Module 55

Firm Costs

What you will learn in this Module:

- The various types of cost a firm faces, including fixed cost, variable cost, and total cost
- How a firm's costs generate marginal cost curves and average cost curves

Module 55: Firm Costs

From the Production Function to Cost Curves

Now that we have learned about the firm's production function, we can use that knowledge to develop its cost curves. To see how a firm's production function is related to its cost curves, let's turn once again to George and Martha's farm. Once George and Martha know their production function, they know the relationship between inputs of labor and land and output of wheat. But if they want to maximize their profits, they need to translate this knowledge into information about the relationship between the quantity of output and cost. Let's see how they can do this.

To translate information about a firm's production function into information about its cost, we need to know how much the firm must pay for its inputs. We will assume that George and Martha face either an explicit or an implicit cost of $400 for the use of the land. As we learned previously, it is irrelevant whether George and Martha must rent the land for $400 from someone else or whether they own the land themselves and forgo earning $400 from renting it to someone else. Either way, they pay an opportunity cost of $400 by using the land to grow wheat. Moreover, since the land is a fixed input for which George and Martha pay $400 whether they grow one bushel of wheat or one hundred, its cost is a **fixed cost**, denoted by *FC*—a cost that does not depend on the quantity of output produced. In business, a fixed cost is often referred to as an "overhead cost."

A **fixed cost** is a cost that does not depend on the quantity of output produced. It is the cost of the fixed input.

We also assume that George and Martha must pay each worker $200. Using their production function, George and Martha know that the number of workers they must hire depends on the amount of wheat they intend to produce. So the cost of labor, which is equal to the number of workers multiplied by $200, is a **variable cost**, denoted by *VC*—a cost that depends on the quantity of output produced. Adding the fixed cost and the variable cost of a given quantity of output gives the **total cost**, or *TC*, of that quantity of output. We can express the relationship among fixed cost, variable cost, and total cost as an equation:

A **variable cost** is a cost that depends on the quantity of output produced. It is the cost of the variable input.

The **total cost** of producing a given quantity of output is the sum of the fixed cost and the variable cost of producing that quantity of output.

(55-1) Total cost = Fixed cost + Variable cost

or

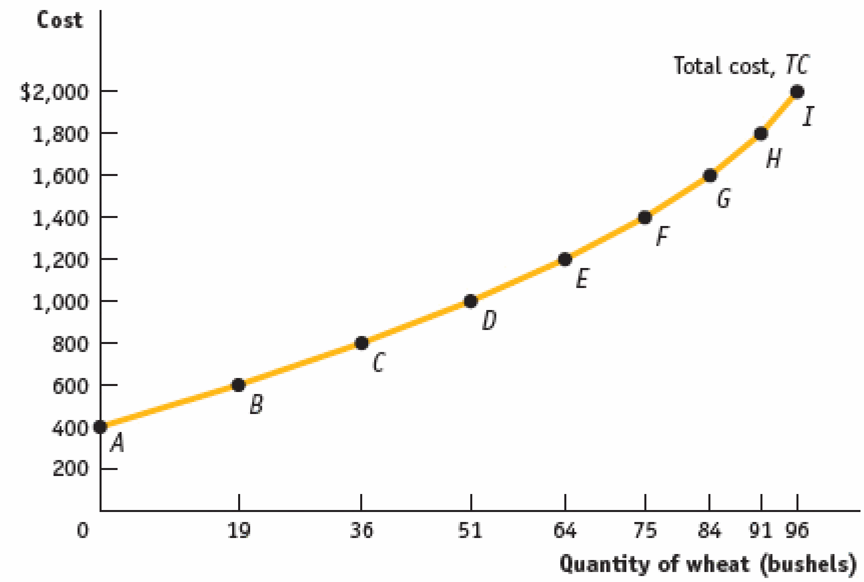
$$TC = FC + VC$$

The table in **Figure 55.1** shows how total cost is calculated for George and Martha's farm. The second column shows the number of workers employed, *L*. The third column shows the corresponding level of output, *Q*, taken from the table in **Figure 54.1**. The fourth column shows the variable cost, *VC*, equal to the number of workers multiplied by $200. The fifth column shows the fixed cost, *FC*, which is $400 regardless of the quantity of wheat produced. The sixth column shows the total cost of output, *TC*, which is the variable cost plus the fixed cost.

figure 55.1

Total Cost Curve for George and Martha's Farm

The table shows the variable cost, fixed cost, and total cost for various output quantities on George and Martha's 10-acre farm. The total cost curve shows how total cost (measured on the vertical axis) depends on the quantity of output (measured on the horizontal axis). The labeled points on the curve correspond to the rows of the table. The total cost curve slopes upward because the number of workers employed, and hence total cost, increases as the quantity of output increases. The curve gets steeper as output increases due to diminishing returns to labor.



Point on graph	Quantity of labor *L* (workers)	Quantity of wheat *Q* (bushels)	Variable cost *VC*	Fixed cost *FC*	Total cost *TC = FC + VC*
A	0	0	$0	$400	$400
B	1	19	200	400	600
C	2	36	400	400	800
D	3	51	600	400	1,000
E	4	64	800	400	1,200
F	5	75	1,000	400	1,400
G	6	84	1,200	400	1,600
H	7	91	1,400	400	1,800
I	8	96	1,600	400	2,000

The first column labels each row of the table with a letter, from *A* to *I*. These labels will be helpful in understanding our next step: drawing the **total cost curve**, a curve that shows how total cost depends on the quantity of output.

The **total cost curve** shows how total cost depends on the quantity of output.

George and Martha's total cost curve is shown in the diagram in **Figure 55.1**, where the horizontal axis measures the quantity of output in bushels of wheat and the vertical axis measures total cost in dollars. Each point on the curve corresponds to one row of the table in **Figure 55.1**. For example, point *A* shows the situation when 0 workers are employed: output is 0, and total cost is equal to fixed cost, $400. Similarly, point *B* shows the situation when 1 worker is employed: output is 19 bushels, and total cost is $600, equal to the sum of $400 in fixed cost and $200 in variable cost.

Like the total product curve, the total cost curve slopes upward: due to the increasing variable cost, the more output produced, the higher the farm's total cost. But unlike the total product curve, which gets flatter as employment rises, the total cost curve gets *steeper*. That is, the slope of the total cost curve is greater as the amount of output produced increases. As we will soon see, the steepening of the total cost curve is also due to diminishing returns to the variable input. Before we can see why, we must first look at the relationships among several useful measures of cost.

Two Key Concepts: Marginal Cost and Average Cost

We've just learned 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 later modules, where we will use them to analyze the firm's output decision and the market supply curve.

Two Key Concepts: Marginal Cost and Aver...

Marginal Cost

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Module 53 explained that marginal cost is the added cost of doing something one more time. In the context of production, marginal cost 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 because the increase in total cost for each unit is clear. 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 one-unit increments.

Selena's Gourmet Salsas produces bottled salsa; **Table 55.1** shows how its costs per day depend on the number of cases of salsa it produces per day. The firm has a fixed cost of $108 per day, shown in the second column, which is the daily rental cost of its food-preparation equipment. The third column shows the variable cost, and the fourth column shows the total cost. Panel (a) of **Figure 55.2** plots the total cost curve. Like the total cost curve for George and Martha's farm in **Figure 55.1**, this curve slopes upward, getting steeper as quantity increases.

table 55.1

Costs at Selena's Gourmet Salsas

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

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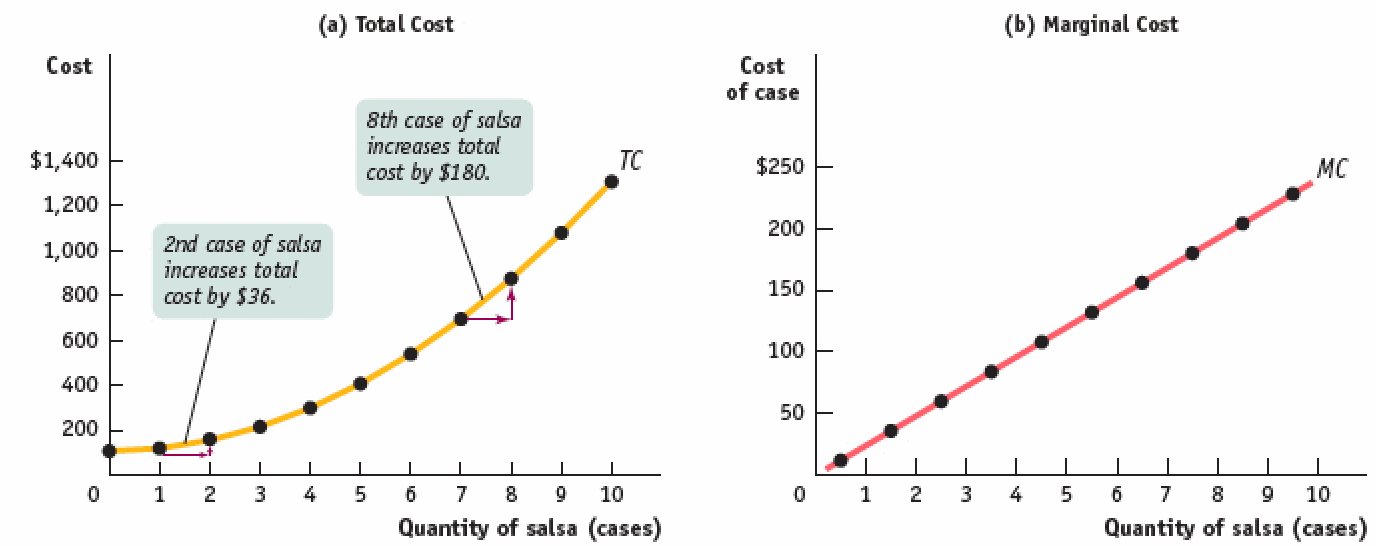
figure 55.2 Total Cost and Marginal Cost Curves for Selena's Gourmet Salsas



Panel (a) shows the total cost curve from Table 55.1. Like the total cost curve in Figure 55.1, 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.

The significance of the slope of the total cost curve is shown by the fifth column of **Table 55.1**, which indicates marginal cost—the additional cost of each additional unit. The general formula for marginal cost is:

$$\text{(55-2)} \quad \text{Marginal cost} = \begin{array}{l}\text{Change in total}\\ \text{cost generated by}\\ \text{one additional unit}\\ \text{of output}\end{array} = \frac{\text{Change in total cost}}{\text{Change in quantity of output}}$$

or

$$MC = \frac{\Delta TC}{\Delta Q}$$

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 it increases from left to right: as you can see in **Table 55.1**, marginal cost at Selena's Gourmet Salsas rises as output increases. And because marginal cost equals the slope of the total cost curve, a higher marginal cost means a steeper slope. Panel (b) of **Figure 55.2** shows the marginal cost curve corresponding to the data in **Table 55.1**. Notice that, as in **Figure 53.1**, we plot the marginal cost for increasing output from 0 to 1 case of salsa halfway between 0 and 1, the marginal cost for increasing output from 1 to 2 cases of salsa halfway between 1 and 2, and so on.

Why does the marginal cost curve slope upward? Because there are diminishing returns to inputs in this example. As output increases, the marginal product of the variable input declines. This implies that

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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 additional cost per additional unit of output also rises.

Recall that the flattening of the total product curve is also due to diminishing returns: if the quantities of other inputs are fixed, the marginal product of an input falls as more of that input is used. The flattening of the total product curve as output increases and the steepening of the total cost 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 decreases. Our next step is to introduce another measure of cost: *average cost*.

Marginal Cost

Average Cost

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In addition to total cost and marginal cost, it's useful to calculate **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:

$$(55\text{-}3)\quad ATC = \frac{\text{Total cost}}{\text{Quantity of output}} = \frac{TC}{Q}$$

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

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 *one more* 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 55.2** uses data from Selena's Gourmet Salsas to calculate average total cost. For example, the total cost of producing 4 cases of salsa is $300, consisting of $108 in fixed cost and $192 in variable cost (from **Table 55.1**). So the average total cost of producing 4 cases of salsa is $300/4 = $75. You can see from **Table 55.2** that as the quantity of output increases, average total cost first falls, then rises.

table **55.2**

Average Costs for Selena's Gourmet Salsas

Quantity of salsa *Q* (cases)	Total cost *TC*	Average total cost of case *ATC = TC/Q*	Average fixed cost of case *AFC = FC/Q*	Average variable cost of case *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

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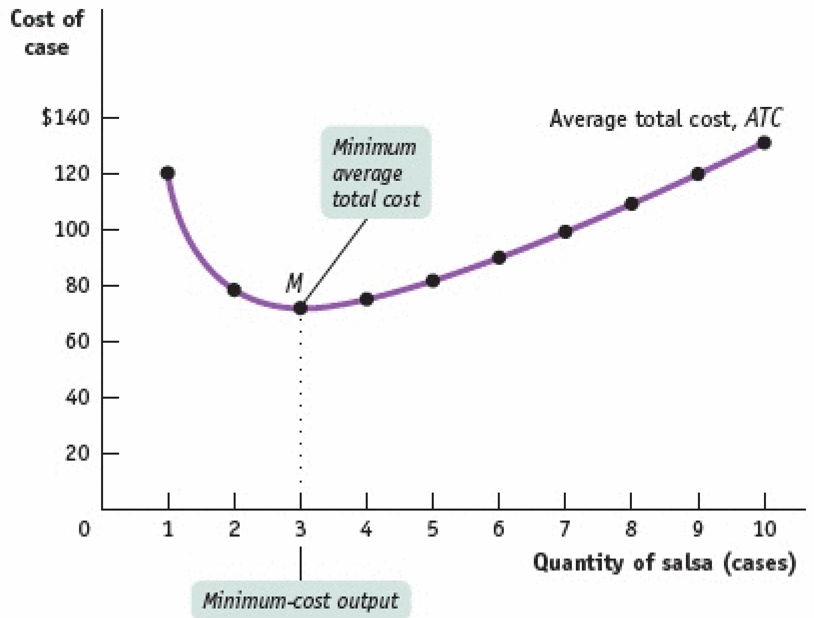
Figure 55.3 plots that data to yield the *average total cost curve*, which shows how average total cost depends on output. As before, cost in dollars is measured on the vertical axis and quantity of output is measured on the horizontal axis. The average total cost curve has a distinctive **U** shape 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 firms in many industries.

figure 55.3

Average Total Cost Curve for Selena's Gourmet Salsas

The average total cost curve at Selena's Gourmet Salsas 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 cases of salsa per day, average total cost is at its minimum level, the minimum average total cost.



To help our understanding of why the average total cost curve is **U**-shaped, **Table 55.2** 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 Selena's Gourmet Salsas produces 4 cases of salsa, average fixed cost is $108/4 = $27 per case. **Average variable cost**, or *AVC*, is variable cost divided by the quantity of output, also known as variable cost per unit of output. At an output of 4 cases, average variable cost is $192/4 = $48 per case. Writing these in the form of equations:

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

$$(55\text{-}4)\quad AFC = \frac{\text{Fixed cost}}{\text{Quantity of output}} = \frac{FC}{Q}$$

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

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

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

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 55.2**: 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 the variable input: each additional unit of output adds more to variable cost than the previous unit because increasing amounts of the variable input are required to make another unit.

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So increasing output has two opposing effects on average total cost—the "spreading effect" and the "diminishing returns effect":

- *The spreading effect*. The larger the output, the greater the quantity of output over which fixed cost is spread, leading to lower average fixed cost.
- *The diminishing returns effect*. The larger the output, the greater the amount of variable input required to produce additional units, leading to higher average variable cost.

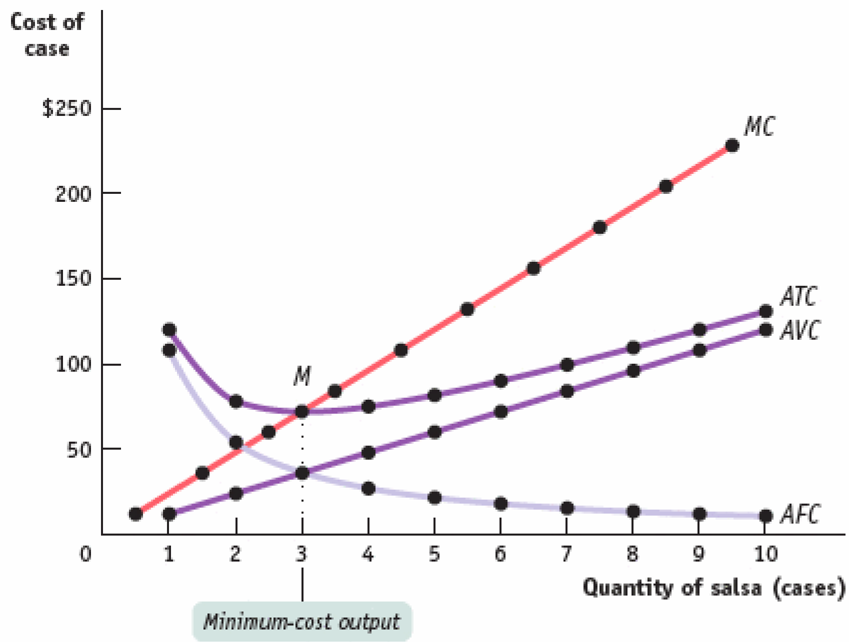
At low levels of output, the spreading effect is very powerful because even small increases in output cause large reductions in average fixed cost. So at low levels of output, the spreading effect dominates the diminishing returns effect and causes the average total cost curve to slope downward. But when output is large, average fixed cost is already quite small, so increasing output further has only a very small spreading effect. Diminishing returns, however, 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 55.3**, the two effects exactly balance each other. At this point average total cost is at its minimum level, the minimum average total cost.

Figure 55.4 brings together in a single picture the four other cost curves that we have derived from the total cost curve for Selena's Gourmet Salsas: 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 **Table 55.1** and **Table 55.2**. As before, cost is measured on the vertical axis and the quantity of output is measured on the horizontal axis.

figure 55.4

Marginal Cost and Average Cost Curves for Selena's Gourmet Salsas

Here we have the family of cost curves for Selena's Gourmet Salsas: 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 from Table 55.2 and Figure 55.3.



Let's take a moment to note some features of the various cost curves. First of all, marginal cost slopes upward—the result of diminishing returns that make an additional unit of output more costly to produce than the one before. Average variable cost also slopes upward—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 unit, in the average variable cost measure. Meanwhile, average fixed cost slopes downward 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 55.4**. This last feature is our next subject of study.

◀ Average Cost ▶

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 of output that corresponds to the minimum average total cost the **minimum-cost output**. In the case of Selena's Gourmet Salsas, the minimum-cost output is three cases of salsa per day.

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

In **Figure 55.4**, 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 total cost curves:

- 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 the minimum-cost output, marginal cost *is greater than* average total cost and average total cost is rising.

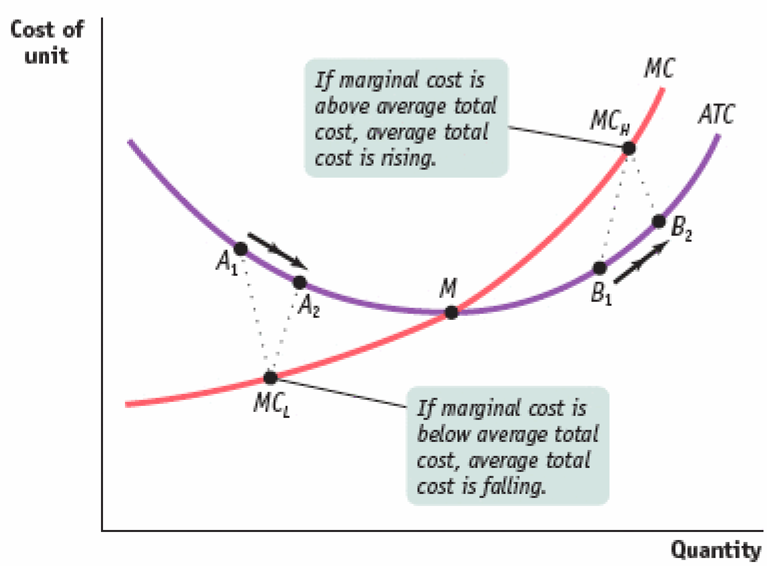
To understand these principles, think about how your grade in one course—say, a 3.0 in physics—affects your overall grade point average. If your GPA before receiving that grade was more than 3.0, the new grade lowers your average.

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 55.5** 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. When the cost of producing the next unit of output is less than average total cost, increasing production reduces average total cost. So any quantity of output at which marginal cost is less than average total cost must be on the downward-sloping segment of the **U**.

figure 55.5

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.



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 movement from B_1 to B_2 in **Figure 55.5**, where the marginal cost, MC_H, is higher than average total cost. So any quantity 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 55.5**: 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.

Minimum Average Total Cost

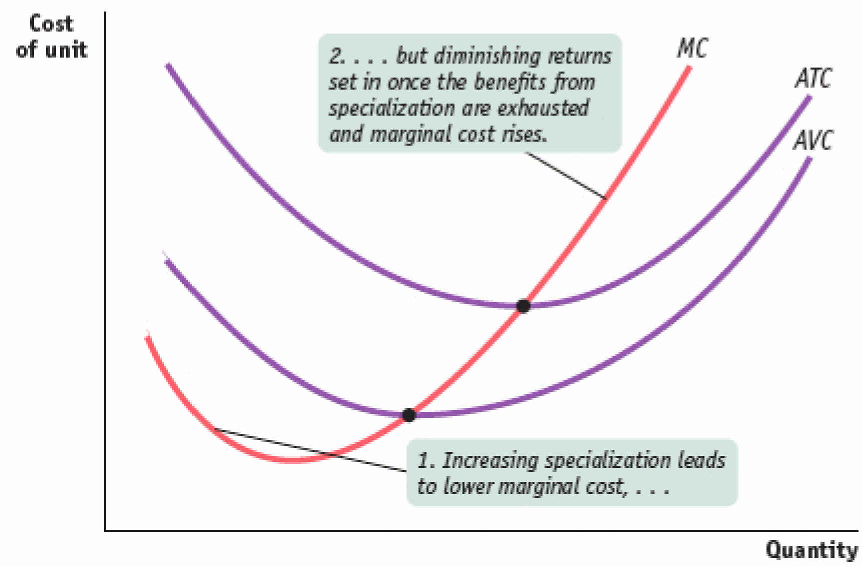
Does the Marginal Cost Curve Always Slope Upward?

Up to this point, we have emphasized the importance of diminishing returns, which lead to a marginal product curve that always slopes downward and a marginal cost curve that always slopes upward. 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: marginal cost curves look like the curve labeled *MC* in **Figure 55.6**.

figure 55.6

More Realistic Cost Curves

A realistic marginal cost curve has a "swoosh" shape. Starting from a very low output level, marginal cost often falls as the firm increases output. That's because hiring additional workers allows greater specialization of their tasks and leads to increasing returns. Once specialization is achieved, however, diminishing returns to additional workers set in and marginal cost rises. The corresponding average variable cost curve is now U-shaped, like the average total cost curve.



This initial downward slope occurs because a firm often finds that, when it starts with only a very small number of workers, employing more workers and expanding output allows its workers to specialize in various tasks. This, in turn, lowers the firm's marginal cost as it expands output. For example, one individual producing salsa would have to perform all the tasks involved: selecting and preparing the ingredients, mixing the salsa, bottling and labeling it, packing it into cases, and so on. As more workers are employed, they can divide the tasks, with each worker specializing in one or a few aspects of salsa-making. This specialization leads to *increasing returns* to the hiring of additional workers and results in a marginal cost curve that initially slopes downward. But once there are enough workers to have completely exhausted the benefits of further specialization, diminishing returns to labor set in and the marginal cost curve changes direction and slopes upward. So typical marginal cost curves actually have the "swoosh" shape shown by *MC* in **Figure 55.6**. For the same reason, average variable cost curves typically look like *AVC* in **Figure 55.6**: they are **U**-shaped rather than strictly upward sloping.

However, as **Figure 55.6** also shows, the key features we saw from the example of Selena's Gourmet Salsas remain true: the average total cost curve is **U**-shaped, and the marginal cost curve passes through the point of minimum average total cost.