Competition is classified as either perfect or imperfect. Farmers and ranchers come as close as any sector in the economy of satisfying the conditions for perfect competition.

The focus of this chapter is on introducing some important physical and economic relationships, which will be broadened in later chapters. A thorough understanding of the concepts presented in this chapter is essential before proceeding with the remaining chapters in this book.

Conditions for Perfect Competition

What does it take to have a perfectly competitive economic situation? Before we discuss how economic decisions are made, let us look at the economic environment in which they are made. An input or product market structure can be classified as perfectly competitive if the following conditions hold:

- The product sold by businesses in a sector is homogeneous. In other words, the product sold by one business is a perfect substitute for the product sold by the other businesses. This enables buyers in the market to choose from a number of sellers.
- Any business can enter or leave the sector without encountering serious barriers for entry. Resources must be free to move into the sector without encountering barriers to entry (e.g., patents, licensing). The same condition holds for resources leaving the sector.
- There must be a large number of sellers of the product. No single seller has a disproportionate influence on price; each is a price taker.
- Perfect information must exist for all participants regarding prices, quantities, qualities, sources of supply, and so on.

When all four conditions hold, we can say a market's structure is perfectly competitive. Businesses that satisfy these conditions are also, by definition, perfectly competitive. A perfectly competitive business is a price taker, or it accepts the price of the product it receives in the product market or pays in the input as given. A corn farmer is a good example of a perfect competitor. There are thousands of corn producers that produce a homogeneous product (e.g., no. 2 yellow corn), each with equal access to corn market information, and each with no ability to control the price of corn they receive, or the price they pay for fuel.

Classification of Inputs

It is helpful to have some broad classifications in mind when discussing production relationships. These classifications not only promote efficient communication but also help to conduct economic analyses. Although not uniformly accepted, classification of inputs into land, labor, capital, and management has proven useful.

Land

Inputs consist of land, labor, capital, and management.

Land includes not only the land forms associated with the earth's crust but also resources such as minerals, forests, groundwater, and other resources given by nature. Such resources are classified as either *renewable* (e.g., forests), or *nonrenewable* resources (e.g., minerals). An example of a key land input in farming activities is productive topsoil, which has many of the attributes of a nonrenewable resource identified in Chapter 2.

Labor

Labor includes all labor services used in production with the exception of managerial activities. In crop production, labor activities include seed bed preparation, planting, irrigation, chemical applications, and harvesting. Labor activities in a canning plant include receiving and grading of fruit and vegetables arriving from the field, blanching, inspection, canning, and warehousing.

Several combines picking and shelling corn demonstrate the combination of land, capital, and labor to produce a raw agricultural product.

Capital

The term *capital* takes on different meanings in different contexts. When using the term *capital*, a banker is referring to stockholders' equity appearing on a bank's balance sheet. In a discussion of input use in the context of production, however, capital refers to manufactured goods such as fuel, chemicals, tractors, trucks, and buildings that provide productive services to their users.[1]

A key aspect of capital goods is that they do not provide consumer satisfaction directly but rather aid in the production of other goods and services. Nondurable capital inputs such as fuel and chemicals are entirely used up during the current production period. Durable capital inputs such as machinery and buildings, on the other hand, are utilized over a period of years.

Management

The final input category is management. Its functions are varied and are easier to conceptualize than to measure. Like the leader of an orchestra, farmers and agribusinesses must make decisions as to how, when, and what to produce when organizing their inputs, when and how to market the business's output, how large to grow, and how to finance business expansion.

In this chapter, we abstract from most of management's differences and instead highlight some concepts common to all inputs, with particular emphasis on technical relationships. Input and product prices will be meshed with these technical relationships in this chapter when we discuss those input-output combinations that achieve a specific economic goal, such as profit maximization.

→ there's whole books on them

Important Production Relationships

Several key relationships between the level of output and the level of input use must be understood before we consider the prices of these inputs and outputs. These relationships include the concept of a production function that reflects this input-output relationship and the concepts of marginal and average product.

The relationship between outputs and inputs is captured in a production function.

The Production Function

A production function characterizes the physical relationship between the use of inputs and the level of output. Suppose you are a salesperson for a fertilizer company, and a farmer asks you to recommend the amount of fertilizer to apply per acre to maximize profit. Before you can recommend the quantity of fertilizer the farmer should apply, you must have some knowledge of the physical relationship between yields and the level of fertilizer use. If the application of more fertilizer has no effect on crop yields, the answer is simple: a profit-maximizing farmer obviously should not apply any additional fertilizer.

link to epidemiology.

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[1] Jargon often comes under attack by those outside a discipline of study. For example, Edwin Newman in *Strictly Speaking*, New York, 1980, Warner Books, has satirized the excessive use of such language. Economics seems to be no better or worse than other disciplines. Indeed, in most introductory classes, learning the jargon is an important portion of the course.

Table 6.1 Production Relationship for TOP-AG, Inc.

Point on Figure 6.1	(1) Daily Labor Use	(2) Daily Output Level	(3) Marginal Physical Product, Δ(2) ÷ Δ(1)	(4) Average Physical Product, (2) ÷ (1)
A	10.0	1.0		.10
B	16.0	3.0	.33	.19
C	20.0	4.8	.45	.24
D	22.0	6.5	.85	.30
E	26.0	8.1	.40	.31
F	32.0	9.6	.25	.30
G	40.0	10.8	.15	.27
H	50.0	11.6	.08	.23
I	62.0	12.0	.03	.19
J	76.0	11.7	−.02	.15

In the general case, where there are *n* number of identifiable inputs, a production function may be expressed as

$$\text{output} = f(\text{quantity of input 1, quantity of input 2, } \ldots, \text{ quantity of input } n) \quad (6.1)$$

which, in words, simply states that the level of output is a function of (i.e., depends on) how much of input 1, input 2, . . . , and input *n* you use. For example, in an early 1880s agricultural setting, crop output was a function of the services provided by labor, land, seed, a workhorse, a few basic implements, and management.

A production function is a rule associating an output to given levels of the inputs used. Output is measured in physical units such as bushels of wheat, gallons of milk, cases of canned peas, etc.[2] If one input in a production is varied, and all the other inputs are held fixed at their existing level, we can rewrite Equation 6.1 as

$$\text{output} = f(\text{labor} \mid \text{capital, land, and management}) \quad (6.2)$$

in which the bar separating the first input from all other inputs indicates that only the first input is being varied and the other inputs are held fixed at existing levels.[3] This enables us to examine the relationship between labor and output as opposed to the other inputs employed in the firm's production process.

Column 2 in Table 6.1 reports the potential output levels the hypothetical firm TOP-AG can achieve per day with specific levels of labor use. One input (labor) is varied here, and all other inputs (capital, land, and management) are held fixed at their current levels. Column 1 in Table 6.1 indicates the level of daily labor use associated with the levels of output in column 2. For example, if the daily use of labor is 10 hours a day, column 2 in Table 6.1 indicates the level of output would be one unit.

[2] Another way of characterizing a production function is to think of it as a cooking recipe. For example, it takes a specific combination of inputs to bake a cake. Baking a cake requires flour, eggs, water, and other ingredients. It also requires labor to blend the ingredients and capital (in the form of an oven and energy) to bake the ingredients.

[3] The terms *output* and *total physical product* can and will be used interchangeably throughout this and subsequent chapters.

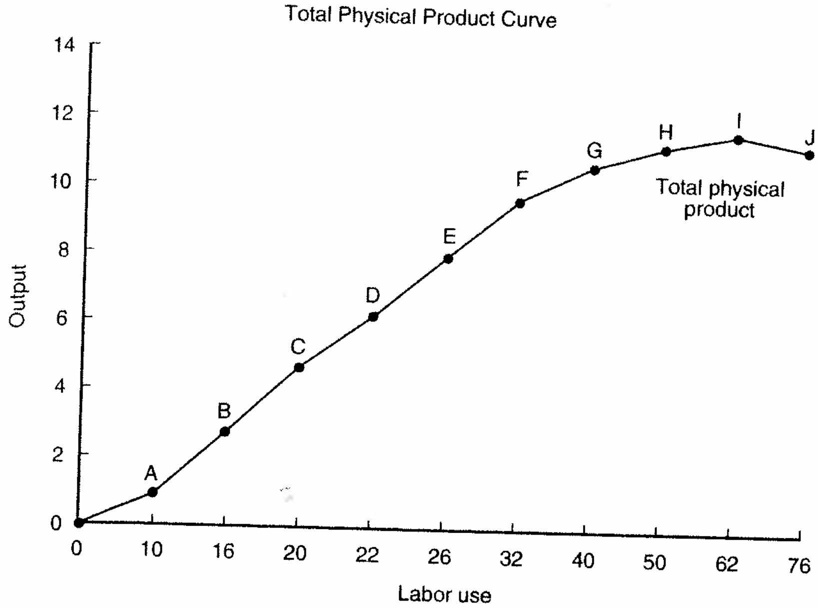

FIGURE 6.1 The marginal physical product curve for TOP-AG crosses the horizontal axis (i.e., negative) when the total physical product curve has reached its peak and begins to decline.

Total Physical Product Curve

The TPP curve shows the relationship between output and one input, holding other inputs in the production function constant.

If we were to connect this and other combinations of output and labor use reported in columns 1 and 2 in Table 6.1, we would obtain the input-output relationship known as the **total physical product curve** presented in Figure 6.1. By reading along the *X*, or horizontal, axis to a particular input level, reading up to the total physical product curve, and then reading over to the *Y*, or vertical, axis, you can determine the level of output associated with this input use.

The total physical product curve typically will initially increase at an increasing rate, then increase at a decreasing rate, and finally decrease over a full range of potential input use levels. These and other properties of the total physical product curve can be better understood by calculating two additional product curves.

Marginal Physical Product Curve

If a farmer adds another pound of fertilizer per acre, will corn yields increase? If so, by how much? Or would more fertilizer "burn out" the crop and cause yields to decline? Does the addition of another employee at a grain elevator expand its output? These questions give rise to the important concept of **marginal physical product**.[4]

The marginal physical product for an input is the change in the level of output associated with a change in the use of a particular input, where all other

[4] Some refer to marginal physical product as simply "marginal product." We will follow the time-honored tradition of using the word *physical* in our discussion, which makes it clear that the units of measurement are in physical units rather than dollars.

inputs used in the production process remain fixed at their existing levels. Stated in equation form, the marginal physical product is equal to

$$\text{marginal physical product} = \frac{\Delta \text{ output}}{\Delta \text{ input}} \tag{6.3}$$

in which the "Δ" sign stands for "change in."

To illustrate the calculation and interpretation of the marginal physical product, consider the data for TOP-AG in Table 6.1. There may be some confusion regarding which level of output to associate with a marginal physical product as you read this table. Why are the values in column 3 on a different line than the other columns in this table? While the other columns represent levels of activity, column 3 reflects changes in levels of activity.

For example, when the daily labor use at TOP-AG is increased from 10 hours to 16 hours, the marginal physical product would be 0.33 units of output (i.e., 0.33 = [3.0 − 1.0] ÷ [16.0 − 10.0]). Thus, if labor use is increased by one hour, the business can complete assembling one-third of another spare part. This value is listed between the rows associated with 10 and 16 hours of labor and one and three units of output. If 20 hours of labor were used, the marginal physical product would be 0.45 units of output (i.e., 0.45 = [4.8 − 3.0] ÷ [20.0 − 16.0]) and so on. The marginal physical product curves for TOP-AG are plotted in Figure 6.2.

The MPP curve shows the change in output from the use of another unit of one input, holding other inputs in the production function constant.

An important relationship exists between the total and marginal physical products. The slope of the total physical product curve (with respect to the use of labor) is approximately equal to the marginal physical product. If the change in labor use is very small, the marginal physical product is exactly equal to the slope of the total physical product curve. In other words, the marginal

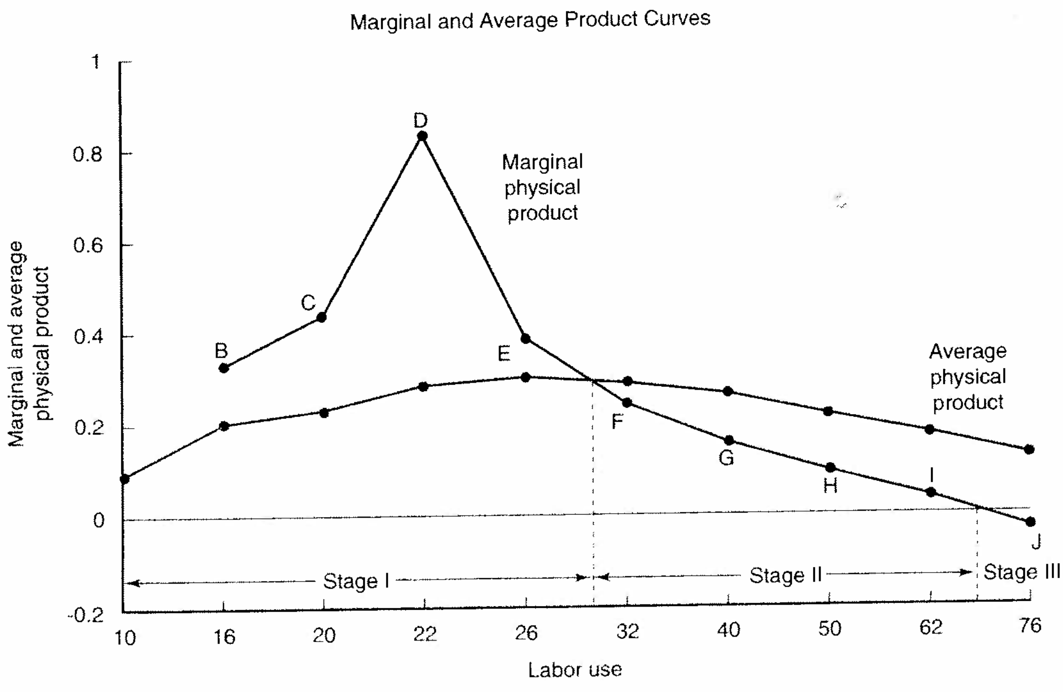

FIGURE 6.2 The marginal physical product curve illustrates the change in output associated with a change in labor input use by TOP-AG. The marginal physical product curve for labor falls below zero at approximately 70 hours of labor use.

physical product curve measures the rate of change in output in response to a change in the use of labor.

The marginal physical product curve takes certain twists and turns as we move along the total physical product curve. For example, the marginal physical product curve cuts the average physical product from the top at approximately 30 hours of labor, where the total physical product curve in Figure 6.1 began to increase at a decreasing rate.[5] A particularly important twist is that, when the total physical product curve is *decreasing*, the marginal physical product curve will be *negative*. This can be seen in Table 6.1 at the point at which TOP-AG increases its use of labor from 62 hours a day to 76 hours. Column 3 shows that the marginal physical product becomes negative at about 70 hours. The point at which the marginal physical product becomes negative corresponds to the point where the total physical product curve begins to decline.[6] Remember the marginal physical product approximates the slope of the total physical product curve. This characteristic will help us identify the rational range of production over the total physical product curve. This issue will be addressed shortly when we discuss the stages of production.

Average Physical Product Curve

A final input-output relationship is the **average physical product**. The average physical product is related to the level of output relative to the level of input use instead of their incremental change. Stated in equation form,

$$\text{average physical product} = \frac{\text{output}}{\text{input}} \tag{6.4}$$

In the context of our example, the average physical product represents the output per hour of *labor* with all other input levels held constant.

The APP curve shows the level of output from a level of use of a specific input, holding other inputs in the production function constant.

Column 4 in Table 6.1 presents the value of the average physical product for labor use for TOP-AG. The average physical product is shown to rise as output rises, but then falls as output expands at a decreasing rate. The average physical product curve for TOP-AG in Figure 6.2 is intercepted from above by the marginal physical product curve as output begins to increase at a decreasing rate.

A review of Table 6.1 and Figure 6.2 suggests the following conclusions:

- If the marginal physical product curve is above the average physical product curve, the average physical product curve must be rising.
- If the marginal physical product curve is below the average physical product curve, the average physical product curve must be falling.
- The marginal physical product curve therefore cuts the average physical product curve from above at that point where the average physical product curve reaches its maximum.

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[5] The nature of the linear segments comprising the total physical product (TPP), marginal physical product (MPP), and average physical product (APP) curves precludes the MPP curve from intersecting the APP curve at its exact maximum and the MPP curve from being precisely zero at the peak of the TPP curve in Figure 6.1. A smoothing of these relationships or small linear segments would more closely approximate these conditions.

[6] You can find the point at which the total physical product curve changes from increasing at an increasing rate to increasing at a decreasing rate by drawing a ray emanating from the origin and seeing where this ray is tangent to the total physical product curve. At this point of tangency, TOP-AG's marginal physical product is equal to its average physical product.

Table 6.2 Stages of Production

Stage	Usage of Labor	Operate?
I	Between 0 and 30	Yes
II	Between 30 and 70	Yes
III	Greater than 70	No

We now have the three input-output relationships we need to evaluate ranges of rational and irrational regions of production.

Stages of Production

To understand the production relationships illustrated in Table 6.1, you may divide them into stages of production. Stage I is the point at which the marginal physical product lies above the average physical product curve. Stage II is the point at which input use begins at the end of stage I and continues until the value of the marginal physical product becomes equal to zero. Stage III is the point at which input use lies to the right of stage II, or at which the marginal physical product is negative.

Returning to the example in Figure 6.2, the stages of production associated with the use of labor by TOP-AG are outlined in Table 6.2. The irrational nature of stage III under normal economic conditions can be easily explained. If input is increased beyond 70 units of labor, output will fall. It is irrational to increase the use of an input if it only leads to less output. Would you recommend that TOP-AG increase its daily use of labor to 76 hours daily knowing that output would fall?

Electing to stop in stage I is also irrational, although it may be more difficult to see why. A good grade on your last examination (marginal physical product) that raises your semester average (average physical product) is an example of an outcome occurring during stage I. If you were permitted to take a make-up test for the last examination and substitute this grade for your original test score, you would likely take this make-up test only if you felt you could increase your semester average grade.

Stage II of production represents the range of interest to economists. Why stop in stage I, and why produce in stage III?

In the context of Table 6.1, look at the values in columns 3 and 4. A marginal physical product of 0.85 units per hour increases the average physical product from 0.24 units to 0.30 units. And a marginal physical product of 0.40 units increases the average physical product from 0.30 units to 0.31 units. But a lower marginal physical product of 0.25 units brings the average physical product down to 0.30 units. The first two observations are in stage I, and the third observation would occur in stage II.

Why should you stop producing if the output of your business is increasing at an increasing rate? As long as the average physical product is rising, you should expand input use. We will leave the presentation of the economic rationale for support of this argument for later in this chapter. At this point, we recognize that stage II appears to hold primary interest for a firm that wishes to maximize its profits.

Figure 6.2 shows that the marginal physical product of labor use is falling throughout stage II. This phenomenon is so frequently observed that it is called a law—the **law of diminishing marginal returns**. This law states that

> as successive units of a variable input are added to a production process with the other inputs held constant, the marginal physical product eventually decreases.

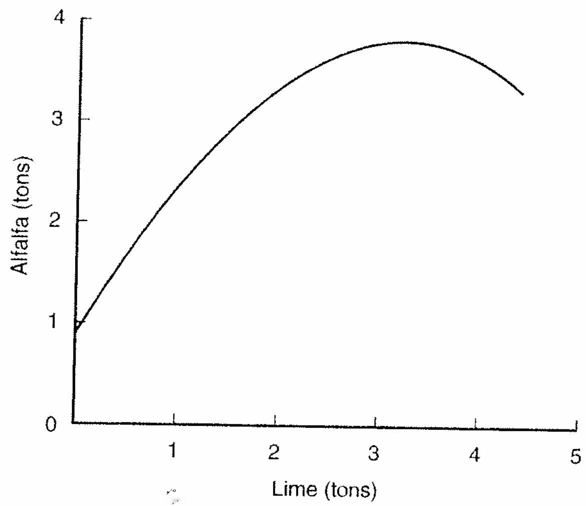


FIGURE 6.3 Input-output relationship between lime and alfalfa.

(*Source:* Hall H, Free W: *On evaluating crop response to lime in the Tennessee Valley Region,* Southern Journal of Agricultural Economics: *75–81, December 1979.)*

Therefore, in the region of greatest economic interest, we would expect to observe diminishing marginal physical product for variable inputs.

A real-world input-output relationship between lime and alfalfa estimated by Free and Hall is illustrated in Figure 6.3. The total physical product curve illustrated here contains only stage II and stage III of production. This curve shows that, when lime is increased beyond three tons per acre, the total physical product curve actually begins to decline—evidence that stage III is present. No rational farmer would want to increase the use of lime beyond this point, which implies a "burning out" of the crop when too much lime is applied.

A farmer obviously would not knowingly apply lime to the point where stage III occurs. If a farmer asked you to identify the application rate in stage II that makes the most economic sense, what would you advise this farmer? Do you have all the information you need to provide the farmer an answer? The answer is no. Although knowledge of the production relationships discussed thus far is extremely important, we must also know the costs of production.

■ Assessing Short-Run Business Costs

Variable costs vary with the level of production. Fixed costs do not.

The total cost of production is the costs associated with the use of *all* inputs to production. A business's **total costs** in the short run can be divided into **fixed costs** and **variable costs**. We learned that fixed costs are those costs that *do not* vary with the level of input use and that variable costs are those costs that *do* vary with the level of input use. It is important to understand the measurement of these and other concepts of cost and their relationship to the level of production activity when making short-run economic decisions.

Two additional cost concepts related to the level of production that are extremely important to economic decision making are marginal costs and average costs. Each of these cost concepts, and how they are related to the total, average, and marginal product curves, is addressed in this section.

Total Costs and the TPP Curve

Figure 6.1 shows that the total physical product (TPP) curve typically first increases at an increasing rate, then increases at a decreasing rate, and finally

Table 6.3 Short-Run Cost Schedule for TOP-AG, Inc., and Selected Cost Concepts

Point on Figure 6.1	(1) Total Output	(2) Total Fixed Cost	(3) Average Fixed Cost, (2) ÷ (1)	(4) Total Variable Cost	(5) Average Variable Cost, (4) ÷ (1)	(6) Total Cost, (2) + (4)	(7) Marginal Cost, Δ(6) ÷ Δ(1)	(8) Average Total Cost, (3) + (5)
A	1.0	100.00	100.00	50.00	50.00	150.00		150.00
B	3.0	100.00	33.33	80.00	26.67	180.00	15.00	60.00
C	4.8	100.00	20.83	100.00	20.83	200.00	11.11	41.67
D	6.5	100.00	15.38	110.00	16.92	210.00	5.88	32.31
E	8.1	100.00	12.35	130.00	16.05	230.00	12.50	28.40
F	9.6	100.00	10.42	160.00	16.67	260.00	20.00	27.08
G	10.8	100.00	9.26	200.00	18.52	300.00	33.33	27.78
H	11.6	100.00	8.62	250.00	21.55	350.00	62.50	30.17
I	12.0	100.00	8.33	310.00	25.83	410.00	150.00	34.17
J	11.7	100.00	8.55	380.00	32.48	480.00	n/a	41.03

decreases. In light of this curve, what do the **total variable cost** curve and **total fixed cost** curve look like?

A complete cost schedule for our hypothetical business TOP-AG is presented in Table 6.3. We have assumed that TOP-AG pays $5 per hour for labor and has fixed costs of $100 per hour. This includes $75 of explicit costs and $25 of implicit costs. No matter what happens to output in column 1, fixed costs in column 2 remain the same. The current property tax assessment owed by a business will be the same whether it produces at its capacity or produces nothing at all.

Total variable costs per hour for our hypothetical business TOP-AG are shown in column 4 of Table 6.3. Looking at both columns 1 and 4, we see that when the level of output rises, the level of total variable costs rises. A factory will need more labor and will incur more labor costs if management decides to expand production.

Figure 6.4*A*, graphically illustrates the nature of the total cost, total variable cost, and total fixed cost series reported in Table 6.3. The total fixed cost curve is parallel to the horizontal axis, thus illustrating its fixed nature when output rises. The total variable cost curve, on the other hand, rises when the level of output rises. Finally, the total cost curve, which reflects both fixed and variable costs, rises when output rises. The constant gap between the total cost curve and total variable cost curve when output rises is equal to $100, or the level of fixed costs for our hypothetical business.

These total cost measures serve as the basis for average variable, average fixed, and average total costs, and for marginal costs.

Average Costs and the APP Curve

The concept of **average cost** involves measuring costs per unit of output, or the level of cost associated with the level of output. The concepts of total costs, fixed costs, and variable costs discussed may be expressed in terms of average costs as

$$\text{average total costs} = \frac{\text{total costs}}{\text{output}} \qquad (6.5)$$

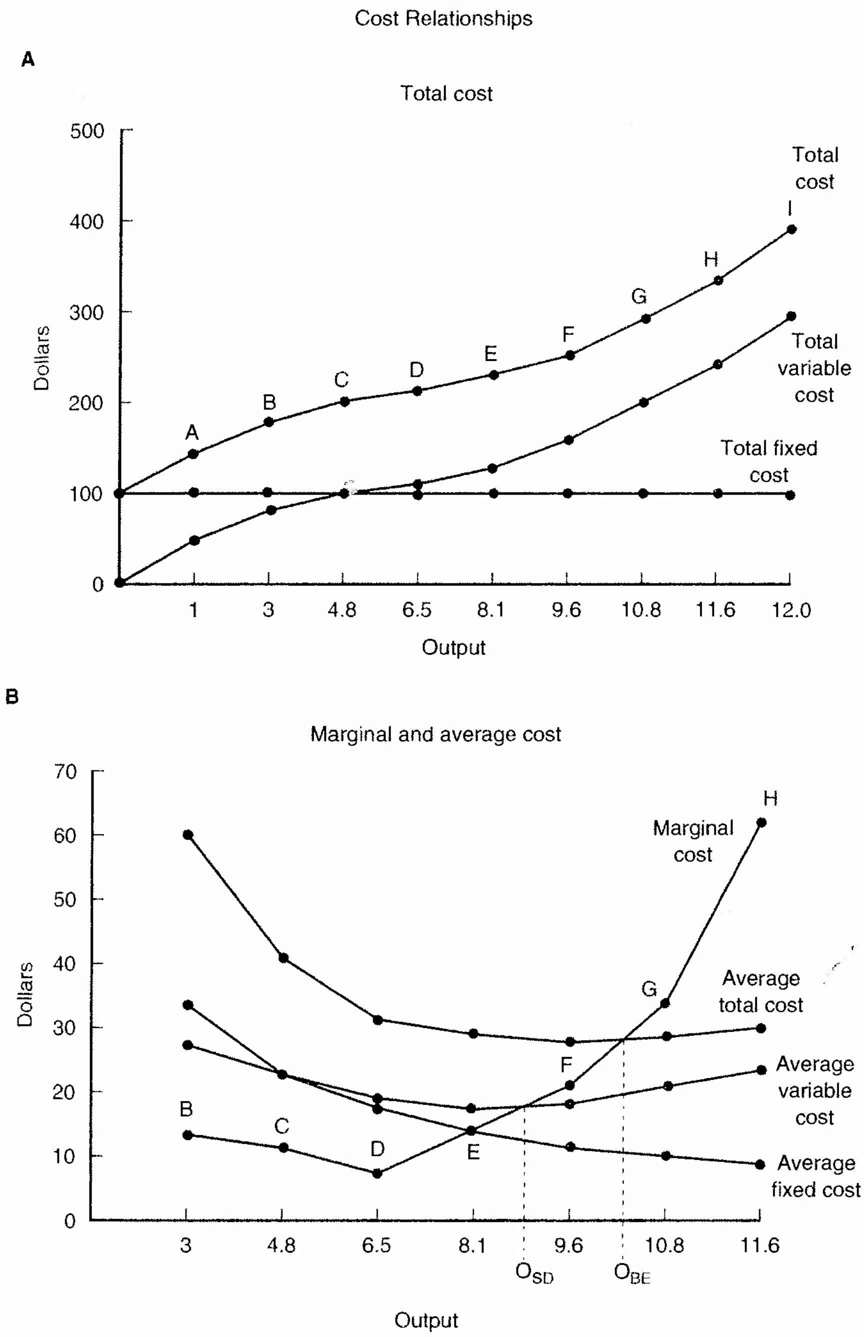


FIGURE 6.4 The cost relationships calculated for TOP-AG in Table 6.3 are plotted above. Output levels O_{BE} and O_{SD} illustrate that the marginal cost curve intersects the average variable and average total cost curves at their minimum.

$$\text{average fixed costs} = \frac{\text{total fixed costs}}{\text{output}} \tag{6.6}$$

$$\text{average variable costs} = \frac{\text{total variable costs}}{\text{output}} \tag{6.7}$$

To determine where in stage II we should produce to maximize profits, we need to study average and marginal costs associated with production.

Average fixed costs for TOP-AG are calculated in column 3 of Table 6.3. **Average variable costs** for this business are calculated in column 5. **Average total costs**, which are equal to average fixed costs plus average variable costs, are calculated in column 8 in Table 6.3. Figure 6.4*B*, illustrates the general nature of these three short-run average cost curves. Average fixed costs decline over the entire range of production because they do not vary with output. Average variable costs, on the other hand, normally decrease up to a certain output level and then increase when output expands further.

If you compare the average variable cost curve in Figure 6.4 with the APP curve in Figure 6.2, you will see that these two curves are mirror images of each other. Although the APP curve for TOP-AG is convex, its average variable cost curve is concave. The maximum of the APP curve of 0.31 units in column 4 of Table 6.1 is attained at 26 hours of daily labor use and 8.1 units of output. The minimum of the average variable cost curve of $16.05 in column 5 of Table 6.3 was also attained at 8.1 units of output. The reason for this inverse relationship is that, when output per unit of labor rises, average variable costs must necessarily decline. (Review Equation 6.7 if this is unclear.)

Marginal Costs and the MPP Curve

Marginal cost is perhaps the most important concept. Marginal cost is the change in the business's total costs per unit of change in output. Marginal cost is measured as

$$\text{marginal cost} = \frac{\Delta \text{ total cost}}{\Delta \text{ output}} \tag{6.8}$$

in which Δ represents the change in a particular item (e.g., costs, output). Marginal cost also represents the slope of the total cost and total variable cost curves.

The level of marginal costs for TOP-AG is calculated in column 7 of Table 6.3. The marginal cost curve for this business is plotted in Figure 6.4, *B*. Like average variable cost, marginal cost first falls and then rises. It cuts the average total cost and average variable cost curves at their minimums (see outputs O_{BE} and O_{SD} in Figure 6.4*B*).[7]

■ Economics of Short-Run Decisions

Now that we have gained an understanding of the physical aspects and cost aspects of production, the next logical issue is to determine the level of output and input use that will maximize the business's current economic profit. Be-

[7] The "BE" and "SD" subscripts refer to the *break-even* and *shutdown* levels of output. These levels of output will take on special significance later in this chapter when we examine how changing market price levels affect the level of output desired by profit-maximizing businesses.

fore we can do this, however, we must discuss two additional revenue concepts, marginal revenue and average revenue.

Marginal and Average Revenue

In the last section, we discussed the calculation of marginal and average costs of production. They have their counterpart on the revenue side. The change in **total revenue** is called **marginal revenue** and it represents the change in revenue from producing more output, or

The marginal revenue under conditions of perfect competition is the price the producer receives from the market.

$$\text{marginal revenue} = \Delta \text{ total revenue} \div \Delta \text{ output} \tag{6.9}$$

which, under perfect competition, will also be equal to the per unit sales price of the product (price per bushel, per ton, per pound, etc.) for the business's product.[8]

If TOP-AG increased its production from 11.6 units per hour to 12 units per hour, its total revenue would increase from \$522 an hour (i.e., 11.6 units of output multiplied by a product price of \$45 per unit) to \$540.

If TOP-AG expands its output from 11.6 units to 12 units per hour, its marginal revenue would be equal to

$$\begin{aligned} \text{marginal revenue} &= (\$540 - \$522) \div (12.0 - 11.6) \\ &= \$18 \div 0.40 \text{ units of output} \\ &= \$45 \end{aligned} \tag{6.10}$$

which is identical to the \$45 market price assumed for TOP-AG's product.

The concept of **average revenue** reflects the revenue per unit of output the business receives for its product, or

$$\text{average revenue} = \text{total revenue} \div \text{output} \tag{6.11}$$

which simply represents another way of looking at the price of the product. If TOP-AG produced 12 units of output an hour and received \$45 for each unit it produced, its total revenue would be \$540 per hour. TOP-AG's average revenue under these circumstances would be

$$\begin{aligned} \text{average revenue} &= \$540 \div 12 \text{ units of output} \\ &= \$45 \end{aligned} \tag{6.12}$$

which is identical to the market price this business receives when it sells its product in the marketplace and to the marginal revenue calculated in Equation 6.10. The marginal revenue and average revenue curves under conditions of perfect competition assumed in this chapter will be perfectly flat, which we will illustrate shortly. This reflects the notion that a business is a price taker; nothing it does will change the price received for its output. In the example presented above, the intercept of these two curves on the vertical, or *Y*, axis would be \$45.

Level of Output: MC = MR

Expansion of the business's variable input use in the current period is profitable at the margin, or as long as the marginal revenue exceeds the marginal cost. A business should not increase the use of an input if marginal cost exceeds

[8] Under imperfect market structures, marginal revenue will differ from market price, which we will discuss in Chapter 9.

Table 6.4 Determination of TOP-AG's Profit-Maximizing Level of Output

Point on Figure 6.1	(1) Total Output	(2) Market Product Price	(3) Total Revenue, (1) × (2)	(4) Total Costs	(5) Economic Profit, (3) − (4)	(6) Marginal Cost, Δ(4) ÷ Δ(1)	(7) Marginal Revenue, Δ(3) ÷ Δ(1)
A	1.0	$45.00	$45.00	$150.00	−$105.00		
B	3.0	45.00	135.00	180.00	−45.00	$15.00	$45.00
C	4.8	45.00	216.00	200.00	16.00	11.11	45.00
D	6.5	45.00	292.50	210.00	82.50	5.88	45.00
E	8.1	45.00	364.50	230.00	134.50	12.50	45.00
F	9.6	45.00	432.00	260.00	172.00	20.00	45.00
G	10.8	45.00	486.00	300.00	186.00	33.33	45.00
H	11.6	45.00	522.00	350.00	172.00	62.50	45.00
I	12.0	45.00	540.00	410.00	130.00	150.00	45.00
J	11.7	45.00	526.50	480.00	46.50	n/a	n/a

marginal revenue, or the change in cost of purchasing additional inputs is greater than the revenue the business would receive from their use. Furthermore, as long as a higher profit is preferred over a smaller profit, a business should not stop expanding production if marginal revenue exceeds marginal cost.

This logic leads to the following economic strategy, under conditions of perfect competition in the short run, in which you produce at the point at which

$$\text{marginal revenue} = \text{marginal cost} \tag{6.13}$$

or to the point at which the marginal revenue from the sale of another unit of output equals the marginal cost of producing this unit.

Profit from production is maximized when the firm operates where marginal cost is equal to marginal revenue.

Let us expand our discussion of TOP-AG developed in Tables 6.1 and 6.3 to determine its profit-maximizing level of output. Rows *F* and *G* of Table 6.4 suggest that when TOP-AG expands its production from 9.6 units of output to 10.8 units of output, the business will achieve an economic profit of $186 per hour. TOP-AG's total revenue would be $486 per hour, while its total costs would be $300 per hour. The entry in column 5 of row *G* of $186 is the largest entry in this column, which suggests that profit is maximized at 10.8 units of output. Is it?

It is very important that you understand the economic rationale underlying the profit-maximizing level of output. If TOP-AG expanded its output to 11.6 units of output, the business's economic profit would fall from $186 to $172 an hour (see row *H* in Table 6.4). Obviously, TOP-AG's management would not wish to expand its operations in the current period if its goal is to maximize profits.

As TOP-AG expanded its output from 9.6 units of output to 10.8 units, its marginal cost was $33.33 as shown in column 6, and its marginal revenue was $45 as shown in column 7. The net benefits from this expansion are positive. But if TOP-AG further expands its operations from 10.8 units per hour to 11.6 units, the marginal cost of doing so would be $62.50 as compared with a marginal revenue of only $45. The level of output that maximizes profit, or the point at which the marginal revenue associated with the expansion just equals the marginal cost associated with the expansion, occurs when marginal cost equals $45. This will occur somewhere between rows *G* and *H*, or between 10.8 and 11.6 units of output as shown in Figure 6.5.

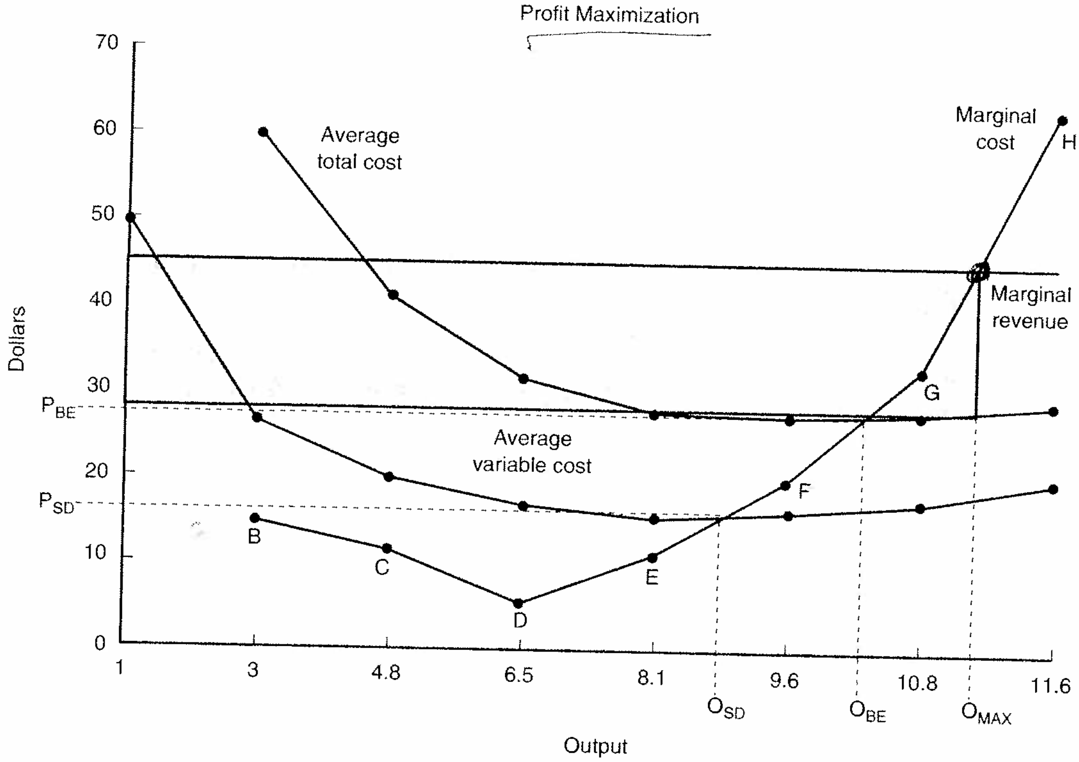


FIGURE 6.5 We can determine graphically what Table 6.4 could only hint at given the levels of production studied in that table. Given the MC = MR criterion expressed in Equation 6.13 for profit maximization, we see that profits would be maximized at O_{MAX}, or slightly more than 11 units of output per hour.

1 max profit O_{MAX}
2 break even O_{BE}
3 shut down O_{SD}

line

Reviewing Figure 6.5, we see that the marginal revenue curve is perfectly flat, reflecting the fact that this business is a price taker. The business thinks that the level of its production is small enough not to have a perceptible impact on the market price. Because we have assumed the presence of perfect competition in this chapter, the marginal revenue curve also reflects the average revenue. The intersection of this marginal revenue curve and the marginal cost curve indicates that output O_{MAX}, or slightly more than 11 units of output, would maximize TOP-AG's profit.

Two additional output levels deserve special mention here—the break-even level of production and the shutdown level of production. If the marginal revenue curve falls in a parallel fashion to the point where it is just tangent with the minimum point on the average total cost curve, the business's average total costs will be exactly equal to its average revenue. The business would be able to meet both its fixed and variable costs of production with the revenue it received during the current period, or **breakeven**.

The level of profit is equal to the level of output multiplied by average profit, or the difference between price and average total cost.

break even point

If the marginal revenue curve were to fall further (again in a parallel fashion) to the point at which it is just tangent to the minimum point on TOP-AG's average variable cost curve, TOP-AG would be just able to cover its variable costs but none of its fixed costs. Further declines in marginal revenue would cause the business to cease operations in the current period. TOP-AG could no longer pay its fuel bill, meet its hired labor payroll, or pay other expenses that vary with the level of production. Either the fuel supplier will stop making deliveries, hired workers will leave, or other factors critical to production will be curtailed. Thus, output level O_{SD} represents the **shutdown** level of production, and the minimum point on TOP-AG's effective marginal cost curve, or its supply curve.

Finally, the level of economic profits in Figure 6.5 is equal to the shaded rectangle formed by the difference between TOP-AG's average revenue and average total cost per unit at output O_{MAX}, or $45 minus approximately $28, multiplied by the quantity of output at O_{MAX}, or approximately 11.1 units. The level of economic profit here would be approximately $189 (i.e., [$45 − $28] × 11.1).

Supply curves.

Level of Resource Use: MVP = MIC

Now that we have determined the level of output at which a business should operate if its management wishes to maximize its profit, we must next determine what this means for the level of resource use. In the single variable input case, such as in our labor example for TOP-AG in Table 6.1, this is a relatively simple process. If you have determined the profit-maximizing level of output, you simply go to column 2 and read over to column 1 and observe the level of input use associated with this output.

An alternative approach to determining profit-maximizing input demands involves comparing the marginal benefit for a given level of input use with the **marginal input cost**. Because revenue is equal to the product price times output, it is clear that the marginal benefit from input use is equal to the change in total revenue per unit change in the input. This marginal benefit is called the **marginal value product**, and for labor is equal to

Marginal value product or MVP represents the additional revenue earned from employing another unit of input. Marginal input cost or MIC is the cost of using that additional unit of input.

$$\text{marginal value product for labor} = MVP_{labor} = MPP_{labor} \times \text{product price} \tag{6.14}$$

The optimum, or profit-maximizing, level of input use occurs when the marginal value product equals the marginal input cost. For the case of labor, the optimal level of labor use is given by

$$MVP_{labor} = \text{wage rate} \tag{6.15}$$

If additional labor were employed beyond this point, the marginal cost (i.e., the wage rate) would exceed the marginal benefits (i.e., the marginal value product for labor).

Let us illustrate the determination of the profit-maximizing level of input use by applying Equation 6.15 to the information presented in Table 6.5. This table illustrates that the price of TOP-AG's product is $45 per unit and the cost of labor is equal to $5 per hour. Multiplying the marginal physical product in column 2 by $45 gives us the marginal value product reported in column 3, or the marginal benefit from adding another hour of labor.

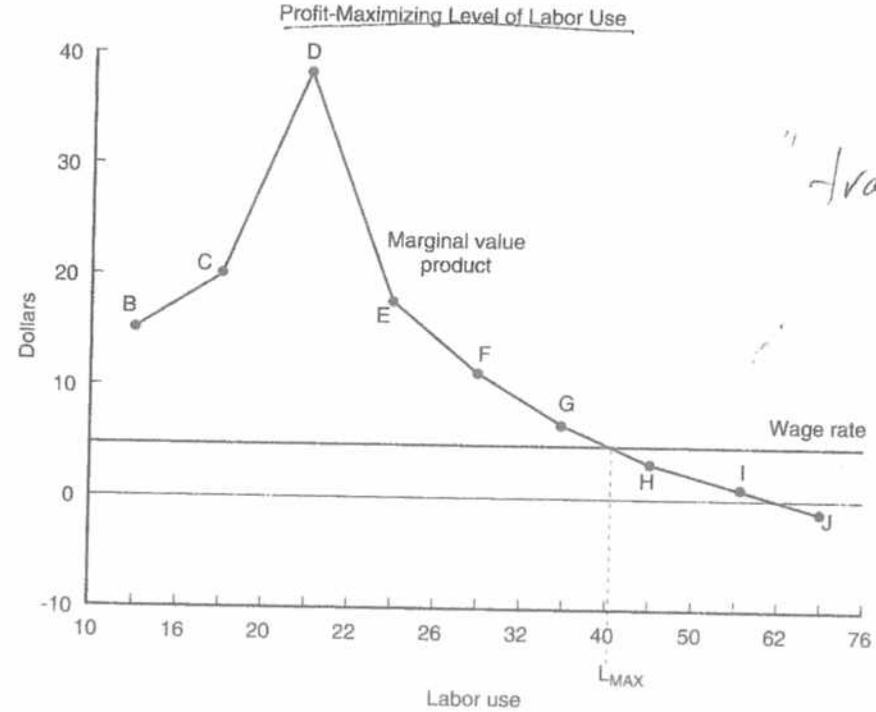
Column 4 in Table 6.5 indicates that TOP-AG is a price taker in the labor market because its increased use of labor had no effect on hourly wage rates. The contribution to profit (marginal net benefit) is reported in column 5. This value is found by subtracting the marginal cost in column 4 from the marginal benefit reported in column 3.

The information in Table 6.5 illustrates that TOP-AG should use slightly more than 40 hours of labor. The wage rate in column 4 would equal the mar-

Table 6.5 Determination of TOP-AG's Profit-Maximizing Level of Labor Use

Point on Figure 6.6	(1) Use of Labor	(2) Marginal Physical Product*	(3) Marginal Value Product, (2) × $45	(4) Wage Rate	(5) Marginal Net Benefit, (3) − (4)	(6) Cumulative Net Benefit
A	10					
B	16	.33	$14.85	5.00	$9.85	9.85
C	20	.45	20.25	5.00	15.25	25.10
D	22	.85	38.25	5.00	33.25	58.35
E	26	.40	18.00	5.00	13.00	71.35
F	32	.25	11.25	5.00	6.25	77.60
G	40	.15	6.75	5.00	1.75	79.35
H	50	.08	3.60	5.00	−1.40	77.95
I	62	.03	1.35	5.00	−3.65	74.30
J	76	−.02	−.90	—	—	—

*Column 3 in Table 6.1.



"translation" of fig 6.5 to level of labor use.

FIGURE 6.6 Equation 6.15 indicates that the profit-maximizing level of input use in the short run occurs at the point at which the marginal value product of labor equals the marginal input cost. In the case of TOP-AG, we see that this occurs at approximately 41 hours of labor per day if the wage rate is $5 an hour, or at quantity L_{MAX}.

ginal value product of using additional labor in column 3. If labor were expanded to 50 hours, the cumulative net benefit in column 6 would be declining.

The marginal value product and marginal input cost relationships calculated in Table 6.5 are plotted in Figure 6.6. Because the marginal value product curve is nothing more than the marginal physical product curve multiplied by a fixed product price, the marginal value product curve looks very much like a marginal physical product curve. As Table 6.5 suggests, the labor use that maximizes profits is about 41 hours, the point at which the marginal value product curve intersects the marginal input cost curve.

The analysis presented in Table 6.5 and Figure 6.6 can be extended to other inputs. It represents a general way of characterizing the profit-maximizing level of input use. Profit maximization requires that the marginal value product (marginal benefit) of each variable input equals its marginal input cost simultaneously.

■ WHAT LIES AHEAD?

The focus of this chapter was on the economic decisions faced by a business in the short-run or current period. We looked at the effects that varying the use of one input (hired labor) would have on output and the business's costs of production. This chapter determined the profit-maximizing level of output in the short run and the profit-maximizing use of a variable input.

Chapter 7 will broaden the focus of the business's decisions by examining the determination of the least-cost combination of variable inputs in the short run and the optimal expansion path for labor and capital over the long run. This chapter will also address the profit-maximizing combination of products to produce.

Summary

The purpose of this chapter was to illustrate the various physical relationships that exist between inputs and outputs with which agricultural economists must be familiar. The major points of this chapter may be summarized as follows:

1. Farm inputs can be classified into land, labor, capital, and management.
2. A production function captures the causal physical relationship between input use and the level of output.
3. The total physical product reflects the level of output of a given level of input use. Marginal physical product represents the change in the level of output associated with a change in the use of a particular input. Finally, average physical product reflects the level of output per unit of input use. In each case, all other inputs are held fixed. The value of the marginal physical product represents the slope of the total physical product curve. No rational farmer would want to produce beyond the point at which the marginal physical product equals zero, because further input use would cause the level of output to fall.

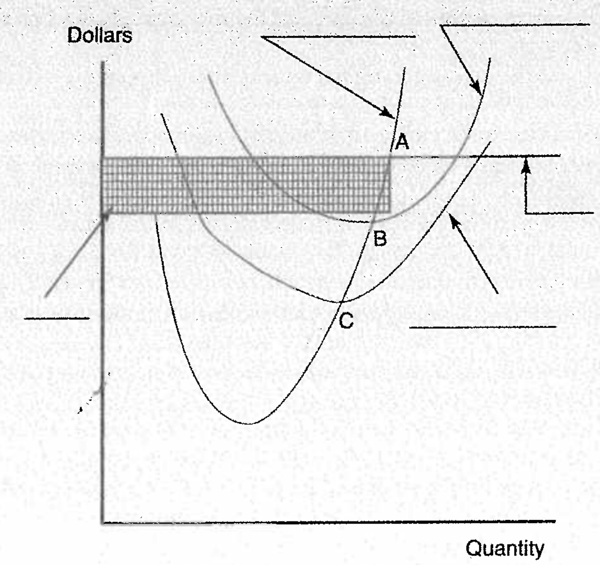
4. There are three stages of production:
   - Stage I is the point at which the marginal physical product curve for a particular input is rising but still lies above the average physical product curve.
   - Stage II is the point at which the marginal physical product equals the average physical product and continues until the marginal physical product for the input in question reaches zero.
   - Stage III is the point at which stage II left off, or where the total physical product curve begins to decline and the marginal physical product curve becomes negative.
5. The law of diminishing marginal returns states that as the use of an input increases, its marginal physical product will eventually fall.
6. Marginal cost is the change in total cost with respect to a change in output. Average cost is total cost divided by total output. Fixed costs are those costs that do not vary with output.
7. The profit-maximizing level of output occurs in the short run at the output level at which MC = MR. The competitive business takes the market price (MR) as given by the marketplace and makes its production decisions by equating MC = MR.
8. The profit-maximizing level of input use occurs in the short run at the input level at which MVP = MIC. The competitive business takes the per unit price of the variable input (MIC) as given by the marketplace and makes its purchasing decisions by equating MVP = MIC.
9. The business will break even (TR = TC) in the short run at the output level where the price the business receives for its product falls to the point at which AR = ATC, or where average profit per unit of output is zero. The business may continue to operate in the short run if AR < ATC, because it can minimize its losses (i.e., cover at least some of its fixed costs).
10. The business will cease operations, or shut down, in the short run if the price the business receives for its product falls to the point at which AR < AVC. When this occurs, the business will no longer be able to cover its variable costs of production (e.g., pay its fuel bill) and will be unable to acquire additional inputs.

Key Terms

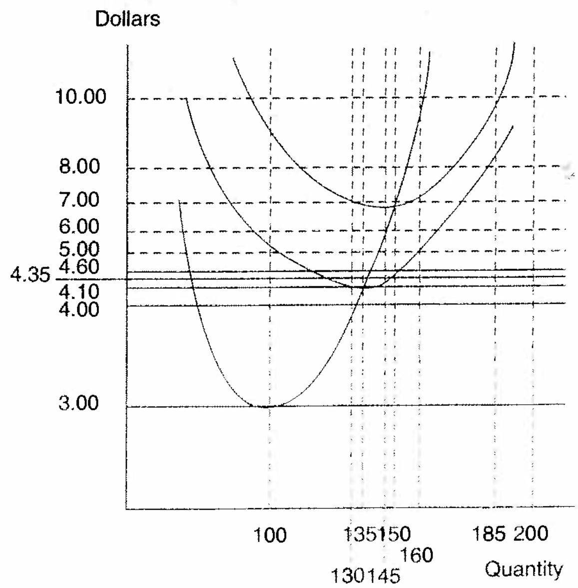
Average cost
Average fixed costs
Average physical product
Average revenue
Average total costs
Average variable costs
Breakeven
Fixed costs
Imperfect competition
Law of diminishing marginal returns
Marginal cost
Marginal input cost
Marginal physical product
Marginal revenue
Marginal value product
Perfect competition
Shutdown
Total costs
Total fixed cost
Total physical product curve
Total revenue
Total variable cost
Variable costs

Testing Your Economic Quotient

1. Please insert the appropriate labels in the blanks in the graph below. Examine the graph carefully to note all labels. Then clearly indicate below the graph the particular significance of point *A*, point *B*, and point *C*.



2. The following graph presents selected cost functions for a typical firm. The dashed lines are inserted for easy reference to give you the corresponding values on the dollar and quantity axes. Please answer the following questions based on this graph.



a. At a price of $7, what would be the level of fixed costs that would be covered by the firm? Show all prices, quantities, and the method of calculation (i.e., what is the dollar amount of the fixed costs that are covered?).

b. What is the level of the break-even price?
The shutdown price?
The break-even quantity?
The shutdown quantity?

c. At a price of $6 and assuming that the firm is a profit maximizer, what would be the level of fixed costs *that would be covered* by the firm? What is the *total* level of fixed costs for the profit maximizing quantity? Show all prices, quantities, and the method of calculation (i.e., what is the dollar amount of the fixed costs that are covered?).

d. What would the level of production and profits for this firm be if the price of the product were $4 per unit?

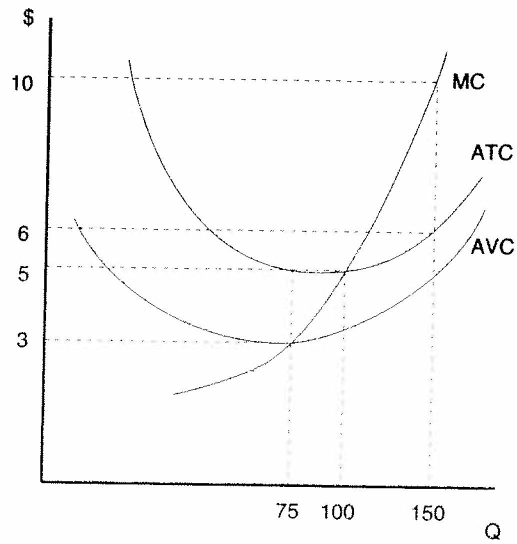
3. The partial table is for a firm operating in a perfectly competitive market. Please complete the table and answer the following questions based on the answers that you provide in the table.

Input Usage	Output	MPP	APP	Output Price	TR	MR	AR	Input Price	FC	TVC	TC	MC
	160	XXX	8.0		1200	XXX						XXXX
30		25								900		
40			4.5									

ATC	AVC	AFC	Profit
			−150

In the preceding example, would the profit-maximizing level of output be less than 20 units, between 20 and 30 units, between 30 and 40 units, or greater than 40 units? Why? (You might find it helpful to include a graph *with* your explanation.)

4. Define the point where firms maximize profits?
5. Define the shutdown point of a perfectly competitive firm.
6. Define the break-even point of a perfectly competitive firm.
7. Define the supply curve of a perfectly competitive firm.



Use the graph on page 129 to answer questions 8 through 10.

8. Find the shutdown point. What is the quantity produced, average total cost, average variable cost, total cost, total variable cost, and profit (loss) at this point?
9. Find the break-even point. What is the quantity produced, average total cost, average variable cost, total cost, total variable cost, and profit (loss) at this point?
10. If MR = 10, then what is the quantity produced, average total cost, average variable cost, total cost, total variable cost, and profit (loss) at this point?
11. Define in words and write the formula for TFC, TC, TVC, MC, AVC, ATC, and AFC. There may be more than one formula for each one.
12. Fill in the missing cells. Assume the firm operates in a perfectly competitive environment in both the input and output markets. Calculate the profit (loss) when the firm receives $0.40 for the product.

L	Q	P(L)	TFC	TVC	TC	MC	ATC	AVC	AFC
2	40	5	110						
	65					.4			
	80							.375	
	90				150				

13. List four conditions for perfect competition.

a.
b.
c.
d.

14. The following information pertains to a production schedule for sorghum from a west Texas farm.

Land (Acres)	Fertilizer (Pounds)	Sorghum Yield (Tons)	MPP	APP	Stage of Production
4	40	68	—		—
4		75		1.25	

a. Which input is the variable input?
b. Which input is the fixed input?
c. Fill in the blanks in the table.

15. Complete the following table:

INPUT	OUTPUT	TFC	TVC	TC	MC	AFC	AVC	ATC
2	20		100	125	—			
	40	—			10			