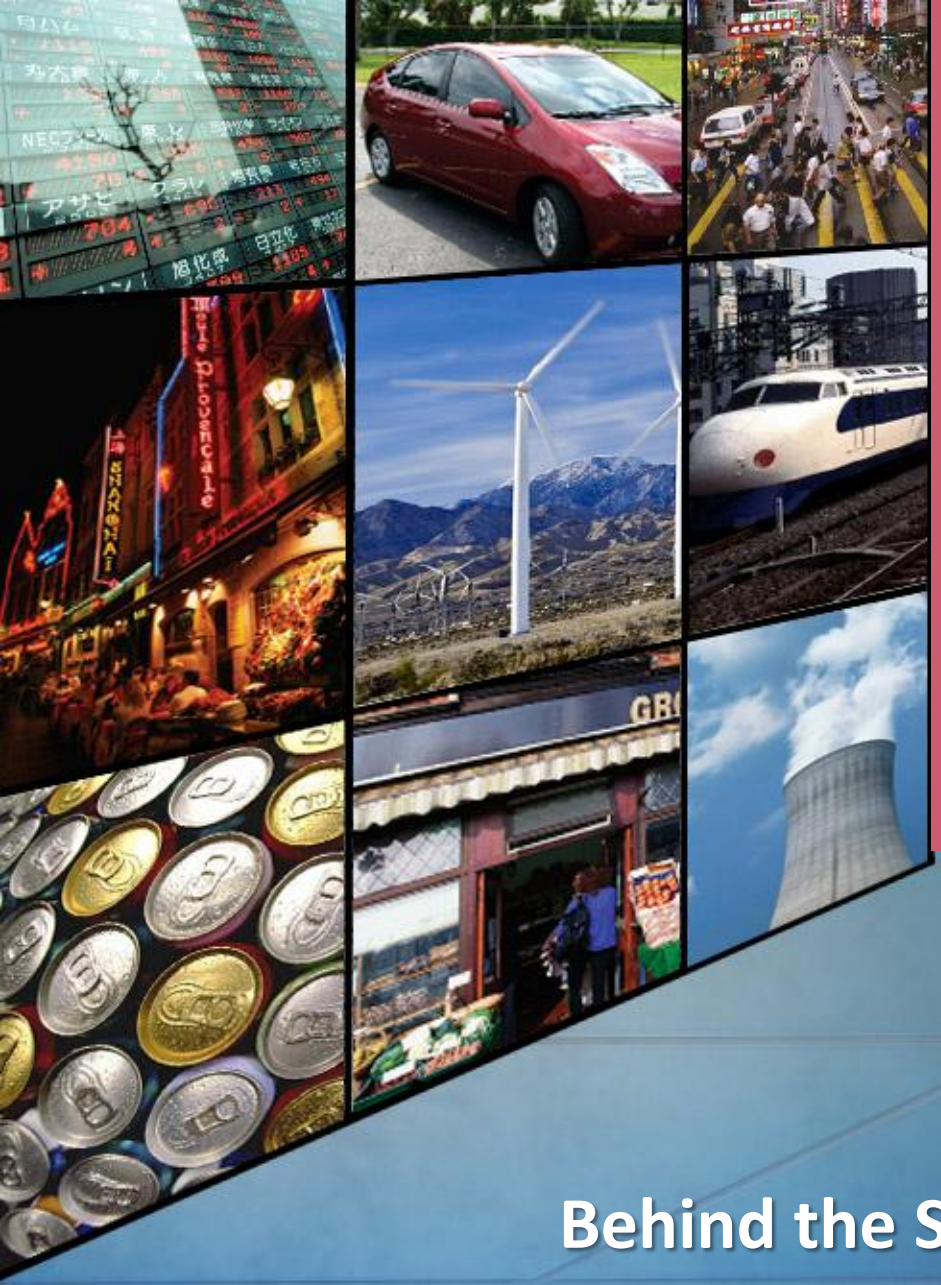


THIRD EDITION

ECONOMICS and MICROECONOMICS

Paul Krugman | Robin Wells

Chapter 11

Behind the Supply Curve: Inputs and Costs

WHAT YOU WILL LEARN IN THIS CHAPTER

- The importance of the firm's production function, the relationship between quantity of inputs and quantity of output
- Why production is often subject to diminishing returns to inputs
- The various types of costs a firm faces and how they generate the firm's marginal and average cost curves
- Why a firm's costs may differ in the short run versus the long run
- How the firm's technology of production can generate increasing returns to scale

The Production Function

- A **production function** is the relationship between the quantity of inputs a firm uses and the quantity of output it produces.

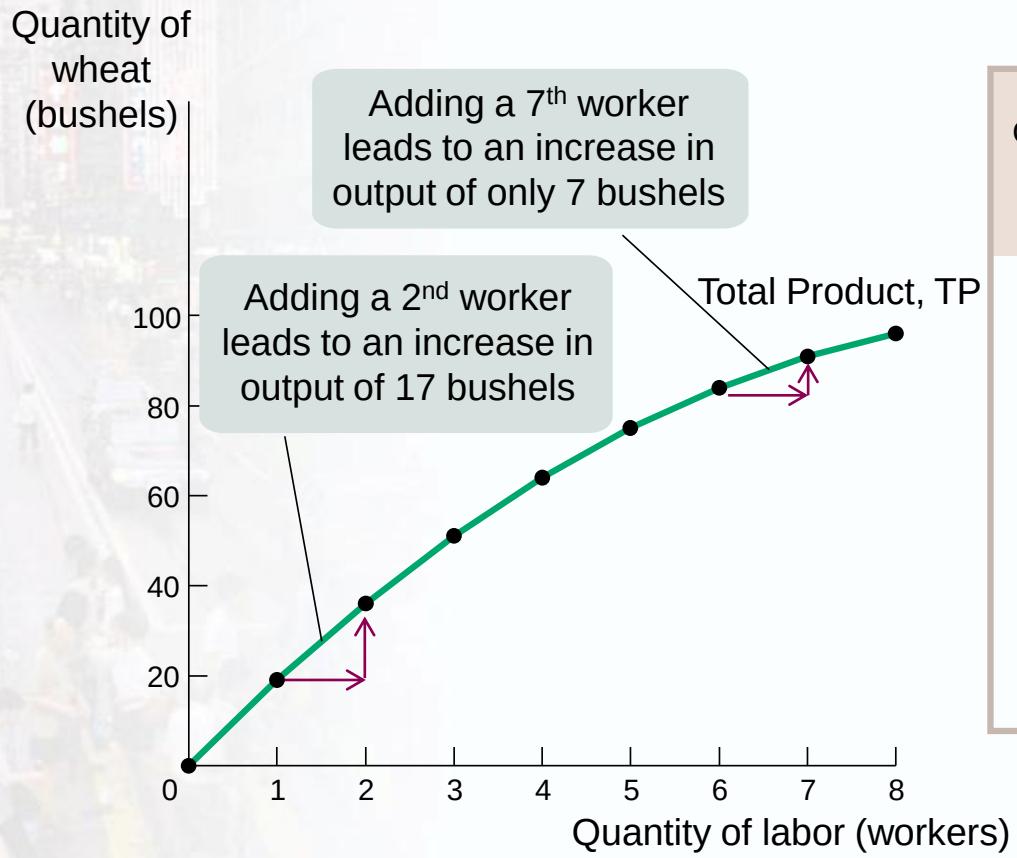
- A **fixed input** is an input whose quantity is fixed for a particular period and cannot be varied.

- A **variable input** is an input whose quantity the firm can vary at any time.

Inputs and Output

- The **long run** is the period in which all inputs can be varied.
- The **short run** is the period in which at least one input is fixed.
- The **total product curve** shows how the quantity of output depends on the quantity of the variable input, for a given quantity of the fixed input.

Production Function and TP Curve for George and Martha's Farm



Quantity of labor *L* (worker)	Quantity of wheat *Q* (bushels)	MP of labor $MPL = \Delta Q / \Delta L$ (bushels per worker)
0	0	
		19
1	19	
		17
2	36	
		15
3	51	
		13
4	64	
		11
5	75	
		9
6	84	
		7
7	91	
		5
8	96	

Although the total product curve in the figure slopes upward along its entire length, the slope isn't constant: as you move up the curve to the right, it flattens out due to changing marginal product of labor.

Marginal Product of Labor

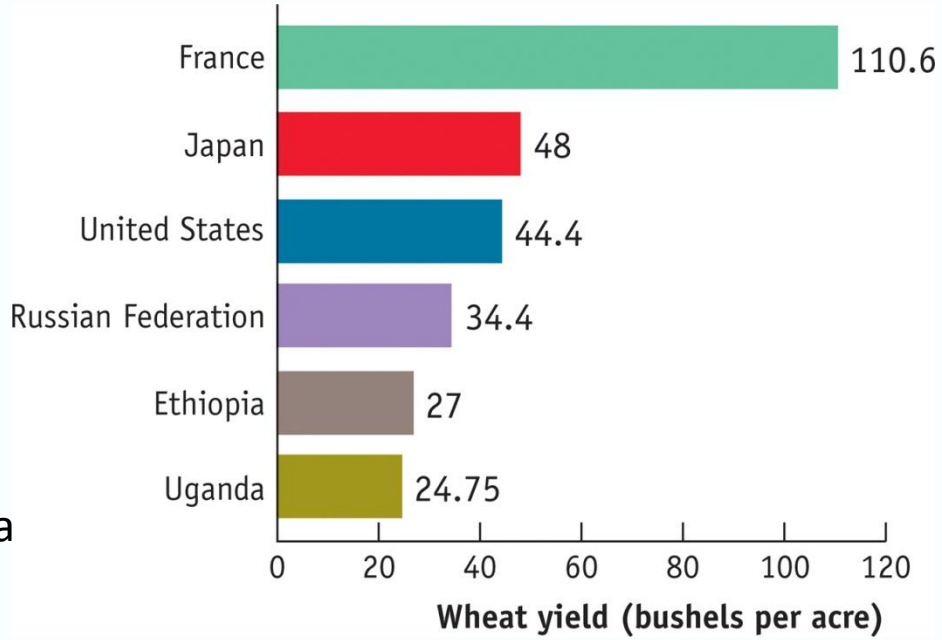
- The **marginal product** of an input is the additional quantity of output that is produced by using one more unit of that input.

$$\text{Marginal product of labor} = \frac{\text{Change in quantity of output}}{\text{Change in quantity of labor}} = \text{Change in quantity of output generated by one additional unit of labor}$$

$$MPL = \Delta Q / \Delta L$$

GLOBAL COMPARISON: Wheat Yields Around The World

- The disparity between France and the United States is striking, given that they are both wealthy countries with comparable agricultural technology.
- In the United States, farmers receive payments from the government to supplement their incomes, but European farmers benefit from price floors.
- In poor countries like Uganda and Ethiopia, foreign aid can lead to significantly depressed yields.
- Foreign aid from wealthy countries ha often taken the form of surplus food, which depresses local market prices, severely hurting the local agriculture that poor countries normally depend on.

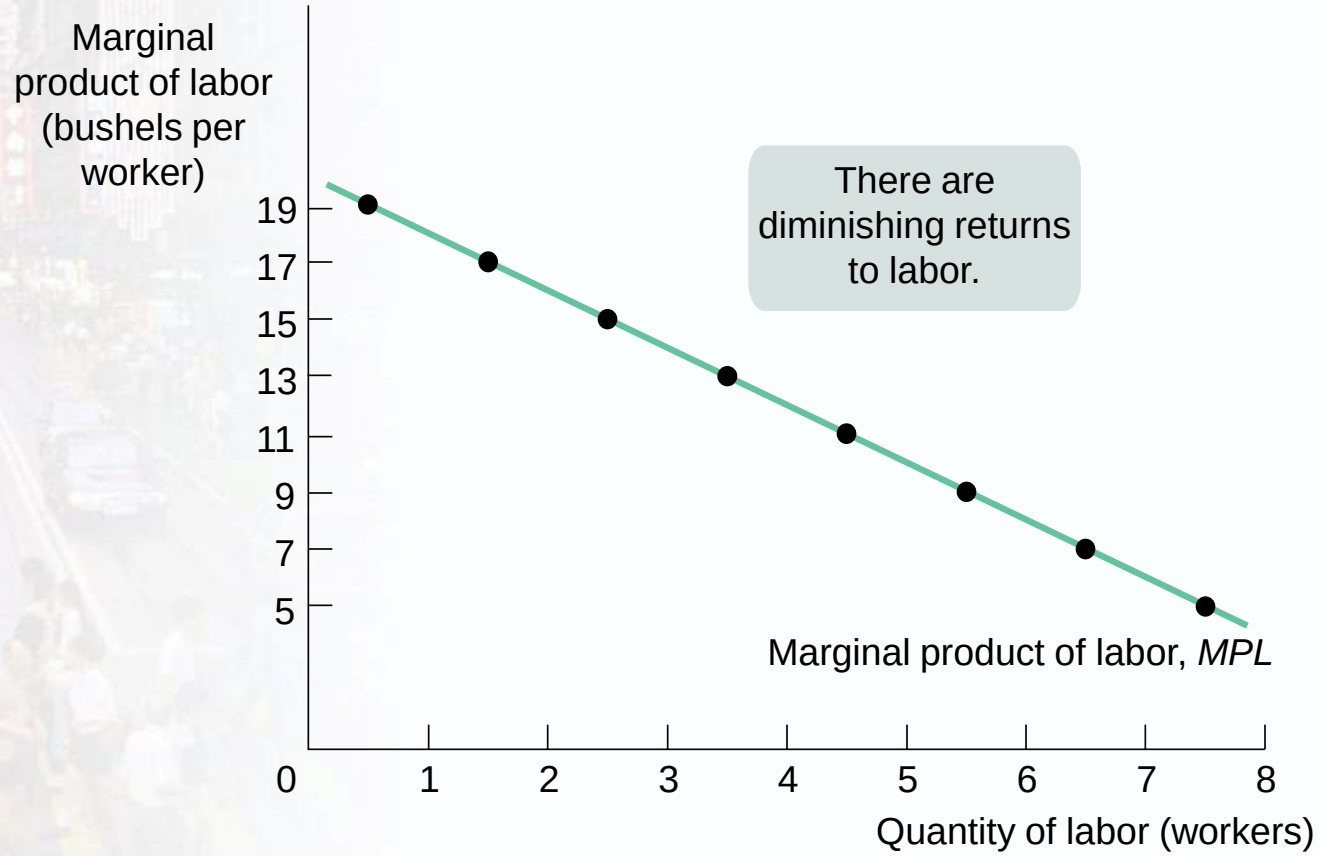


Diminishing Returns to an Input

- There are **diminishing returns to an input** when an increase in the quantity of that input, holding the levels of all other inputs fixed, leads to a decline in the marginal product of that input.

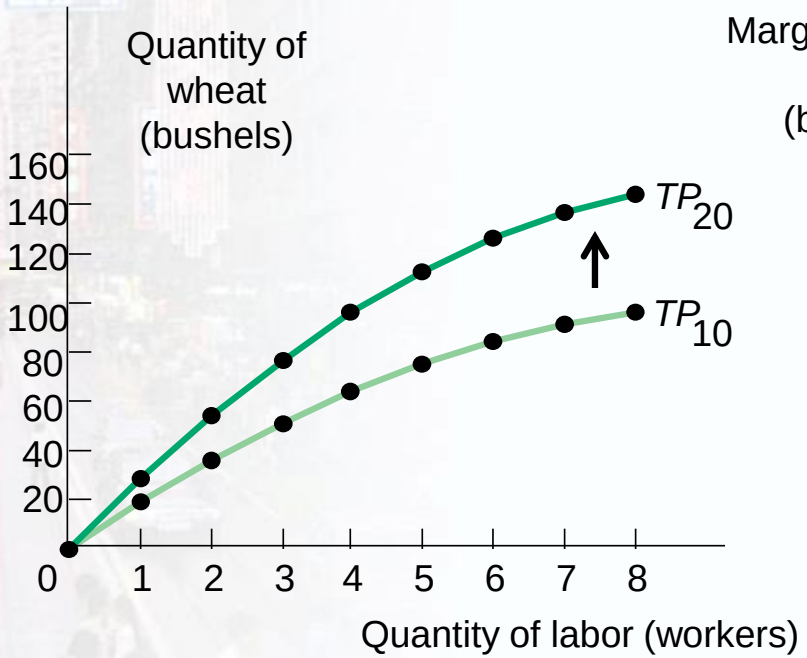
- The following marginal product of labor curve illustrates this concept clearly.

Marginal Product of Labor Curve

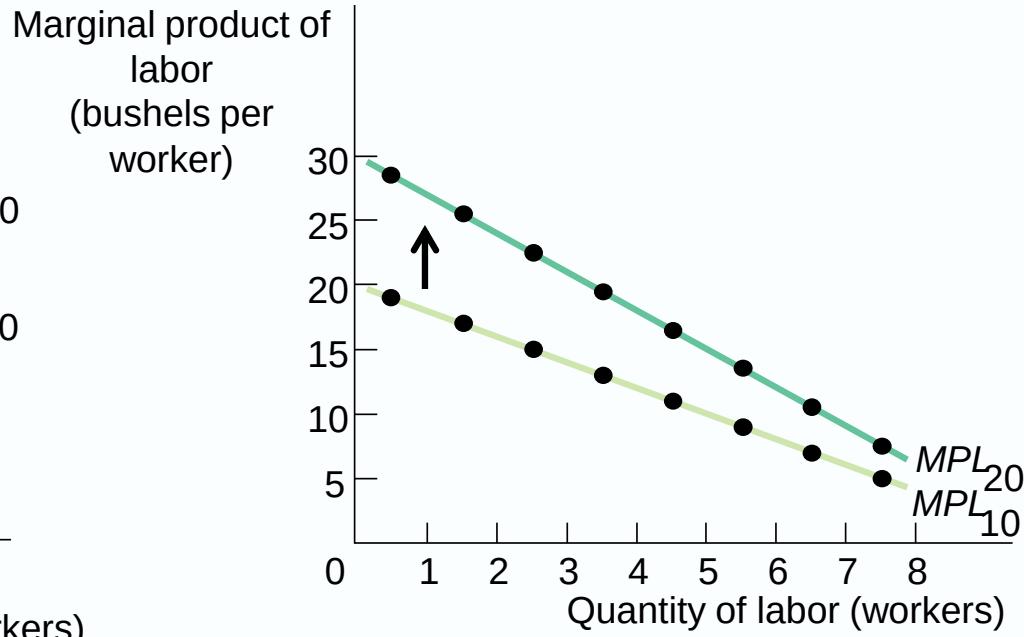


Here, the first worker employed generates an **increase in output** of 19 bushels, the second worker generates an increase of 17 bushels, and so on…

Total Product, Marginal Product, and the Fixed Input



(a) Total Product Curves



(b) Marginal Product Curves

With more land, each worker can produce more wheat. So an increase in the fixed input shifts the total product curve up from TP_{10} to TP_{20}.

This shift also implies that the marginal product of each worker is higher when the farm is larger. As a result, an increase in acreage also shifts the marginal product of labor curve up from MPL_{10} to MPL_{20}.

Pitfalls

What's a Unit?

- The marginal product of labor (or any other input) is defined as the increase in the quantity of output when you increase the quantity of that input by one unit.
- What do we mean by a "unit" of labor? Is it an additional hour of labor, an additional week, or a person-year?
- The answer is that it doesn't matter, *as long as you are consistent.*
- One common source of error in economics is getting units confused—say, comparing the output added by an additional *hour* of labor with the cost of employing a worker for a *week*.
  - Whatever units you use, always be careful that you use the same units throughout your analysis of any problem.

From the Production Function to Cost Curves

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

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

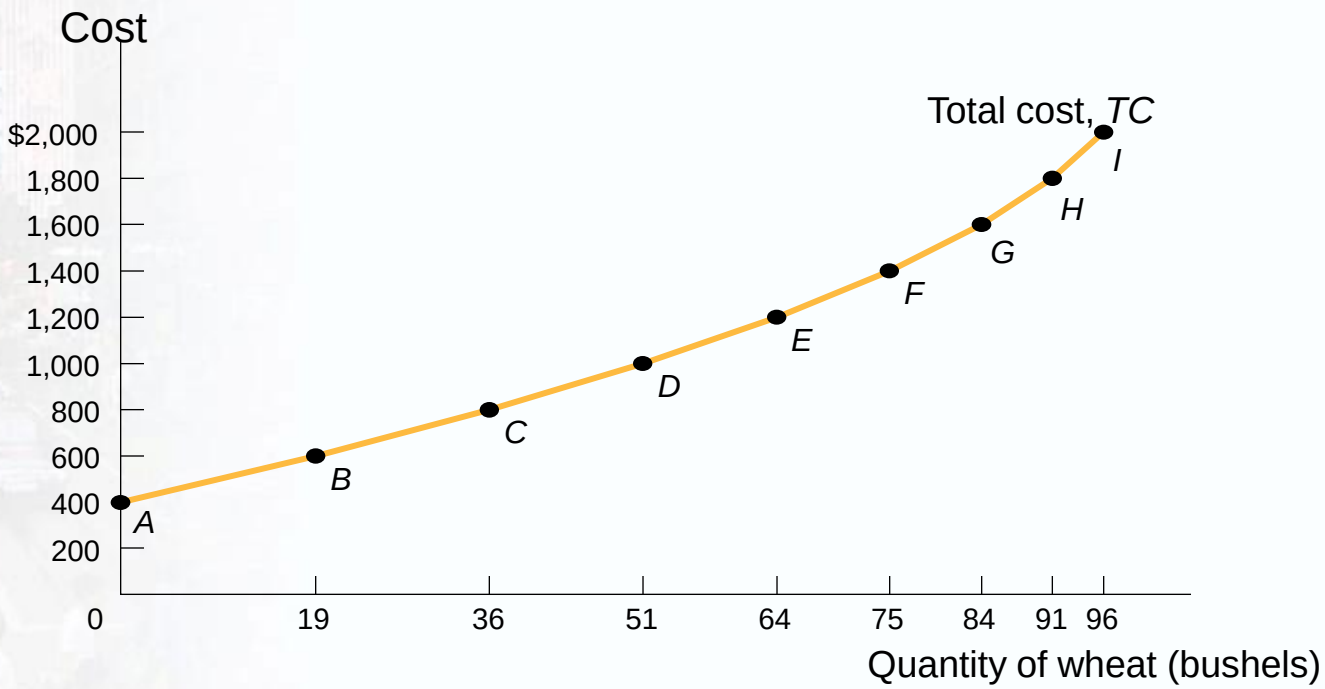
Total Cost Curve

- 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.

$$TC = FC + VC$$

- The *total cost curve* becomes steeper as more output is produced due to diminishing returns.

Total Cost Curve for George and Martha's Farm



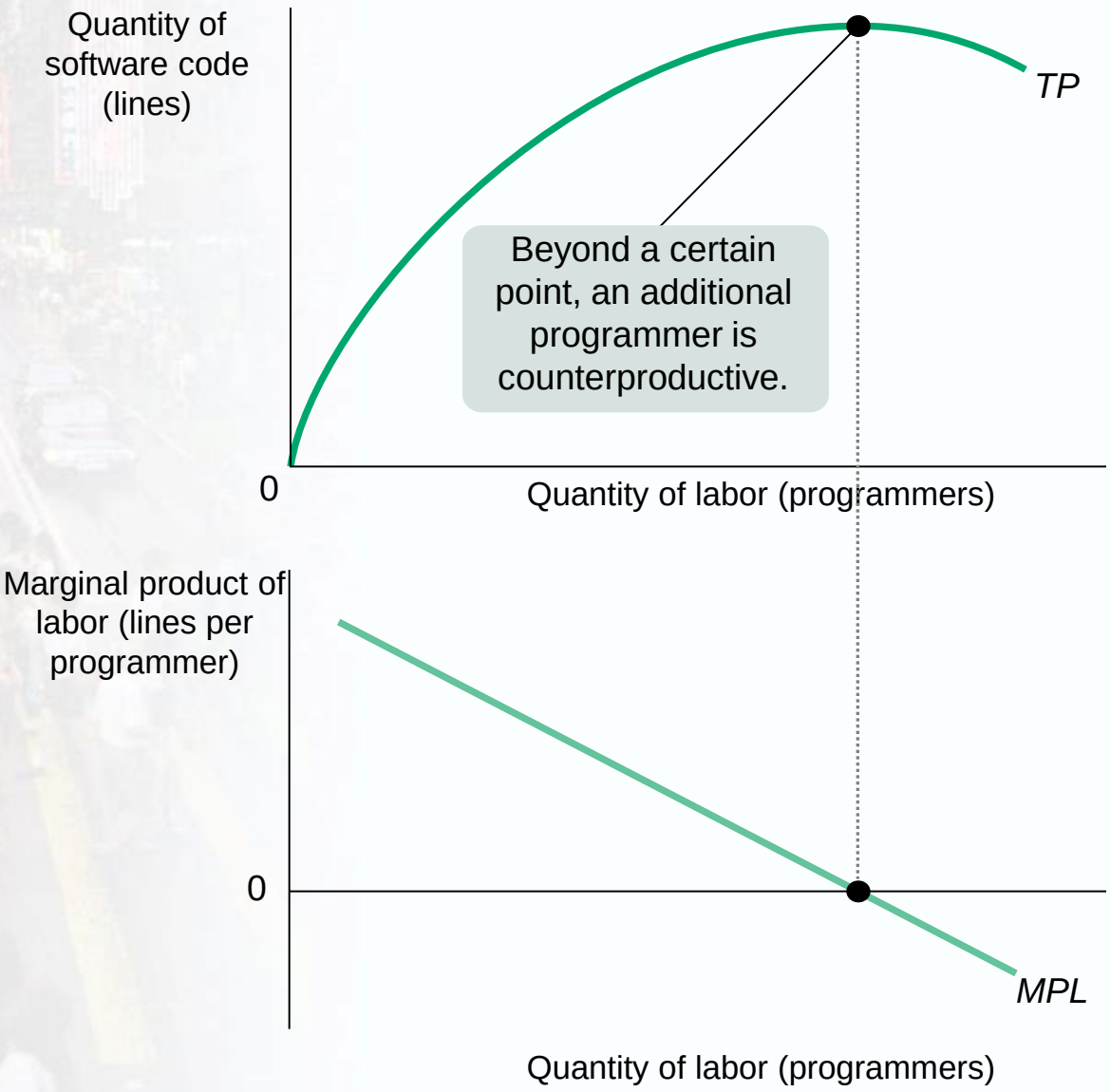
Point on graph	Quantity of labor *L* (worker)	Quantity of wheat *Q* (bushels)	Variable cost (*VC*)	Fixed Cost (*FC*)	Total cost (*TC = FC + VC*)
A	0	0	$O	$400	$400
B	1	19	200	400	600
C	2	36	400	400	800
D	3	51	600	400	1,000
E	4	64	800	400	1,200
F	5	75	1,000	400	1,400
G	6	84	1,200	400	1,600
H	7	91	1,400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

ECONOMICS IN ACTION

The Mythical Man-Month

- "Adding another programmer on a project actually *increases* the time to completion."
  - The source of the diminishing returns lies in the nature of the production function for a programming project: Each programmer must coordinate his or her work with that of all the other programmers on the project, leading to each person spending more and more time communicating with others as the number of programmers increases.

ECONOMICS IN ACTION: The Mythical Man-Month



Two Key Concepts: Marginal Cost and Average Cost

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

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

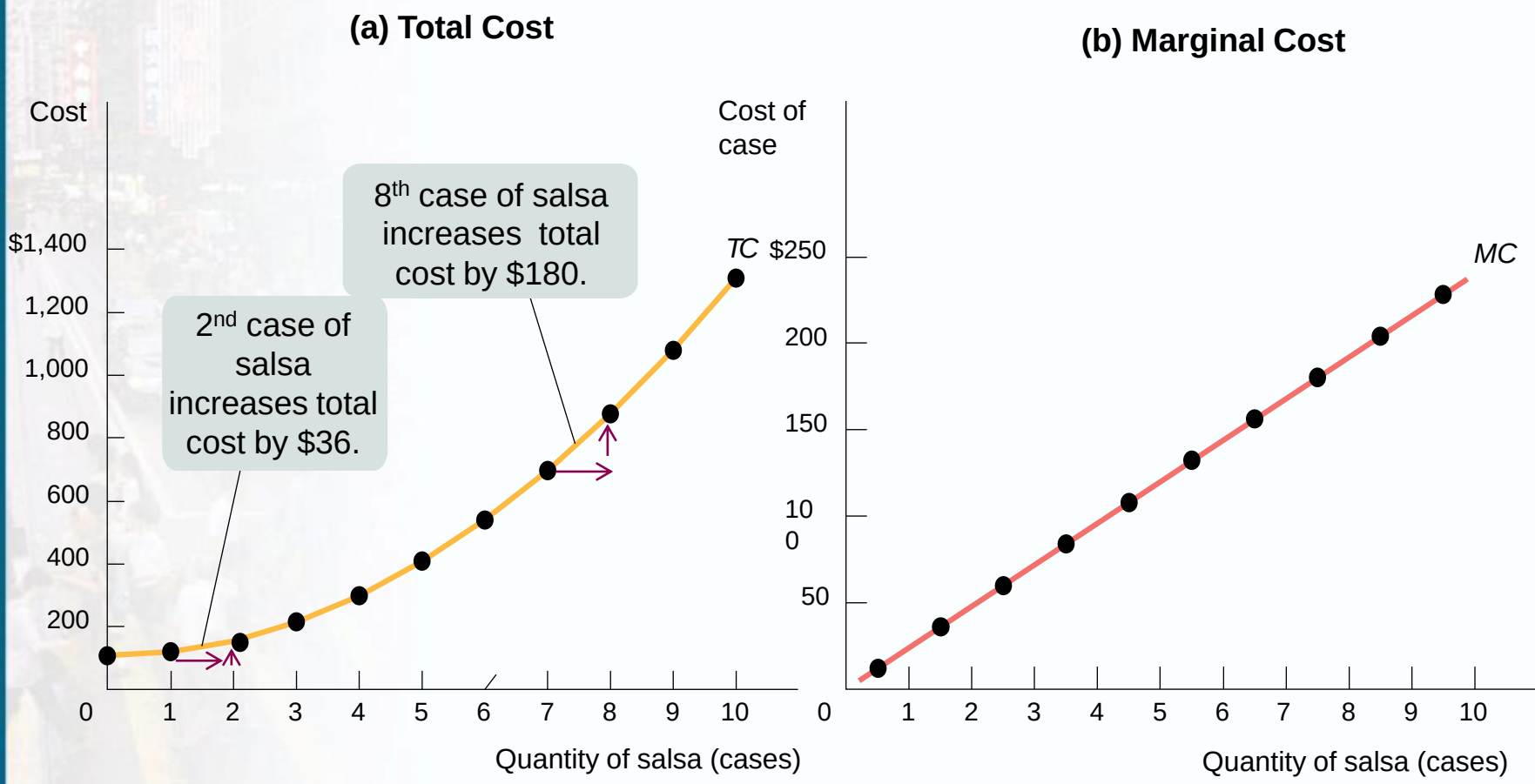
As in the case of marginal product, marginal cost is equal to ***rise*** (the increase in total cost) divided by ***run*** (the increase in the quantity of output).

Costs at Selena's Gourmet Salsas

TABLE 11-1 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 = ΔTC/ΔQ*
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	

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



Why is the Marginal Cost Curve Upward Sloping?

- The marginal cost curve is 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.

Average Cost

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

$$ATC = TC/Q = \text{(Total Cost) / (Quantity of Output)}$$

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

Average Cost

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

$$AFC = FC/Q = \text{(Fixed Cost) / (Quantity of Output)}$$

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

$$AVC = VC/Q = \text{(Variable Cost) / (Quantity of Output)}$$

Average Total Cost Curve

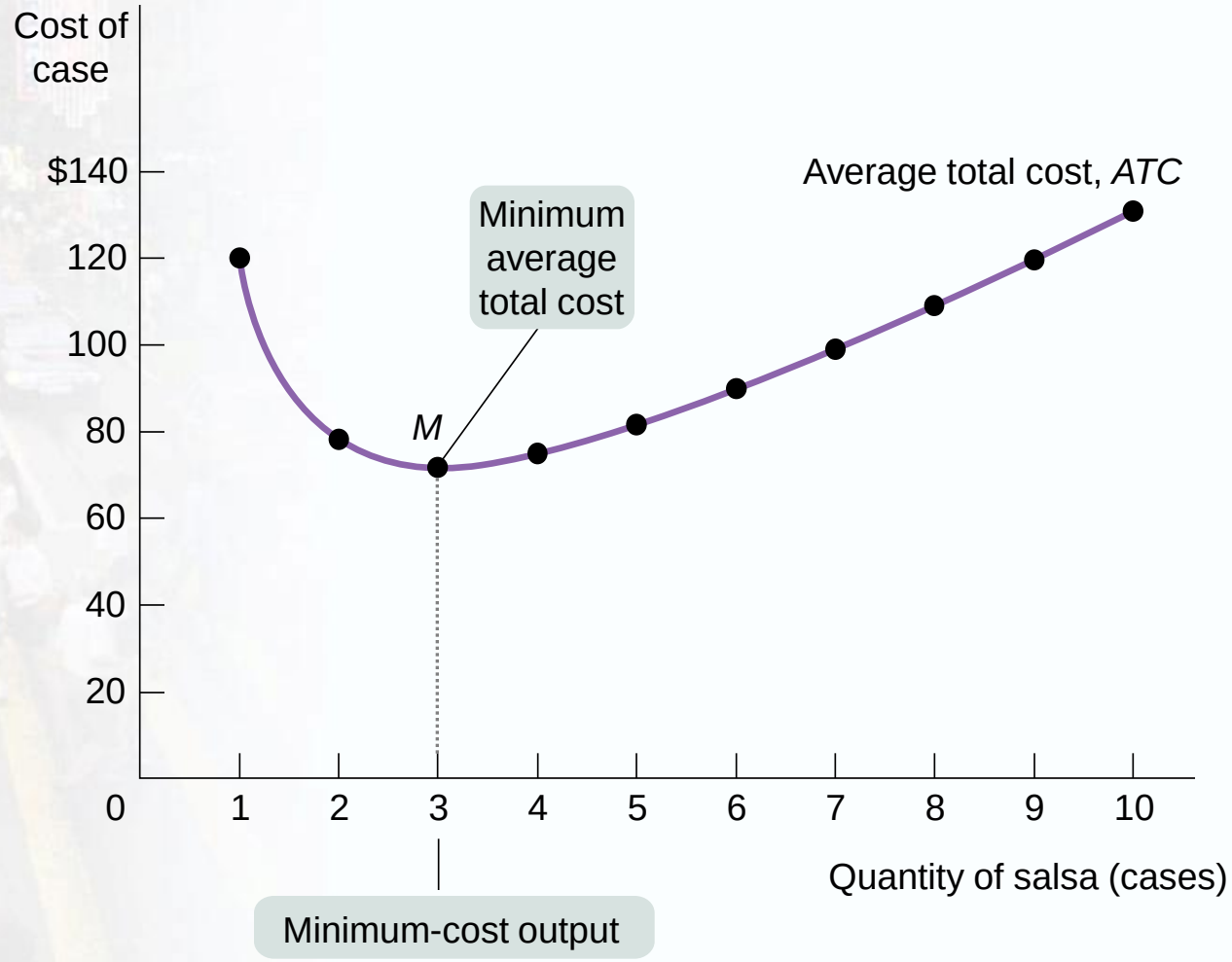
- Increasing output, therefore, has two opposing effects on average total cost—the **spreading effect** and the **diminishing returns effect**:
  - ***The spreading effect***: the larger the output, the greater the quantity of output over which fixed cost is spread, leading to lower the average fixed 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

Average Costs for Selena's Gourmet Salsas

TABLE 11-2 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

Average Total Cost Curve for Selena's Gourmet Salsas



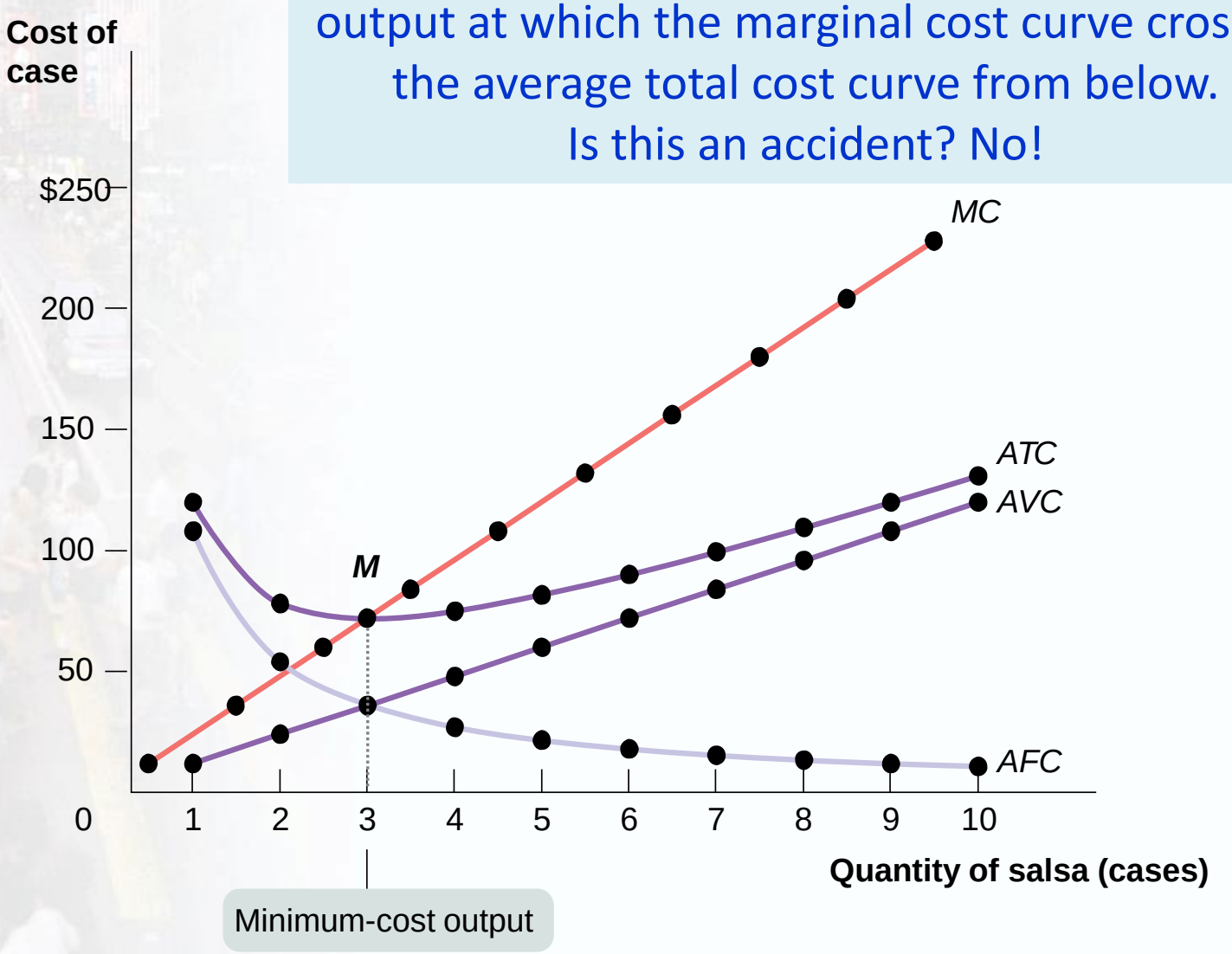
Putting the Four Cost Curves Together

Note that:

1. Marginal cost is upward sloping due to diminishing returns.
2. Average variable cost also is upward sloping, but is flatter than the marginal cost curve.
3. Average fixed cost is downward sloping because of the spreading effect.
4. The marginal cost curve intersects the average total cost curve from below, crossing it at its lowest point. This last feature is our next subject of study.

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

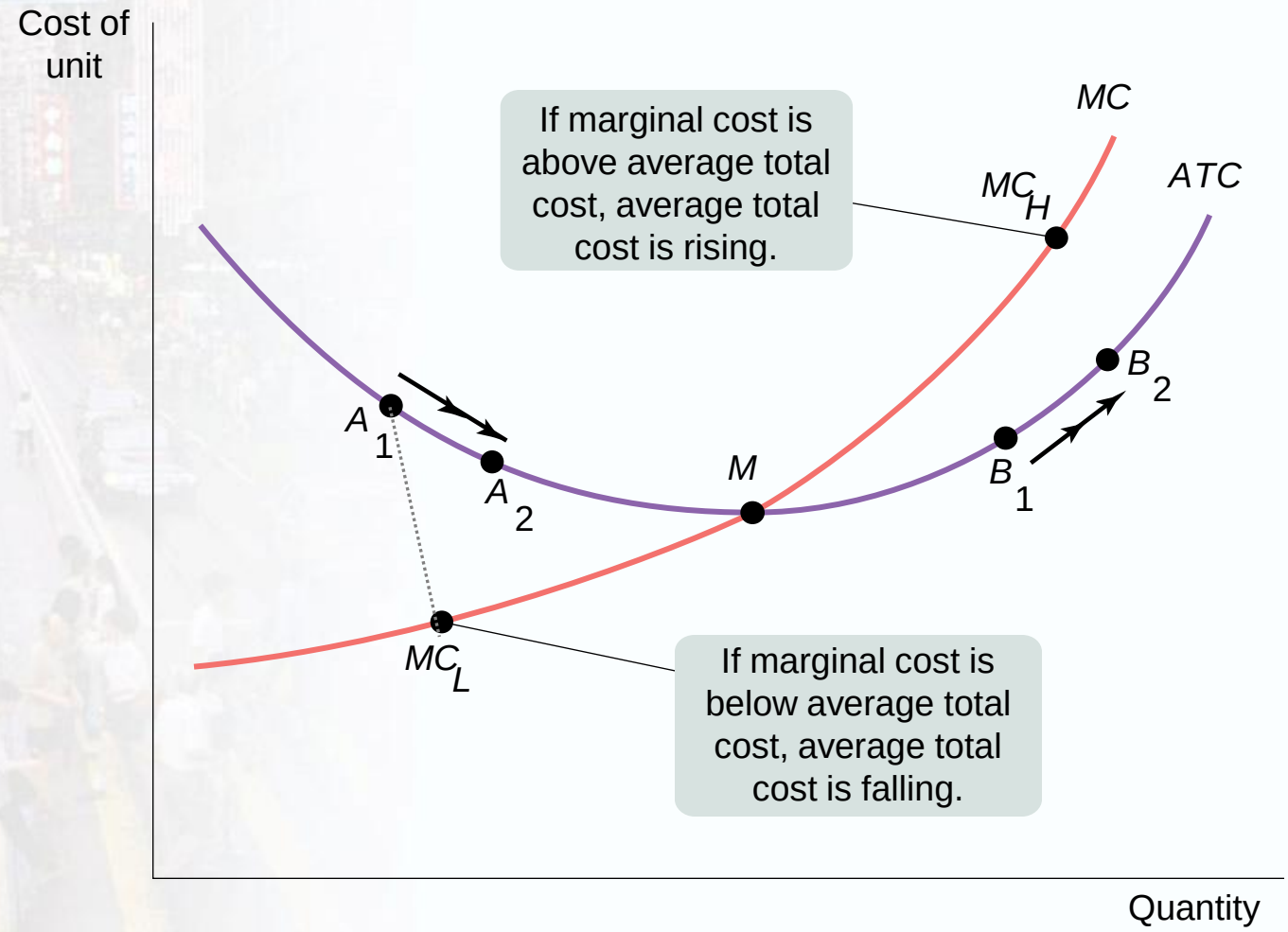
The bottom of the U curve is at the level of output at which the marginal cost curve crosses the average total cost curve from below.
Is this an accident? No!



General Principles that Are Always True About a Firm's Marginal and Average Total Cost Curves

- 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.
  - 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.

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

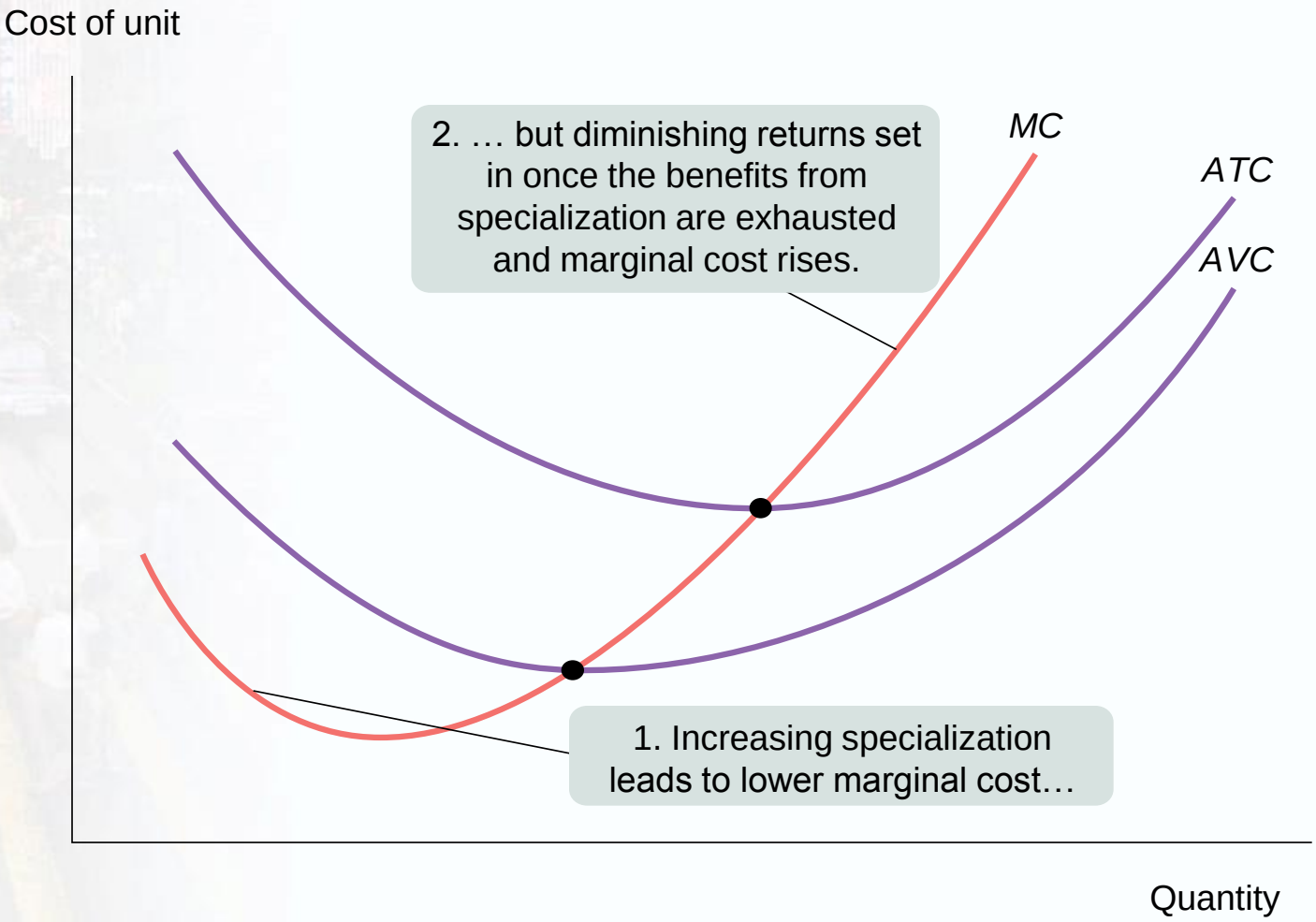


When marginal cost equals average total cost, we must be at the bottom of the U, because only at that point is average total cost neither falling nor rising.

Does the Marginal Cost Curve Always Slope Upward?

- In practice, 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.
- This initial downward slope occurs because a firm that employs only a few workers often cannot reap the benefits of specialization of labor.
- This specialization can lead to *increasing* returns at first, and so to a downward-sloping marginal cost curve.
- Once there are enough workers to permit specialization, however, *diminishing* returns set in.

More Realistic Cost Curves



Don’t Put Out the Welcome Mat

- With our abundant supply of undeveloped land, real estate developers have long found it profitable to buy big parcels of land, build a large number of homes, and create entire new communities.
  - But what is profitable for developers is not necessarily good for the existing residents.

ECONOMICS IN ACTION

Don’t Put Out the Welcome Mat

- In the past few years, real estate developers have encountered increasingly stiff resistance from local residents because of the additional costs—the marginal costs—imposed on existing homeowners from new developments.
  - The local tax rate that new homeowners pay on their new homes is the same as what existing homeowners pay on their older homes.
  - That tax rate reflects the current total cost of services, and the taxes that an average homeowner pays reflect the average total cost of providing services to a household.

ECONOMICS IN ACTION

Don’t Put Out the Welcome Mat

- The average total cost of providing services is based on the town’s use of existing facilities, such as the existing school buildings, the existing number of teachers, the existing fleet of school buses, and so on.

ECONOMICS IN ACTION

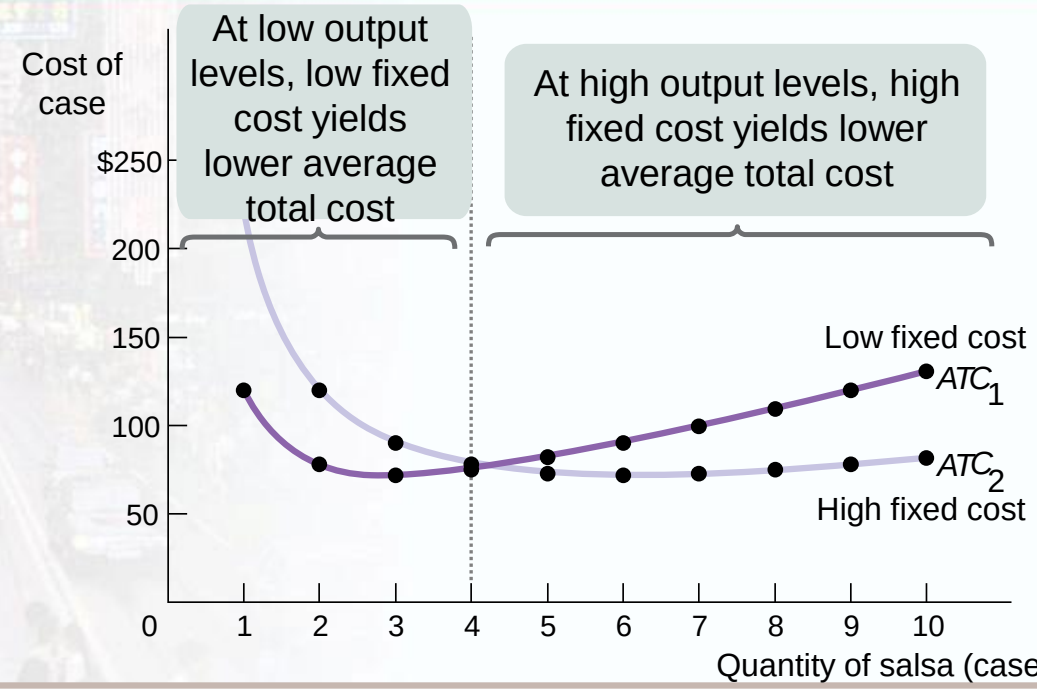
Don't Put Out the Welcome Mat

- But when a large development of homes is constructed, those facilities are no longer adequate: new schools must be built, new teachers hired, and so on.
  - The quantity of output increases.
  - So the *marginal* cost of providing municipal services per household associated with a new, large-scale development turns out to be much higher than the *average total cost* per household of existing homes.
  - As a result, new developments and facilities cause everyone's local tax rate to go up.

Short-Run versus Long-Run Costs

- In the short run, fixed cost is completely outside the control of a firm. But all inputs are variable in the long run: This means that in the long run fixed cost may also be varied.
- In the long run, in other words, a firm's fixed cost becomes a variable it can choose.
- The firm will choose its fixed cost in the long run based on the level of output it expects to produce.

Choosing the Level of Fixed Cost of Selena's Gourmet Salsas



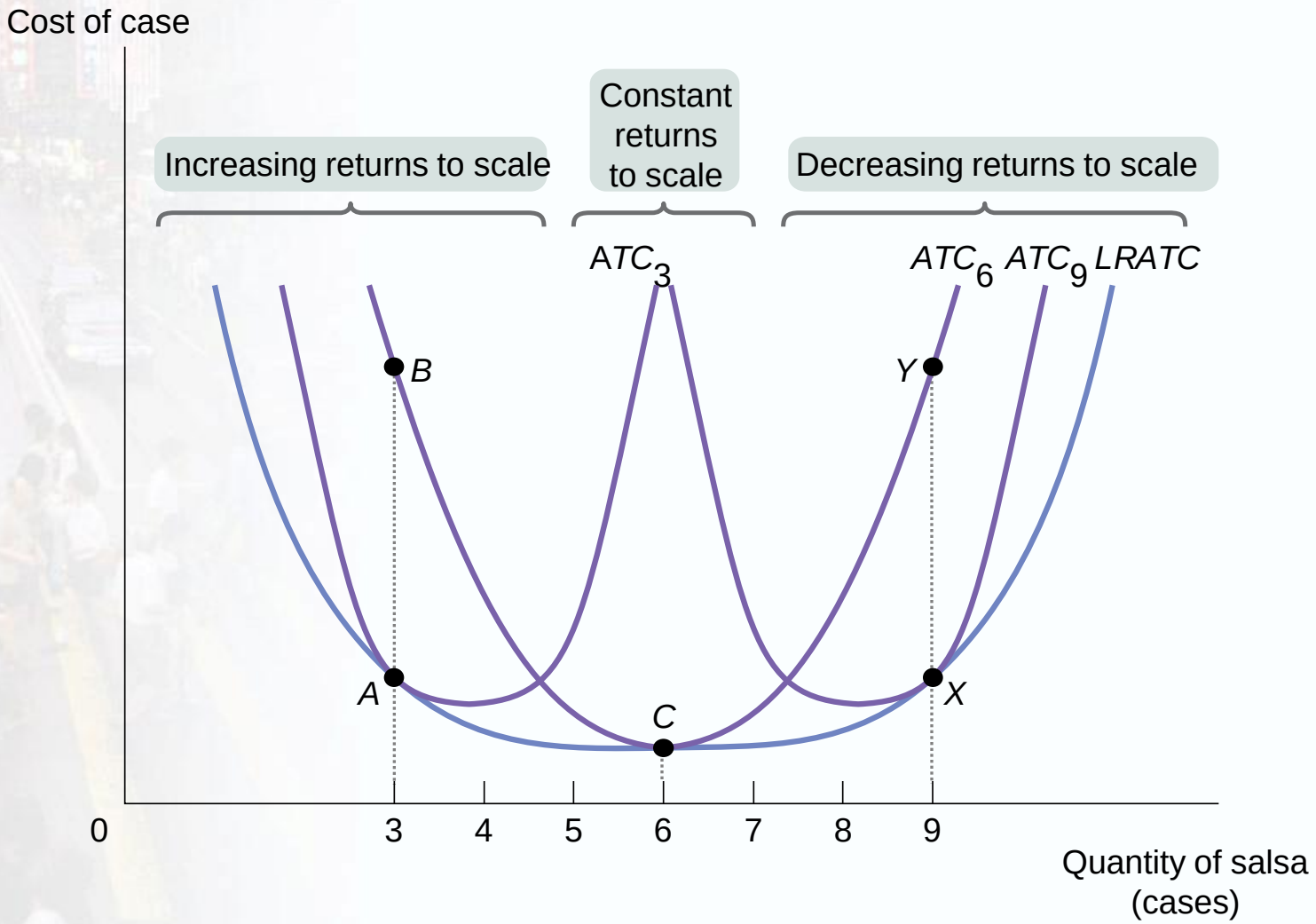
	Low fixed cost (FC = \$108)			High fixed cost (FC = \$216)		
Quantity of salsa (salsa)	High variable cost	Total cost	Average total cost of case ATC_1	Low variable cost	Total cost	Average total cost of case ATC_2
1	\$12	\$120	\$120.00	\$6	\$222	\$222.00
2	48	156	78.00	24	240	120.00
3	108	216	72.00	54	270	90.00
4	192	300	75.00	96	312	78.00
5	300	408	81.60	150	366	73.20
6	432	540	90.00	216	432	72.00
7	588	696	99.43	294	510	72.86
8	768	876	109.50	384	600	75.00
9	972	1,080	120.00	486	702	78.00
10	1,200	1,308	130.80	600	816	81.60

There is a trade-off between higher fixed cost and lower variable cost for any given output level, and vice versa. But as output goes up, average total cost is lower with the higher amount of fixed cost.

The Long-Run Average Total Cost Curve

- The **long-run average total cost curve** shows the relationship between output and average total cost when fixed cost has been chosen to minimize average total cost for each level of output.

Short-Run and Long-Run Average Total Cost Curves



Returns to Scale

- There are **increasing returns to scale (economies of scale)** when long-run average total cost declines as output increases.
- There are decreasing returns to scale (**diseconomies of scale)** when long-run average total cost increases as output increases.
- There are **constant returns to scale** when long-run average total cost is constant as output increases.

Summing Up Costs

TABLE 11-3 Concepts and Measures of Cost

	Measurement	Definition	Mathematical term
Short run	Fixed cost	Cost that does not depend on the quantity of output produced	*FC*
	Average fixed cost	Fixed cost per unit of output	$AFC = FC/Q$
Short run and long run	Variable cost	Cost that depends on the quantity of output produced	*VC*
	Average variable cost	Variable cost per unit of output	$AVC = VC/Q$
	Total cost	The sum of fixed cost (short run) and variable cost	$TC = FC$ (short run) $+ VC$
	Average total cost (average cost)	Total cost per unit of output	$ATC = TC/Q$
	Marginal cost	The change in total cost generated by producing one more unit of output	$MC = \Delta TC/\Delta Q$
Long run	Long-run average total cost	Average total cost when fixed cost has been chosen to minimize average total cost for each level of output	*LRATC*

ECONOMICS IN ACTION

There's No Business Like Snow Business

- Anyone who has lived both in a snowy city, like Chicago, and in a city that only occasionally experiences significant snowfall, like Washington, D.C., is aware of the differences in total cost that arise from making different choices about fixed cost.
  - In Washington, even a minor snowfall—say, an inch or two overnight—is enough to create chaos during the next morning's commute.
  - The same snowfall in Chicago has hardly any effect at all.
  - The reason is not that Washingtonians are wimps and Chicagoans are made of sterner stuff; it is that Washington, where it rarely snows, has only a fraction as many snowplows and other snow-clearing equipment as cities where heavy snow is a fact of life.

ECONOMICS IN ACTION

There's No Business Like Snow Business

- In this sense Washington and Chicago are like two producers who expect to produce different levels of output, where the "output" is snow removal.
- Washington, which rarely has significant snow, has chosen a low level of fixed cost in the form of snow-clearing equipment.
- This makes sense under normal circumstances but leaves the city unprepared when major snow does fall.
- Chicago knows that it will face lots of snow so chooses to accept the higher fixed cost that leaves it in a position to respond effectively.

Summary

SUMMARY

1. The relationship between inputs and output is a producer's **production function**.

   In the **short run**, the quantity of a **fixed input** cannot be varied but the quantity of a **variable input** can.

   In the **long run**, the quantities of all inputs can be varied.

   For a given amount of the fixed input, the **total product curve** shows how the quantity of output changes as the quantity of the variable input changes.

Summary

SUMMARY

2. **There are diminishing returns to an input** when its marginal product declines as more of the input is used, holding the quantity of all other inputs fixed.

3. **Total cost** is equal to the sum of **fixed cost**, which does not depend on output, and **variable cost**, which does depend on output.

Summary

SUMMARY

4. **Average total cost**, total cost divided by quantity of output, is the cost of the average unit of output, and marginal cost is the cost of one more unit produced.

   U-shaped average total cost curves are typical, because average total cost consists of two parts: **average fixed cost**, which falls when output increases (the spreading effect), and **average variable cost**, which rises with output (the diminishing returns effect).

Summary

SUMMARY

5. When average total cost is U-shaped, the bottom of the U is the level of output at which average total cost is minimized, the point of **minimum-cost output**.

   This is also the point at which the marginal cost curve crosses the average total cost curve from below.

Summary

SUMMARY

6. In the long run, a producer can change its fixed input and its level of fixed cost.

   The **long-run average total cost curve** shows the relationship between output and average total cost when fixed cost has been chosen to minimize average total cost at each level of output.

7. As output increases, there are **increasing returns to scale** if long-run average total cost declines; **decreasing returns to scale** if it increases; and **constant returns to scale** if it remains constant. Scale effects depend on the technology of production.

KEY TERMS

KEY TERM

- Production function
- Fixed input
- Variable input
- Long run
- Short run
- Total product curve
- Marginal product
- Diminishing returns to an input
- Fixed cost
- Variable cost
- Total cost
- Total cost curve
- Average total cost
- Average cost
- U-shaped average total cost curve
- Average fixed cost
- Average variable cost
- Minimum-cost output
- Long-run average total cost curve
- Increasing returns to scale
- Decreasing returns to scale
- Constant returns to scale