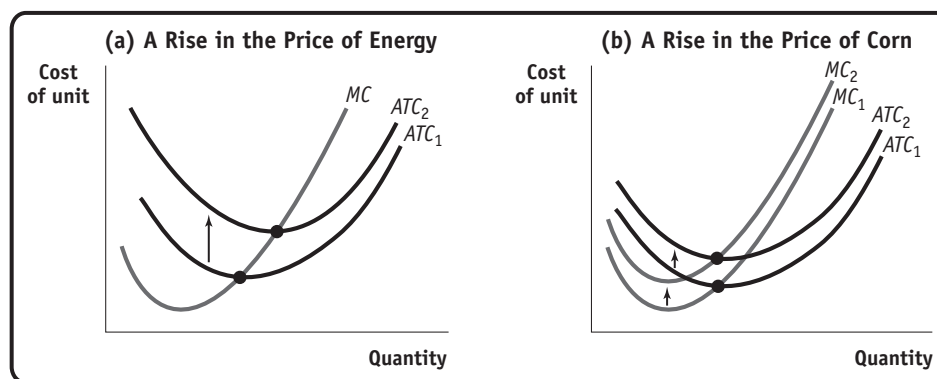


Behind the Supply Curve: Inputs and Costs

1. Changes in the price of key commodities have a significant impact on a company's bottom line. For virtually all companies, the price of energy is a substantial portion of their costs. In addition, many industries—such as those that produce beef, chicken, high-fructose corn syrup and ethanol—are highly dependent on the price of corn. In particular, corn has seen a significant increase in price.
 - a. Explain how the cost of energy can be both a fixed cost and a variable cost for a company.
 - b. Suppose energy is a fixed cost and energy prices rise. What happens to the company's average total cost curve? What happens to its marginal cost curve? Illustrate your answer with a diagram.
 - c. Explain why the cost of corn is a variable cost but not a fixed cost for an ethanol producer.
 - d. When the cost of corn goes up, what happens to the average total cost curve of an ethanol producer? What happens to its marginal cost curve? Illustrate your answer with a diagram.

Solution

1. a. Energy required to keep a company operating regardless of how much output is produced represents a fixed cost, such as the energy costs of operating office buildings, factories, and stores that must be maintained independent of the amount of output produced. In addition, energy is a variable cost because producing more output almost always requires using more energy.
- b. When fixed costs increase, so will average total costs. The average total cost curve will shift upward. In panel (a) of the accompanying diagram, this is illustrated by the movement of the average total cost curve from its initial position, ATC_1 , to its new position, ATC_2 . The marginal cost curve is not affected if the variable costs do not change. So the marginal cost curve remains at its initial position, MC .



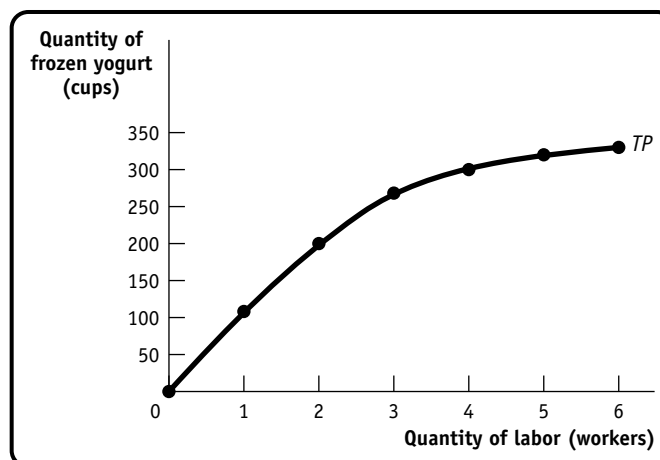
- c. Since corn is an input into the production of ethanol, producing a larger quantity of ethanol requires a larger quantity of corn, making corn a variable cost.

- d. When variable costs increase, so do average total costs and marginal costs. Both curves will shift upward. In panel (b) of the accompanying diagram, the movement of the average total cost curve is illustrated by the shift from its initial position, ATC_1 , to its new position, ATC_2 . The movement of the marginal cost curve is illustrated by the shift from its initial position, MC_1 , to its new position, MC_2 .
2. Marty's Frozen Yogurt is a small shop that sells cups of frozen yogurt in a university town. Marty owns three frozen-yogurt machines. His other inputs are refrigerators, frozen-yogurt mix, cups, sprinkle toppings, and, of course, workers. He estimates that his daily production function when he varies the number of workers employed (and at the same time, of course, yogurt mix, cups, and so on) is as shown in the accompanying table.

Quantity of labor (workers)	Quantity of frozen yogurt (cups)
0	0
1	110
2	200
3	270
4	300
5	320
6	330

- a. What are the fixed inputs and variable inputs in the production of cups of frozen yogurt?
- b. Draw the total product curve. Put the quantity of labor on the horizontal axis and the quantity of frozen yogurt on the vertical axis.
- c. What is the marginal product of the first worker? The second worker? The third worker? Why does marginal product decline as the number of workers increases?

- Solution**
2. a. The fixed inputs are those whose quantities do not change as the quantity of output changes: frozen-yogurt machines, refrigerators, and the shop. The variable inputs are those whose quantities do change as the quantity of output changes: frozen-yogurt mix, cups, sprinkle toppings, and workers.
- b. The accompanying diagram illustrates the total product curve.



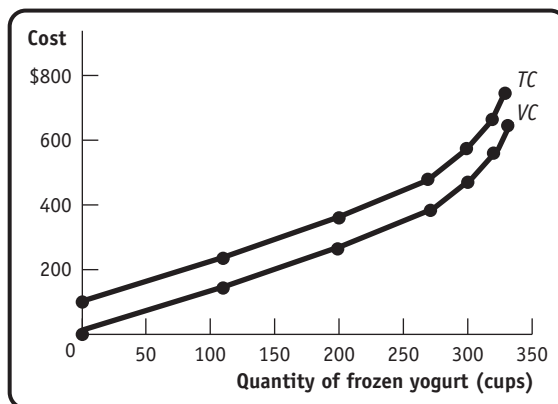
- c. The marginal product, *MPL*, of the first worker is 110 cups. The *MPL* of the second worker is 90 cups. The *MPL* of the third worker is 70 cups. The *MPL* of labor declines as more and more workers are added due to the principle of diminishing returns to labor. Since the number of frozen-yogurt machines is fixed, as workers are added there are fewer and fewer machines for each worker to work with, making each additional worker less and less productive.
3. The production function for Marty's Frozen Yogurt is given in Problem 2. Marty pays each of his workers \$80 per day. The cost of his other variable inputs is \$0.50 per cup of yogurt. His fixed cost is \$100 per day.
- What is Marty's variable cost and total cost when he produces 110 cups of yogurt? 200 cups? Calculate variable and total cost for every level of output given in Problem 2.
 - Draw Marty's variable cost curve. On the same diagram, draw his total cost curve.
 - What is the marginal cost per cup for the first 110 cups of yogurt? For the next 90 cups? Calculate the marginal cost for all remaining levels of output.

Solution

3. a. Marty's variable cost, *VC*, is his wage cost (\$80 per worker per day) and his other input costs (\$0.50 per cup). His total cost, *TC*, is the sum of the variable cost and his fixed cost of \$100 per day. The answers are given in the accompanying table.

Quantity of frozen yogurt (cups)	Quantity of labor (workers)	<i>VC</i>	<i>TC</i>	<i>MC</i> of cup
0	0	\$0	\$100	
110	1	$1 \times 80 + 110 \times 0.5 = 135$	235	\$1.23
200	2	$2 \times 80 + 200 \times 0.5 = 260$	360	1.39
270	3	$3 \times 80 + 270 \times 0.5 = 375$	475	1.64
300	4	$4 \times 80 + 300 \times 0.5 = 470$	570	3.17
320	5	$5 \times 80 + 320 \times 0.5 = 560$	660	4.50
330	6	$6 \times 80 + 330 \times 0.5 = 645$	745	8.50

- b. The accompanying diagram shows the variable cost and total cost curves.



- c. Marginal cost, *MC*, per cup of frozen yogurt is shown in the table in part a; it is the change in total cost divided by the change in quantity of output.

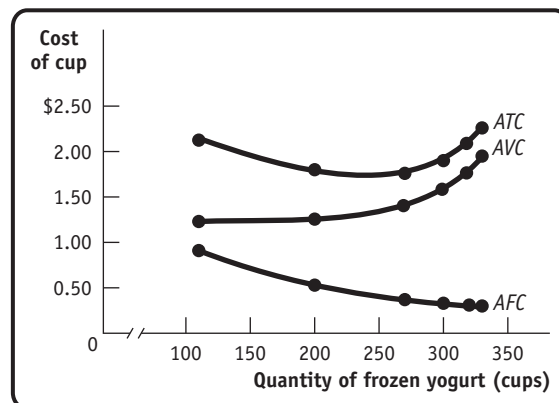
4. The production function for Marty's Frozen Yogurt is given in Problem 2. The costs are given in Problem 3.
- For each of the given levels of output, calculate the average fixed cost (*AFC*), average variable cost (*AVC*), and average total cost (*ATC*) per cup of frozen yogurt.
 - On one diagram, draw the *AFC*, *AVC*, and *ATC* curves.
 - What principle explains why the *AFC* declines as output increases? What principle explains why the *AVC* increases as output increases? Explain your answers.
 - How many cups of frozen yogurt are produced when average total cost is minimized?

Solution

4. a. The average fixed cost, average variable cost, and average total cost per cup of yogurt are given in the accompanying table. (Numbers are rounded.)

Quantity of frozen yogurt (cups)	<i>VC</i>	<i>TC</i>	<i>AFC</i> of cup	<i>AVC</i> of cup	<i>ATC</i> of cup
0	\$0	\$100	—	—	—
110	135	235	\$0.91	\$1.23	\$2.14
200	260	360	0.50	1.30	1.80
270	375	475	0.37	1.39	1.76
300	470	570	0.33	1.57	1.90
320	560	660	0.31	1.75	2.06
330	645	745	0.30	1.95	2.26

- b. The accompanying diagram shows the *AFC*, *AVC*, and *ATC* curves.



- AFC* declines as output increases due to the spreading effect. The fixed cost is spread over more and more units of output as output increases. *AVC* increases as output increases due to the diminishing returns effect. Due to diminishing returns to labor, it costs more to produce each additional unit of output.
- Average total cost is minimized when 270 cups of yogurt are produced. At lower quantities of output, the fall attributable to the spreading effect dominates changes in average total cost. At higher quantities of output, the rise attributable to the diminishing returns effect dominates changes in average total cost.

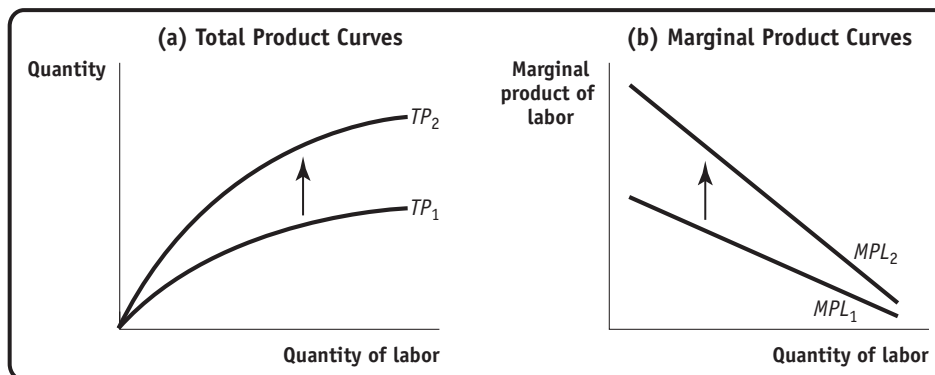
5. Labor costs represent a large percentage of total costs for many firms. According to data from the Bureau of Labor Statistics, U.S. labor costs were up 0.8% in 2013, compared to 2012.
- When labor costs increase, what happens to average total cost and marginal cost? Consider a case in which labor costs are only variable costs and a case in which they are both variable and fixed costs.

An increase in labor productivity means each worker can produce more output. Recent data on productivity show that labor productivity in the U.S. nonfarm business sector grew by 1.7% between 1970 and 1999, by 2.6% between 2000 and 2009, and by 1.1% between 2010 and 2013.

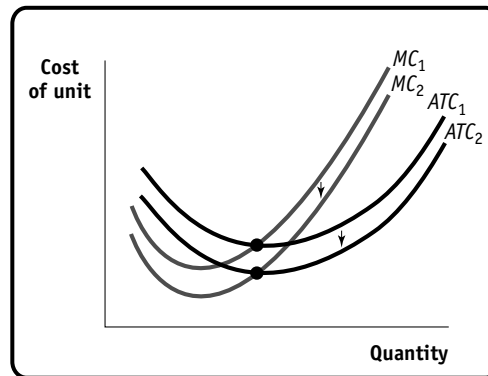
- When productivity growth is positive, what happens to the total product curve and the marginal product of labor curve? Illustrate your answer with a diagram.
- When productivity growth is positive, what happens to the marginal cost curve and the average total cost curve? Illustrate your answer with a diagram.
- If labor costs are rising over time on average, why would a company want to adopt equipment and methods that increase labor productivity?

Solution

5. a. When labor costs are a variable cost but not a fixed cost, an increase in labor costs leads to an increase in both average total cost and marginal cost. When labor costs are a variable cost and a fixed cost, the result is the same: both the average total cost and the marginal cost increase.
- b. When productivity growth is positive, any given quantity of labor can produce more output, causing the total product curve to shift upward. Since each unit of labor can produce more output, the marginal product of labor will increase and the marginal product of labor curve will shift upward. In panel (a) of the accompanying diagram, the upward shift of the total product curve is illustrated by the movement from its initial position, TP_1 , to its new position, TP_2 . In panel (b), the upward shift of the marginal product of labor curve is illustrated by the movement from its initial position, MPL_1 , to its new position, MPL_2 .



- c. When productivity growth is positive, the marginal cost curve and the average total cost curve will both shift downward, assuming labor costs have not changed. In the accompanying diagram, the movement of the average total cost curve is illustrated by the shift from its initial position, ATC_1 , to its new position, ATC_2 . The movement of the marginal cost curve is illustrated by the shift from its initial position, MC_1 , to its new position, MC_2 .



- d. Rising labor costs will shift the average total cost and marginal cost curves upward. Productivity growth will counteract this, shifting the average total cost and marginal cost curves downward.
6. Magnificent Blooms is a florist specializing in floral arrangements for weddings, graduations, and other events. Magnificent Blooms has a fixed cost associated with space and equipment of \$100 per day. Each worker is paid \$50 per day. The daily production function for Magnificent Blooms is shown in the accompanying table.

Quantity of labor (workers)	Quantity of floral arrangements
0	0
1	5
2	9
3	12
4	14
5	15

- a. Calculate the marginal product of each worker. What principle explains why the marginal product per worker declines as the number of workers employed increases?
- b. Calculate the marginal cost of each level of output. What principle explains why the marginal cost per floral arrangement increases as the number of arrangements increases?

Solution

6. a. *MPL*, shown in the accompanying table for the five workers, is the change in output resulting from the employment of one additional worker per day. *MPL* falls as the quantity of labor increases due to the principle of diminishing returns.

Quantity of labor <i>L</i> (workers)	Quantity of floral arrangements <i>Q</i>	Marginal product of labor <i>MPL</i> = $\Delta Q/\Delta L$ (floral arrangements per worker)	Variable cost <i>VC</i> = number of workers \times wage rate	Total cost <i>TC</i> = <i>FC</i> + <i>VC</i>	Marginal cost of floral arrangement <i>MC</i> = $\Delta TC/\Delta Q$
0	0		\$0	\$100	
1	5	5	50	150	\$10.00 (= 50/5)
2	9	4	100	200	12.50 (= 50/4)
3	12	3	150	250	16.67 (= 50/3)
4	14	2	200	300	25.00 (= 50/2)
5	15	1	250	350	50.00 (= 50/1)

- b. The marginal cost, *MC*, of floral arrangements is the change in total cost divided by the change in output. So, to compute *MC*, we first need to compute total cost, $TC = FC + VC$, as shown in the table. *MC* per floral arrangement is also shown in the table. *MC* increases as output increases due again to the principle of diminishing returns.

7. You have the information shown in the accompanying table about a firm's costs. Complete the missing data.

Quantity	<i>TC</i>	<i>MC</i>	<i>ATC</i>	<i>AVC</i>
0	\$20		—	—
1	?	\$20	?	?
2	?	10	?	?
3	?	16	?	?
4	?	20	?	?
5	?	24	?	?

Solution

7. The accompanying table contains the complete cost data. The total cost of producing one unit of output is the total cost of producing zero units of output plus the marginal cost of increasing output from zero to one, and so forth. The average total cost is just the total cost divided by output. Since the total cost of producing zero output is \$20, the variable cost is $TC - \$20$. The average variable cost is then just the variable cost divided by output.

Quantity of output	TC	MC of unit	ATC of unit	AVC of unit
0	\$20.00		—	—
1	40.00	\$20.00	\$40.00	\$20.00
2	50.00	10.00	25.00	15.00
3	66.00	16.00	22.00	15.33
4	86.00	20.00	21.50	16.50
5	110.00	24.00	22.00	18.00

8. Evaluate each of the following statements. If a statement is true, explain why; if it is false, identify the mistake and try to correct it.
- A decreasing marginal product tells us that marginal cost must be rising.
 - An increase in fixed cost increases the minimum-cost output.
 - An increase in fixed cost increases marginal cost.
 - When marginal cost is above average total cost, average total cost must be falling.

Solution

8. a. True. If each additional unit of the input adds less to output than the previous unit (decreasing marginal product), then in order to produce additional output, the firm needs to use increasingly more of the input; that is, the marginal cost of production increases.
- b. True. As the fixed cost rises, the average fixed cost also rises; that is, the spreading effect is now larger. It is the spreading effect that causes average total cost to decline. Since this effect is now larger, it dominates the diminishing returns effect over a greater quantity of output. That is, average total cost decreases over a greater quantity of output.
- c. False. An increase in fixed cost does not change marginal cost. Marginal cost is the additional cost of producing an additional unit of output. Fixed cost does not change as output is increased, and so the additional cost of producing an additional unit of output is independent of the fixed cost.
- d. False. When marginal cost is above average total cost, average total cost must be rising. If the additional cost of producing one more unit of output is greater than what it costs to produce each unit of output on average, then producing that one more unit of output must increase the average total cost.

9. Mark and Jeff operate a small company that produces souvenir footballs. Their fixed cost is \$2,000 per month. They can hire workers for \$1,000 per worker per month. Their monthly production function for footballs is as given in the accompanying table.

Quantity of labor (workers)	Quantity of footballs
0	0
1	300
2	800
3	1,200
4	1,400
5	1,500

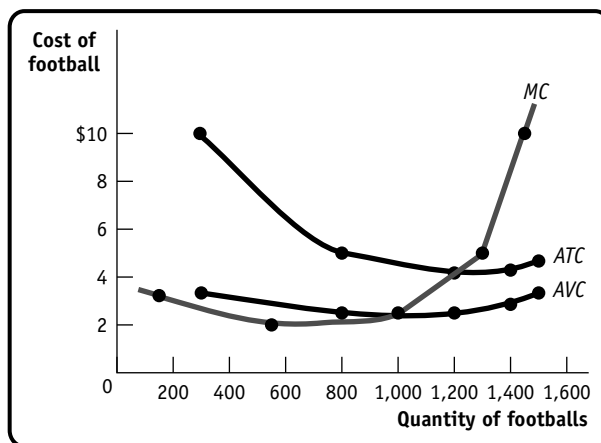
- For each quantity of labor, calculate average variable cost (AVC), average fixed cost (AFC), average total cost (ATC), and marginal cost (MC).
- On one diagram, draw the AVC, ATC, and MC curves.
- At what level of output is Mark and Jeff's average total cost minimized?

Solution

9. a. The AVC, AFC, ATC, TC, and MC are given in the accompanying table.

Quantity of labor (workers)	Quantity of footballs	AVC of football	AFC of football	ATC of football	TC of footballs	MC of football
0	0	—	—	—	\$2,000.00	
1	300	\$3.33	\$6.67	\$10.00	3,000.00	\$3.33
2	800	2.50	2.50	5.00	4,000.00	2.00
3	1,200	2.50	1.67	4.17	5,000.00	2.50
4	1,400	2.86	1.43	4.29	6,000.00	5.00
5	1,500	3.33	1.33	4.67	7,000.00	10.00

- b. The accompanying diagram shows the AVC, ATC, and MC curves.



- c. According to the table, Mark and Jeff's average total cost is minimized at 1,200 footballs per month, where the ATC is \$4.17.

- 10.** You produce widgets. Currently you produce four widgets at a total cost of \$40.
- What is your average total cost?
 - Suppose you could produce one more (the fifth) widget at a marginal cost of \$5. If you do produce that fifth widget, what will your average total cost be? Has your average total cost increased or decreased? Why?
 - Suppose instead that you could produce one more (the fifth) widget at a marginal cost of \$20. If you do produce that fifth widget, what will your average total cost be? Has your average total cost increased or decreased? Why?

- 10.** **a.** Your average total cost is $\$40/4 = \10 per widget.
- b.** If you produce one more widget, you are producing five widgets at a total cost of $\$40 + \$5 = \$45$. Your average total cost is therefore $\$45/5 = \9 . Your average total cost has decreased because the marginal cost of the additional widget is below the average total cost before you produced the additional widget.
- c.** If you produce one more widget, you are producing five widgets at a total cost of $\$40 + \$20 = \$60$. Your average total cost is therefore $\$60/5 = \12 . Your average total cost has increased because the marginal cost of the additional widget is above the average total cost before you produced the additional widget.
- 11.** In your economics class, each homework problem set is graded on the basis of a maximum score of 100. You have completed 9 out of 10 of the problem sets for the term, and your current average grade is 88. What range of grades for your 10th problem set will raise your overall average? What range will lower your overall average? Explain your answer.

- 11.** Any grade for your 10th problem set greater than 88 will raise your overall average; any grade lower than 88 will lower it. This is the same principle at work as that for average total cost and marginal cost. If the marginal cost curve (the 10th grade) is above the average total cost curve (the average over the first 9 grades), then the average total cost is rising (that is, the average over the 10 sets is greater than the average over the 9 sets). And if the marginal cost curve (the 10th grade) is below the average total cost curve (the average over the first 9 grades), then the average total cost is falling (that is, the average over the 10 sets is lower than the average over the 9 sets). To see this arithmetically, note that your current average, 88, is found by

$$\frac{\text{Sum of grades for first 9 sets}}{9} = 88 = \text{Average over first 9 sets}$$

Hence,

$$\text{Sum of grades for first 9 sets} = 88 \times 9 = 792$$

So your overall grade—the grade over all 10 problem sets—is

$$\frac{792}{10} + \frac{\text{Grade for 10th set}}{10} = \text{Overall average}$$

If your 10th grade is 90, then your overall grade is

$$\frac{792}{10} + \frac{90}{10} = 79.2 + 9.0 = 88.2$$

which is greater than 88. And if your 10th grade is 86, then your overall grade is

$$\frac{792}{10} + \frac{86}{10} = 79.2 + 8.6 = 87.8$$

which is less than 88.

- 12.** Don owns a small concrete-mixing company. His fixed cost is the cost of the concrete-batching machinery and his mixer trucks. His variable cost is the cost of the sand, gravel, and other inputs for producing concrete; the gas and maintenance for the machinery and trucks; and his workers. He is trying to decide how many mixer trucks to purchase. He has estimated the costs shown in the accompanying table based on estimates of the number of orders his company will receive per week.

Quantity of trucks	FC	VC		
		20 orders	40 orders	60 orders
2	\$6,000	\$2,000	\$5,000	\$12,000
3	7,000	1,800	3,800	10,800
4	8,000	1,200	3,600	8,400

- a. For each level of fixed cost, calculate Don's total cost for producing 20, 40, and 60 orders per week.
- b. If Don is producing 20 orders per week, how many trucks should he purchase and what will his average total cost be? Answer the same questions for 40 and 60 orders per week.

- 12.** a. The answers are given in the accompanying table.

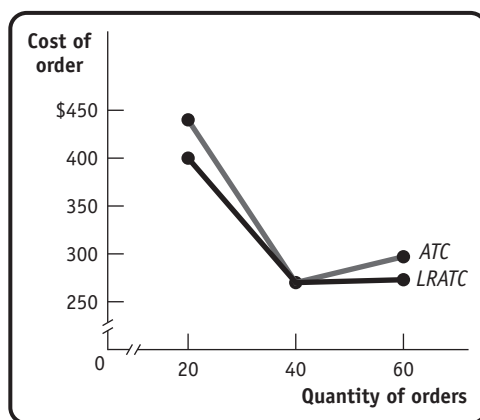
Quantity of trucks	TC		
	20 orders	40 orders	60 orders
2	\$8,000	\$11,000	\$18,000
3	8,800	10,800	17,800
4	9,200	11,600	16,400

- b. Don should choose the number of trucks that minimizes average total cost for each level of output. Given this, Don should buy 2 trucks if he is producing 20 orders per week. His average total cost per order will be \$400. He should buy 3 trucks if he is producing 40 orders per week. His average total cost per order will then be \$270. He should buy 4 trucks if he is producing 60 orders per week. His average total cost per order will then be \$273.
- 13.** Consider Don's concrete-mixing business described in Problem 12. Assume that Don purchased 3 trucks, expecting to produce 40 orders per week.
- a. Suppose that, in the short run, business declines to 20 orders per week. What is Don's average total cost per order in the short run? What will his average total cost per order in the short run be if his business booms to 60 orders per week?
- b. What is Don's long-run average total cost for 20 orders per week? Explain why his short-run average total cost of producing 20 orders per week when the number of trucks is fixed at 3 is greater than his long-run average total cost of producing 20 orders per week.

- c. Draw Don's long-run average total cost curve. Draw his short-run average total cost curve if he owns 3 trucks.

Solution

13. a. In the short run, producing 20 orders per week with 3 trucks, Don's average total cost per order will be $(\$7,000 + \$1,800)/20 = \$440$. If he instead produces 60 orders per week with 3 trucks, his average total cost per order will be \$297.
- b. The long-run average total cost of producing 20 orders per week is \$400 because Don would choose the number of trucks (2 trucks) that minimizes the total cost of producing 20 orders. His short-run average total cost is greater than the long-run minimum because, using 3 trucks, the level of the fixed input is greater than he needs to optimally produce 20 orders per week.
- c. The accompanying diagram shows Don's LRATC and ATC.



14. True or false? Explain your reasoning.
- a. The short-run average total cost can never be less than the long-run average total cost.
- b. The short-run average variable cost can never be less than the long-run average total cost.
- c. In the long run, choosing a higher level of fixed cost shifts the long-run average total cost curve upward.

Solution

14. a. True. The long-run average total cost is the average total cost you get by choosing the most favorable level of fixed cost in the long run; that is, it is the lowest average total cost that is possible when you can adjust how much of the fixed input you use. In other words, the long-run average total cost of producing a certain level of output is the lowest average total cost with which that level of output can be produced.
- b. False. The long-run average total cost is the lowest average total cost possible. But average variable cost will always be less than average total cost (it is lower than the average total cost by just the amount of the average fixed cost). So short-run average variable cost can be lower than long-run average total cost.
- c. False. In the long run, choosing a higher level of fixed cost allows you to move along and to the right on the long-run average total cost curve. In the long run, if you want to produce a larger quantity of output, you would optimally increase the level of fixed cost (this will decrease the average variable cost). You will do this in such a way as to spend the lowest possible average total cost; that is, you will be on the long-run average total cost curve but farther to the right (at a larger quantity of output).

15. Wolfsburg Wagon (WW) is a small automaker. The accompanying table shows WW's long-run average total cost.

Quantity of cars	LRATC of car
1	\$30,000
2	20,000
3	15,000
4	12,000
5	12,000
6	12,000
7	14,000
8	18,000

- For which levels of output does WW experience increasing returns to scale?
- For which levels of output does WW experience decreasing returns to scale?
- For which levels of output does WW experience constant returns to scale?

Solution

15. a. WW's long-run average total cost is decreasing over the range of output between 1 and 4 cars. So over that range, WW experiences increasing returns to scale.
- b. WW's long-run average total cost is increasing over the range of output between 6 and 8 cars. So over that range, WW experiences decreasing returns to scale.
- c. WW's long-run average total cost is constant over the range of output between 4 and 6 cars. So over that range, WW experiences constant returns to scale.

16. The accompanying table shows a car manufacturer's total cost of producing cars.

Quantity of cars	TC
0	\$500,000
1	540,000
2	560,000
3	570,000
4	590,000
5	620,000
6	660,000
7	720,000
8	800,000
9	920,000
10	1,100,000

- What is this manufacturer's fixed cost?
- For each level of output, calculate the variable cost (VC). For each level of output except zero output, calculate the average variable cost (AVC), average total cost (ATC), and average fixed cost (AFC). What is the minimum-cost output?
- For each level of output, calculate this manufacturer's marginal cost (MC).
- On one diagram, draw the manufacturer's AVC, ATC, and MC curves.

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- 16.** a. The manufacturer's fixed cost is \$500,000. Even when no output is produced, the manufacturer has a cost of \$500,000.
- b. The accompanying table shows VC , calculated as $TC - FC$; AVC , calculated as VC/Q ; ATC , calculated as TC/Q ; and AFC , calculated as FC/Q . (Numbers are rounded.) The minimum-cost output is 8 cars, the level at which ATC is minimized.

Quantity of cars	TC	MC of car	VC	AVC of car	ATC of car	AFC of car
0	\$500,000		\$0	—	—	—
1	540,000	\$40,000	40,000	\$40,000	\$540,000	\$500,000
2	560,000	20,000	60,000	30,000	280,000	250,000
3	570,000	10,000	70,000	23,333	190,000	166,667
4	590,000	20,000	90,000	22,500	147,500	125,000
5	620,000	30,000	120,000	24,000	124,000	100,000
6	660,000	40,000	160,000	26,667	110,000	83,333
7	720,000	60,000	220,000	31,429	102,857	71,429
8	800,000	80,000	300,000	37,500	100,000	62,500
9	920,000	120,000	420,000	46,667	102,222	55,556
10	1,100,000	180,000	600,000	60,000	110,000	50,000

- c. The table also shows MC , the additional cost per additional car produced. Notice that MC is below ATC for levels of output less than the minimum-cost output and above ATC for levels of output greater than the minimum-cost output.
- d. The AVC , ATC , and MC curves are shown in the accompanying diagram.

