

N. Gregory Mankiw

# Principles of Economics

Sixth Edition

13



## The Costs of Production

*Premium  
PowerPoint  
Slides by  
Ron Cronovich  
2012 UPDATE*

# ACTIVE LEARNING 1

## Brainstorming costs

You run Ford Motor Company.

- List three different costs you have.
- List three different business decisions that are affected by your costs.



***In this chapter,  
look for the answers to these questions:***

- What is a production function? What is marginal product? How are they related?
- What are the various costs, and how are they related to each other and to output?
- How are costs different in the short run vs. the long run?
- What are “economies of scale”?

# Total Revenue, Total Cost, Profit

- We assume that the firm's goal is to maximize profit.

$$\text{Profit} = \text{Total revenue} - \text{Total cost}$$

the amount a  
firm receives  
from the sale  
of its output

the market  
value of the  
inputs a firm  
uses in  
production

# Costs: Explicit vs. Implicit

- **Explicit costs** require an outlay of money, e.g., paying wages to workers.
- **Implicit costs** do not require a cash outlay, e.g., the opportunity cost of the owner's time.
- Remember one of the Ten Principles:  
*The cost of something is what you give up to get it.*
- This is true whether the costs are implicit or explicit. Both matter for firms' decisions.

# Explicit vs. Implicit Costs: An Example

You need \$100,000 to start your business.

The interest rate is 5%.

- Case 1: borrow \$100,000
  - explicit cost = \$5000 interest on loan
- Case 2: use \$40,000 of your savings, borrow the other \$60,000
  - explicit cost = \$3000 (5%) interest on the loan
  - implicit cost = \$2000 (5%) *foregone* interest you could have earned on your \$40,000.

***In both cases, total (exp + imp) costs are \$5000.***

# Economic Profit vs. Accounting Profit

- **Accounting profit**  
= total revenue minus total explicit costs
- **Economic profit**  
= total revenue minus total costs (including explicit and implicit costs)
- Accounting profit ignores implicit costs, so it's higher than economic profit.

## ACTIVE LEARNING 2

### Economic profit vs. accounting profit

The equilibrium rent on office space has just increased by \$500/month.

Determine the effects on accounting profit and economic profit if

- a. you rent your office space
- b. you own your office space



# ACTIVE LEARNING 2

## Answers

The rent on office space increases \$500/month.

**a.** You rent your office space.

Explicit costs increase \$500/month.

Accounting profit & economic profit each fall \$500/month.

**b.** You own your office space.

Explicit costs do not change,  
so accounting profit does not change.

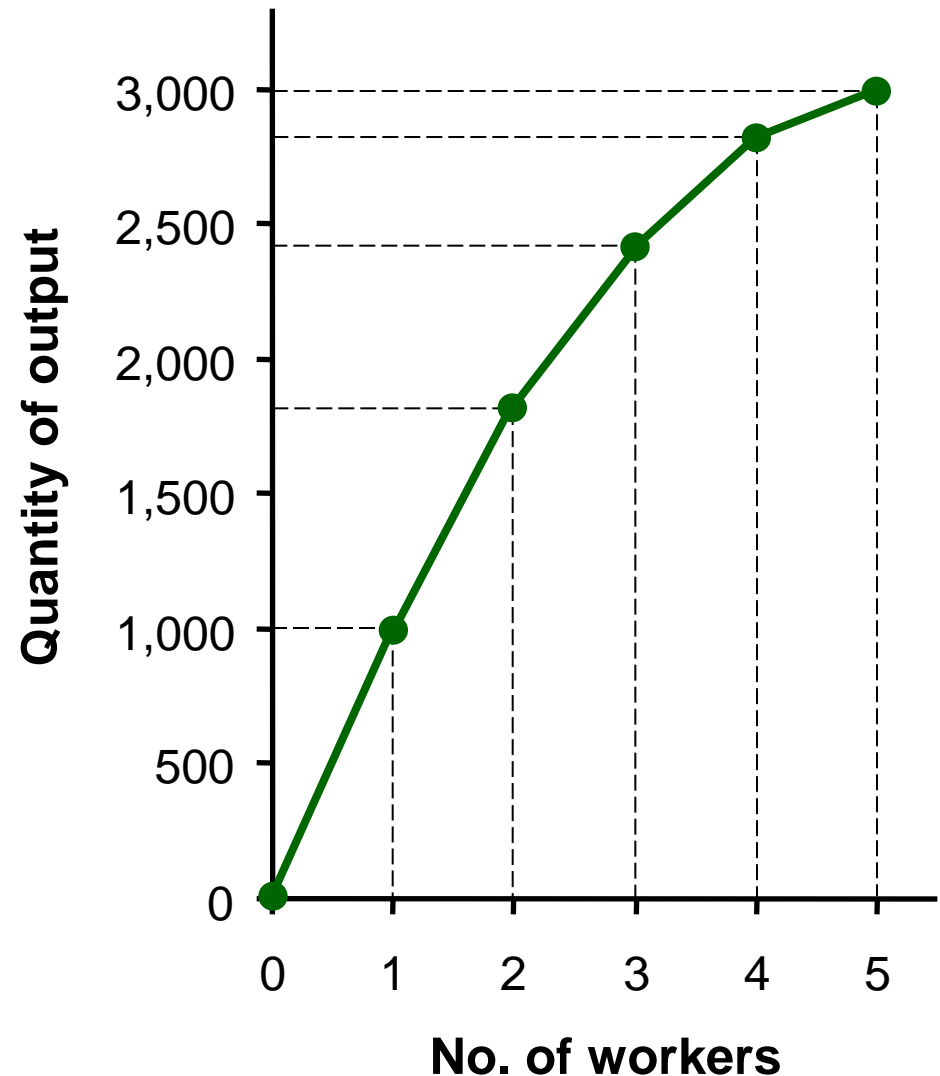
Implicit costs increase \$500/month (opp. cost  
of using your space instead of renting it),  
so economic profit falls by \$500/month.

# The Production Function

- A **production function** shows the relationship between the quantity of inputs used to produce a good and the quantity of output of that good.
- It can be represented by a table, equation, or graph.
- Example 1:
  - Farmer Jack grows wheat.
  - He has 5 acres of land.
  - He can hire as many workers as he wants.

# EXAMPLE 1: Farmer Jack's Production Function

<b><i>L</i></b> (no. of workers)	<b><i>Q</i></b> (bushels of wheat)
0	0
1	1000
2	1800
3	2400
4	2800
5	3000



# Marginal Product

- If Jack hires one more worker, his output rises by the *marginal product of labor*.
- The **marginal product** of any input is the increase in output arising from an additional unit of that input, holding all other inputs constant.

- Notation:

$\Delta$  (delta) = “change in...”

Examples:

$\Delta Q$  = change in output,  $\Delta L$  = change in labor

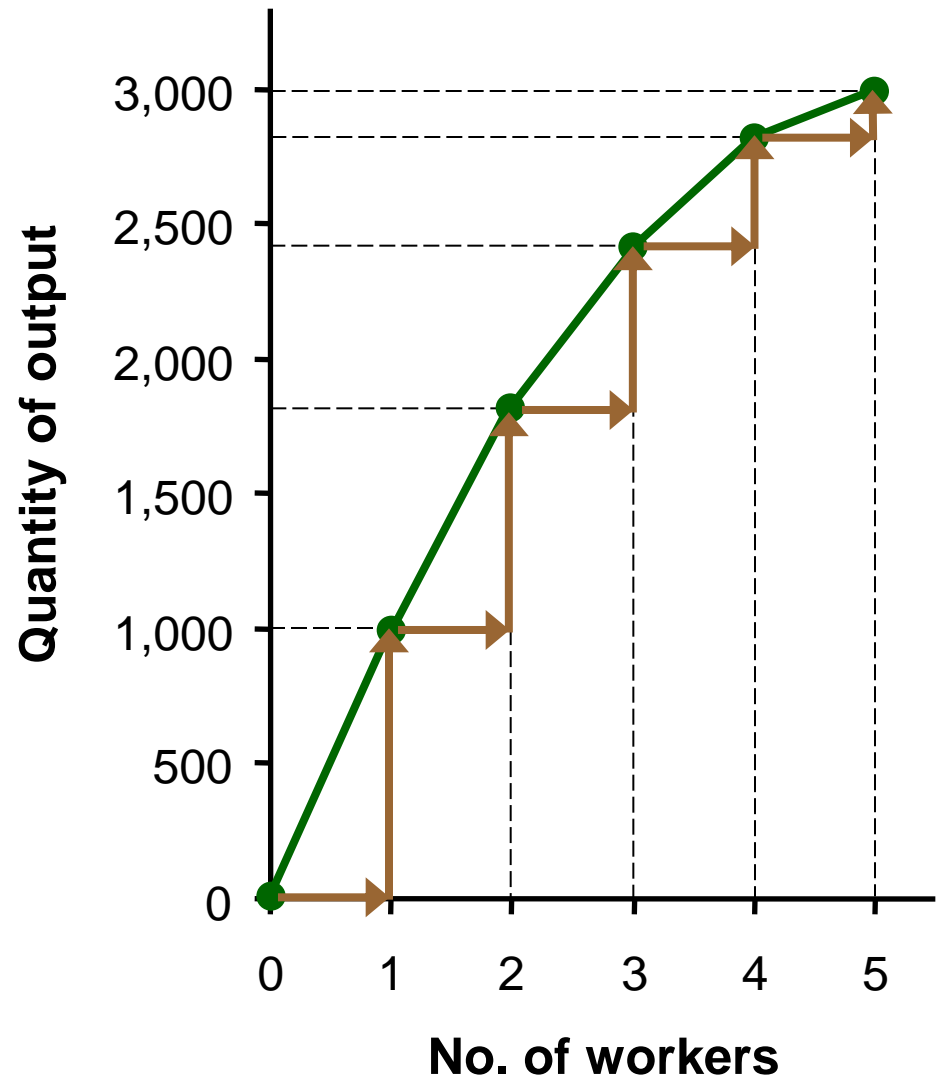
- Marginal product of labor ( $MPL$ ) =  $\frac{\Delta Q}{\Delta L}$

# EXAMPLE 1: Total & Marginal Product

	<b><i>L</i></b> (no. of workers)	<b><i>Q</i></b> (bushels of wheat)		<b><i>MPL</i></b>
	0	0		
$\Delta L = 1$	1	1000	$\Delta Q = 1000$	1000
$\Delta L = 1$	2	1800	$\Delta Q = 800$	800
$\Delta L = 1$	3	2400	$\Delta Q = 600$	600
$\Delta L = 1$	4	2800	$\Delta Q = 400$	400
$\Delta L = 1$	5	3000	$\Delta Q = 200$	200

# EXAMPLE 1: $MPL = \text{Slope of Prod Function}$

$L$ (no. of workers)	$Q$ (bushels of wheat)	$MPL$
0	0	
1	1000	1000
2	1800	800
3	2400	600
4	2800	400
5	3000	200



# Why MPL Is Important

- Recall one of the Ten Principles:  
*Rational people think at the margin.*
- When Farmer Jack hires an extra worker,
  - his costs rise by the wage he pays the worker
  - his output rises by *MPL*
- Comparing them helps Jack decide whether he should hire the worker.

# Why MPL Diminishes

- Farmer Jack's output rises by a smaller and smaller amount for each additional worker. Why?
- As Jack adds workers, the average worker has less land to work with and will be less productive.
- In general, *MPL* diminishes as *L* rises whether the fixed input is land or capital (equipment, machines, etc.).
- **Diminishing marginal product:**  
the marginal product of an input declines as the quantity of the input increases (other things equal)



# EXAMPLE 1: Farmer Jack's Costs

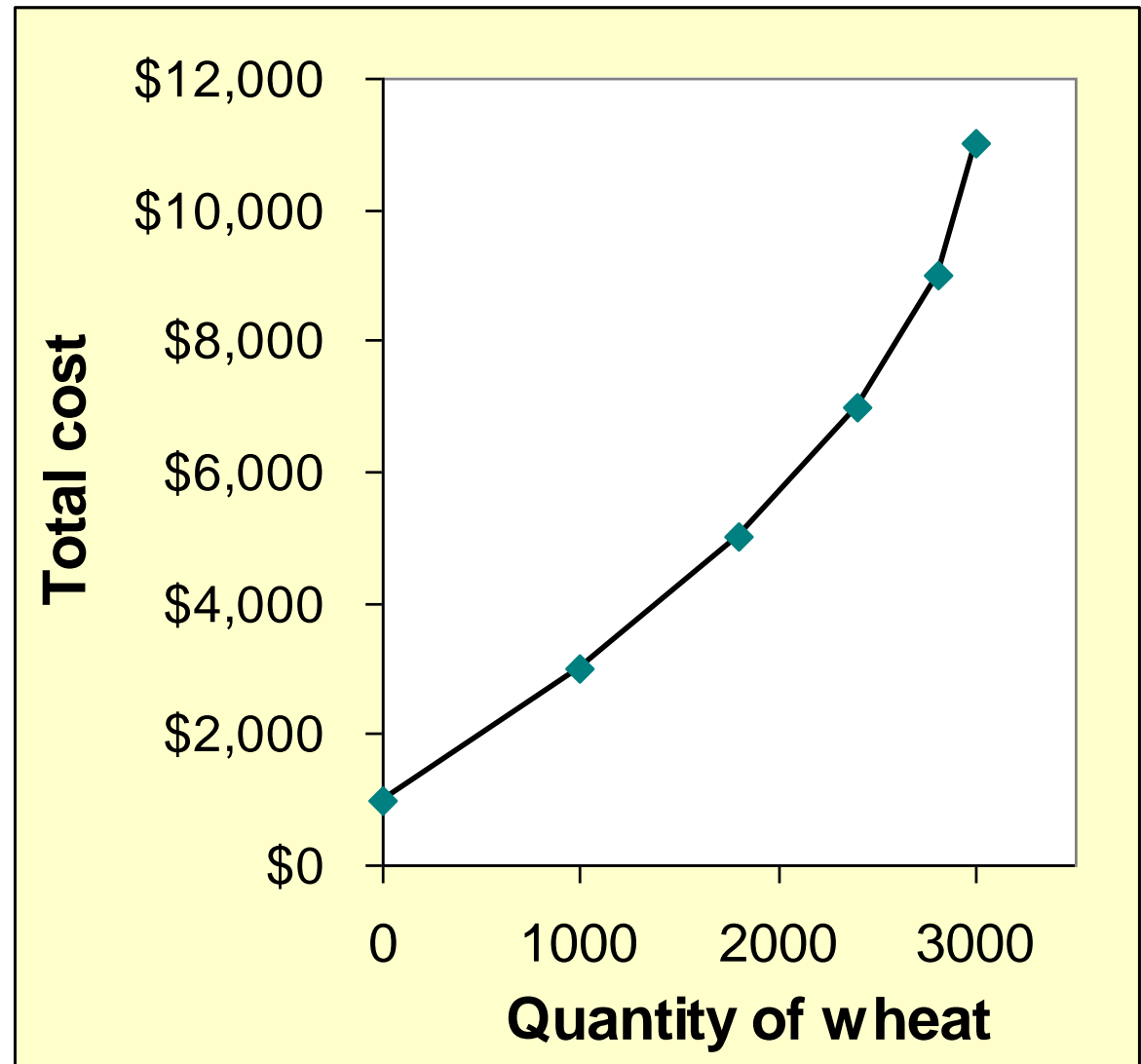
- Farmer Jack must pay \$1000 per month for the land, regardless of how much wheat he grows.
- The market wage for a farm worker is \$2000 per month.
- So Farmer Jack's costs are related to how much wheat he produces....

## EXAMPLE 1: Farmer Jack's Costs

<b><i>L</i></b> (no. of workers)	<b><i>Q</i></b> (bushels of wheat)	Cost of land	Cost of labor	Total Cost
0	0	\$1,000	\$0	\$1,000
1	1000	\$1,000	\$2,000	\$3,000
2	1800	\$1,000	\$4,000	\$5,000
3	2400	\$1,000	\$6,000	\$7,000
4	2800	\$1,000	\$8,000	\$9,000
5	3000	\$1,000	\$10,000	\$11,000

# EXAMPLE 1: Farmer Jack's Total Cost Curve

<b>Q</b> (bushels of wheat)	<b>Total Cost</b>
0	\$1,000
1000	\$3,000
1800	\$5,000
2400	\$7,000
2800	\$9,000
3000	\$11,000



# Marginal Cost

- **Marginal Cost** ( $MC$ )

is the increase in Total Cost from producing one more unit:

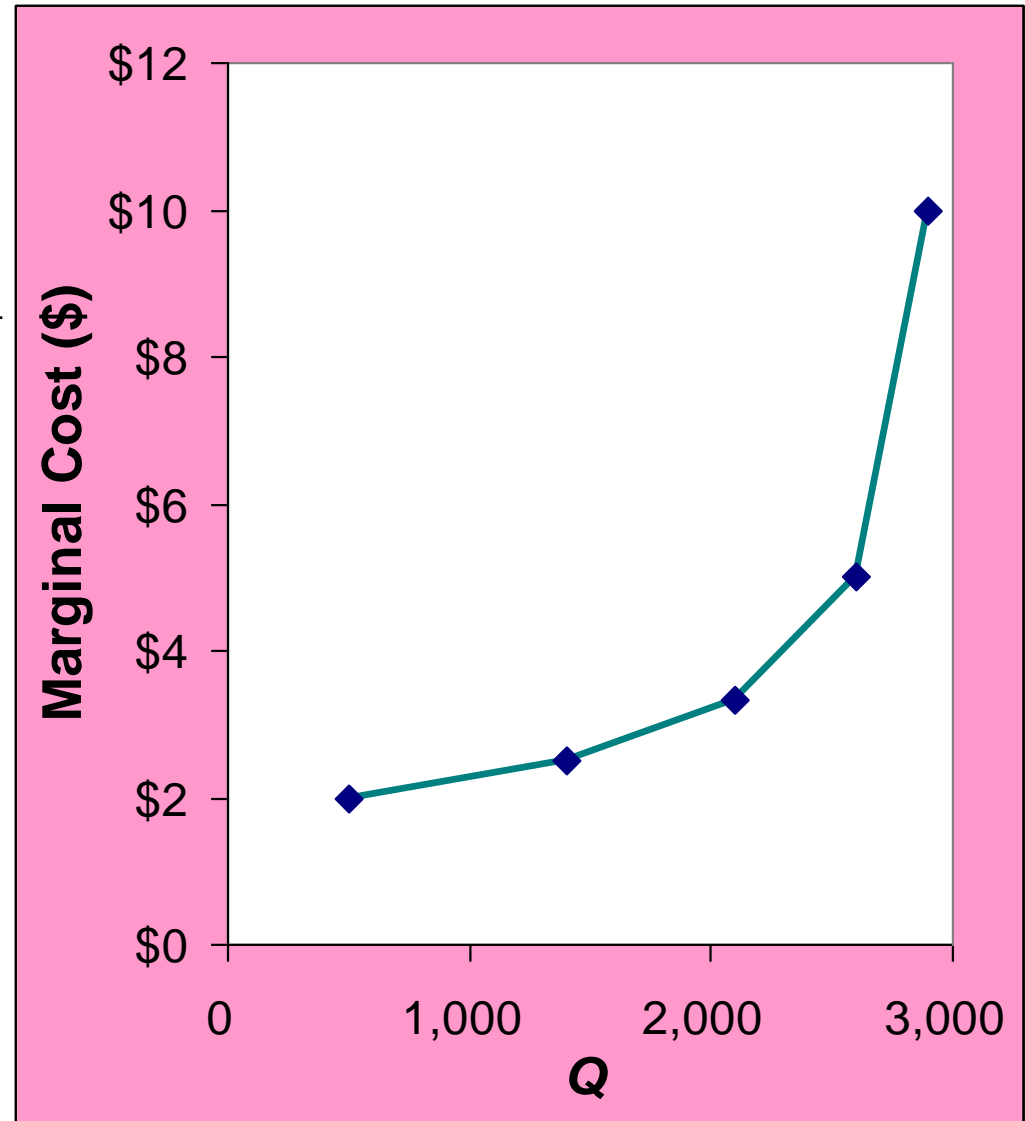
$$MC = \frac{\Delta TC}{\Delta Q}$$

# EXAMPLE 1: Total and Marginal Cost

	<b>Q</b> (bushels of wheat)	<b>Total Cost</b>		<b>Marginal Cost (MC)</b>
	0	\$1,000		
$\Delta Q = 1000$	1000	\$3,000	$\Delta TC = \$2000$	\$2.00
$\Delta Q = 800$	1800	\$5,000	$\Delta TC = \$2000$	\$2.50
$\Delta Q = 600$	2400	\$7,000	$\Delta TC = \$2000$	\$3.33
$\Delta Q = 400$	2800	\$9,000	$\Delta TC = \$2000$	\$5.00
$\Delta Q = 200$	3000	\$11,000	$\Delta TC = \$2000$	\$10.00

# EXAMPLE 1: The Marginal Cost Curve

<b>Q</b> (bushels of wheat)	<b>TC</b>	<b>MC</b>
0	\$1,000	
		\$2.00
1000	\$3,000	
		\$2.50
1800	\$5,000	
		\$3.33
2400	\$7,000	
		\$5.00
2800	\$9,000	
		\$10.00
3000	\$11,000	



# Why MC Is Important

- Farmer Jack is rational and wants to maximize his profit. To increase profit, should he produce more or less wheat?
- To find the answer, Farmer Jack needs to “think at the margin.”
- If the cost of additional wheat ( $MC$ ) is less than the revenue he would get from selling it, then Jack’s profits rise if he produces more.

# Fixed and Variable Costs

- **Fixed costs ( $FC$ )** do not vary with the quantity of output produced.
  - For Farmer Jack,  $FC = \$1000$  for his land
  - Other examples:  
cost of equipment, loan payments, rent
- **Variable costs ( $VC$ )** vary with the quantity produced.
  - For Farmer Jack,  $VC =$  wages he pays workers
  - Other example: cost of materials
- **Total cost ( $TC$ )** =  $FC + VC$

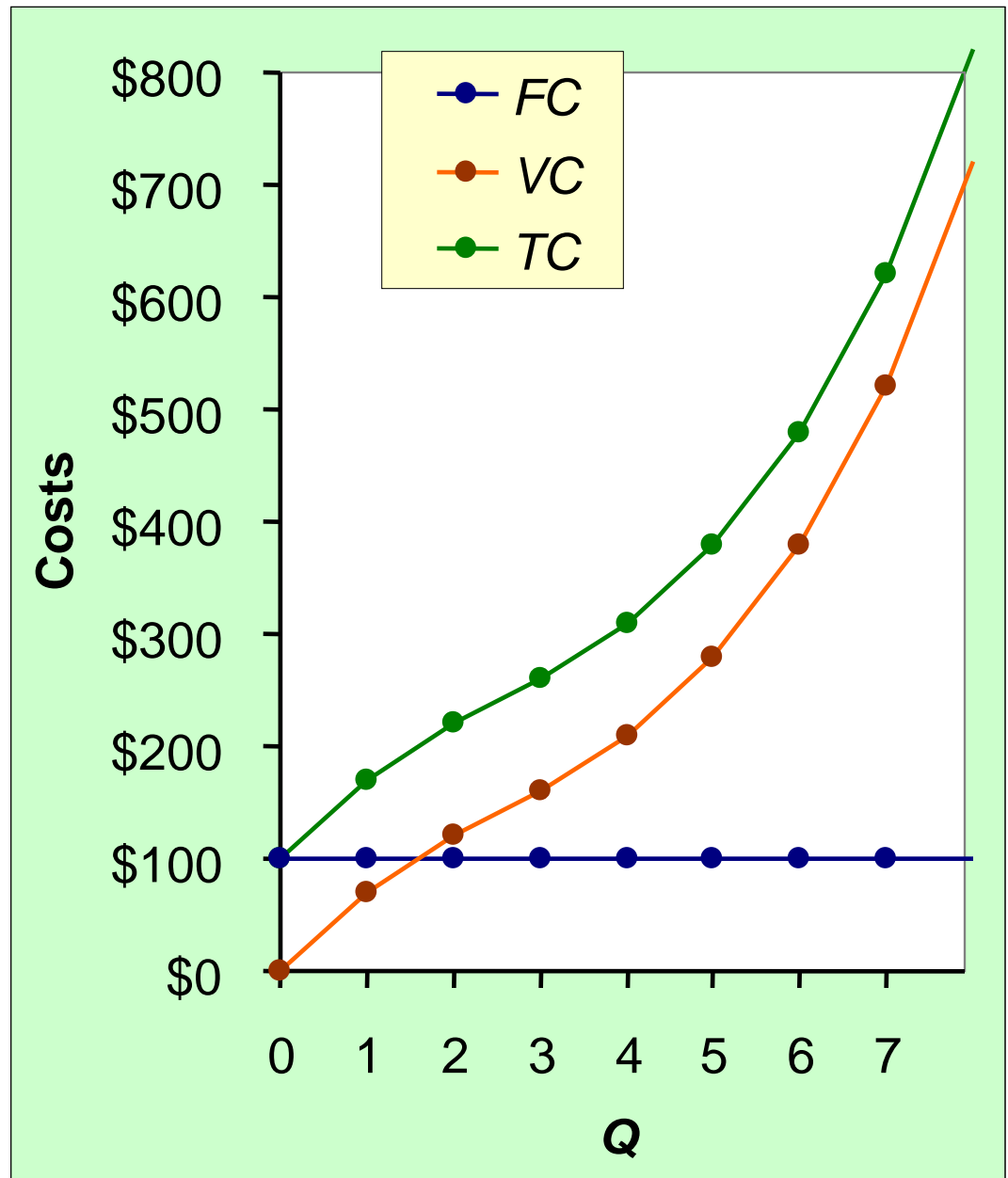


## EXAMPLE 2

- Our second example is more general, applies to any type of firm producing any good with any types of inputs.

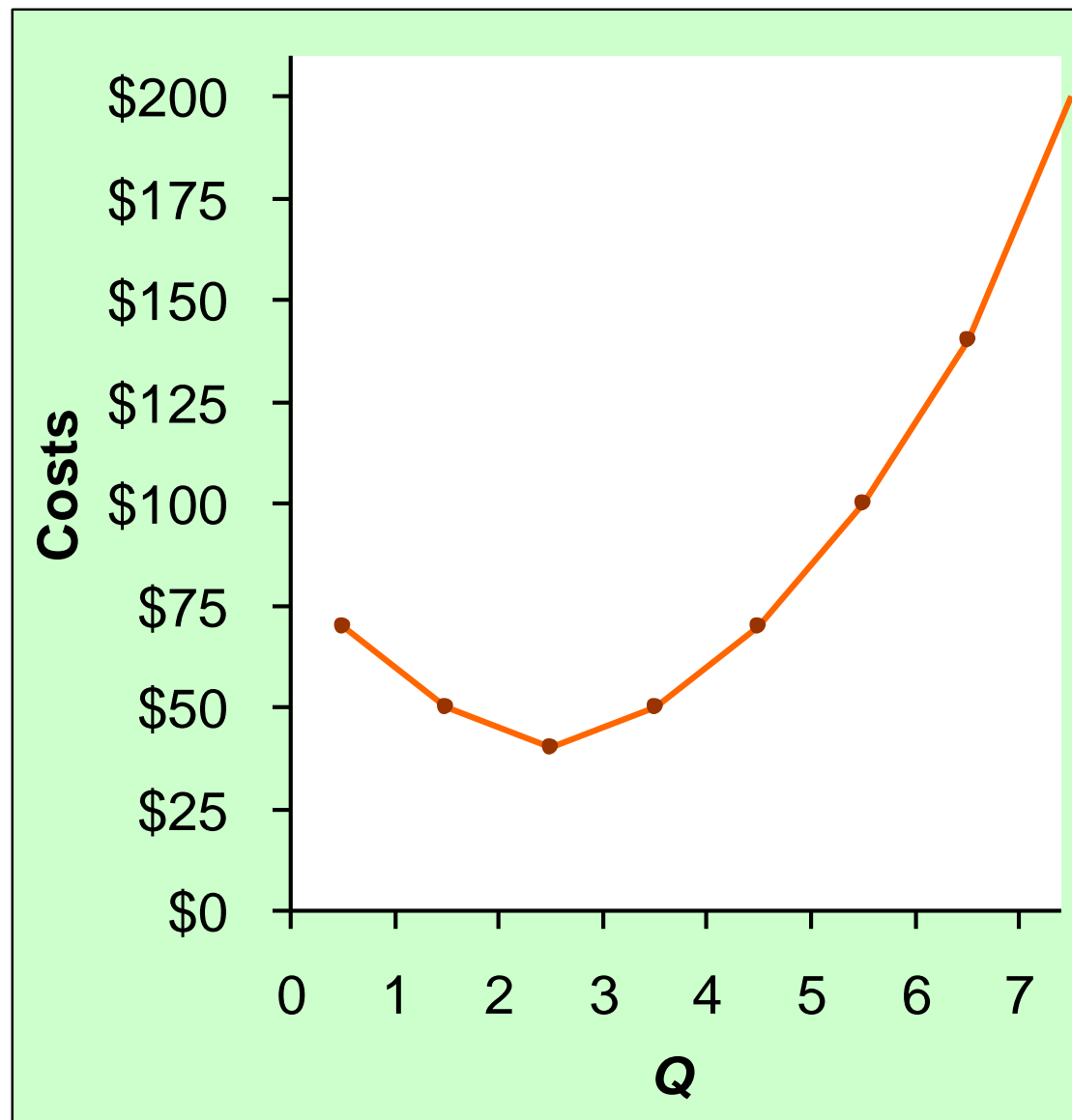
## EXAMPLE 2: Costs

$Q$	$FC$	$VC$	$TC$
0	\$100	\$0	\$100
1	100	70	170
2	100	120	220
3	100	160	260
4	100	210	310
5	100	280	380
6	100	380	480
7	100	520	620



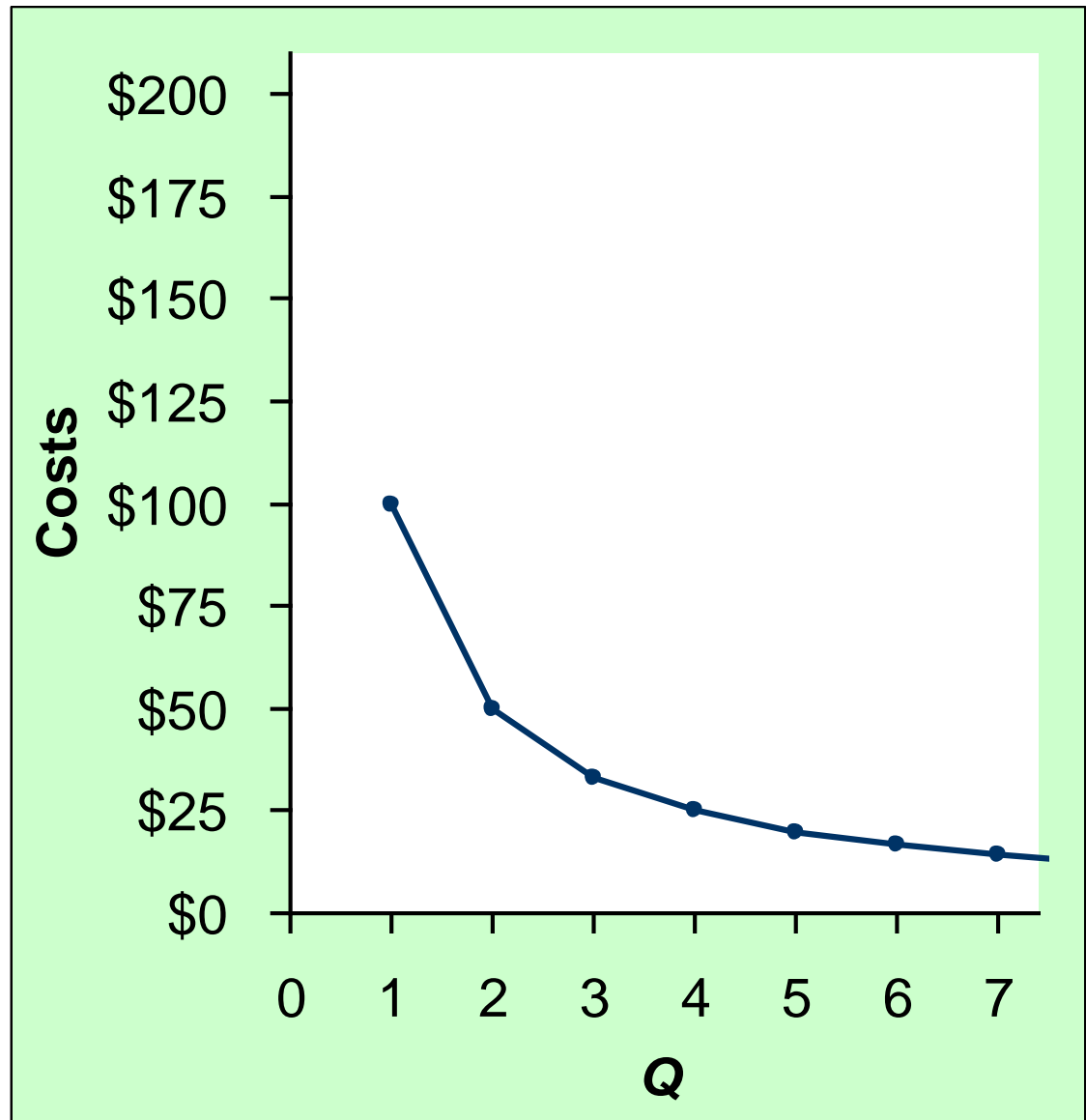
## EXAMPLE 2: Marginal Cost

$Q$	$TC$	$MC$
0	\$100	
1	170	\$70
2	220	50
3	260	40
4	310	50
5	380	70
6	480	100
7	620	140



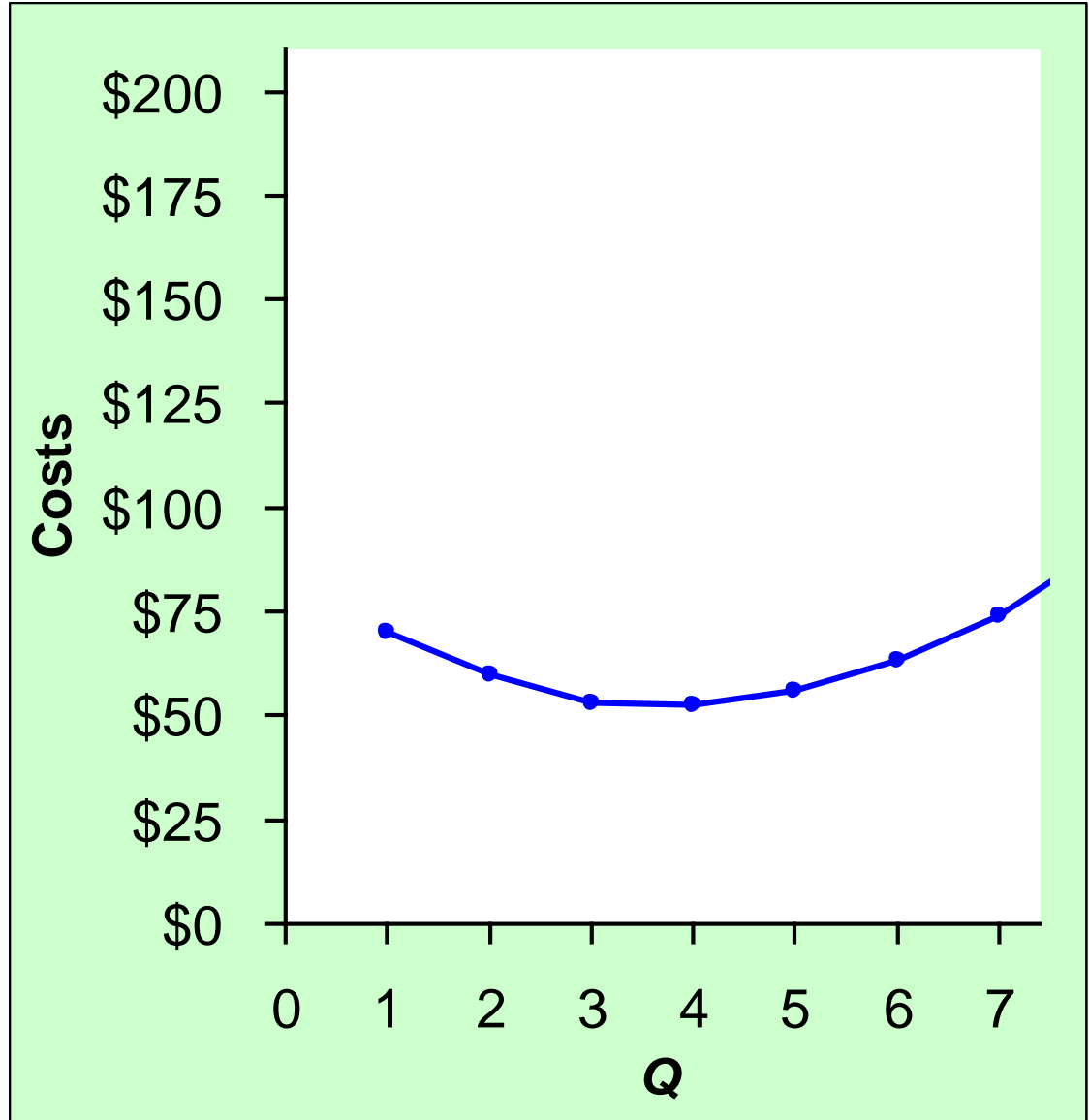
## EXAMPLE 2: Average Fixed Cost

$Q$	$FC$	$AFC$
0	\$100	n/a
1	100	\$100
2	100	50
3	100	33.33
4	100	25
5	100	20
6	100	16.67
7	100	14.29



## EXAMPLE 2: Average Variable Cost

$Q$	$VC$	$AVC$
0	\$0	n/a
1	70	\$70
2	120	60
3	160	53.33
4	210	52.50
5	280	56.00
6	380	63.33
7	520	74.29



## EXAMPLE 2: Average Total Cost

$Q$	$TC$	$ATC$	$AFC$	$AVC$
0	\$100	n/a	n/a	n/a
1	170	\$170	\$100	\$70
2	220	110	50	60
3	260	86.67	33.33	53.33
4	310	77.50	25	52.50
5	380	76	20	56.00
6	480	80	16.67	63.33
7	620	88.57	14.29	74.29

**Average total cost ( $ATC$ )** equals total cost divided by the quantity of output:

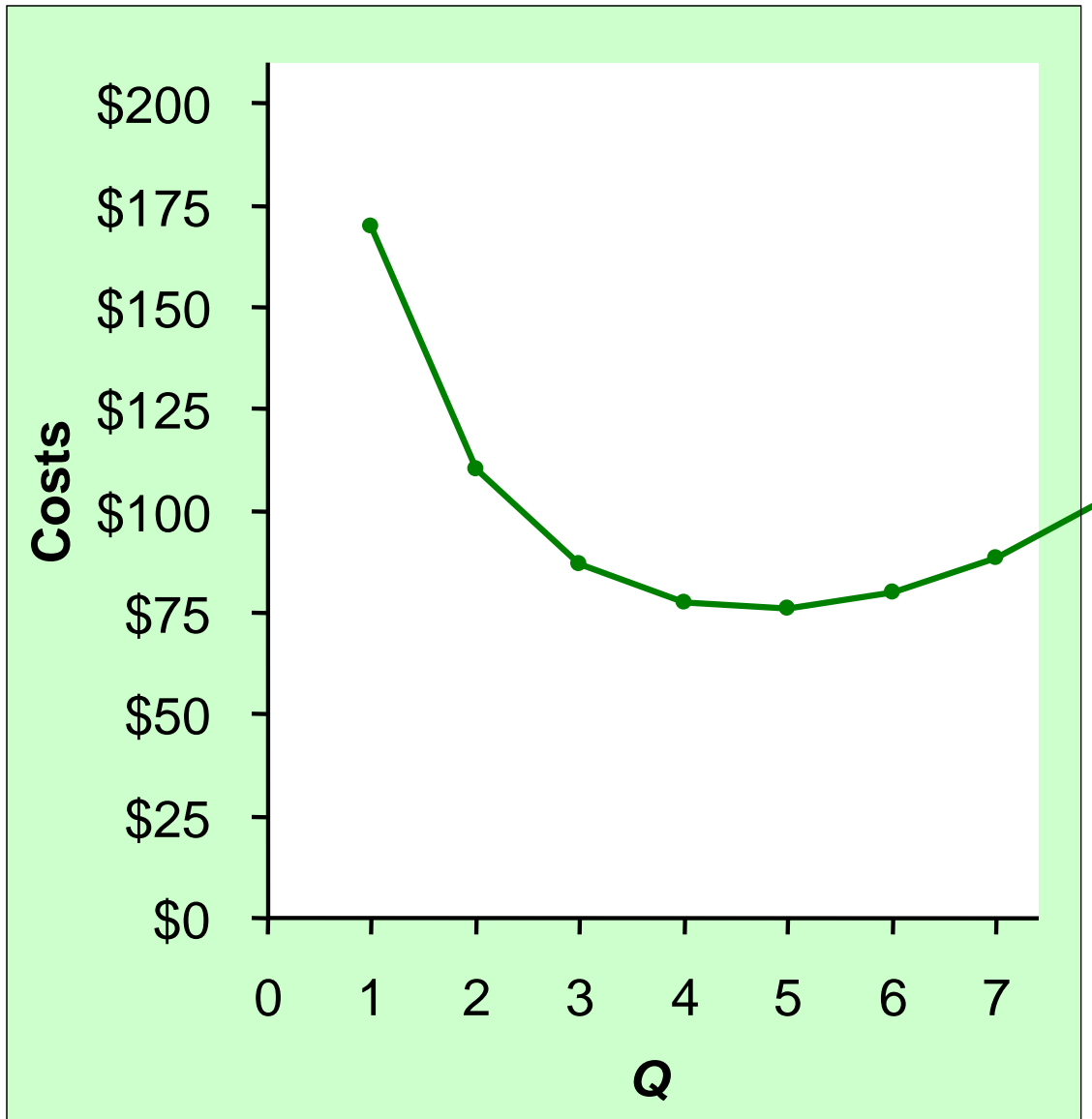
$$ATC = TC/Q$$

Also,

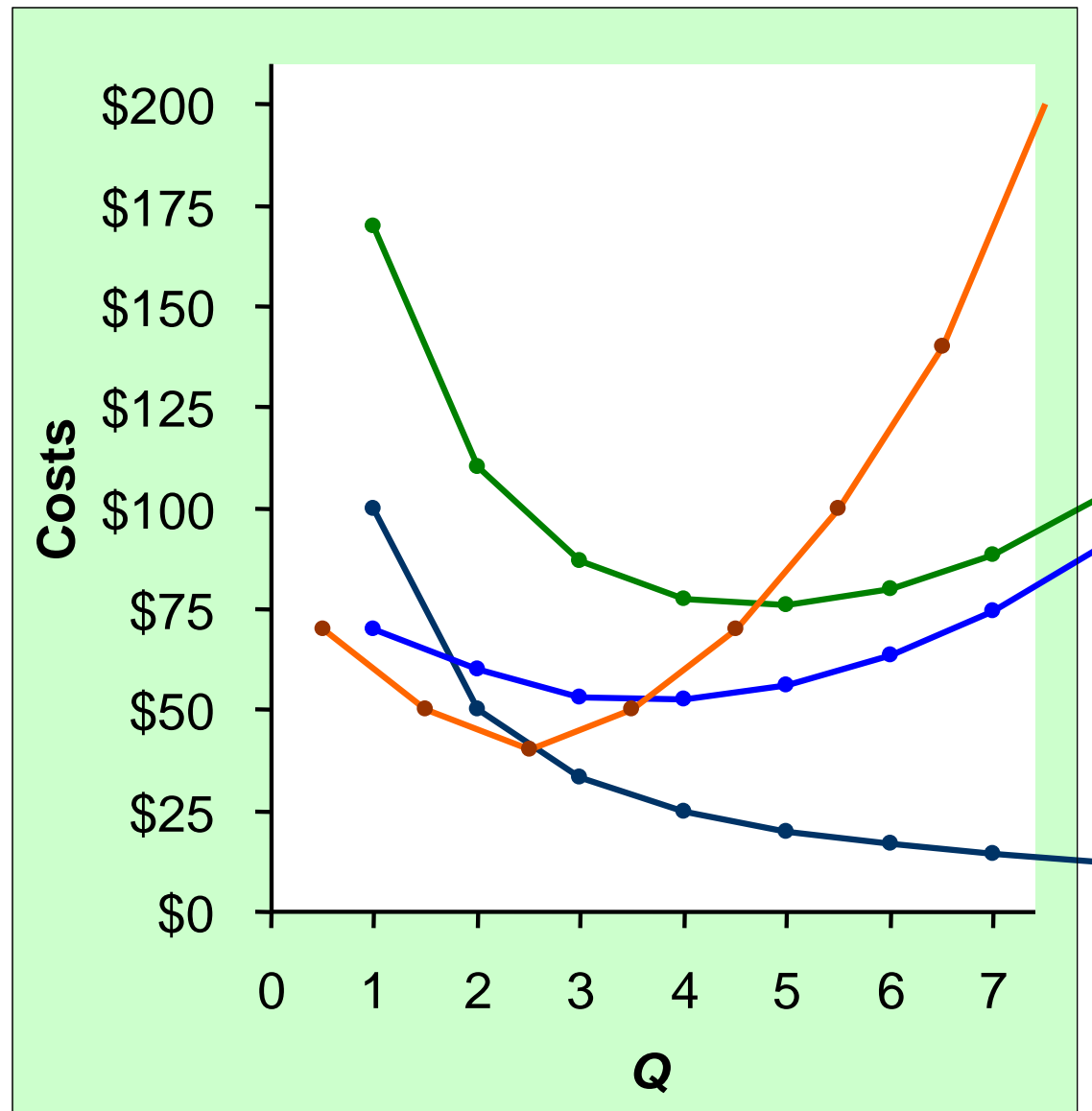
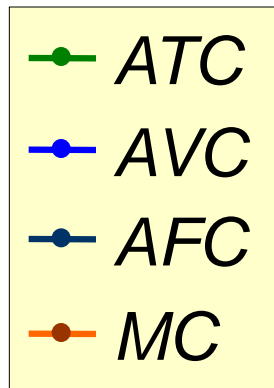
$$ATC = AFC + AVC$$

## EXAMPLE 2: Average Total Cost

$Q$	$TC$	$ATC$
0	\$100	n/a
1	170	\$170
2	220	110
3	260	86.67
4	310	77.50
5	380	76
6	480	80
7	620	88.57



## EXAMPLE 2: The Various Cost Curves Together





# ACTIVE LEARNING 3

## Calculating costs

Fill in the blank spaces of this table.

<i>Q</i>	<i>VC</i>	<i>TC</i>	<i>AFC</i>	<i>AVC</i>	<i>ATC</i>	<i>MC</i>
0		\$50	<i>n/a</i>	<i>n/a</i>	<i>n/a</i>	
1	10			\$10	\$60.00	\$10
2	30	80				
3			16.67	20	36.67	30
4	100	150	12.50		37.50	
5	150			30		
6	210	260	8.33	35	43.33	60

# ACTIVE LEARNING 3

## Answers

First, deduce  $FC = \$50$  and use  $FC + VC = TC$ .

Q	VC	TC	AFC	AVC	ATC	MC
0	\$0	\$50	n/a	n/a	n/a	
1	10	60	\$50.00	\$10	\$60.00	\$10
2	30	80	25.00	15	40.00	20
3	60	110	16.67	20	36.67	30
4	100	150	12.50	25	37.50	40
5	150	200	10.00	30	40.00	50
6	210	260	8.33	35	43.33	60

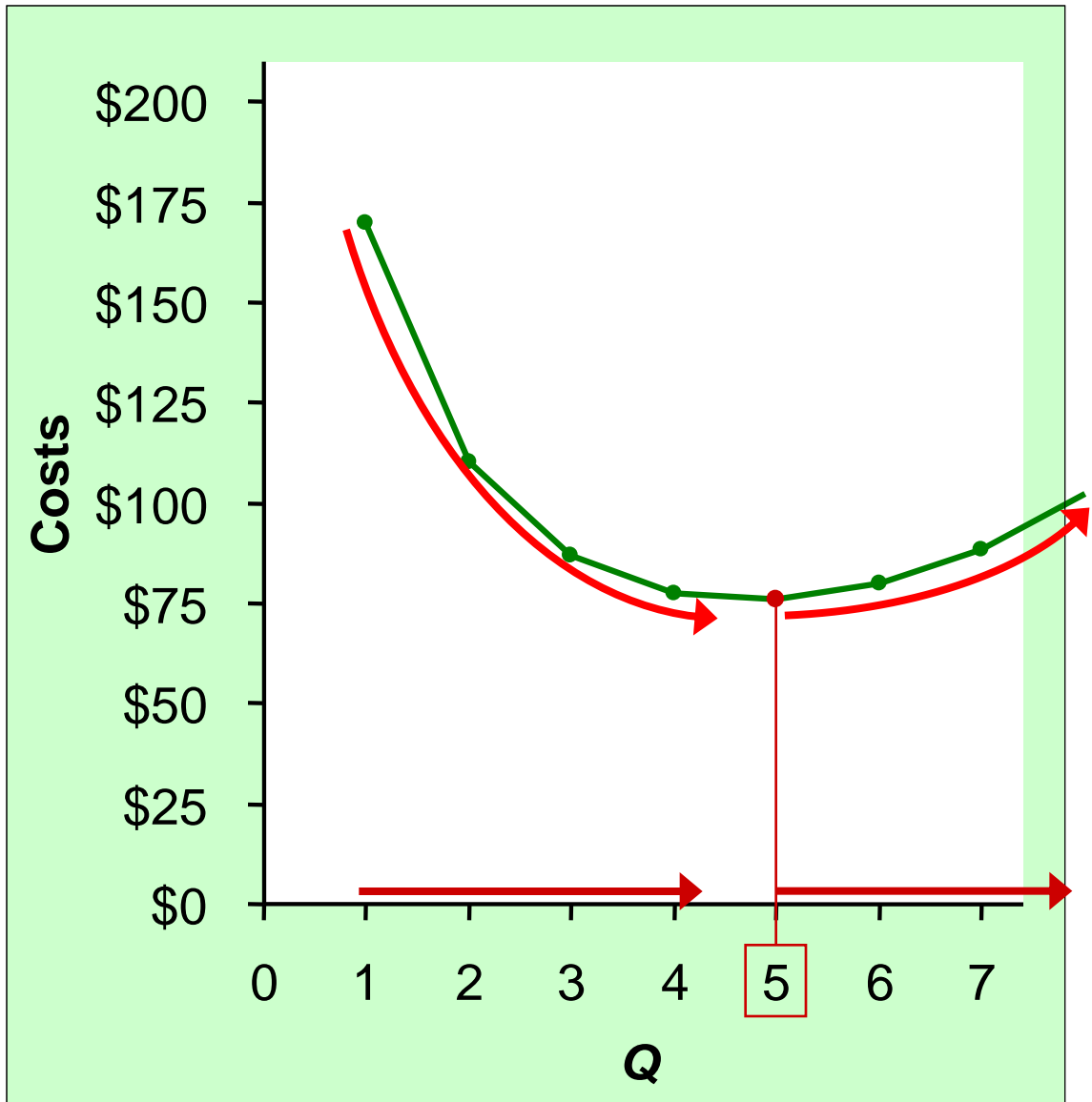
## EXAMPLE 2: Why ATC Is Usually U-Shaped

As  $Q$  rises:

Initially,  
falling  $AFC$   
pulls  $ATC$  down.

Eventually,  
rising  $AVC$   
pulls  $ATC$  up.

**Efficient scale:**  
The quantity that  
minimizes  $ATC$ .

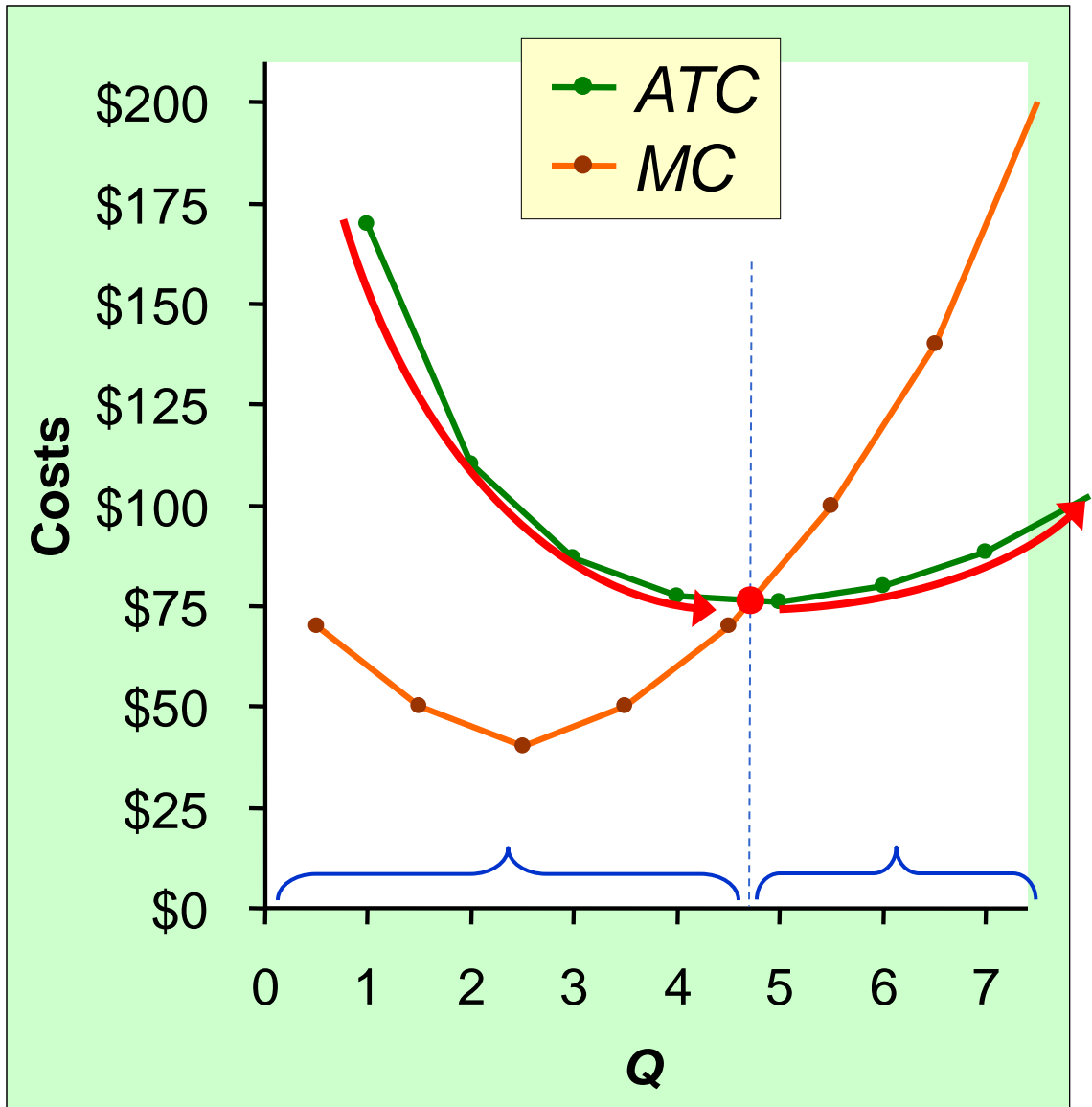


## EXAMPLE 2: ATC and MC

When  $MC < ATC$ ,  
 $ATC$  is falling.

When  $MC > ATC$ ,  
 $ATC$  is rising.

The  $MC$  curve  
crosses the  
 $ATC$  curve at  
the  $ATC$  curve's  
minimum.



# Costs in the Short Run & Long Run

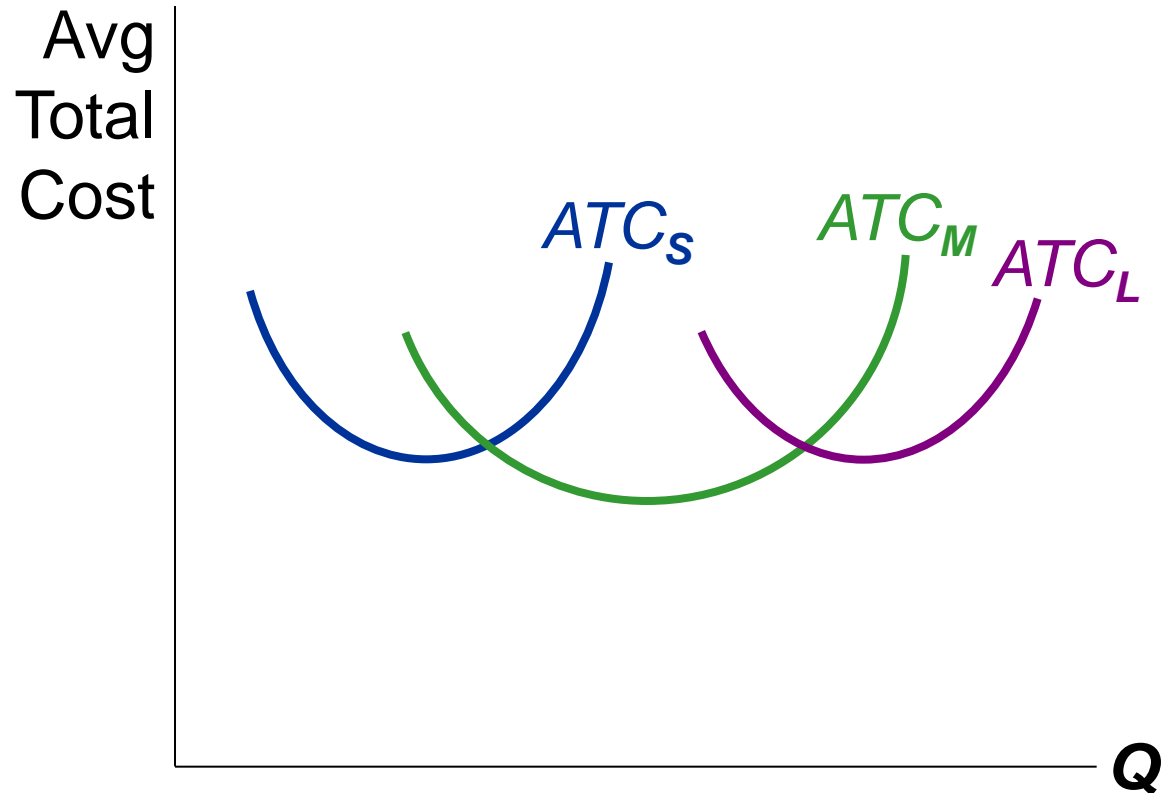
- Short run:  
Some inputs are fixed (e.g., factories, land).  
The costs of these inputs are  $FC$ .
- Long run:  
All inputs are variable  
(e.g., firms can build more factories,  
or sell existing ones).
- In the long run,  $ATC$  at any  $Q$  is cost per unit  
using the most efficient mix of inputs for that  $Q$   
(e.g., the factory size with the lowest  $ATC$ ).

## EXAMPLE 3: LRATC with 3 factory sizes

Firm can choose from three factory sizes: **S**, **M**, **L**.

Each size has its own *SRATC* curve.

The firm can change to a different factory size in the long run, but not in the short run.

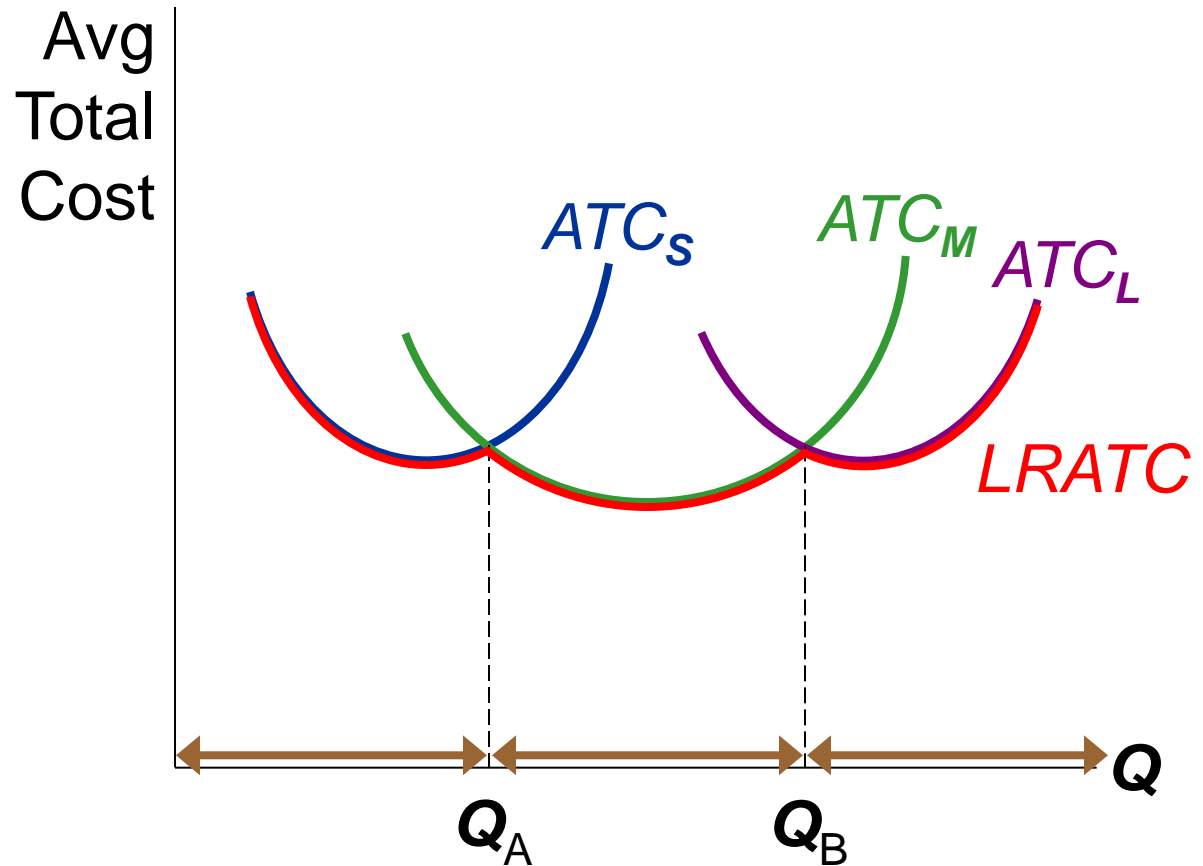


## EXAMPLE 3: LRATC with 3 factory sizes

To produce less than  $Q_A$ , firm will choose size **S** in the long run.

To produce between  $Q_A$  and  $Q_B$ , firm will choose size **M** in the long run.

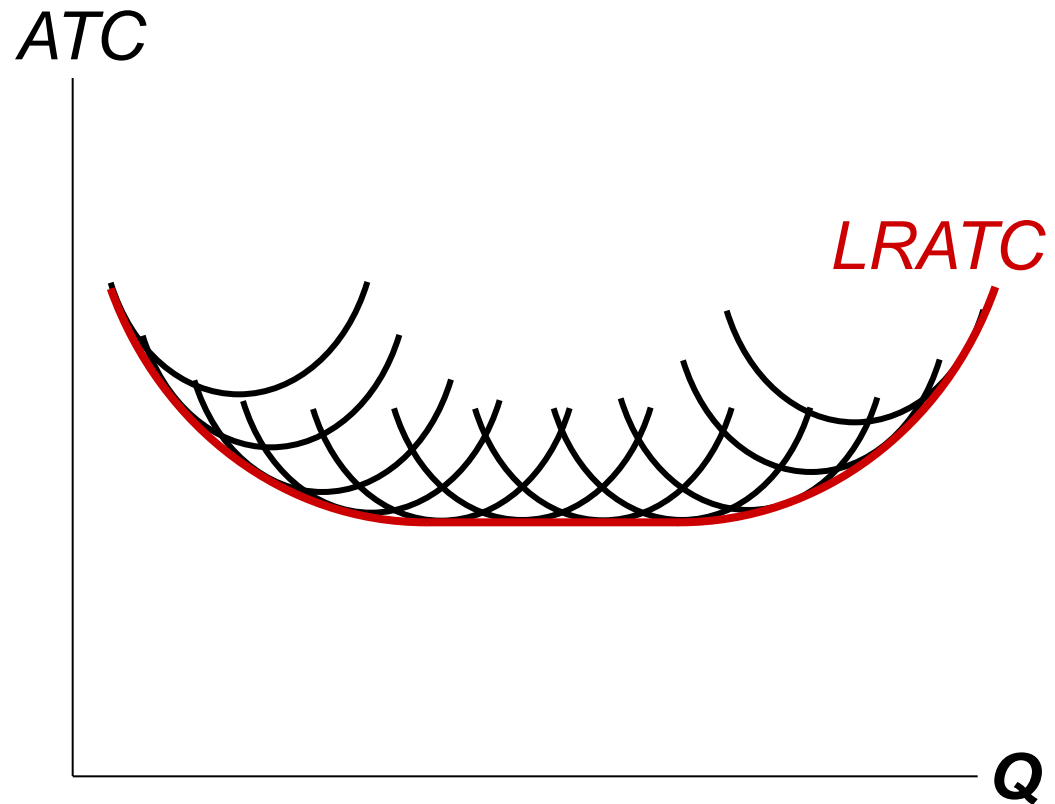
To produce more than  $Q_B$ , firm will choose size **L** in the long run.



# A Typical LRATC Curve

In the real world, factories come in many sizes, each with its own *SRATC* curve.

So a typical *LRATC* curve looks like this:



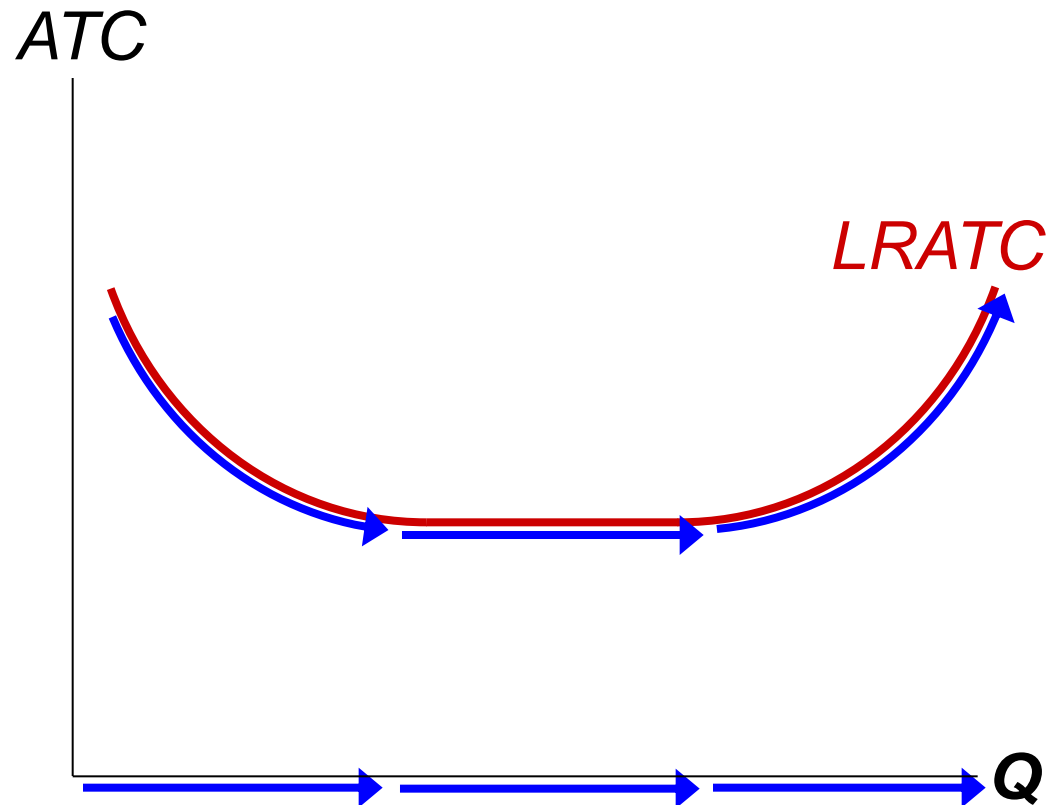


# How ATC Changes as the Scale of Production Changes

**Economies of scale:**  $ATC$  falls as  $Q$  increases.

**Constant returns to scale:**  $ATC$  stays the same as  $Q$  increases.

**Diseconomies of scale:**  $ATC$  rises as  $Q$  increases.



# How ATC Changes as the Scale of Production Changes

- Economies of scale occur when increasing production allows greater specialization: workers more efficient when focusing on a narrow task.
  - More common when  $Q$  is low.
- Diseconomies of scale are due to coordination problems in large organizations. E.g., management becomes stretched, can't control costs.
  - More common when  $Q$  is high.

# CONCLUSION

- Costs are critically important to many business decisions, including production, pricing, and hiring.
- This chapter has introduced the various cost concepts.
- The following chapters will show how firms use these concepts to maximize profits in various market structures.

# SUMMARY

- Implicit costs do not involve a cash outlay, yet are just as important as explicit costs to firms' decisions.
- Accounting profit is revenue minus explicit costs. Economic profit is revenue minus total (explicit + implicit) costs.
- The production function shows the relationship between output and inputs.

# SUMMARY

- The marginal product of labor is the increase in output from a one-unit increase in labor, holding other inputs constant. The marginal products of other inputs are defined similarly.
- Marginal product usually diminishes as the input increases. Thus, as output rises, the production function becomes flatter, and the total cost curve becomes steeper.
- Variable costs vary with output; fixed costs do not.

# SUMMARY

- Marginal cost is the increase in total cost from an extra unit of production. The *MC* curve is usually upward-sloping.
- Average variable cost is variable cost divided by output.
- Average fixed cost is fixed cost divided by output. *AFC* always falls as output increases.
- Average total cost (sometimes called “cost per unit”) is total cost divided by the quantity of output. The *ATC* curve is usually U-shaped.

# SUMMARY

- The  $MC$  curve intersects the  $ATC$  curve at minimum average total cost.  
When  $MC < ATC$ ,  $ATC$  falls as  $Q$  rises.  
When  $MC > ATC$ ,  $ATC$  rises as  $Q$  rises.
- In the long run, all costs are variable.
- Economies of scale:  $ATC$  falls as  $Q$  rises.  
Diseconomies of scale:  $ATC$  rises as  $Q$  rises.  
Constant returns to scale:  $ATC$  remains constant as  $Q$  rises.