Chapter 7 The Cost of Production

Read Pindyck and Rubinfeld (2013), Chapter 7

CHAPTER 7 OUTLINE

7.1 Measuring Cost: Which Costs Matter?
7.2 Cost in the Short Run
7.3 Cost in the Long Run
7.4 Long-Run versus Short-Run Cost Curves
7.5 Production with Two Outputs—Economies of Scope
7.1 Measuring Cost: Which Costs Matter?

- **Economic Cost versus Accounting Cost**
  - **accounting cost**  Actual expenses plus depreciation charges for capital equipment.
  - **economic cost**  Cost to a firm of utilizing economic resources in production.

**Opportunity Cost**

- **opportunity cost**  Cost associated with opportunities forgone when a firm’s resources are not put to their best alternative use.

The concept of opportunity cost is particularly useful in situations where alternatives that are forgone do not reflect monetary outlays.

\[
\text{Economic cost} = \text{Opportunity cost}
\]

**Sunk Costs**

- **sunk cost**  Expenditure that has been made and cannot be recovered.

Because a sunk cost cannot be recovered, it should not influence the firm’s decisions.

For example, consider the purchase of specialized equipment for a plant. Suppose the equipment can be used to do only what it was originally designed for and cannot be converted for alternative use. The expenditure on this equipment is a sunk cost. Because it has no alternative use, its opportunity cost is zero. Thus it should not be included as part of the firm’s economic costs.

A prospective sunk cost is an investment. Here the firm must decide whether that investment in specialized equipment is economical.
EXAMPLE 7.1  CHOOSING THE LOCATION FOR A NEW LAW SCHOOL BUILDING

The Northwestern University Law School has long been located in Chicago, along the shores of Lake Michigan. However, the main campus of the university is located in the suburb of Evanston. In the mid-1970s, the law school began planning the construction of a new building.

The downtown location had many prominent supporters. They argued in part that it was cost-effective to locate the new building in the city because the university already owned the land. A large parcel of land would have to be purchased in Evanston if the building were to be built there.

Does this argument make economic sense? No. It makes the common mistake of failing to appreciate opportunity cost. From an economic point of view, it is very expensive to locate downtown because the opportunity cost of the valuable lakeshore location is high: That property could have been sold for enough money to buy the Evanston land with substantial funds left over.

In the end, Northwestern decided to keep the law school in Chicago. This was a costly decision. It may have been appropriate if the Chicago location was particularly valuable to the law school, but it was inappropriate if it was made on the presumption that the downtown land had no cost.

7.1  MEASURING COST: WHICH COSTS MATTER?

Fixed Costs and Variable Costs

- **total cost (TC or C)**  Total economic cost of production, consisting of fixed and variable costs.

- **fixed cost (FC)**  Cost that does not vary with the level of output and that can be eliminated only by shutting down.

- **variable cost (VC)**  Cost that varies as output varies.

The only way that a firm can eliminate its fixed costs is by shutting down.
Fixed Costs and Variable Costs

**Shutting Down**

Shutting down doesn’t necessarily mean going out of business. By reducing the output of a factory to zero, the company could eliminate the costs of raw materials and much of the labor. The only way to eliminate fixed costs would be to close the doors, turn off the electricity, and perhaps even sell off or scrap the machinery.

**Fixed or Variable?**

How do we know which costs are fixed and which are variable?

Over a very short time horizon—say, a few months—most costs are fixed. Over such a short period, a firm is usually obligated to pay for contracted shipments of materials.

Over a very long time horizon—say, ten years—nearly all costs are variable. Workers and managers can be laid off (or employment can be reduced by attrition), and much of the machinery can be sold off or not replaced as it becomes obsolete and is scrapped.

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**Fixed vs. Sunk Costs**

Shutting down doesn’t necessarily mean going out of business. Fixed costs can be avoided if the firm shuts down a plant or goes out of business.

Sunk costs, on the other hand, are costs that have been incurred and cannot be recovered.

When a firm’s equipment is too specialized to be of use in any other industry, most if not all of this expenditure is sunk, i.e., cannot be recovered.

Why distinguish between fixed and sunk costs? Because fixed costs affect the firm’s decisions looking forward, whereas sunk costs do not. Fixed costs that are high relative to revenue and cannot be reduced might lead a firm to shut down—eliminating those fixed costs and earning zero profit might be better than incurring ongoing losses. Incurring a high sunk cost might later turn out to be a bad decision (for example, the unsuccessful development of a new product), but the expenditure is gone and cannot be recovered by shutting down. Of course a prospective sunk cost is different and, as we mentioned earlier, would certainly affect the firm’s decisions looking forward.
AMORTIZING SUNK COSTS

- **amortization**  Policy of treating a one-time expenditure as an annual cost spread out over some number of years.

Amortizing large capital expenditures and treating them as ongoing fixed costs can simplify the economic analysis of a firm’s operation. As we will see, for example, treating capital expenditures this way can make it easier to understand the tradeoff that a firm faces in its use of labor versus capital.

For simplicity, we will usually treat sunk costs in this way as we examine the firm’s production decisions. When distinguishing sunk from fixed costs does become essential to the economic analysis, we will let you know.

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**EXAMPLE 7.2  SUNK, FIXED, AND VARIABLE COSTS: COMPUTERS, SOFTWARE, AND PIZZAS**

It is important to understand the characteristics of production costs and to be able to identify which costs are fixed, which are variable, and which are sunk.

Good examples include the personal computer industry (where most costs are variable), the computer software industry (where most costs are sunk), and the pizzeria business (where most costs are fixed).

Because computers are very similar, competition is intense, and profitability depends on the ability to keep costs down. Most important are the cost of components and labor.

A software firm will spend a large amount of money to develop a new application. The company can recoup its investment by selling as many copies of the program as possible.

For the pizzeria, sunk costs are fairly low because equipment can be resold if the pizzeria goes out of business. Variable costs are low—mainly the ingredients for pizza and perhaps wages for a workers to produce and deliver pizzas.
Marginal and Average Cost

Marginal Cost (MC)

- **marginal cost (MC)** Increase in cost resulting from the production of one extra unit of output.

Because fixed cost does not change as the firm’s level of output changes, marginal cost is equal to the increase in variable cost or the increase in total cost that results from an extra unit of output.

We can therefore write marginal cost as

\[ MC = \frac{\Delta VC}{\Delta q} = \frac{\Delta TC}{\Delta q} \]

Average Total Cost (ATC)

- **average total cost (ATC)** Firm’s total cost divided by its level of output.

- **average fixed cost (AFC)** Fixed cost divided by the level of output.

- **average variable cost (AVC)** Variable cost divided by the level of output.
### Marginal and Average Cost

#### Marginal Cost (MC)

**TABLE 7.1** A Firm’s Costs

<table>
<thead>
<tr>
<th>Rate of Output (Units per Year)</th>
<th>Fixed Cost (Dollars per Year)</th>
<th>Variable Cost (Dollars per Year)</th>
<th>Total Cost (Dollars per Year)</th>
<th>Marginal Cost (Dollars per Unit)</th>
<th>Average Fixed Cost (Dollars per Unit)</th>
<th>Average Variable Cost (Dollars per Unit)</th>
<th>Average Total Cost (Dollars per Unit)</th>
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E1. Joe quits his computer programming job, where he was earning a salary of $50,000 per year, to start his own computer software business in a building that he owns and was previously renting out for $24,000 per year. In his first year of business he has the following expenses, salary paid to himself, $40,000; rent, $0; other expenses, $25,000. Find the accounting cost and the economic cost associated with Joe’s computer software business.

Q3. Please explain whether the following statements are true or false.

a) If the owner of a business pays himself no salary, then the accounting cost is zero, but the economic cost is positive.

b) A firm that has positive accounting profit does not necessarily have positive economic profit.

c) If a firm hires a currently unemployed worker, the opportunity cost of utilizing the worker’s services is zero.
The change in variable cost is the per-unit cost of the extra labor $w$ times the amount of extra labor needed to produce the extra output $\Delta L$. Because $\Delta VC = w \Delta L$, it follows that

$$MC = \frac{\Delta VC}{\Delta q} = \frac{w \Delta L}{\Delta q}$$

The extra labor needed to obtain an extra unit of output is $\Delta L / \Delta q = 1/\text{MP}_L$. As a result,

$$MC = \frac{w}{\text{MP}_L} \quad (7.1)$$

**Diminishing Marginal Returns and Marginal Cost**

Diminishing marginal returns means that the marginal product of labor declines as the quantity of labor employed increases.

As a result, when there are diminishing marginal returns, marginal cost will increase as output increases.

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**The Shapes of the Cost Curves**

In (a) total cost $TC$ is the vertical sum of fixed cost $FC$ and variable cost $VC$.

In (b) average total cost $ATC$ is the sum of average variable cost $AVC$ and average fixed cost $AFC$.

Marginal cost $MC$ crosses the average variable cost and average total cost curves at their minimum points.
THE AVERAGE-MARGINAL RELATIONSHIP

Marginal and average costs are another example of the average-marginal relationship described in Chapter 6 (with respect to marginal and average product).

Because average total cost is the sum of average variable cost and average fixed cost and the AFC curve declines everywhere, the vertical distance between the ATC and AVC curves decreases as output increases.

TOTAL COST AS A FLOW

Total cost is a flow: the firm produces a certain number of units per year. Thus its total cost is a flow—for example, some number of dollars per year. For simplicity, we will often drop the time reference, and refer to total cost in dollars and output in units.

Knowledge of short-run costs is particularly important for firms that operate in an environment in which demand conditions fluctuate considerably. If the firm is currently producing at a level of output at which marginal cost is sharply increasing, and if demand may increase in the future, management might want to expand production capacity to avoid higher costs.

E9. The short-run cost function of a company is given by the equation $TC = 200 + 55q$, where $TC$ is the total cost and $q$ is the total quantity of output, both measured in thousands.

a) What is the company’s fixed cost?
b) If the company produced 100,000 units of goods, what would be its average variable cost?
c) What would be its marginal cost of production?
d) What would be its average fixed cost?
e) Suppose the company borrows money and expands its factory. Its fixed cost rises by $50,000, but its variable cost falls to $45,000 per 1000 units. The cost of interest ($i$) also enters into the equation. Each 1-point increase in the interest rate raises costs by $3,000. Write the new cost equation.
7.3 COST IN THE LONG RUN

The User Cost of Capital

- **user cost of capital**  
  Annual cost of owning and using a capital asset, equal to economic depreciation plus forgone interest.

The user cost of capital is given by the *sum of the economic depreciation and the interest (i.e., the financial return) that could have been earned had the money been invested elsewhere*. Formally,

\[
\text{User Cost of Capital} = \text{Economic Depreciation} + (\text{Interest Rate})(\text{Value of Capital})
\]

We can also express the user cost of capital as a *rate* per dollar of capital:

\[
r = \text{Depreciation rate} + \text{Interest rate}
\]

**Example: Purchase of a Boeing 777 for $150 million**

- Life of the airplane = 30 years
- Annual Amortized cost is $5 million per year
- Interest rate = 10%

  user cost of capital  = economic depreciation + foregone interest

**In the first year:**

user cost of capital  = economic depreciation + (interest rate)(value of capital)  
= $5 \text{ million} + (0.10)(\$150 \text{ million})  
= $20 \text{ million}

**In the tenth year:**

user cost of capital  = economic depreciation + (interest rate)(value of capital)  
= $5 \text{ million} + (0.10)(\$100 \text{ million})  
= $15 \text{ million}

We can also express the user cost of capital as a *rate* per dollar of capital:

\[
r = \text{depreciation rate} + \text{interest rate}
\]

\[
r = 1/30+0.10  
= 13.33\%
\]
The Cost-Minimizing Input Choice

We now turn to a fundamental problem that all firms face: how to select inputs to produce a given output at minimum cost.

For simplicity, we will work with two variable inputs: labor (measured in hours of work per year) and capital (measured in hours of use of machinery per year).

The Price of Capital

The price of capital is its user cost, given by

\[ r = \text{Depreciation rate} + \text{Interest rate}. \]

The Rental Rate of Capital

- rental rate  Cost per year of renting one unit of capital.

If the capital market is competitive, the rental rate should be equal to the user cost, \( r \).

Why? Firms that own capital expect to earn a competitive return when they rent it. This competitive return is the user cost of capital.

Capital that is purchased can be treated as though it were rented at a rental rate equal to the user cost of capital.

The Isocost Line

- isocost line  Graph showing all possible combinations of labor and capital that can be purchased for a given total cost.

To see what an isocost line looks like, recall that the total cost \( C \) of producing any particular output is given by the sum of the firm’s labor cost \( wL \) and its capital cost \( rK \):

\[ C = wL + rK \quad (7.2) \]

If we rewrite the total cost equation as an equation for a straight line, we get

\[ K = C/r - (w/r)L \]

It follows that the isocost line has a slope of \( \Delta K/\Delta L = -(w/r) \), which is the ratio of the wage rate to the rental cost of capital.
7.3 COST IN THE LONG RUN

The Isocost Line

Figure 7.3
Producing a Given Output at Minimum Cost

Isocost curves describe the combination of inputs to production that cost the same amount to the firm. Isocost curve $C_1$ is tangent to isoquant $q_1$ at $A$ and shows that output $q_1$ can be produced at minimum cost with labor input $L_1$ and capital input $K_1$. Other input combinations—$L_2$, $K_2$ and $L_3$, $K_3$—yield the same output but at higher cost.

Figure 7.4
Input Substitution When an Input Price Changes

Facing an isocost curve $C_1$, the firm produces output $q_1$ at point $A$ using $L_1$ units of labor and $K_1$ units of capital. When the price of labor increases, the isocost curves become steeper. Output $q_1$ is now produced at point $B$ on isocost curve $C_2$ by using $L_2$ units of labor and $K_2$ units of capital.
Recall that in our analysis of production technology, we showed that the marginal rate of technical substitution of labor for capital (MRTS) is the negative of the slope of the isoquant and is equal to the ratio of the marginal products of labor and capital:

\[
MRTS = -\frac{\Delta K}{\Delta L} = \frac{MP_L}{MP_K}
\]  

(7.3)

It follows that when a firm minimizes the cost of producing a particular output, the following condition holds:

\[
\frac{MP_L}{MP_K} = \frac{w}{r}
\]

We can rewrite this condition slightly as follows:

\[
\frac{MP_L}{w} = \frac{MP_K}{r}
\]  

(7.4)

**EXAMPLE 7.4  THE EFFECT OF EFFLUENT FEES ON INPUT CHOICES**

An effluent fee is a per-unit fee that the steel firm must pay for the effluent that goes into the river.

**FIGURE 7.5**

**THE COST-MINIMIZING RESPONSE TO AN EFFLUENT FEE**

When the firm is not charged for dumping its wastewater in a river, it chooses to produce a given output using 10,000 gallons of wastewater and 2000 machine-hours of capital at A. However, an effluent fee raises the cost of wastewater, shifts the isocost curve from FC to DE, and causes the firm to produce at B—a process that results in much less effluent.
Cost Minimization with Varying Output Levels

- **expansion path** Curve passing through points of tangency between a firm’s isocost lines and its isoquants.

The firm can hire labor $L$ at $w = $10/hour and rent a unit of capital $K$ for $r = $20/hour. Given these input costs, we have drawn three of the firm’s isocost lines. Each isocost line is given by the following equation:

$$C = (10/\text{hour})(L) + (20/\text{hour})(K)$$

The expansion path is a straight line with a slope equal to

$$\Delta K/\Delta L = (50 - 25)/(100 - 50) = \frac{1}{2}$$

**The Expansion Path and Long-Run Costs**

To move from the expansion path to the cost curve, we follow three steps:

1. Choose an output level represented by an isoquant. Then find the point of tangency of that isoquant with an isocost line.
2. From the chosen isocost line, determine the minimum cost of producing the output level that has been selected.
3. Graph the output-cost combination.
The Inflexibility of Short-Run Production

When a firm operates in the short run, its cost of production may not be minimized because of inflexibility in the use of capital inputs. Output is initially at level $q_1$. In the short run, output $q_2$ can be produced only by increasing labor from $L_1$ to $L_3$ because capital is fixed at $K_1$. In the long run, the same output can be produced more cheaply by increasing labor from $L_1$ to $L_2$ and capital from $K_1$ to $K_2$.

EXAMPLE 7.5  REDUCING THE USE OF ENERGY

ENERGY EFFICIENCY THROUGH CAPITAL SUBSTITUTION FOR LABOR

Greater energy efficiency can be achieved if capital is substituted for energy. This is shown as a movement along isoquant $q_1$ from point $A$ to point $B$, with capital increasing from $K_1$ to $K_2$ and energy decreasing from $E_2$ to $E_1$ in response to a shift in the isocost curve from $C_0$ to $C_1$. 
EXAMPLE 7.5 REDUCING THE USE OF ENERGY

FIGURE 7.7b
ENERGY EFFICIENCY THROUGH TECHNOLOGICAL CHANGE

Technological change implies that the same output can be produced with smaller amounts of inputs. Here the isoquant labeled $q_1$ shows combinations of energy and capital that will yield output $q_1$; the tangency with the isocost line at point $C$ occurs with energy and capital combinations $E_2$ and $K_2$. Because of technological change the isoquant shifts inward, so the same output $q_1$ can now be produced with less energy and capital, in this case at point $D$, with energy and capital combination $E_1$ and $K_1$.

E11. Suppose that a firm’s production function is $q = 10L^{1/2}K^{1/2}$. The cost of a unit of labor is $20 and the cost of a unit of capital is $80.

a) The firm is currently producing 100 units of output and has determined that the cost-minimizing quantities of labor and capital are 20 and 5, respectively. Graphically illustrate this using isoquants and isocost lines.

b) The firm now wants to increase output to 140 units. If capital is fixed in the short run, how much labor will the firm require? Illustrate this point graphically and find the firm’s new total cost.

c) Graphically identify the cost-minimizing level of capital and labor in the long run if the firm wants to produce 140 units.

d) If the marginal rate of technical substitution is $K/L$, find the optimal level of capital and labor required to produce the 140 units of output.
Long-Run Average Cost

When a firm is producing at an output at which the long-run average cost (LAC) is falling, the long-run marginal cost (LMC) is less than LAC. Conversely, when LAC is increasing, LMC is greater than LAC. The two curves intersect at A, where the LAC curve achieves its minimum.

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**long-run average cost curve (LAC)**
Curve relating average cost of production to output when all inputs, including capital, are variable.

**short-run average cost curve (SAC)**
Curve relating average cost of production to output when level of capital is fixed.

**long-run marginal cost curve (LMC)**
Curve showing the change in long-run total cost as output is increased incrementally by 1 unit.
Economies and Diseconomies of Scale

- **economies of scale**  
  Situation in which output can be doubled for less than a doubling of cost.

- **diseconomies of scale**  
  Situation in which a doubling of output requires more than a doubling of cost.

**Increasing Returns to Scale:**  
Output more than doubles when the quantities of all inputs are doubled.

**Economies of Scale:**  
A doubling of output requires less than a doubling of cost.

• **Economies of Scale**

As output increases, the firm’s average cost of producing that output is likely to decline, at least to a point.

This can happen for the following reasons:

1. If the firm operates on a larger scale, workers can specialize in the activities at which they are most productive.

2. Scale can provide flexibility. By varying the combination of inputs utilized to produce the firm’s output, managers can organize the production process more effectively.

3. The firm may be able to acquire some production inputs at lower cost because it is buying them in large quantities and can therefore negotiate better prices. The mix of inputs might change with the scale of the firm’s operation if managers take advantage of lower-cost inputs.
• Diseconomies of Scale

At some point, however, it is likely that the average cost of production will begin to increase with output.

There are three reasons for this shift:

1. At least in the short run, factory space and machinery may make it more difficult for workers to do their jobs effectively.

2. Managing a larger firm may become more complex and inefficient as the number of tasks increases.

3. The advantages of buying in bulk may have disappeared once certain quantities are reached. At some point, available supplies of key inputs may be limited, pushing their costs up.

7.4 LONG-RUN VERSUS SHORT-RUN COST CURVES

Economies and Diseconomies of Scale

Economies of scale are often measured in terms of a cost-output elasticity, $E_C$. $E_C$ is the percentage change in the cost of production resulting from a 1-percent increase in output:

\[
E_C = \frac{(\Delta C / C) / (\Delta q / q)}{(7.5)}
\]

To see how $EC$ relates to our traditional measures of cost, rewrite the equation as follows:

\[
E_C = (\Delta C / \Delta q) / (C / q) = MC / AC
\]  

(7.6)

EC < 1 economies to scale
EC > 1 diseconomies to scale
7.4 LONG-RUN VERSUS SHORT-RUN COST CURVES

The Relationship Between Short-Run and Long-Run Cost

Figure 7.9

Long-Run Cost with Economies and Diseconomies of Scale

The long-run average cost curve LAC is the envelope of the short-run average cost curves SAC₁, SAC₂, and SAC₃. With economies and diseconomies of scale, the minimum points of the short-run average cost curves do not lie on the long-run average cost curve.

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7.5 PRODUCTION WITH TWO OUTPUTS—ECONOMIES OF SCOPE

Product Transformation Curves

Figure 7.10

Product Transformation Curve

The product transformation curve describes the different combinations of two outputs that can be produced with a fixed amount of production inputs. The product transformation curves O₁ and O₂ are bowed out (or concave) because there are economies of scope in production.

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Economies and Diseconomies of Scope

- **economies of scope**  Situation in which joint output of a single firm is greater than output that could be achieved by two different firms when each produces a single product.

- **diseconomies of scope**  Situation in which joint output of a single firm is less than could be achieved by separate firms when each produces a single product.

The Degree of Economies of Scope

To measure the degree to which there are economies of scope, we should ask what percentage of the cost of production is saved when two (or more) products are produced jointly rather than individually.

\[
SC = \frac{C(q_1) + C(q_2) - C(q_1, q_2)}{C(q_1, q_2)}
\]  

- **degree of economies of scope (SC)**  Percentage of cost savings resulting when two or more products are produced jointly rather than individually.

- **SC > 0 economies of scope**
- **SC < 0 diseconomies of scope**
EXAMPLE 7.6  ECONOMIES OF SCOPE IN THE TRUCKING INDUSTRY

In the trucking business, several related products can be offered, depending on the size of the load and the length of the haul. This range of possibilities raises questions about both economies of scale and economies of scope.

The scale question asks whether large-scale, direct hauls are more profitable than individual hauls by small truckers. The scope question asks whether a large trucking firm enjoys cost advantages in operating direct quick hauls and indirect, slower hauls.

Because large firms carry sufficiently large truckloads, there is usually no advantage to stopping at an intermediate terminal to fill a partial load.

Because other disadvantages are associated with the management of very large firms, the economies of scope get smaller as the firm gets bigger.

The study suggests, therefore, that to compete in the trucking industry, a firm must be large enough to be able to combine loads at intermediate stopping points.

E14. A computer company produces hardware and software using the same plant and labor. The total cost of producing computer processing units $H$ and software programs $S$ is given by

$$TC = aH + bS - cHS$$

where $a$, $b$, and $c$ are positive. Is this total cost function consistent with the presence of economies or diseconomies of scale? With economies or diseconomies of scope?
RECAP: CHAPTER 7

• Measuring Cost: Which Costs Matter?
• Cost in the Short Run
• Cost in the Long Run
• Long-Run versus Short-Run Cost Curves
• Production with Two Outputs—Economies of Scope