MICROECONOMICS

An Integrated Approach

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maintain a Web site, you also avoid the cost of leasing computer time from the local Internet service provider. Thus, while the computer leasing cost was sunk with respect to the decision to scale back operations by one day, it is nonsunk with respect to the decision to cease operations altogether.

What about the costs of your SUV? Suppose that you plan to get rid of it, which means that you can avoid your $100 a month insurance bill. Your insurance costs are therefore nonsunk. But also suppose that you customized the SUV, for example by painting your logo on it. Because of this and because of the general wariness that the public has about buying used vehicles, you can recover only 30 percent of the cost you paid for it. Thus, by exiting the business, you can offset 30 percent of your car payment. This means that 70 percent of your car payment is sunk (it can't be avoided if you go out of business), while 30 percent is nonsunk (it is avoided when you go out of business and sell your SUV). Thus, to summarize, when you contemplate exiting the business, your merchandising, gasoline, leasing, and insurance expenses are nonsunk (i.e., avoidable). Moreover, 30 percent of your car payment is avoidable. The remaining 70 percent of it is a sunk cost.

Similar Problem: 7.1

7.2 THE COST-MINIMIZATION PROBLEM

Now that we have introduced a variety of different cost concepts, let's apply them to analyze an important decision problem for a firm: How to choose a combination of inputs to minimize the cost of producing a given quantity of output. We saw in Chapter 6 that firms can typically produce a given amount of output using many different input combinations. Of all the input combinations that can be chosen, a firm that wants to make its owners as wealthy as possible should choose the one that minimizes its costs of production. The problem of finding the input combination that minimizes a firm's costs of production is called the **cost-minimization problem**, and a firm that seeks to minimize the cost of producing a given amount of output is called a **cost-minimizing firm**.

LONG RUN VERSUS SHORT RUN

We will study the firm's cost-minimization problem in the long run and in the short run. Although the terms *long run* and *short run* seem to connote a length of time, it is more useful to think of them as pertaining to the degree to which the firm faces constraints in its decision-making flexibility. A firm that makes a **long-run** decision faces a blank slate: It is free to vary the quantities of all its inputs as much as it desires. When our sporting goods firm in the previous section decides whether to build a new bowling ball factory, it faces a long-run decision. It is free to choose whether to build the factory, and if so, how large to make it. As it does this, it can simultaneously choose other input quantities such as the size of the work force to employ and the amount of land that will surround the factory. Because the firm can, in principle, avoid the costs of all inputs by choosing not to produce, the costs associated with long-run decisions are necessarily nonsunk.

By contrast, a firm facing a **short-run** decision is subject to constraints. It is unable to adjust the quantities of some of its inputs, and/or it is unable to reverse the consequences of initial decisions that it has made regarding those inputs. For example, once our bowling ball firm builds a factory, it will, at least for a while, face short-run decisions, such as how many workers it should employ given the physical constraints of its capacity.

In microeconomics, the concept of short run and long run are convenient analytical simplifications to help us focus our attention on the interesting features of the problem at hand. In reality, firms face a continuum of "runs"; some decisions involve "blanker slates" than others. In this section, we first focus on long-run cost minimization in order to study carefully the trade-offs that firms can make in input choices when they start with a blank slate. In the next section, we turn to short-run cost minimization to highlight how constraints on input usage can limit the firm's ability to make its costs as low as possible.

THE LONG-RUN COST-MINIMIZATION PROBLEM

The cost-minimization problem is another example of constrained optimization that we discussed in Chapter 1. We want to minimize the firm's total costs, subject to the requirement that the firm produce a given amount of output. We have encountered two other examples of constrained optimization problems so far: The problem of maximizing utility subject to a budget constraint (utility maximization) in Chapter 4 and the problem of minimizing consumption expenditures, subject to achieving a minimum level of utility (expenditure minimization), also discussed in Chapter 4. You will see that the cost-minimization problem closely resembles the expenditure-minimization problem from consumer choice theory.

Let's study the long-run cost-minimization problem for a firm that uses two inputs: labor and capital. Each input has a price. The price of a unit of labor services—also called the wage rate—is w. This price per unit of capital services is r. The price of labor could either be an explicit cost or implicit cost. It would be an explicit cost if the firm (as most firms do) hires workers in the open market. It could be an implicit cost if the firm's owner is providing his or her own labor to run the firm and in so doing, sacrifices outside employment opportunities. Similarly, the price of capital could either be an explicit cost or an implicit cost. It would be an explicit cost if the firm leased capital services from another firm (e.g., an e-commerce firm that leases computer time on a server to host its Web site). It would be an implicit cost if the firm owned the physical capital and, by using it in its own business, sacrificed the opportunity to sell capital services to other firms.

The firm has decided to produce Q_0 units of output during the next year. In later chapters we will study how the firm makes output decisions. For now, the quantity Q_0 is exogenous. To understand this, you might imagine that the manufacturing manager of the firm has been told how much to produce. The problem is to figure out how to produce that amount in the cost-minimizing way. Thus, the manager must choose a quantity of capital, K, and a quantity of labor, L, to minimize the total cost $TC = wL + rK$ of producing Q_0 units of output. This total cost is the sum of all the economic costs the firm incurs when it hires labor and capital services to produce output.

ISOCOST LINES

Let's now try to solve the firm's cost-minimization problem graphically. Our first step is to draw isocost lines. An isocost line is a set of combinations of labor and capital that have the same total cost (TC) for the firm. An isocost line is analogous to a budget line from the theory of consumer choice.

Consider, for example, a case in which $w = \$10$ per labor hour, $r = \$20$ per machine hour, and $TC = \$1$ million per year. The \$1 million isocost line is described by the equation

$$1{,}000{,}000 = 10L + 20K.$$

This can be rewritten as

$$K = \frac{1{,}000{,}000}{20} - \frac{1}{2}L.$$

The \$2 million and \$3 million isocost lines have similar equations:

$$K = \frac{2{,}000{,}000}{20} - \frac{1}{2}L$$

$$K = \frac{3{,}000{,}000}{20} - \frac{1}{2}L$$

More generally, for an arbitrary level of total cost TC_0, and input prices w and r, the equation of the isocost line is

$$K = \frac{TC_0}{r} - \frac{w}{r}L.$$

Figure 7.1 shows graphs of these isocost lines for a variety of different total cost levels, TC_0, TC_1, TC_2 where $TC_2 > TC_1 > TC_0$. In general, there are an infinite number of isocost lines, one corresponding to every possible level of total cost. Figure 7.1 illustrates that the slope of every isocost line is the same: With K on the vertical axis and L on the horizontal axis, that slope is $-w/r$, or minus the ratio of the price of labor to the price of capital. The K-axis intercept of any particular isocost line is the cost level for that isocost line divided by the price of capital. Thus, for the TC_0 isocost line, the K-axis intercept is TC_0/r. Similarly, the L-axis intercept of the TC_0 isocost line is TC_0/w. Notice that as we move to the northeast in the isocost map in Figure 7.1, isocost lines correspond to higher levels of cost.

GRAPHICAL CHARACTERIZATION OF THE SOLUTION TO THE LONG-RUN COST-MINIMIZATION PROBLEM

Figure 7.2 shows isocost lines and the isoquant corresponding to Q_0 units of output. The solution to the firm's cost-minimization problem occurs at point A, where the isoquant is just tangent to an isocost line. That is, of all the input

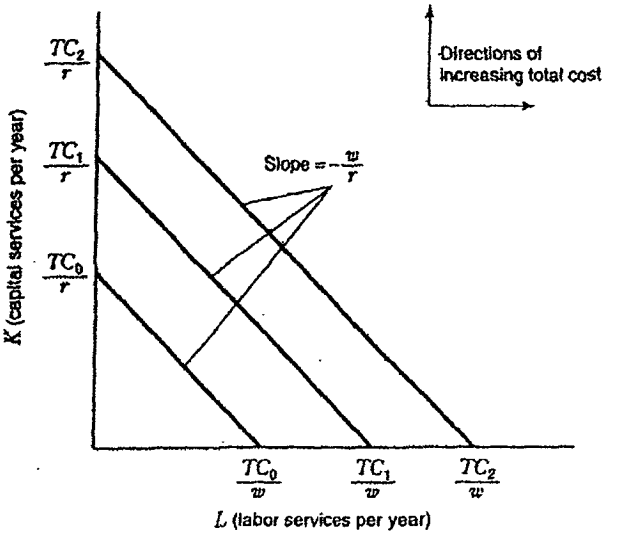

FIGURE 7.1 Isocost Lines
The figure shows isocost lines for a variety of different cost levels. As we move to the northeast in the isocost map, isocost lines correspond to higher levels of total cost.

combinations along the isoquant, point A provides the firm with the lowest level of cost.

To verify this, consider several other points in Figure 7.2, such as E, F, and G:

- Point G is "off" the Q_0 isoquant altogether. Although this input combination *could* produce Q_0 units of output, in using it the firm would be wasting inputs

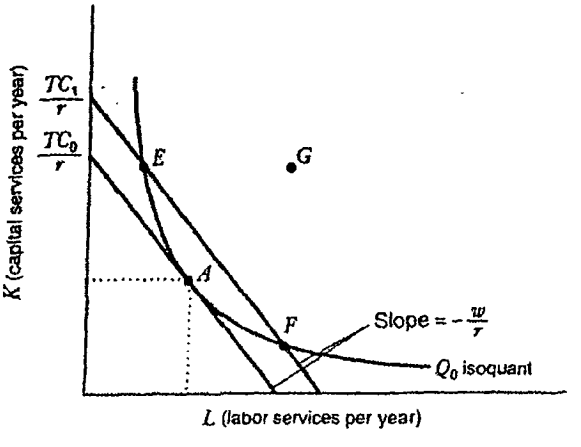

FIGURE 7.2 Cost-Minimizing Input Combination
The cost-minimizing input combination occurs at point A. Point G is not optimal because the firm can produce Q_0 units of output using fewer units of both capital and labor. Points E and F are technically efficient, but they *do* not minimize cost because the firm can lower cost from TC_1 to TC_0 by moving to input combination A.

(i.e., point G is technically inefficient). This point cannot be optimal because input combination A also produces Q_0 units of output but uses fewer units of labor and capital.

- Points E and F are technically efficient, but they are not cost-minimizing because they are on an isocost line that correspond to a higher level of cost than the isocost line passing through the cost-minimizing point A. By moving from point E to A or from F to A, the firm can produce the same amount of output, but at a lower total cost.

Note that at the cost-minimizing point A, the isoquant is just tangent to an isocost line, which means that the slope of the isoquant is equal to the slope of the isocost line. In Chapter 6, we saw that minus the slope of the isoquant is called the marginal rate of technical substitution of labor for capital, $MRTS_{L,K}$, and that

$$MRTS_{L,K} = \frac{MP_L}{MP_K},$$

As we just illustrated, the slope of an isocost line is $-w/r$. Thus, the cost-minimizing condition is

$$\text{slope of isoquant} = \text{slope of isocost line},$$

$$-MRTS_{L,K} = -\frac{w}{r},$$

$$\frac{MP_L}{MP_K} = \frac{w}{r}, \tag{7.1}$$

$$\text{ratio of marginal products} = \text{ratio of input prices}$$

In Figure 7.2, the optimal input combination A is an interior optimum. An interior optimum involves positive amounts of both inputs ($L > 0$ and $K > 0$), and the optimum occurs at a tangency between the isoquant and an isocost line. Equation (7.1) tells us that at an interior optimum, the ratio of the marginal products of labor and capital equals the ratio of the price of labor to the price of capital. We could also rewrite (7.1) to state the optimality condition in this form:

$$\frac{MP_L}{w} = \frac{MP_K}{r}, \tag{7.2}$$

This condition tells us that at a cost-minimizing input combination, the additional output per dollar spent on labor services equals the additional output per dollar spent on capital services. Thus, if we are minimizing costs, we get equal "bang for the buck" from each input. Recall that we obtained a similar condition at the solution to a consumer's utility-maximization problem in Chapter 4.

To see why equation (7.2) must hold, consider a noncost-minimizing point such as E. At point E, the slope of the isoquant is more negative than the slope of the isocost line. Therefore,

$$-\frac{MP_L}{MP_K} < -\frac{w}{r},$$