

Behind the Supply Curve: >> Inputs and Costs

Section 2: Two Key Concepts: Marginal Cost and Average Cost

We've just seen how to derive a firm's total cost curve from its production function. Our next step is to take a deeper look at total cost by deriving two extremely useful measures: *marginal cost* and *average cost*. As we'll see, these two measures of the cost of production have a somewhat surprising relationship to each other. Moreover, they will prove to be vitally important in Chapter 9, where we will use them to analyze the firm's output decision and the market supply curve.



Marginal Cost

We defined marginal cost in Chapter 7: it is the change in total cost generated by producing one more unit of output. We've already seen that marginal product is easiest to calculate if data on output are available in increments of one unit of input. Similarly, marginal cost is easiest to calculate if data on total cost are available in increments of one unit of output. When the data come in less convenient increments, it's still possible to calculate marginal cost over each interval. But for the sake of simplicity, let's work with an example in which the data come in convenient increments.

Ben's Boots produces leather footwear; Table 8-1 shows how its costs per day depend on the number of boots it produces per day. The firm has fixed cost of \$108 per day, shown in the second column, which represents the daily cost of its boot-making machine. The third column shows the variable cost, and the fourth column shows the total cost. Panel (a) of Figure 8-5 plots the total cost curve. Like the total cost curve for George and Martha's farm in Figure 8-4 in "Section 1: The Production Function," this curve is upward sloping, getting steeper as you move up it to the right.

The significance of the slope of the total cost curve is shown by the fifth column of Table 8-1, which calculates *marginal cost*: the cost of each additional unit. The general formula for marginal cost is

$$(8-3) \text{ Marginal cost} = \frac{\text{Change in total cost}}{\text{Change in quantity of output}} = \frac{\text{Change in total cost generated by one additional unit of output}}{\text{output}}$$

or

$$MC = \Delta TC / \Delta Q$$

As in the case of marginal product, marginal cost is equal to "rise" (the increase in total cost) divided by "run" (the increase in the quantity of output). So just as marginal product is equal to the slope of the total product curve, marginal cost is equal to the slope of the total cost curve.

Now we can understand why the total cost curve gets steeper as we move up it to the right: as you can see in Table 8-1, the marginal cost at Ben's Boots rises as output increases. Panel (b) of Figure 8-5 shows the *marginal cost curve* corresponding to the data in Table 8-1. Notice that, as in Figure 8-2 in "Section 1: The Production Function," we plot the marginal cost for increasing output from 0 to 1 pair of boots halfway between 0 and 1, the marginal cost for increasing output from 1 to 2 pairs of boots halfway between 1 and 2, and so on.



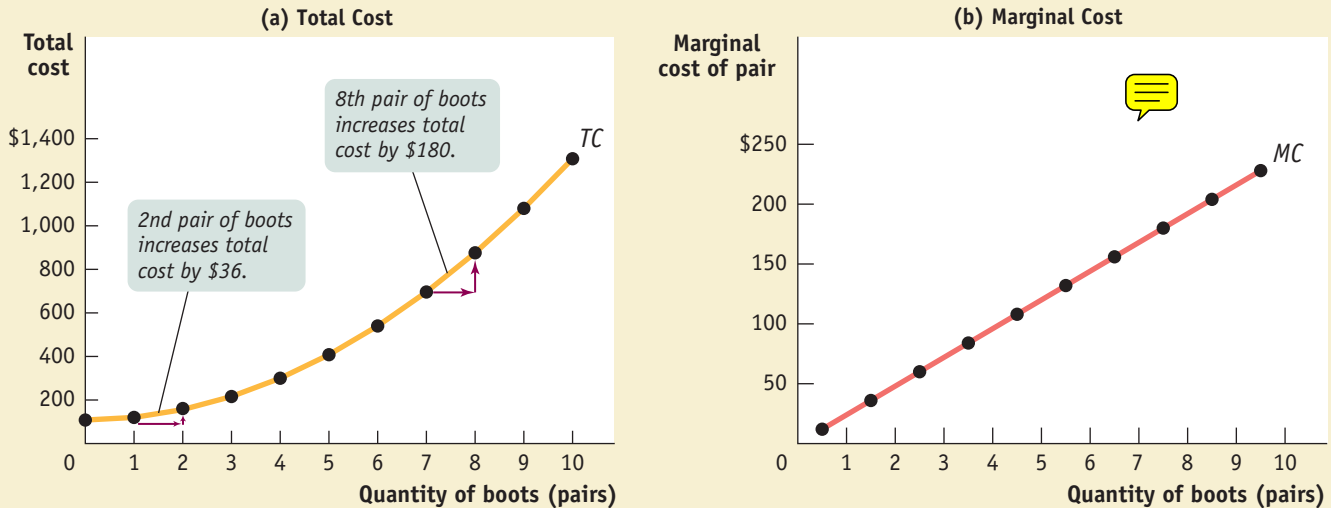
Why is the marginal cost curve upward sloping? Because there are diminishing returns to inputs in this example. As output increases, the marginal product of the variable input declines. This implies that more and more of the variable input must be used to produce each additional unit of output as the amount of output already produced rises. And since each unit of the variable input must be paid for, the cost per additional unit of output also rises.

TABLE 8-1
Costs at Ben's Boots

Quantity of boots Q (pairs)	Fixed cost FC	Variable cost VC	Total cost $TC = FC + VC$	Marginal cost of pair $MC = \Delta TC / \Delta Q$
0	\$108	\$0	\$108	
1	108	12	120	\$12
2	108	48	156	36
3	108	108	216	60
4	108	192	300	84
5	108	300	408	108
6	108	432	540	132
7	108	588	696	156
8	108	768	876	180
9	108	972	1,080	204
10	108	1,200	1,308	228

In addition, recall that the flattening of the total product curve is also due to diminishing returns to inputs in production: the marginal product of an input falls as more of that input is used if the quantities of other inputs are fixed. The flattening of the total product curve as output increases and the steepening of the total cost

Figure 8-5 Total Cost and Marginal Cost Curves for Ben's Boots



Panel (a) shows the total cost curve from Table 8-1. Like the total cost curve in Figure 8-4 in "Section 1: The Production Function," it slopes upward and gets steeper as we move up it to the right. Panel (b) shows the marginal cost curve. It also slopes upward, reflecting diminishing returns to the variable input. [>web...](#)

curve as output increases are just flip-sides of the same phenomenon. That is, as output increases, the marginal cost of output also increases because the marginal product of the variable input is falling.

We will return to marginal cost in Chapter 9, when we consider the firm's profit-maximizing output decision. But our next step is to introduce another measure of cost: *average cost*.

Average Cost

Average total cost, often referred to simply as **average cost**, is total cost divided by quantity of output produced.

In addition to total cost and marginal cost, it's useful to calculate one more measure, **average total cost**, often simply called **average cost**. The average total cost is total cost divided by the quantity of output produced; that is, it is equal to total cost per unit of output. If we let ATC denote average total cost, the equation looks like this:

$$(8-4) \quad ATC = \frac{\text{Total cost}}{\text{Quantity of output}} = TC/Q$$

Average total cost is important because it tells the producer how much the *average* or *typical* unit of output costs to produce. Marginal cost, meanwhile, tells the producer how much the *last* unit of output costs to produce. Although they may look very similar, these two measures of cost typically differ. And confusion between them is a major source of error in economics, both in the classroom and in real life.

Table 8-2 uses the data from Ben's Boots to calculate average total cost. For example, the total cost of producing 4 pairs of boots is \$300, consisting of \$108 in fixed cost and \$192 in variable cost (see Table 8-1). You can see from Table 8-2 that as quantity of output increases, average total cost first falls, then rises.

Figure 8-6 plots that data to yield the *average total cost curve*, which shows how average total cost depends on output. As before, cost in dollars is measured on the vertical axis and quantity of output is measured on the horizontal axis. The average total

A **U-shaped average total cost curve** falls at low levels of output, then rises at higher levels.

Average fixed cost is the fixed cost per unit of output.

Average variable cost is the variable cost per unit of output.

cost curve has a distinctive U shape that corresponds to how average total cost first falls and then rises as output increases. Economists believe that such **U-shaped average total cost curves** are the norm for producers in many industries.

To help our understanding of why the average total cost curve is U-shaped, Table 8-2 breaks average total cost into its two underlying components, *average fixed cost* and *average variable cost*. **Average fixed cost**, or *AFC*, is fixed cost divided by the quantity of output, also known as the fixed cost per unit of output. For example, if Ben's Boots produces 4 pairs of boots, average fixed cost is $\$108/4 = \27 per pair of boots. **Average variable cost**, or *AVC*, is variable cost divided by the quantity of out-

TABLE 8-2

Average Costs for Ben's Boots

Quantity of boots Q (pairs)	Total cost TC	Average total cost of pair $ATC = TC/Q$	Average fixed cost of pair $AFC = FC/Q$	Average variable cost of pair $AVC = VC/Q$
1	\$120	\$120.00	\$108.00	\$12.00
2	156	78.00	54.00	24.00
3	216	72.00	36.00	36.00
4	300	75.00	27.00	48.00
5	408	81.60	21.60	60.00
6	540	90.00	18.00	72.00
7	696	99.43	15.43	84.00
8	876	109.50	13.50	96.00
9	1,080	120.00	12.00	108.00
10	1,308	130.80	10.80	120.00

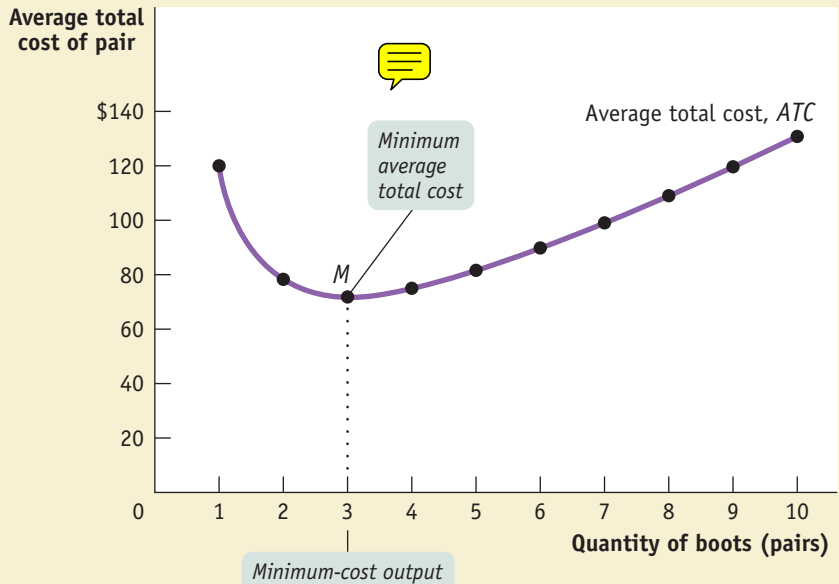
put, also known as variable cost per unit of output. At an output of 4 pairs of boots, average variable cost is $\$192/4 = \48 per pair. Writing these in the form of equations,

$$(8-5) \text{ AFC} = \frac{\text{Fixed cost}}{\text{Quantity of output}} = \text{FC}/Q$$

Figure 8-6

Average Total Cost Curve for Ben's Boots

The average total cost curve at Ben's Boots is U-shaped. At low levels of output, average total cost falls because the "spreading effect" of falling average fixed cost dominates the "diminishing returns effect" of rising average variable cost. At higher levels of output, the opposite is true and average total cost rises. At point *M*, corresponding to an output of three pairs of boots per day, average total cost is at its minimum level. [>web...](#)



$$AVC = \frac{\text{Variable cost}}{\text{Quantity of output}} = VC/Q$$

Average total cost is the sum of average fixed cost and average variable cost; it has a U shape because these components move in opposite directions as output rises.

Average fixed cost falls as more output is produced because the numerator (the fixed cost) is a fixed number but the denominator (the quantity of output) increases as more is produced. Another way to think about this relationship is that, as more output is produced, the fixed cost is spread over more units of output; the end result is that the fixed cost *per unit of output*—the average fixed cost—falls. You can see this effect in the fourth column of Table 8-2: average fixed cost drops continuously as output increases.

Average variable cost, however, rises as output increases. As we've seen, this reflects diminishing returns to inputs in production: each additional unit of output incurs more variable cost to produce than the previous unit. So variable cost rises at a faster rate than the quantity of output increases.

Increasing output, therefore, has two opposing effects on average total cost—the “spreading effect” and the “diminishing returns effect”:

- The spreading effect: the larger the output, the more production that can “share” the fixed cost, and therefore the lower the average fixed cost.
- The diminishing returns effect: the more output produced, the more variable inputs it requires to produce additional units, and therefore the higher the average variable cost.

At low levels of output, the spreading effect is very powerful because even small increases in output cause large reductions in average fixed cost. So at low levels of output, the spreading effect dominates the diminishing returns effect and causes the average total cost curve to slope downward. But when output is large, average fixed cost is

already quite small, so increasing output further has only a very small spreading effect. Diminishing returns, on the other hand, usually grow increasingly important as output rises. As a result, when output is large, the diminishing returns effect dominates the spreading effect, causing the average total cost curve to slope upward. At the bottom of the U-shaped average total cost curve, point *M* in Figure 8-6, the two effects exactly balance each other. At this point average total cost is at its minimum level.

Figure 8-7 brings together in a single picture four members of the family of cost curves that we have derived from the total cost curve: the marginal cost curve (*MC*), the average total cost curve (*ATC*), the average variable cost curve (*AVC*), and the average fixed cost curve (*AFC*). All are based on the information in Tables 8-1 and 8-2. As before, cost is measured on the vertical axis and quantity is measured on the horizontal axis.

Let's take a moment to note some features of the various cost curves. First of all, marginal cost is upward sloping—the result of diminishing returns that make an additional unit of output more costly to produce than the one before. Average variable cost also is upward sloping—again, due to diminishing returns—but is flatter than the marginal cost curve. This is because the higher cost of an additional unit of output is averaged across all units, not just the additional units, in the average variable cost measure. Meanwhile, average fixed cost is downward sloping because of the spreading effect.

Finally, notice that the marginal cost curve intersects the average total cost curve from below, crossing it at its lowest point, point *M* in Figure 8-7. This last feature is our next subject of study.

Minimum Average Total Cost

For a U-shaped average total cost curve, average total cost is at its minimum level at the bottom of the U. Economists call the quantity that corresponds to the minimum

The **minimum-cost output** is the quantity of output at which average total cost is lowest—the bottom of the U-shaped average total cost curve.

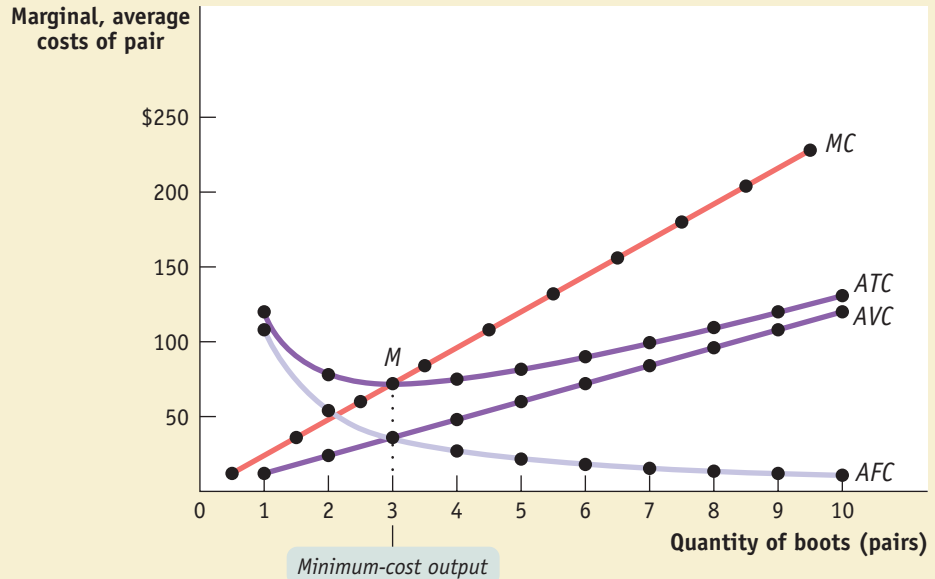
average total cost the **minimum-cost output**. In the case of Ben's Boots, the minimum-cost output is three pairs of boots per day.

In Figure 8-7, the bottom of the U is at the level of output at which the marginal cost curve crosses the average total cost curve from below. Is this an accident? No—it reflects general principles that are always true about a firm's marginal cost and average cost curves:

Figure 8-7

Marginal Cost and Average Cost Curves for Ben's Boots

Here we have the family of cost curves for Ben's Boots: the marginal cost curve (*MC*), the average total cost curve (*ATC*), the average variable cost curve (*AVC*), and the average fixed cost curve (*AFC*). Note that the average total cost curve is U-shaped and the marginal cost curve crosses the average total cost curve at the bottom of the U, point *M*, corresponding to the minimum average total cost in Table 8-2 and Figure 8-6. [→web...](#)



- At the minimum-cost output, average total cost is *equal to* marginal cost.
- At output less than the minimum-cost output, marginal cost is *less than* average total cost and average total cost is falling.
- And at output greater than minimum-cost output, marginal cost is *greater than* average total cost and average total cost is rising.

To understand this principle, think about how your grade in one course—say, a 3.0 in physics—affects your overall grade point average. If your GPA before receiving that grade was more than 3.0, the new grade lowers your average.

Similarly, if marginal cost—the cost of producing one more unit—is less than average total cost, producing that extra unit lowers average total cost. This is shown in Figure 8-8 by the movement from A_1 to A_2 . In this case, the marginal cost of producing an additional unit of output is low, as indicated by the point MC_L , on the marginal cost curve. And when the cost of producing the next unit of output is less than average total cost, increasing production reduces average total cost. So any level of output at which marginal cost is less than average total cost must be on the downward-sloping segment of the U.

But if your grade in physics is more than the average of your previous grades, this new grade raises your GPA. Similarly, if marginal cost is greater than average total cost, producing that extra unit raises average total cost. This is illustrated by the move from B_1 to B_2 in Figure 8-8, where the marginal cost, MC_H , is higher than average total cost. So any level of output at which marginal cost is greater than average total cost must be on the upward-sloping segment of the U.

Finally, if a new grade is exactly equal to your previous GPA, the additional grade neither raises nor lowers that average—it stays the same. This corresponds to point M in Figure 8-8: when marginal cost equals average total cost, we must be at the bottom of the U, because only at that point is average total cost neither falling nor rising.



Does the Marginal Cost Curve Always Slope Upward?

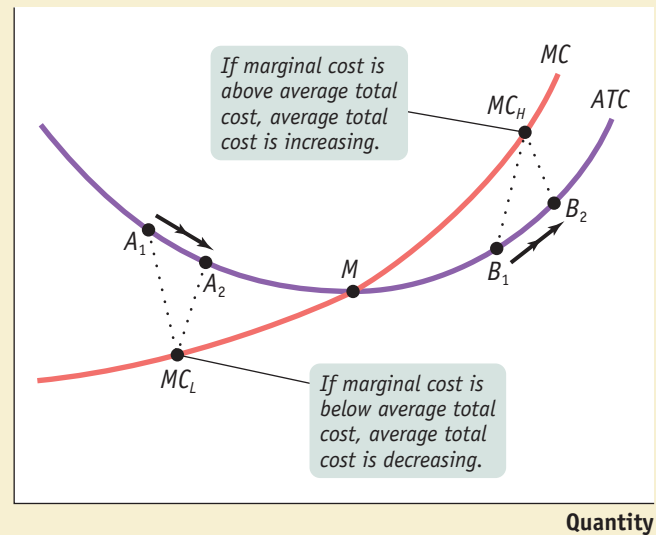
Up to this point, we have emphasized the importance of diminishing returns, which lead to a marginal product curve that is always downward sloping and a marginal cost curve that is always upward sloping. In practice, however, economists believe that marginal cost curves often slope *downward* as a firm increases its production from zero up to some low level, sloping upward only at higher levels of production: they look like the curve MC in Figure 8-9.

Figure 8-8

The Relationship Between the Average Total Cost and the Marginal Cost Curves

To see why the marginal cost curve (MC) must cut through the average total cost curve at the minimum average total cost (point M), corresponding to the minimum-cost output, we look at what happens if marginal cost is different from average total cost. If marginal cost is *less* than average total cost, an increase in output must reduce average total cost, as in the movement from A_1 to A_2 . If marginal cost is *greater* than average total cost, an increase in output must increase average total cost, as in the movement from B_1 to B_2 .

Marginal,
average
costs
of unit



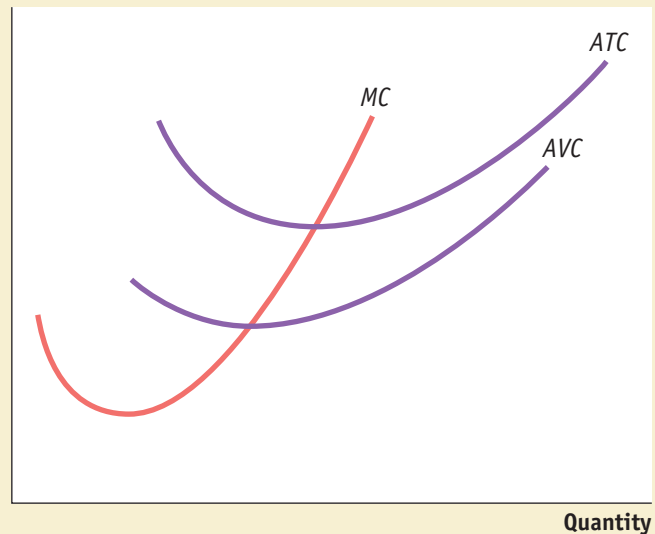
This initial downward slope occurs because a firm that employs only a few workers often cannot reap the benefits of specialization of labor. For example, one individual producing boots would have to perform all the tasks involved: making soles, shaping the upper part, sewing the pieces together, and so on. As more workers are employed, they can divide the tasks, with each worker specializing in one or a few aspects of boot-making. This specialization can lead to *increasing* returns at first, and so to a downward-sloping marginal cost curve. Once there are enough workers to per-

Figure 8-9

More Realistic Cost Curves

In practice, the marginal cost curve often begins with a section that slopes downward. As output rises from a low level, a firm is capable of engaging in specialization and division of labor, which leads to increasing returns. At higher levels of output, however, diminishing returns lead to upward-sloping marginal cost. When marginal cost has a downward-sloping section, average variable cost is U-shaped. However, the basic results—U-shaped average total cost, and marginal cost that cuts through the minimum average total cost—remain the same. [>web...](#)

Marginal,
average
costs
of unit



mit specialization, however, diminishing returns set in. So typical marginal cost curves actually have the “swoosh” shape shown by MC in Figure 8-9. For the same reason, average variable cost curves typically look like AVC in Figure 8-9: they are U-shaped rather than strictly upward sloping.

However, as Figure 8-9 also shows, the key features we saw from the example of Ben’s Boots remain true: the average total cost curve is U-shaped, and the marginal cost curve passes through the point of minimum average total cost as well as through the point of minimum average variable cost. ■