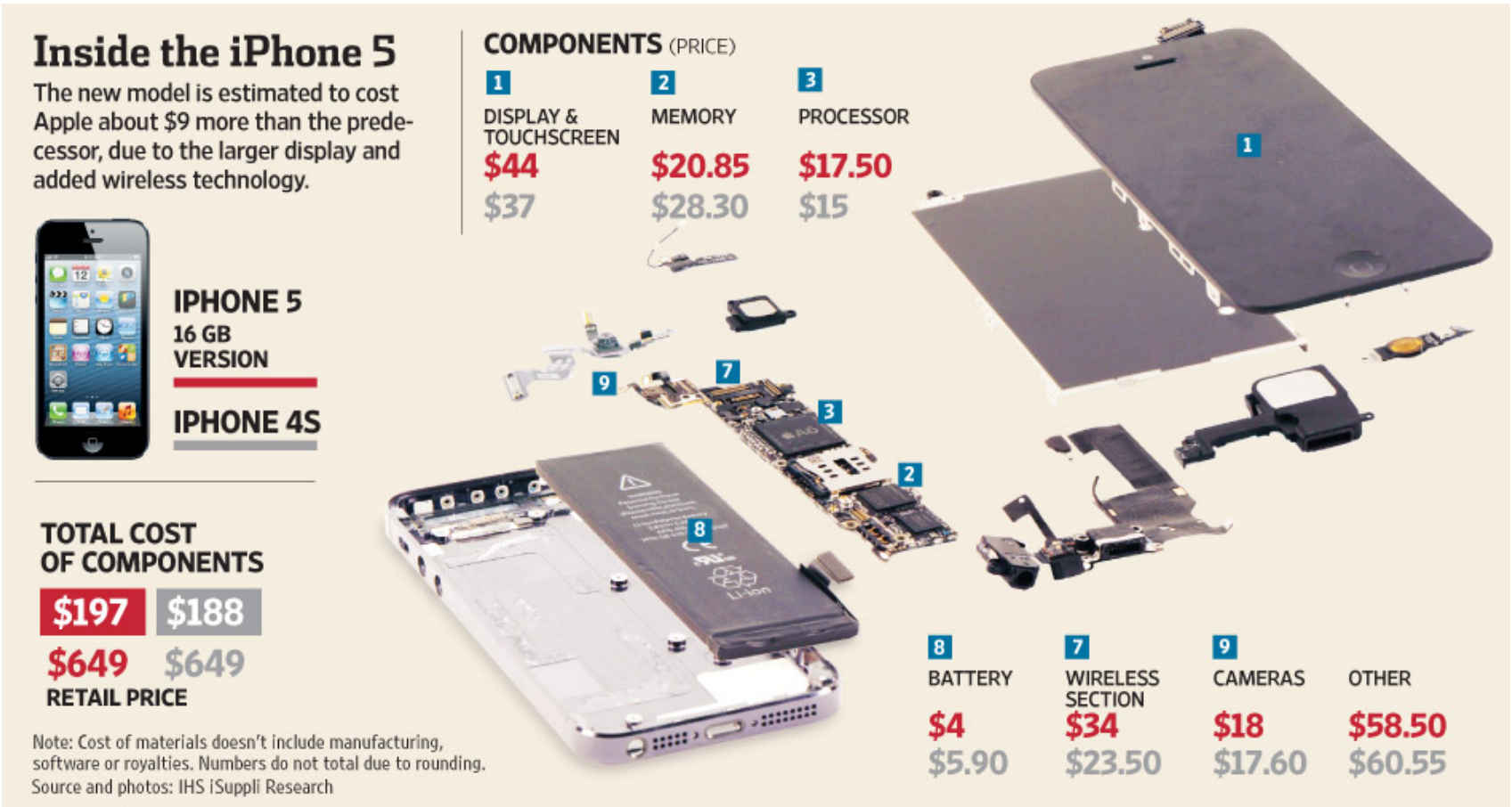
Motivation

Figure: Production of pineapple

Motivation

Figure: iPhone supply chain by Apple



Chapter 5: Theory on producer behaviors

June 3, 2020

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Theory of production

Production function

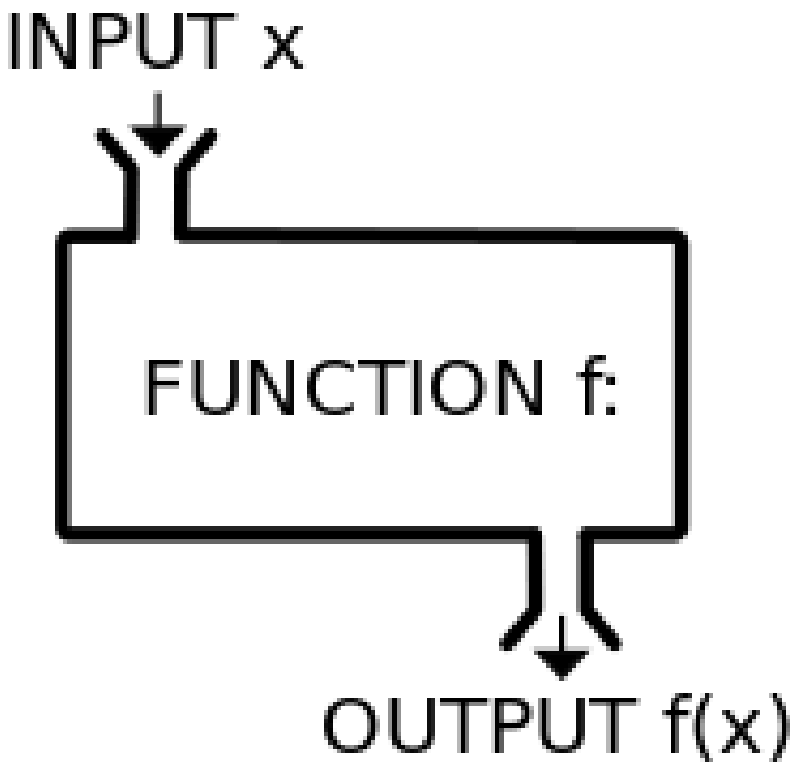
A production function: Function showing the *highest output* that a firm can produce for every specified combination of inputs applies to *a given technology*.

Given technology is a given state of knowledge about the various methods that might be used to transform inputs into outputs.

As the technology becomes more advanced and the production function changes, a firm can obtain more output for a given set of inputs.

Theory of production

Figure: Production function



Theory of production

Production function

Production function is a compact description of how inputs (capital K, L labor) are turned into output Q.

$$\mathbf{Q = f(K,L)} \tag{1}$$

Short-run versus Long-run

Short-run production

The short-run production is the production in which one input, labor, is variable, and the other, capital, is fixed

Long-run production

The long-run production is the production in which both labor and capital are variable.

Production with one variable input (labour)

Average product of labour (Labour productivity) Output per unit of labour.

$$AP_L = \frac{Output}{Labour} = \frac{Q}{L} \tag{2}$$

Marginal product of labour: The increase in output that arises from an additional unit of **labour**

$$MP_L = \frac{\Delta Output}{\Delta Labour} = \frac{\Delta Q}{\Delta L} \tag{3}$$

Production with one variable input (labour)

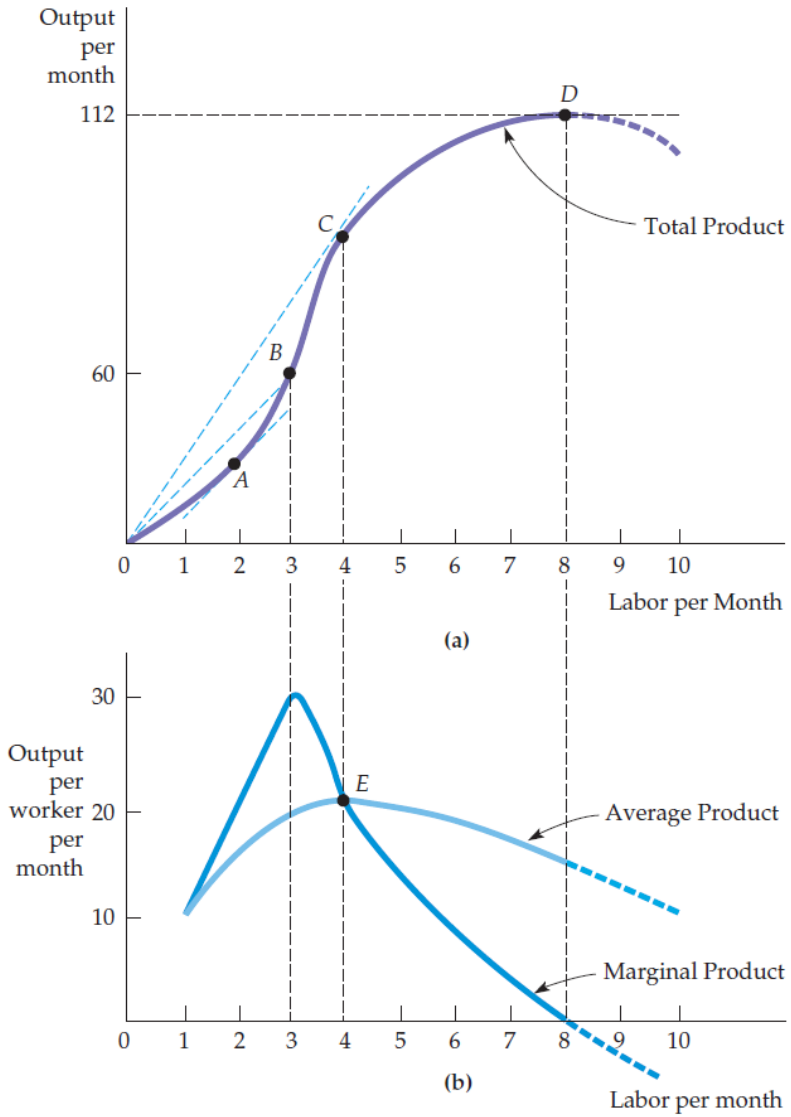
AMOUNT OF LABOR (L)	AMOUNT OF CAPITAL (K)	TOTAL OUTPUT (q)	AVERAGE PRODUCT (q/L)	MARGINAL PRODUCT ($\Delta q/\Delta L$)
0	10	0	—	—
1	10	10	10	10
2	10	30	15	20
3	10	60	20	30
4	10	80	20	20
5	10	95	19	15
6	10	108	18	13
7	10	112	16	4
8	10	112	14	0
9	10	108	12	−4
10	10	100	10	−8

Diminishing marginal product

The marginal product of an input declines as the quantity of the input increases

Explain: As the number of workers increases, additional workers have to share equipment and work in more crowded conditions.

Total output, Marginal product and Average product



Total output, Marginal product and Average product

The marginal product is **above** the average product when the average product is increasing and **below** the average product when the average product is decreasing.

It follows, therefore, that the marginal product must **equal** the average product when the average product reaches its maximum. This happens at point E.

The Law of Diminishing Marginal Returns

Principle that as the use of **an input increases** with **other inputs fixed**, the resulting **additions to output will eventually decrease**.

The law of diminishing marginal returns describes a declining marginal product but not necessarily a negative one.

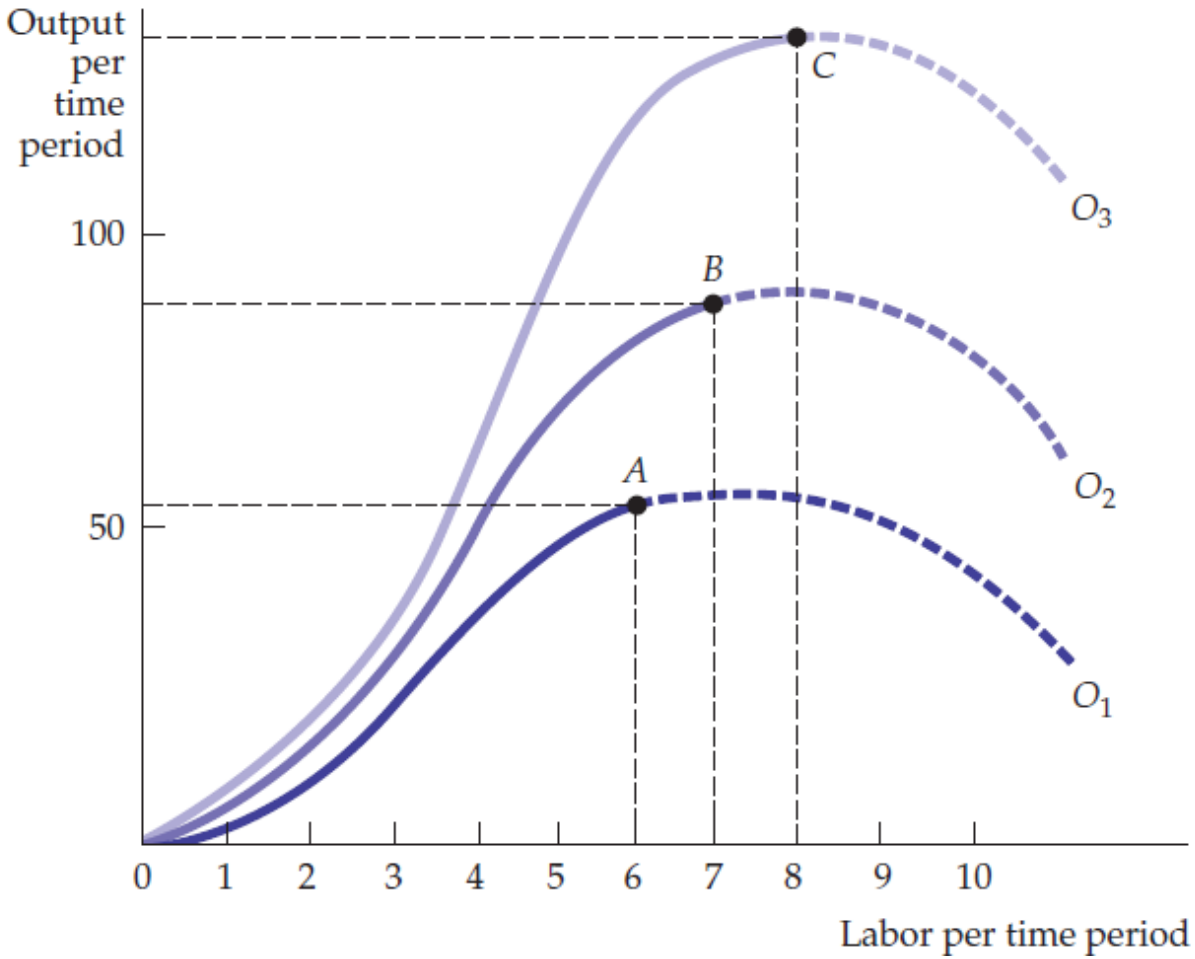
The law of diminishing marginal returns applies to a given production technology

Is there food crisis?

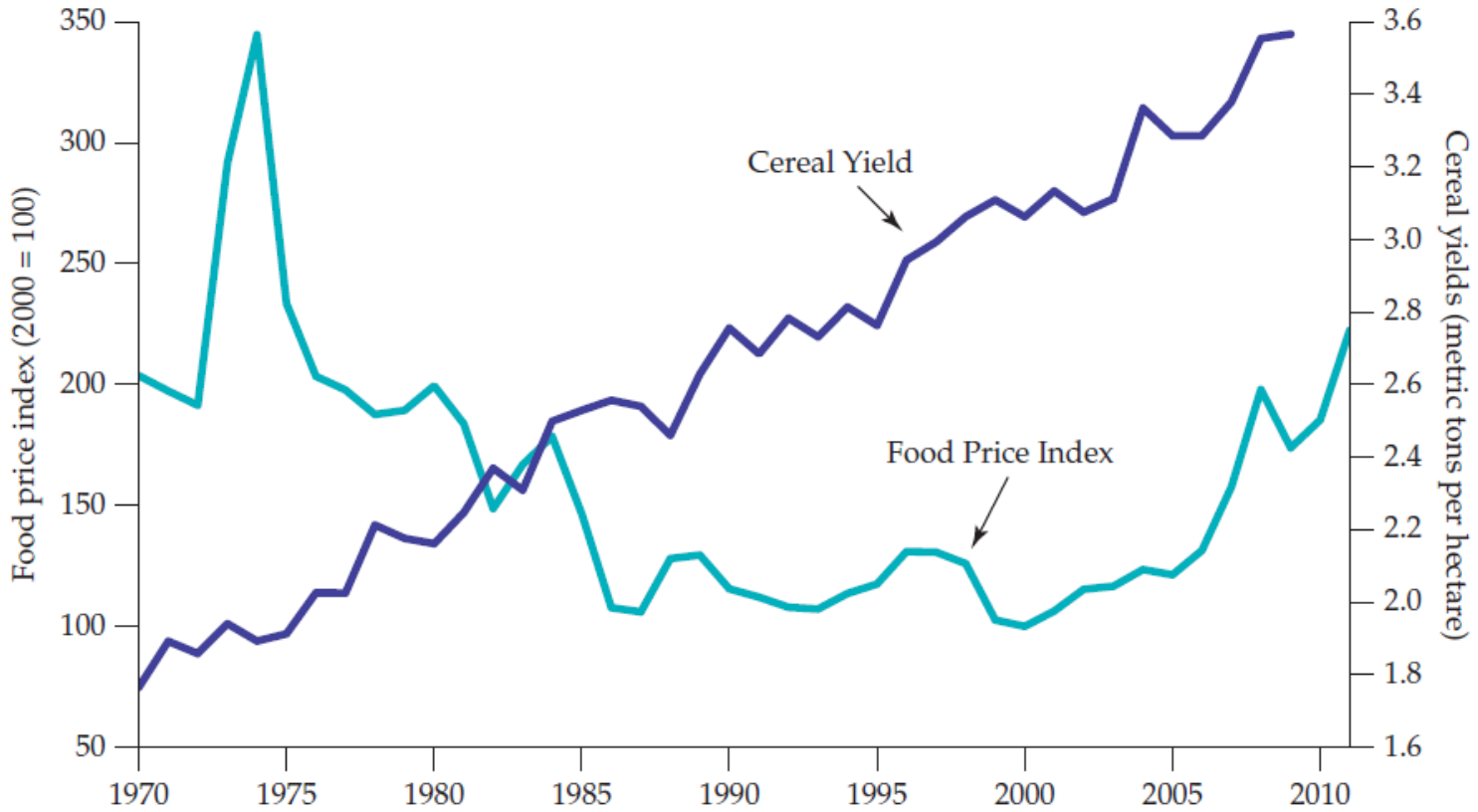
Political economist Thomas Malthus (1766–1834) believed that the world's limited amount of land would not be able to supply enough food as the population grew.

He predicted that as both the marginal and average productivity of labor fell and there were more mouths to feed, mass hunger and starvation would result.

Improvements in technology, despite of diminishing returns to labor



Cereal yields have increased while the average world price of food has declined since the 1970s



Production with two variable inputs

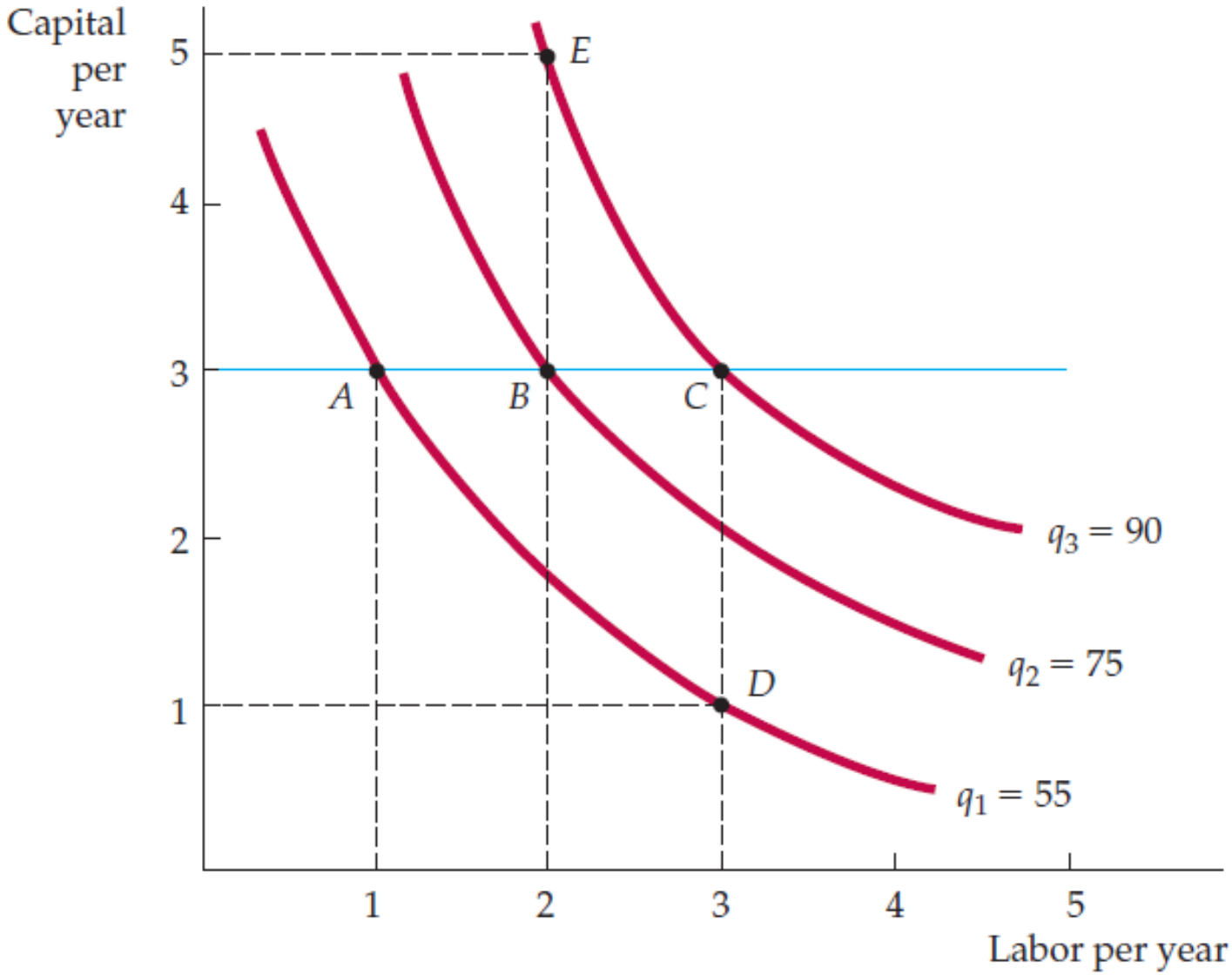
	LABOR INPUT				
CAPITAL INPUT	1	2	3	4	5
1	20	40	55	65	(75)
2	40	60	(75)	85	90
3	55	(75)	90	100	105
4	65	85	100	110	115
5	(75)	90	105	115	120

Production with two variable inputs

Isoquant

An isoquant is a curve that shows all the possible combinations of inputs that yield the same output.

Isoquants


Capital per year
5
4
3
2
1
E
A
B
C
D
$q_3 = 90$
$q_2 = 75$
$q_1 = 55$
1
2
3
4
5
Labor per year

Isoquants

Production isoquants show the various combinations of inputs necessary for the firm to produce a given output.

A set of isoquants, or **isoquant map**, describes the firm's production function. Output increases as we move from isoquant q1 (at which 55 units per year are produced at points such as A and D), to isoquant q2 (75 units per year at points such as B), and to isoquant q3 (90 units per year at points such as C and E).

Isoquants show the **flexibility** that firms have when making production decisions: They can usually obtain a particular output by substituting one input for another.

Substitution Among Inputs

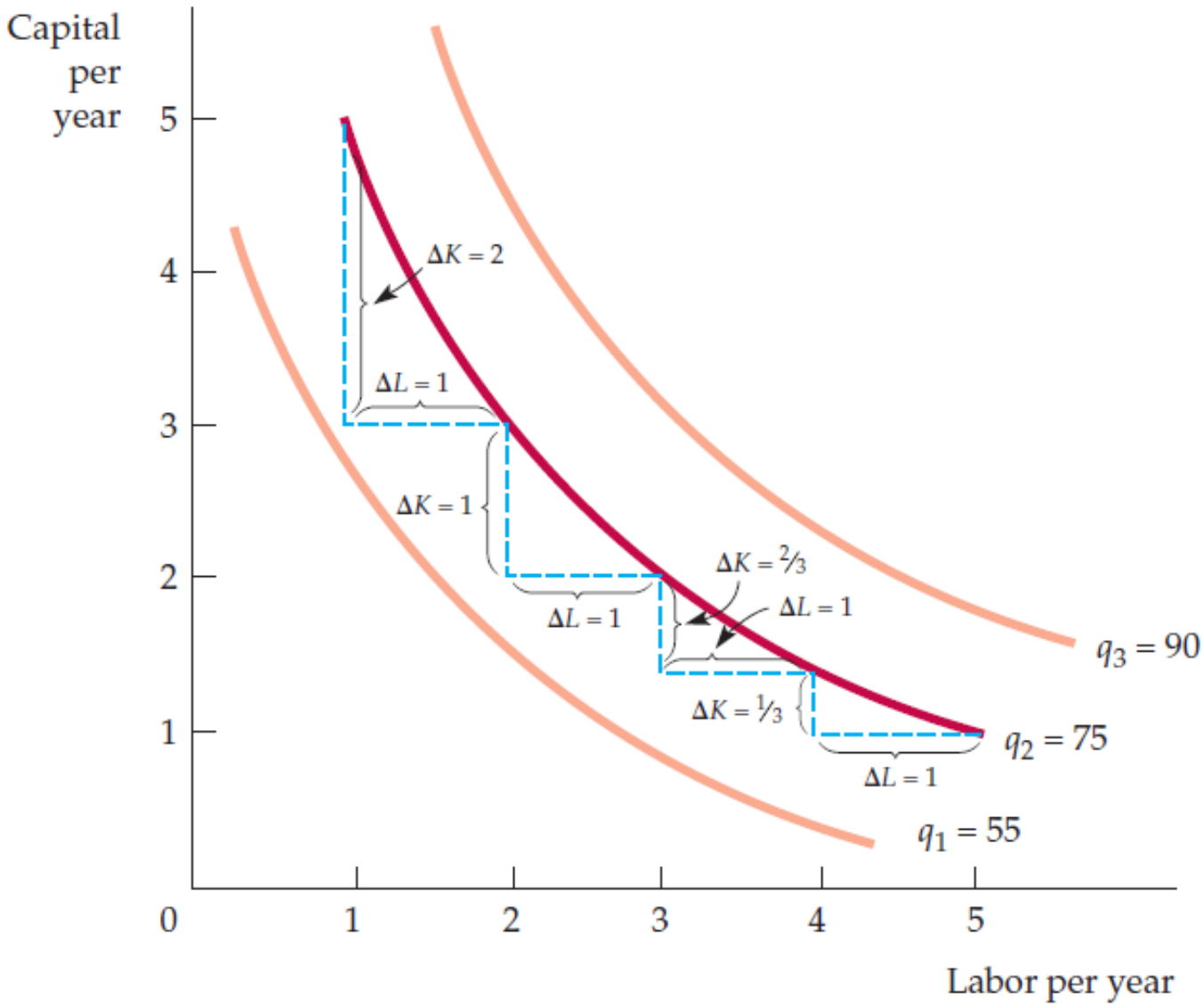
Marginal rate of technical substitution (MRTS)

Amount by which the quantity of one input can be reduced when one extra unit of another input is used, so that output remains constant.

MRTS = − Change in capital input/change in labor input

MRTS = $-\Delta K/\Delta L$(for a fixed level of q)

Marginal rate of technical substitution (MRTS)



Marginal rate of technical substitution (MRTS)

The **slope of the isoquant** at any point measures the marginal rate of technical substitution—the ability of the firm to replace capital with labor while maintaining the same level of output. On isoquant q2, the MRTS falls from 2 to 1 to 2/3 to 1/3.

Diminishing MRTS

The MRTS falls as moving down along an isoquant. The mathematical implication is that isoquants, like indifference curves, are convex, or bowed inward. This is indeed the case for most production technologies.

The diminishing MRTS tells us that the productivity of any one input is limited. As more and more labor is added to the production process in place of capital, the productivity of labor falls. Similarly, when more capital is added in place of labor, the productivity of capital falls. Production needs a balanced mix of both inputs.

Diminishing MRTS

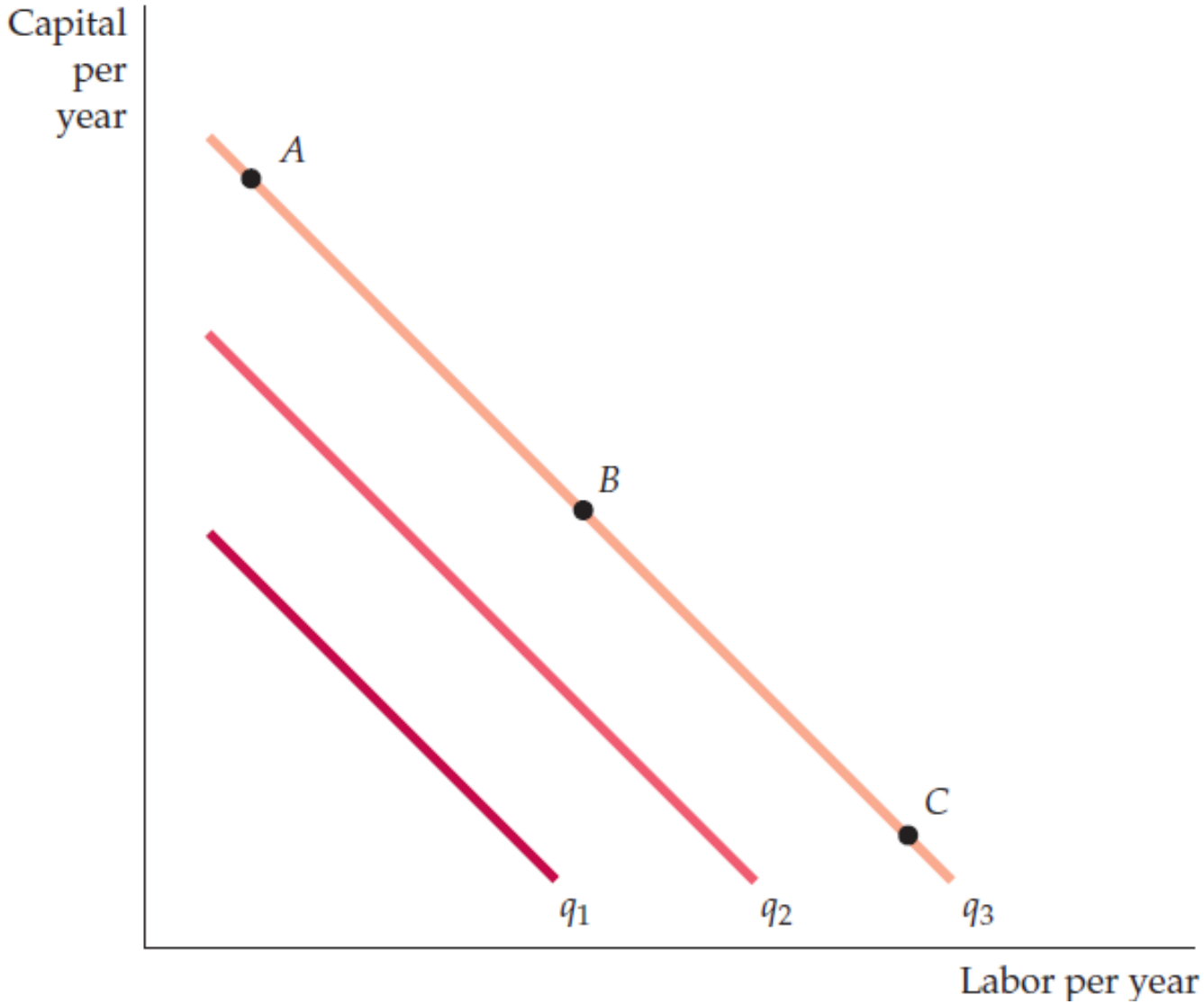
Additional output from increased use of labor $= MP_L \Delta L$

Reduction in output from decreased use of capital = - $MP_K \Delta K$

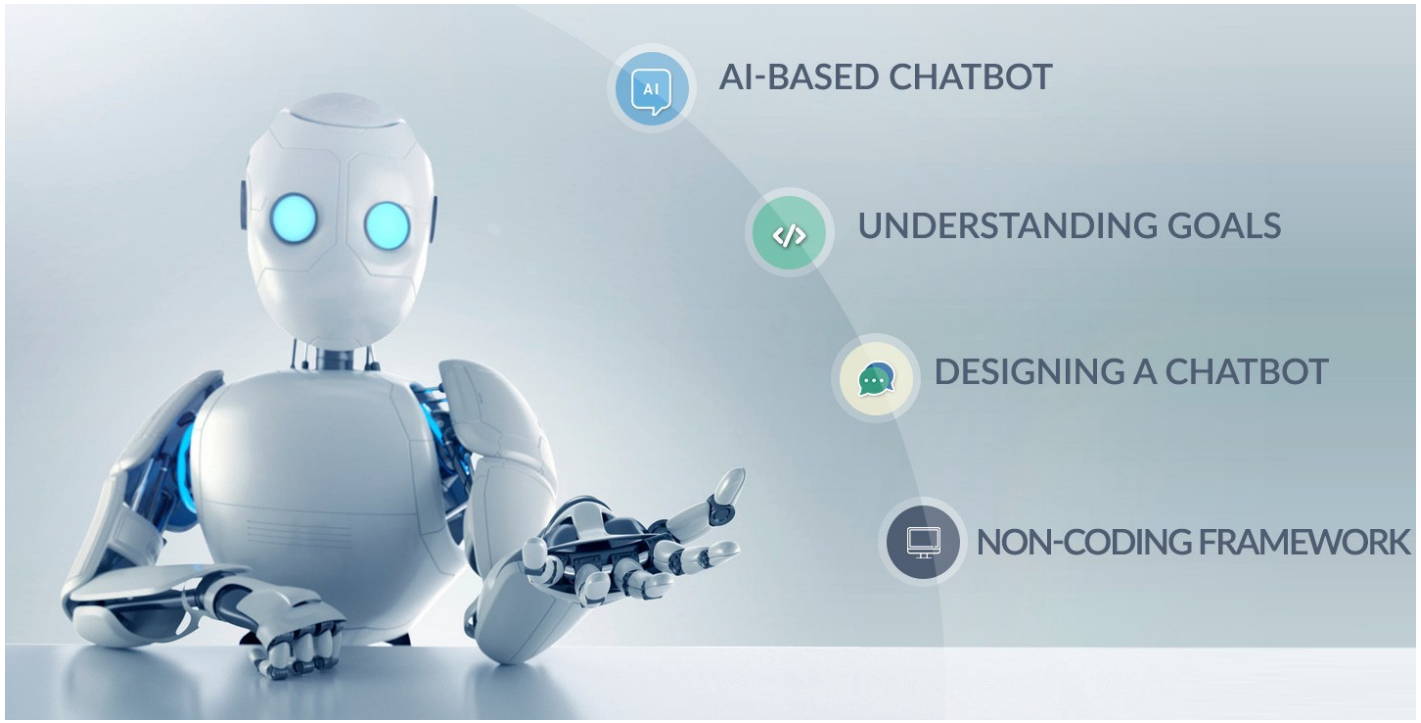
Because we are keeping output constant by moving along an isoquant, the total change in output must be zero. Thus,
$(MP_L \Delta L) + (MP_K \Delta K) = 0$

The marginal rate of technical substitution between two inputs is equal to the ratio of the marginal products of the inputs:
$(MP_L)/(MP_K) = -(\Delta K/\Delta L) = MRTS$

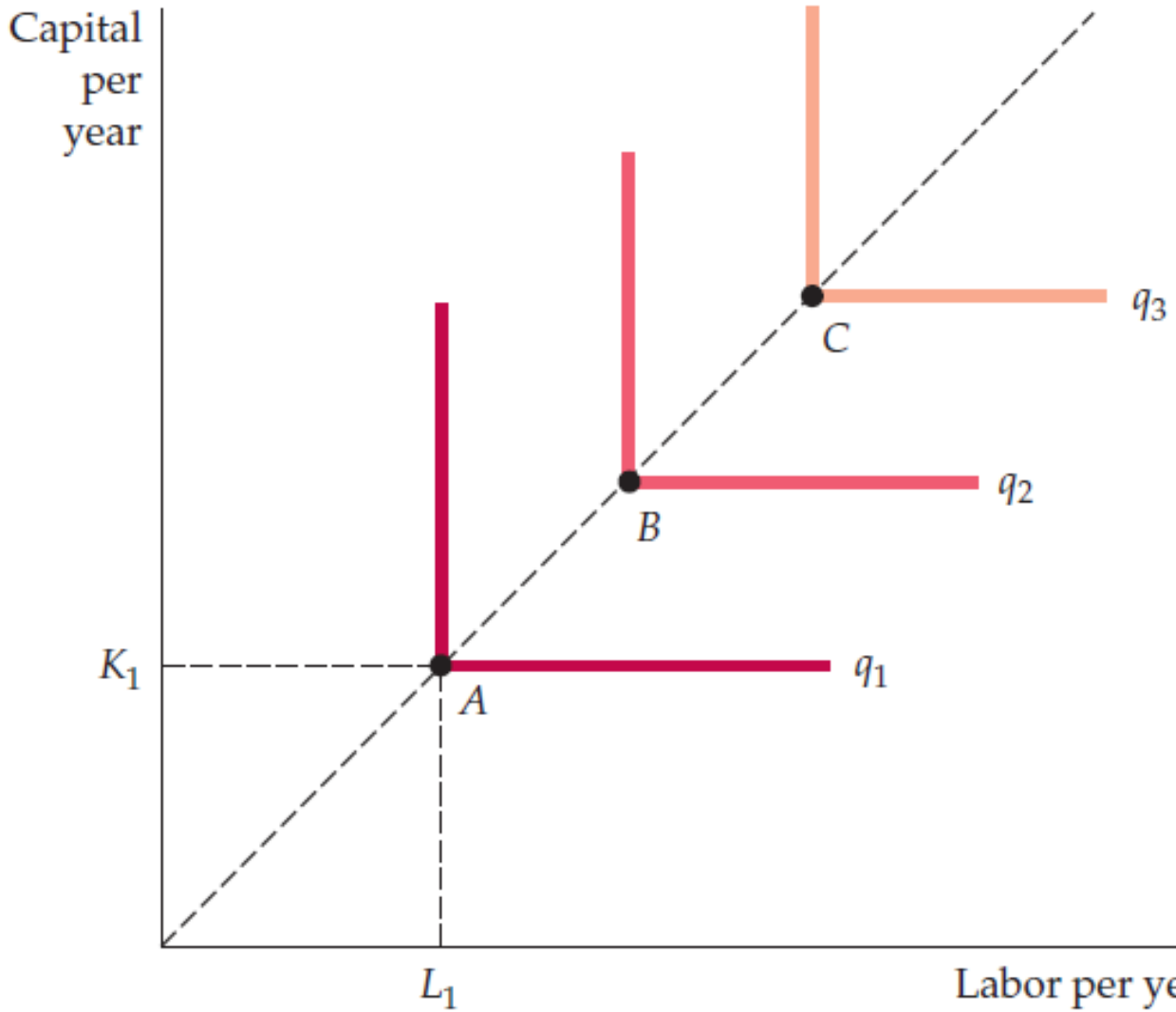
Special isoquant: inputs are perfect substitutes



Chatbot vs Livechat in Customer Services



Special isoquant: fixed-proportions production function



Special isoquant: fixed-proportions production function

Theory of cost

Term	Definition	Mathematical Description
Explicit costs	Costs that require an outlay of money by the firm	
Implicit costs	Costs that do not require an outlay of money by the firm	
Fixed costs	Costs that do not vary with the quantity of output produced	FC
Variable costs	Costs that vary with the quantity of output produced	VC
Total cost	The market value of all the inputs that a firm uses in production	$TC = FC + VC$
Average fixed cost	Fixed cost divided by the quantity of output	$AFC = FC/Q$
Average variable cost	Variable cost divided by the quantity of output	$AVC = VC/Q$
Average total cost	Total cost divided by the quantity of output	$ATC = TC/Q$
Marginal cost	The increase in total cost that arises from an extra unit of production	$MC = \Delta TC/\Delta Q$

Theory of cost

Economic Cost

Cost to a firm of utilizing economic resources in production.

Accounting Cost

Actual expenses plus depreciation charges for capital equipment.

Opportunity cost

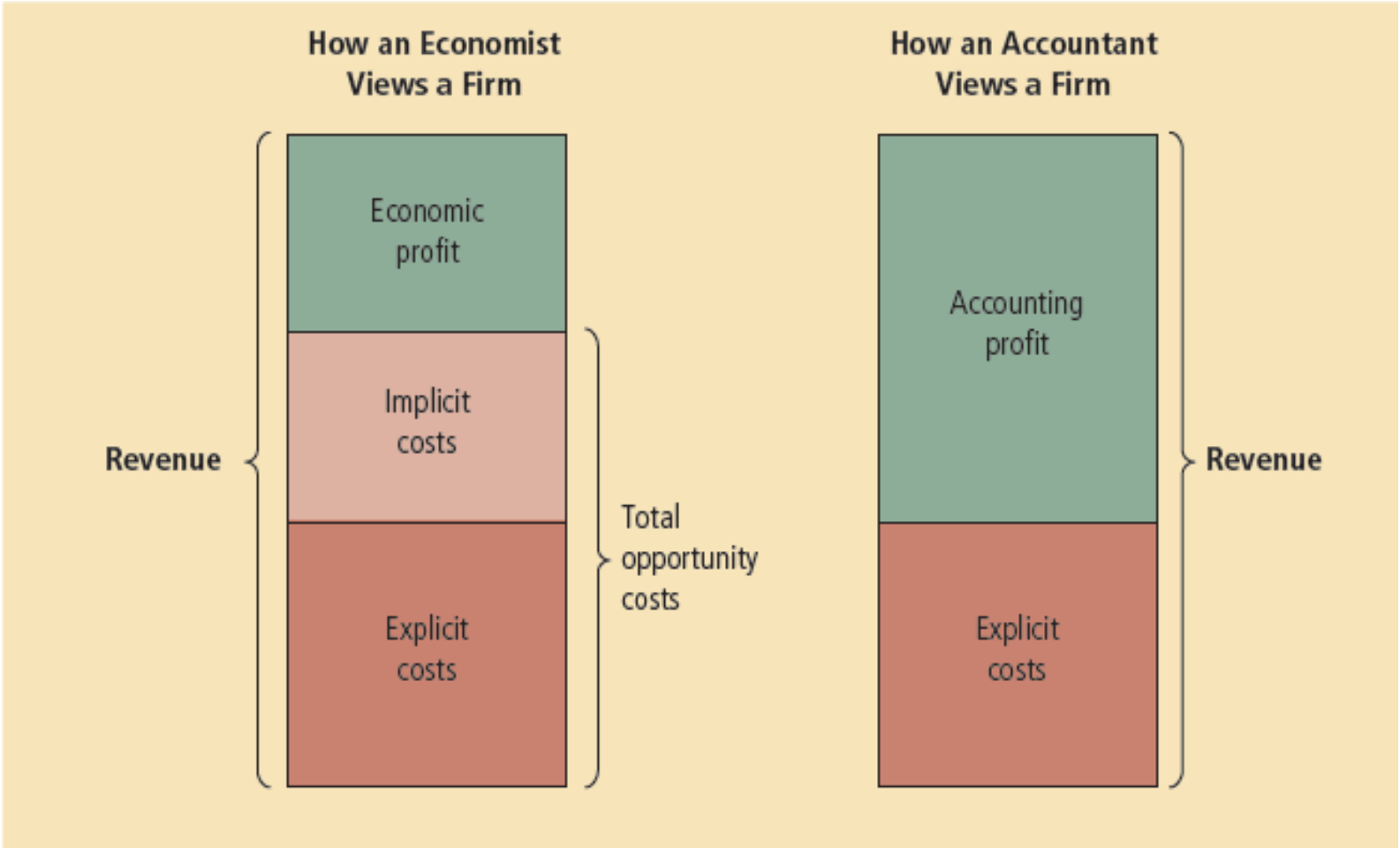
Cost associated with opportunities forgone when a firm's resources are not put to their best alternative use.

Opportunity cost

Consider a firm that owns a building and therefore pays no rent for office space. Does this mean the cost of office space is zero?

The firm's managers and accountant might say yes, but an economist would disagree. The economist would note that the firm could have earned rent on the office space by leasing it to another company

Economist vs Accountant: Revenue = Cost + Profit



Total cost, Fixed cost and Variable cost

Total cost (TC or C)

Total economic cost of production, consisting of fixed and variable costs.

TC = FC + VC

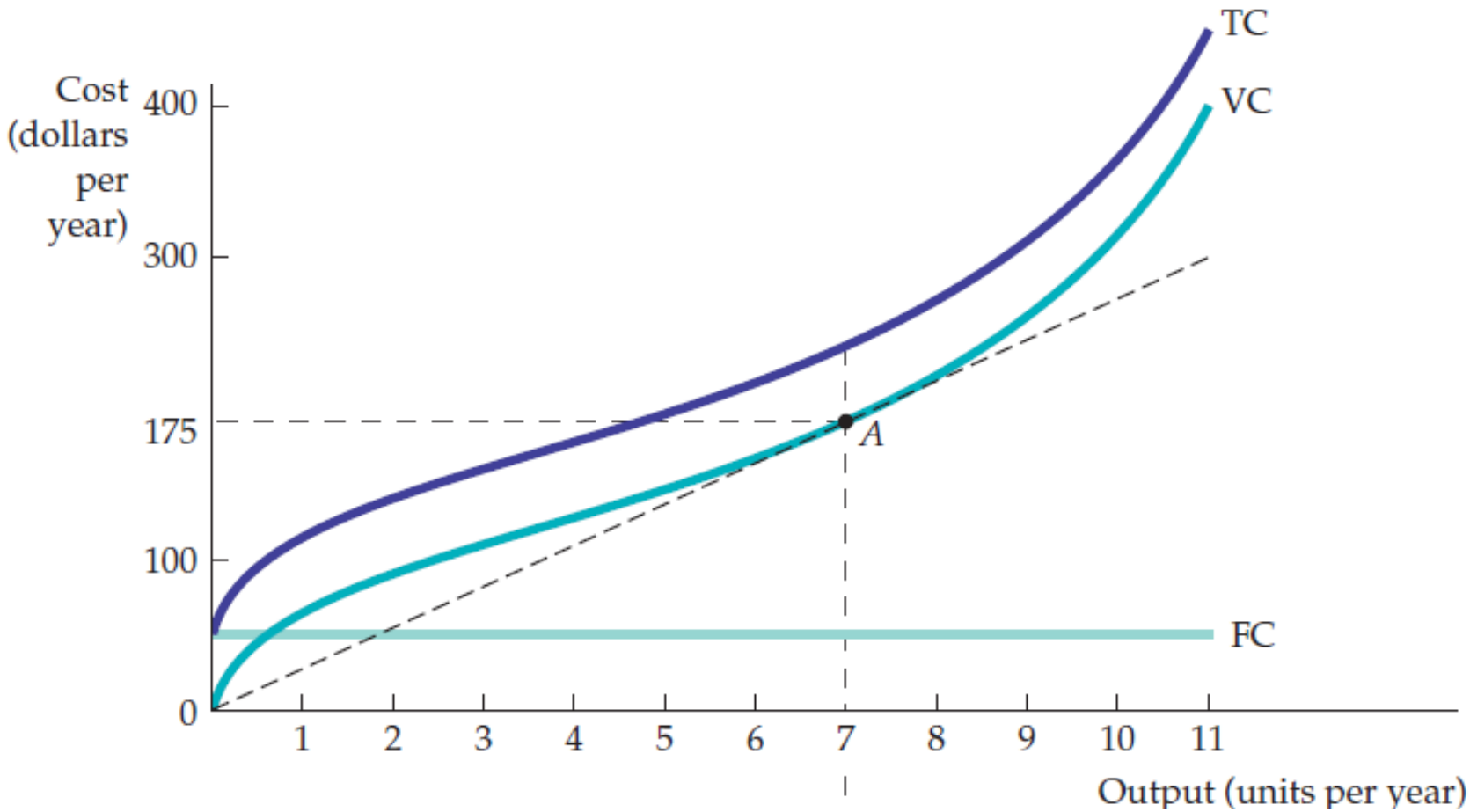
Fixed cost (FC)

Cost that does not vary with the level of output and that can be eliminated only by shutting down.

Variable cost (VC)

Cost that varies as output varies.

Distance between TC and VC is FC



What is the fixed cost of a Pizzeria

Consider the following cost information for a pizzeria:

Quantity	Total Cost	Variable Cost
0 dozen pizzas	$300	$ 0
1	350	50
2	390	90
3	420	120
4	450	150
5	490	190
6	540	240

Average cost

Average total cost (ATC)

Firm's total cost divided by its level of output.

$$ATC = \frac{TC}{Q}$$

Average fixed cost (AFC)

Fixed cost divided by the level of output.

$$AFC = \frac{FC}{Q}$$

Average variable cost (AVC)

Variable cost divided by the level of output.

$$AVC = \frac{VC}{Q}$$

Marginal cost

Marginal cost (MC)

Increase in cost resulting from the production of one extra unit of output.

MC is the derivative of TC (and VC) when taking the first differentiation of TC subject to Q

$$MC = \frac{\Delta TC}{\Delta Q} = TC' = (VC + FC)' = VC'(becauseFCisfixed)$$

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

Cost in short-run (One variable input: Labour)

MC is the derivative of VC when taking the first differentiation of VC subject to Q

In short-run: $\Delta VC = w\Delta L$

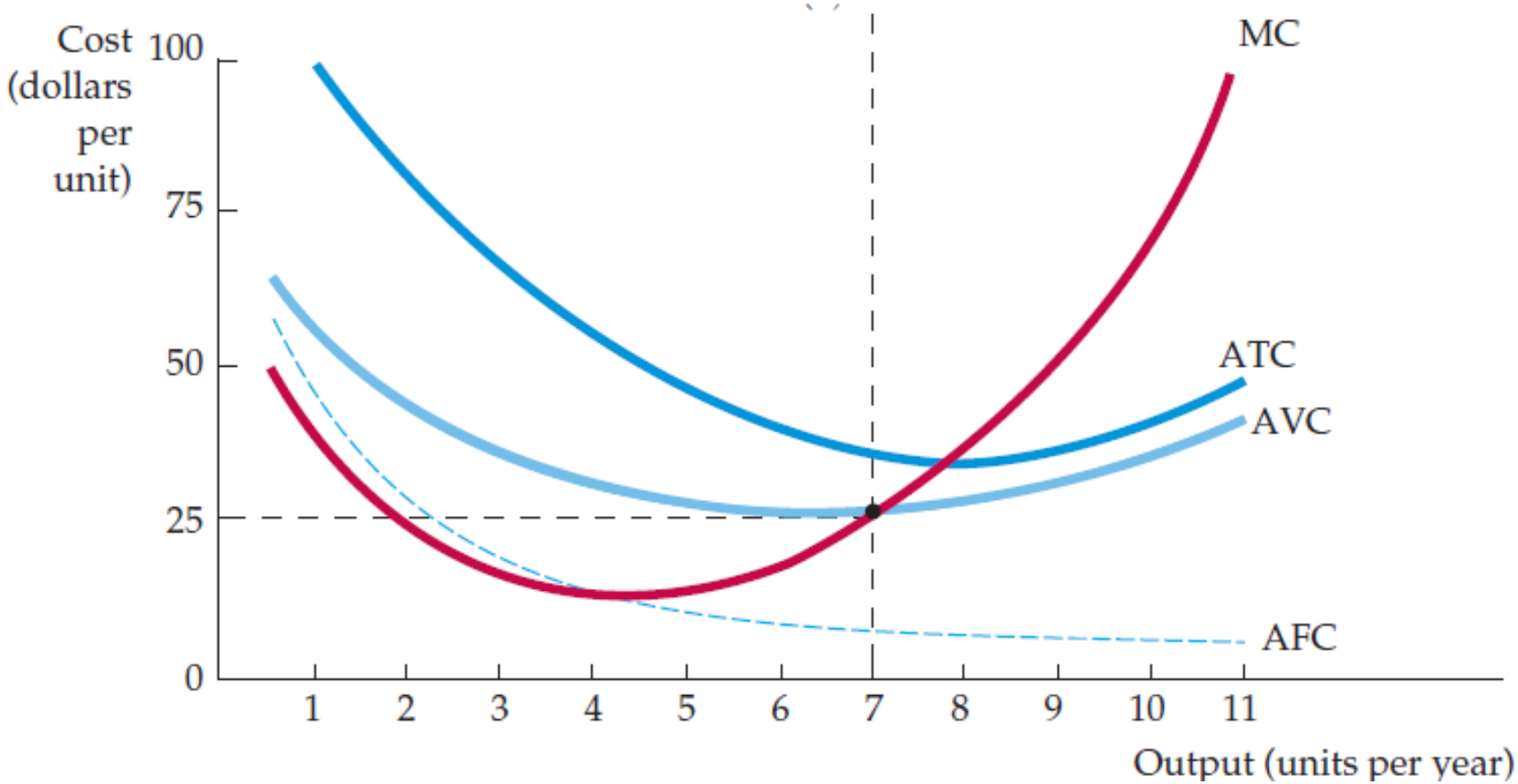
$$MC = \frac{\Delta VC}{\Delta Q} = \frac{w\Delta L}{\Delta Q}$$

Diminishing marginal returns and Marginal cost

Recall: Diminishing marginal returns means that the marginal product of labor declines as the quantity of labor employed increases.

When there are diminishing marginal returns, marginal cost will increase as output increases.

Shape of cost curves:MC and ATC, AVC, AFC



MC crosses AVC and ATC at their minimum points

Average total cost ATC is the sum of average variable cost AVC and average fixed cost AFC (vertically).

Marginal cost MC crosses the average variable cost and average total cost curves at their minimum points.

The ATC curve shows the average total cost of production

Because ATC = AVC + AFC, and AFC curve declines when output increases, the **vertical distance between the ATC and AVC** curves **decreases** as **output increases**.

The AVC cost curve reaches its minimum point at a lower output than the ATC curve

This is because MC = AVC at its minimum point and MC = ATC at its minimum point.

Because ATC is always greater than AVC and the marginal cost curve MC is rising, the minimum point of the ATC curve must lie above and to the right of the minimum point of the AVC curve.

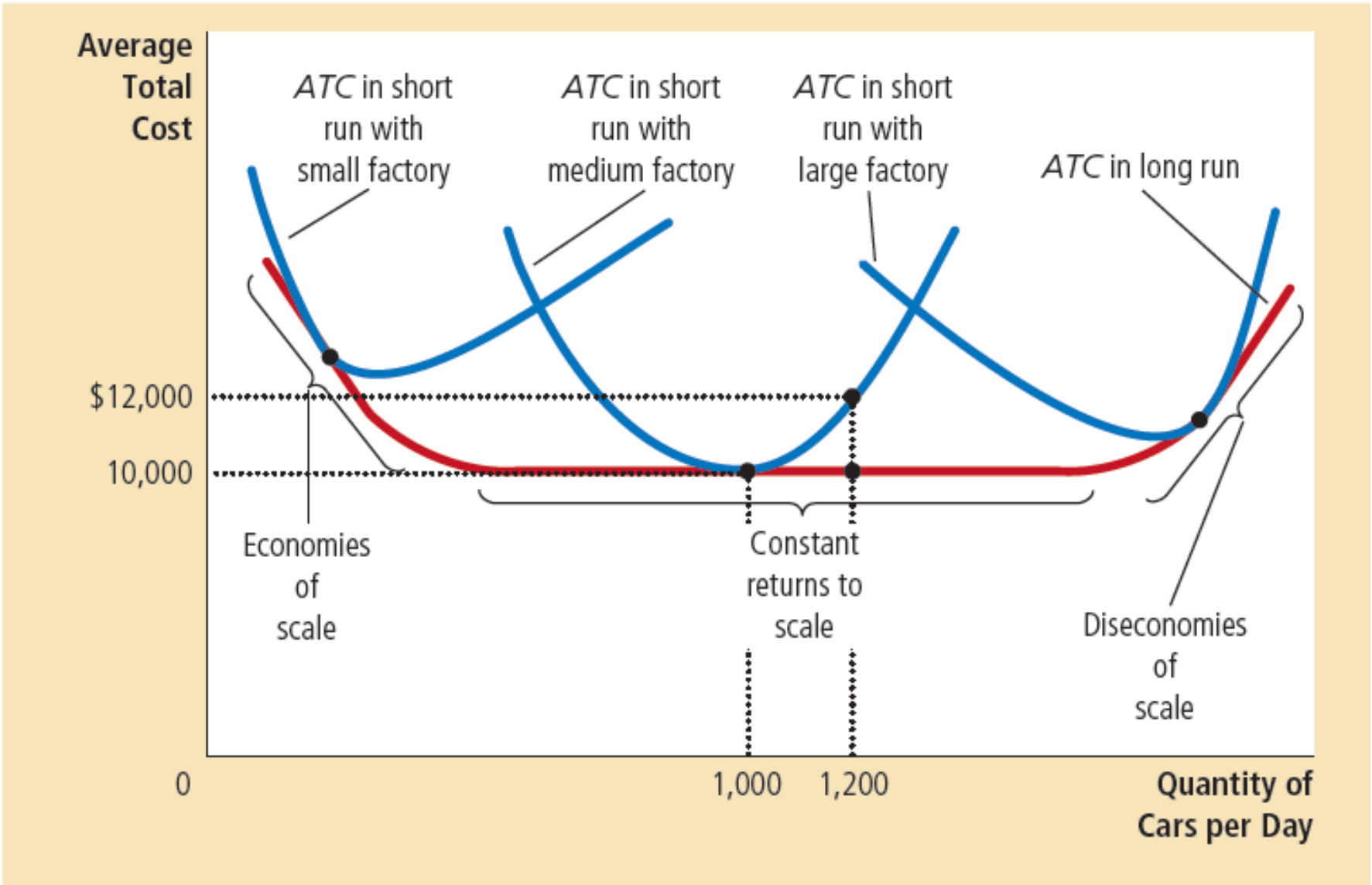
Cost in long-run

The Relationship between Short-Run and Long-Run Average Total Cost: Case study of car manufacturer Ford Motor Company

Over a period of only a few months, Ford cannot adjust the number or size of its car factories. The only way it can produce additional cars is to hire more workers at the factories it already has. The cost of these factories is, therefore, a **fixed cost in the short run**. By contrast, over a

period of several years, Ford can expand the size of its factories, build new factories, or close old ones. The cost of its factories is a **variable cost in the long run**.

Long-run vs short-run curves



Long-run vs short-run curves

The long-run average-total-cost curve is a much flatter U-shape than the short-run average-total cost curve.

In addition, **all the short-run curves lie on or above the long-run curve**. These properties arise because firms have greater flexibility in the long run.

In essence, in the long run, the firm gets to choose which short-run curve it wants to use. But in the short run, it has to use whatever short-run curve it has chosen in the past.

Economies and Diseconomies of Scale

Economies of scale

the property whereby long-run average total cost falls as the quantity of output increases

Diseconomies of scale

the property whereby long-run average total cost rises as the quantity of output increases

Constant returns to scale

the property whereby long-run average total cost stays the same as the quantity of output changes

What might cause economies or diseconomies of scale?

Economies of scale

often arise because **higher production levels** allow **specialization** among workers, which permits each worker to become better at a specific task. For instance, if Ford hires a large number of workers and produces a large number of cars, it can reduce costs with modern assembly-line production.

Diseconomies of scale

can arise because of **coordination problems** that are inherent in any **large organization**. The more cars Ford produces, the more stretched the management team becomes, and the less effective the managers become at keeping costs down.

Does Boeing exhibit economies or diseconomies of scale?

If Boeing produces 9 jets per month, its long-run total cost is $9.0 million per month. If it produces 10 jets per month, its long-run total cost is $9.5 million per month.