

ECO2011 Basic Microeconomics

Mankiw Chapter 13 (Production and Costs)

Pindyck Chapter 6 (Production)

Pindyck Chapter 7 (Cost)

2025

Agenda

1. Motivation

2. Production

2.1. Production function

2.2. Production with one variable inputs (short-run)

2.3. Production with two variable inputs (long-run)

3. Cost

3.1. Explicit cost vs. Implicit cost (thus economic vs. accounting profits)

3.2. Definitions of various costs and their relationships (total cost, marginal cost, fixed cost, variable cost, average total cost, average fixed cost, average variable cost)

3.3. Cost in the short run

3.4. Cost in the long run

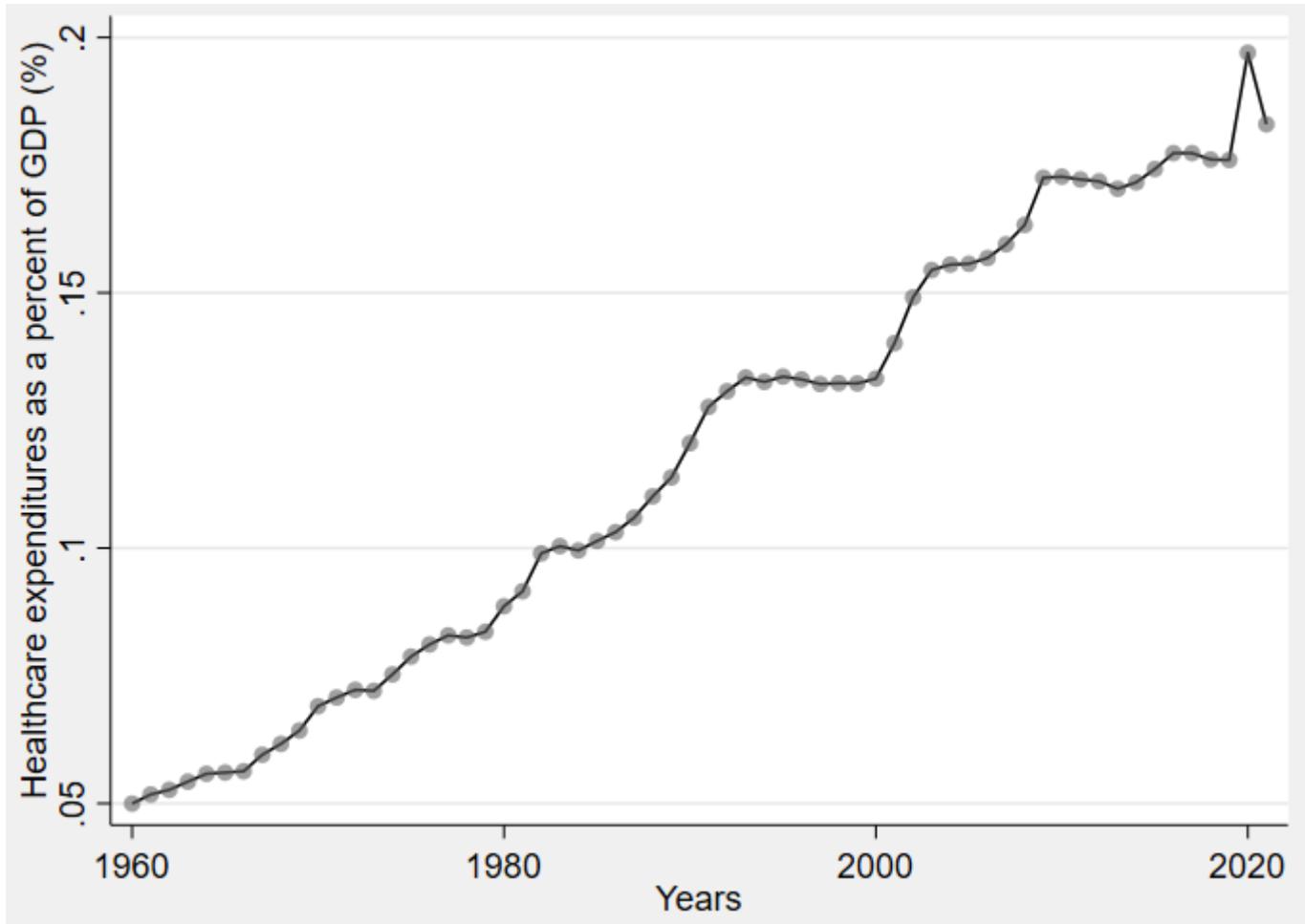
Motivation: Near-empty Restaurants

Question: Why does restaurants stay open when there are only few customers?

ADRIAN SHERRATT/ALAMY STOCK PHOTO

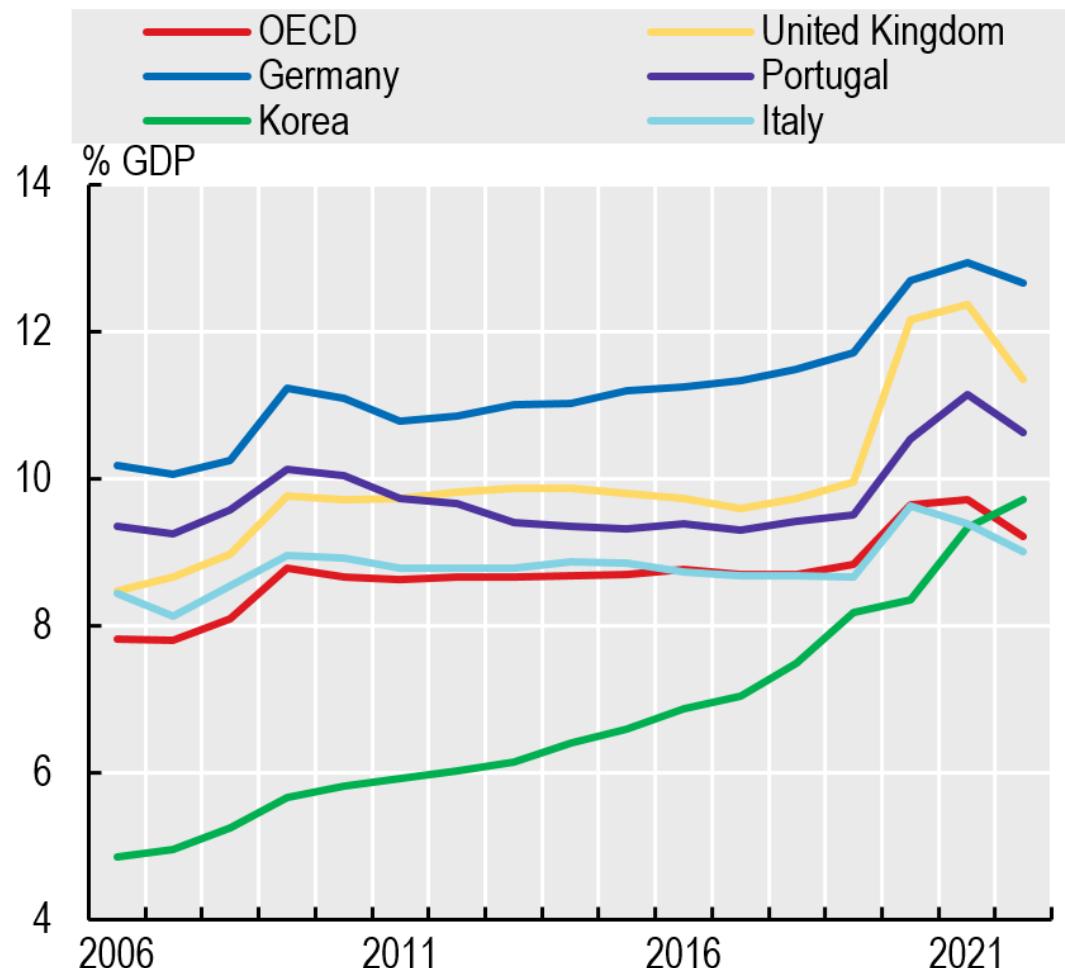


Motivation: Health Care Expenditures in the US



Sources: Centers for Medicare & Medicaid Services.

Health Care Spending in Other Countries



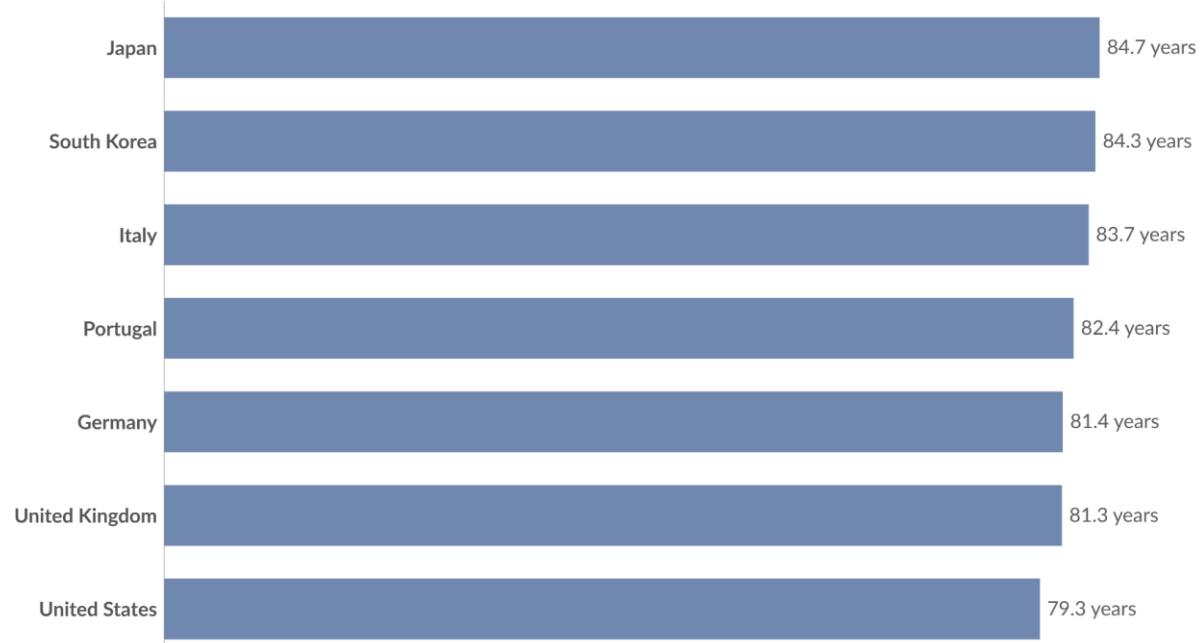
Source: OECD Health Statistics 2023.

Average Life Expectancy in 2023

Life expectancy, 2023

Our World
in Data

Period life expectancy¹ is the number of years the average person born in a certain year would live if they experienced the same chances of dying at each age as people did that year.



Data source: Riley (2005); Zijdeman et al. (2015); HMD (2024); UN WPP (2024)

OurWorldinData.org/life-expectancy | CC BY

1. Period life expectancy Period life expectancy is a metric that summarizes death rates across all age groups in one particular year. For a given year, it represents the average lifespan for a hypothetical group of people, if they experienced the same age-specific death rates throughout their whole lives as the age-specific death rates seen in that particular year.

Learn more in our articles:

- [Life expectancy – what does this actually mean?](#)
- [Period versus cohort measures: what's the difference?](#)

Introduction

- In the last few lectures, we focused on the demand side of the market—the preferences and behavior of consumers. Now we turn to the supply side and examine the behavior of producers.
- The production decisions of firms are analogous to the purchasing decisions of consumers, and can likewise be understood in three steps:
 1. Production Technology
 2. Cost Constraints
 3. Input Choices

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Production Function

- Production function
 - Function showing the highest output that a firm can produce for every specified combination of inputs.
$$q = F(K, L)$$
 - Production functions describe what is technically feasible when the firm operates efficiently—that is, when the firm uses each combination of inputs as effectively as possible.
 - Gets flatter as production rises

Example: Farmer Jack

Example 1:

- Farmer Jack grows wheat.
- He has 10 acres of land (fixed resource).
- He can hire as many workers as he wants.
 - The quantity of output produced varies with the number of workers hired



Internet photo



Internet photo

Production with One Variable Input (Labor)

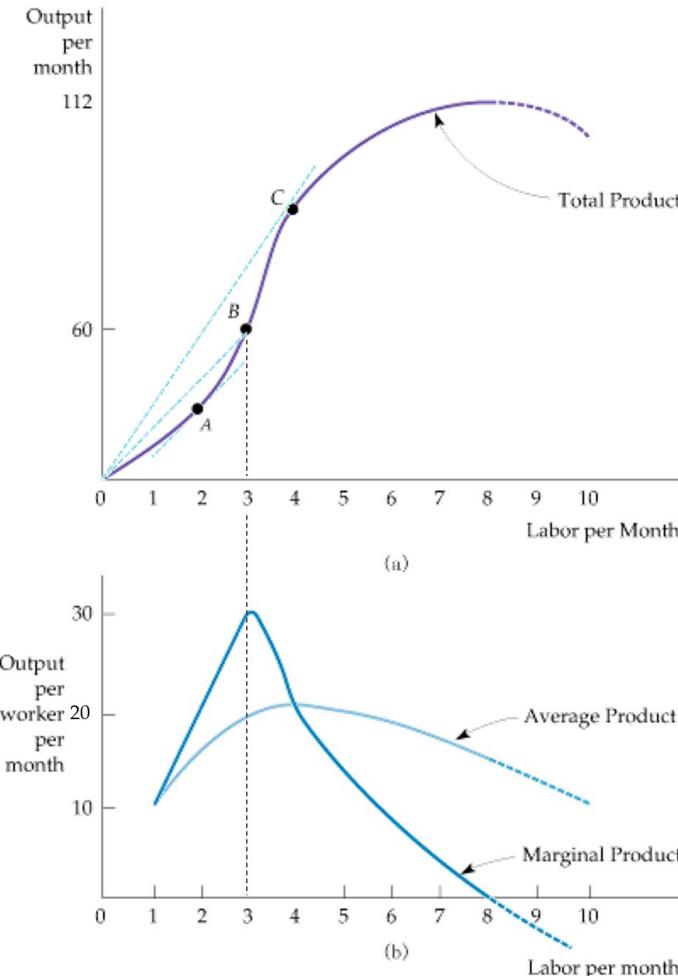
TABLE 6.1

PRODUCTION WITH ONE VARIABLE INPUT

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

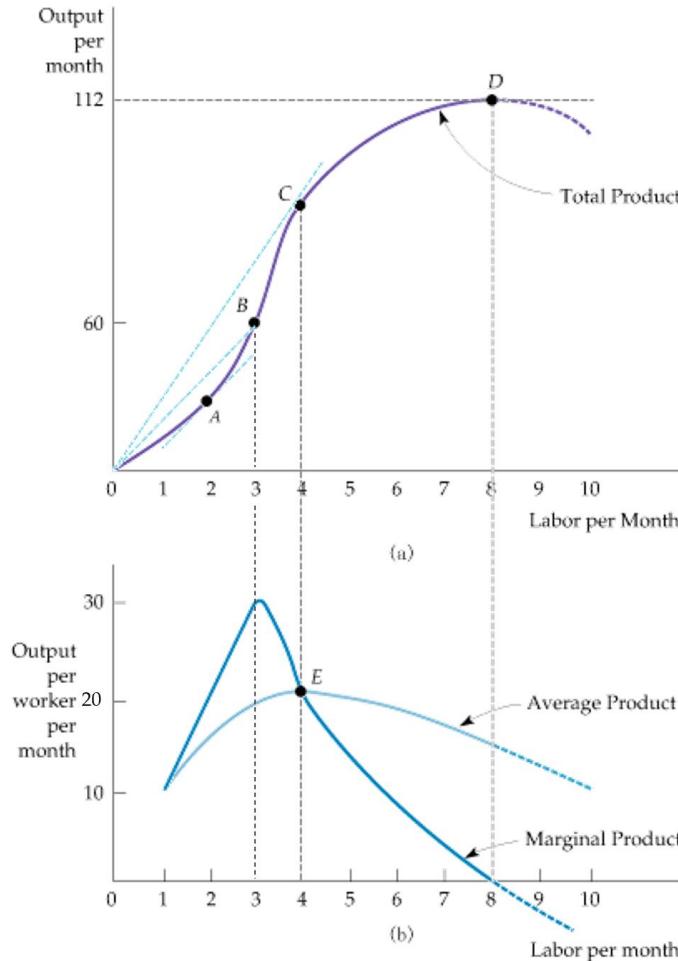
The Slopes of the Product Curve

- The total product curve in (a) shows the output produced for different amounts of labor input.
- The average and marginal products in (b) can be obtained (using the data in Table 6.1) from the total product curve.
- At point A in (a), the marginal product is 20 because the tangent to the total product curve has a slope of 20.
- At point B in (a) the average product of labor is 20, which is the slope of the line from the origin to B.
- The average product of labor at point C in (a) is given by the slope of the line 0C.



The Slopes of the Product Curve

- To the left of point E in (b), the marginal product is above the average product and the average is increasing; to the right of E, the marginal product is below the average product and the average is decreasing.
- As a result, E represents the point at which the average and marginal products are equal, when the average product reaches its maximum.
- At D, when total output is maximized, the slope of the tangent to the total product curve is 0, as is the marginal product.



Marginal Product

- Marginal product
 - Increase in output that arises from an additional unit of input
 - Other inputs constant. If the capital input increased from 10 to 20, the marginal product of labor most likely would increase.
 - Slope of the production function
- Marginal product of labor, MPL
 - $MPL = \Delta Q / \Delta L$
 - If Jack hires one more worker, his output rises by the marginal product of labor.
- Average Product
 - Output per unit of a particular input.
 - $APL = q / L$

The Relationship Between the Average and Marginal Products

- In general, the average product of labor is given by the slope of the line drawn from the origin to the corresponding point on the total product curve.
- In general, the marginal product of labor at a point is given by the slope of the total product at that point.
- Note the graphical relationship between average and marginal products in (a). When the marginal product of labor is greater than the average product, the average product of labor increases.
- At C, the average and marginal products of labor are equal.
- Finally, as we move beyond C toward D, the marginal product falls below the average product. You can check that the slope of the tangent to the total product curve at any point between C and D is lower than the slope of the line from the origin.

Why MPL Is Important

- ‘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.

Diminishing MPL

- Diminishing marginal product
 - Marginal product of an input declines as the quantity of the input increases
 - Production function gets flatter as more inputs are being used:
 - The slope of the production function decreases

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.).

Production with Two Variable Inputs

TABLE 6.4 PRODUCTION WITH TWO VARIABLE INPUTS

		LABOR INPUT				
		1	2	3	4	5
CAPITAL INPUT	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	

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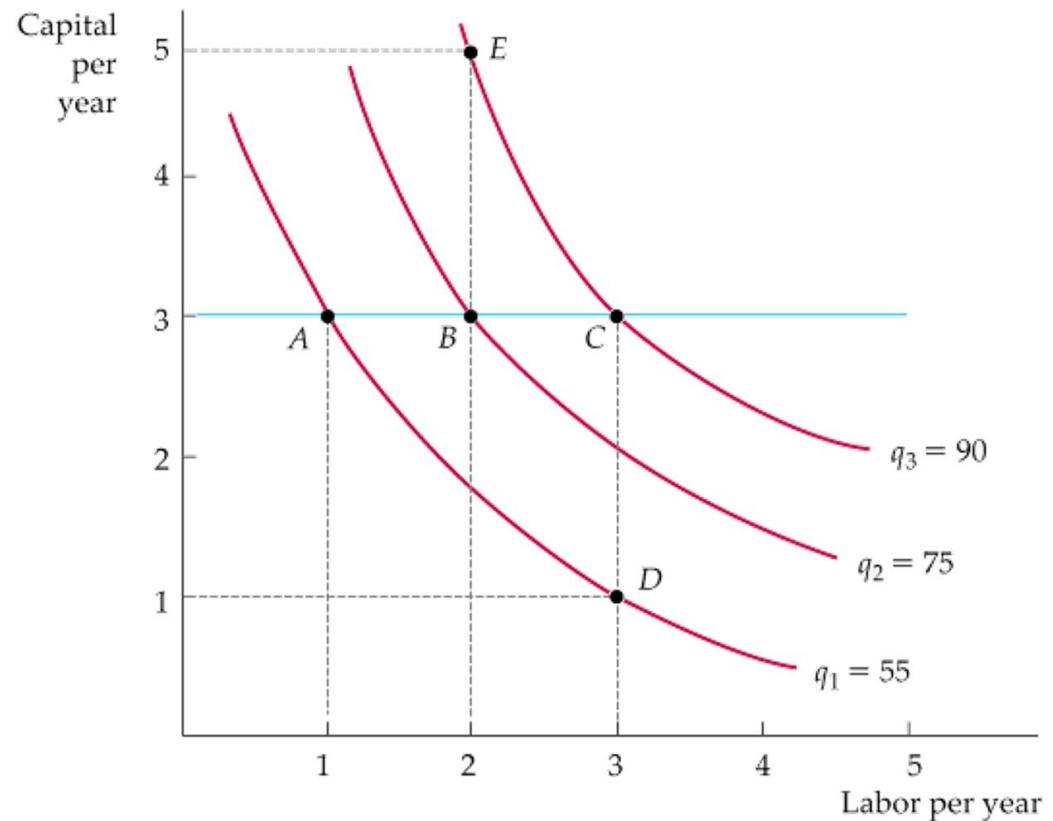
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- Isoquants: curve showing all possible combinations of inputs that yield the same output.
- Isoquant map: graph combining a number of isoquants, used to describe a production function.

Production with Two Variable Inputs

- A set of isoquants, or isoquant map, describes the firm's production function.
- Output increases as we move from isoquant q_1 (at which 55 units per year are produced at points such as A and D), to isoquant q_2 (75 units per year at points such as B), and to isoquant q_3 (90 units per year at points such as C and E).
- By drawing a horizontal line at a particular level of capital—say 3, we can observe diminishing marginal returns. Reading the levels of output from each isoquant as labor is increased, we note that each additional unit of labor generates less and less additional output.



Diminishing Marginal Returns

- Isoquants show the flexibility that firms have when making production decisions: They can usually obtain a particular output by substituting one input for another. It is important for managers to understand the nature of this flexibility.
- Diminishing Marginal Returns
 - Even though both labor and capital are variable in the long run, it is useful for a firm that is choosing the optimal mix of inputs to ask what happens to output as each input is increased, with the other input held fixed.
 - Because adding one factor while holding the other factor constant eventually leads to lower and lower incremental output, the isoquant must become steeper as more capital is added in place of labor and flatter when labor is added in place of capital.
 - There are also diminishing marginal returns to capital. With labor fixed, the marginal product of capital decreases as capital is increased.

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.

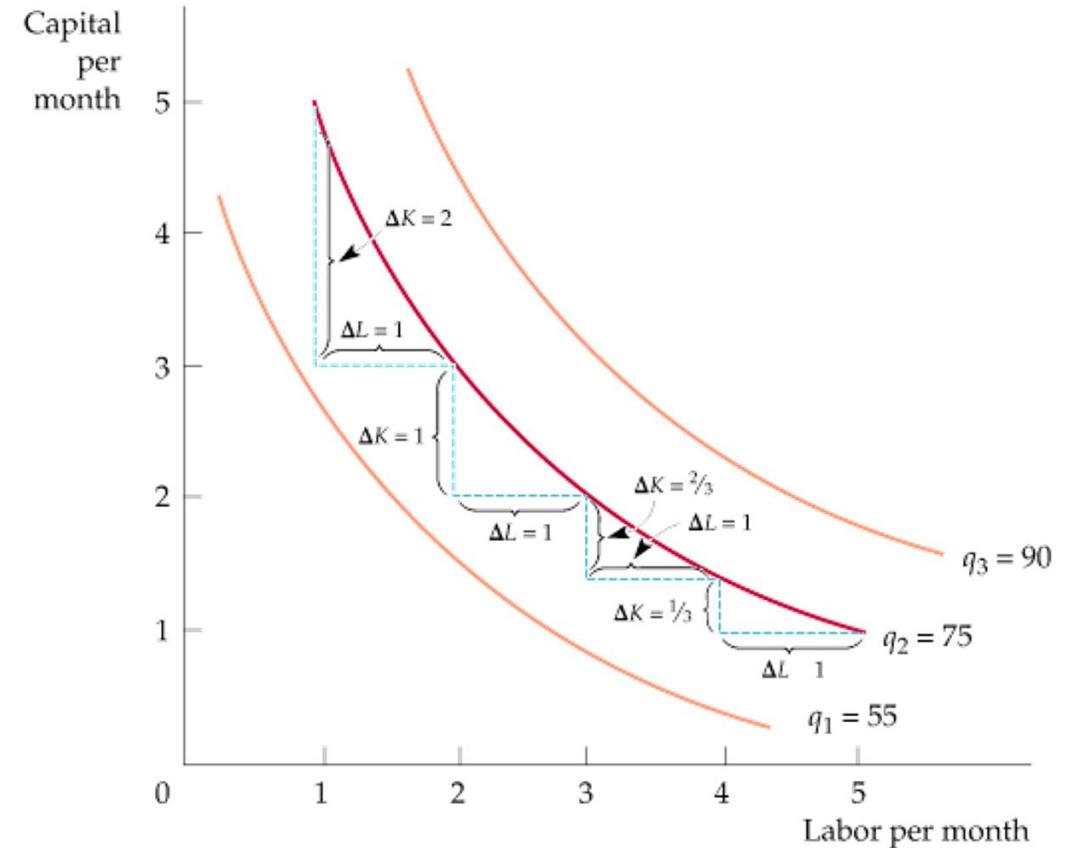
$$\begin{aligned} \text{MRTS} &= -\text{Change in capital input}/\text{change in labor input} \\ &= -\Delta K/\Delta L \text{ (for a fixed level of } q) \end{aligned}$$

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,
$$(MP_L)(\Delta L) + (MP_K)(\Delta K) = 0$$
- Now, by rearranging terms we see that
$$(MP_L)/(MP_K) = -(\Delta K / \Delta L) = MRTS$$

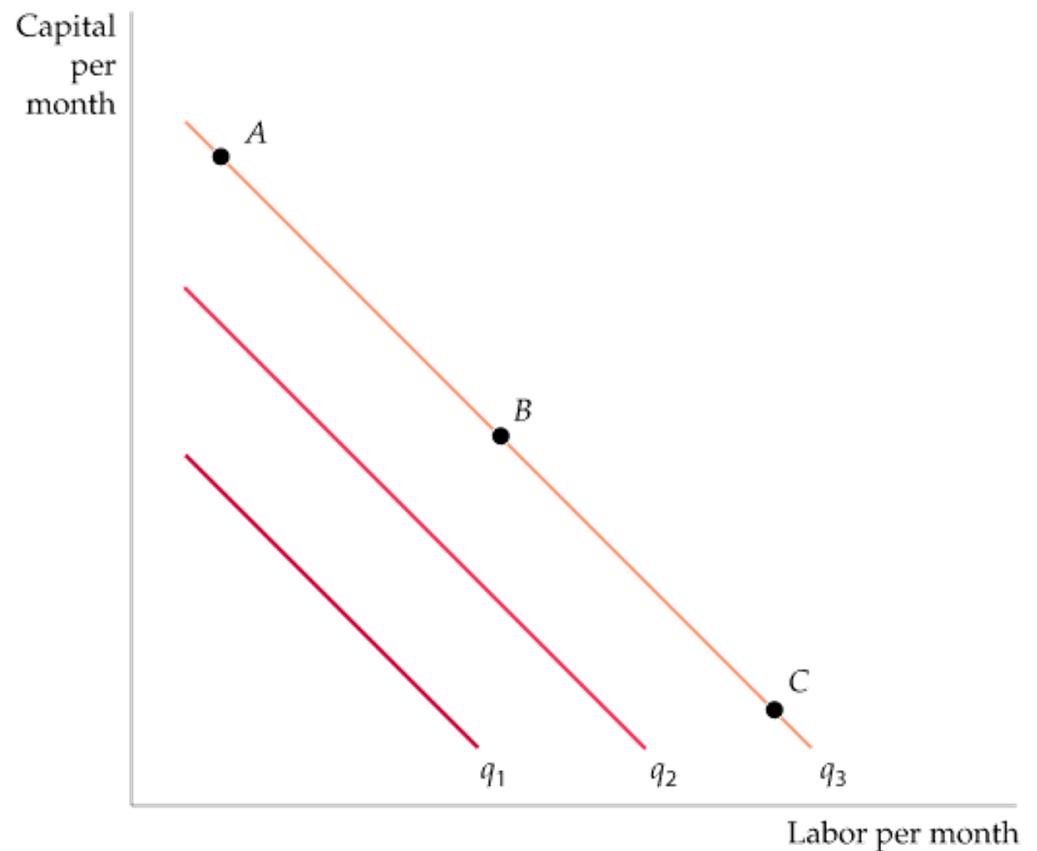
Diminishing MRTS

- Like indifference curves, isoquants are downward sloping and convex. 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 q_2 , the MRTS falls from 2 to 1 to $2/3$ to $1/3$.



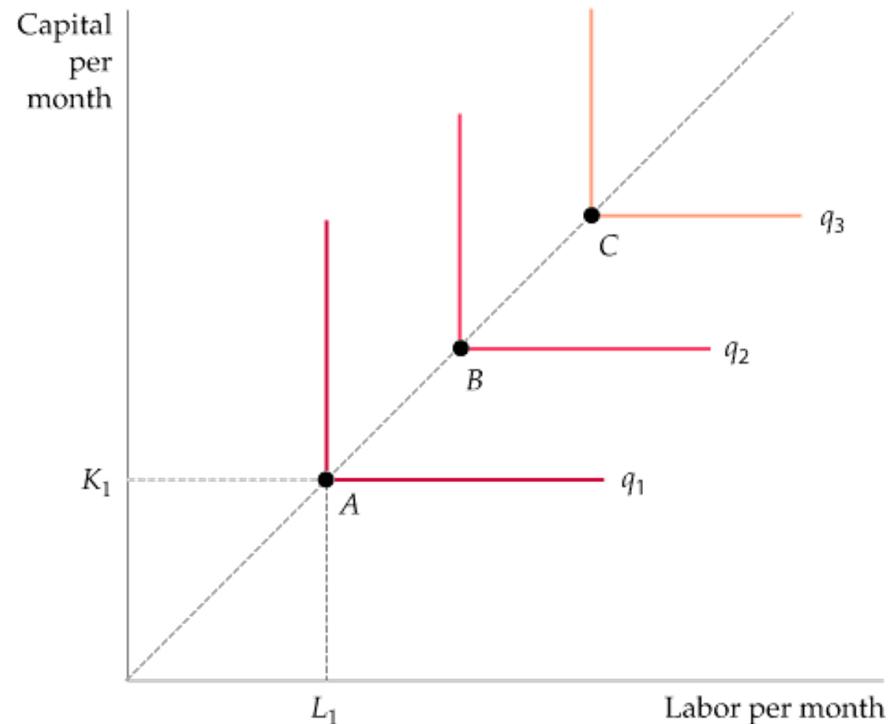
Production Functions—Two Special Cases

- **perfect substitutes:** when the isoquants are straight lines, the MRTS is constant. Thus the rate at which capital and labor can be substituted for each other is the same no matter what level of inputs is being used.
- Points A, B, and C represent three different capital-labor combinations that generate the same output q_3 .



Production Functions—Two Special Cases

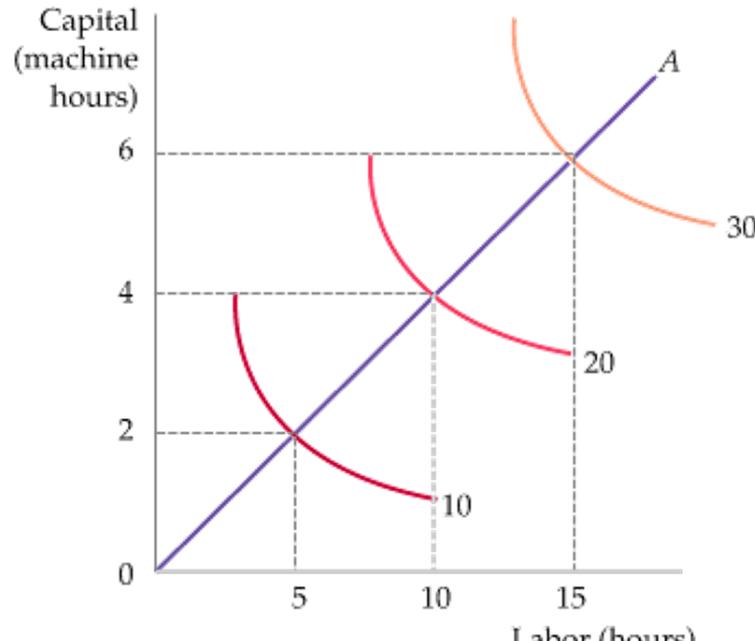
- **fixed-proportions production function** sometimes called a **Leontief production function**: production function with L-shaped isoquants, so that only one combination of labor and capital can be used to produce each level of output. As at point A on isoquant q_1 , point B on isoquant q_2 , and point C on isoquant q_3 . Adding more labor alone does not increase output, nor does adding more capital alone.
- The fixed-proportions production function describes situations in which methods of production are limited.



Returns to Scale

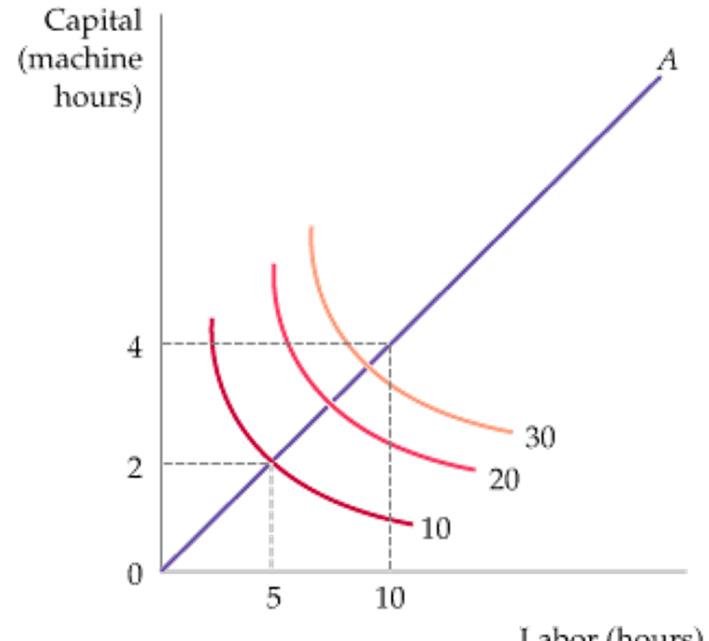
- returns to scale: rate at which output increases as inputs are increased proportionately.
 - increasing returns to scale: situation in which output more than doubles when all inputs are doubled.
 - constant returns to scale: situation in which output doubles when all inputs are doubled.
 - decreasing returns to scale: situation in which output less than doubles when all inputs are doubled.

Returns to Scale



(a)

When a firm's production process exhibits constant returns to scale as shown by a movement along line oA in part (a), the isoquants are equally spaced as output increases proportionally.



(b)

However, when there are increasing returns to scale as shown in (b), the isoquants move closer together as inputs are increased along the line.

Example: Returns to Scale in the Carpet Industry

- Innovations have reduced costs and greatly increased carpet production. Innovation along with competition have worked together to reduce real carpet prices.
- Carpet production is capital intensive. Over time, the major carpet manufacturers have increased the scale of their operations by putting larger and more efficient tufting machines into larger plants. At the same time, the use of labor in these plants has also increased significantly. The result? Proportional increases in inputs have resulted in a more than proportional increase in output for these larger plants.



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Costs: Explicit vs. Implicit

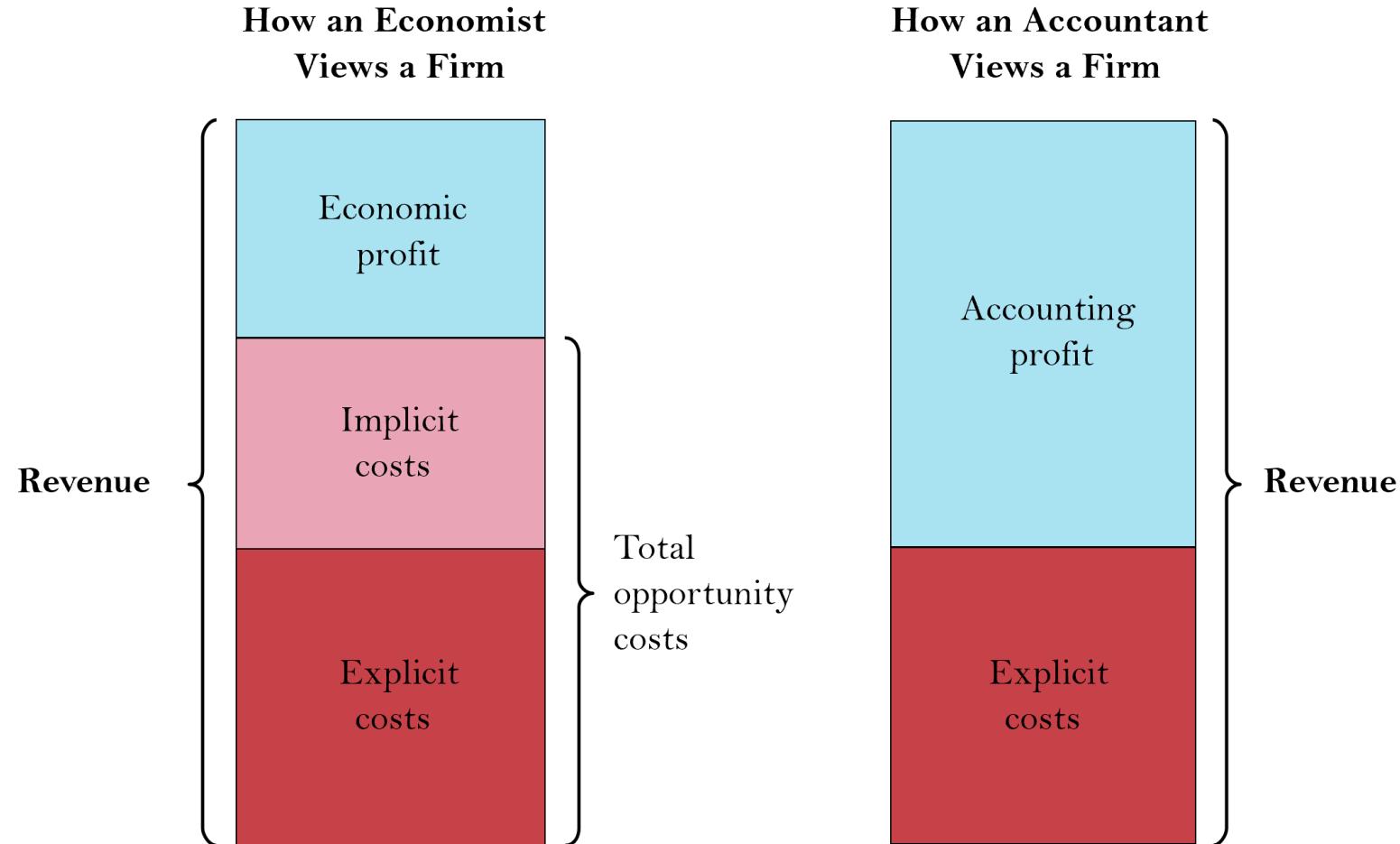
- ‘The cost of something is what you give up to get it.’
- Explicit costs
 - Require an outlay of money
 - E.g., paying wages to workers.
- Implicit costs
 - Do not require a cash outlay
 - E.g., the opportunity cost of the owner’s time.
- Total cost = Explicit + Implicit costs

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.



Economic Profit vs. Accounting Profit



Active Learning

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

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.

Case Study: Choosing the Location for a New Law School Building

The Northwestern University Law School has long been located in Chicago, along the shores of Lake Michigan. However, the main campus of the university is located in the suburb of Evanston. In the mid-1970s, the law school began planning the construction of a new building.

The downtown location had many prominent supporters. They argued in part that it was cost-effective to locate the new building in the city because the university already owned the land. A large parcel of land would have to be purchased in Evanston if the building were to be built there.

Does this argument make economic sense?

In the end, Northwestern decided to keep the law school in Chicago. This was a costly decision.

Is it appropriate if the Chicago location was particularly valuable to the law school?

Is it appropriate if it was made on the presumption that the downtown land had no cost?

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.

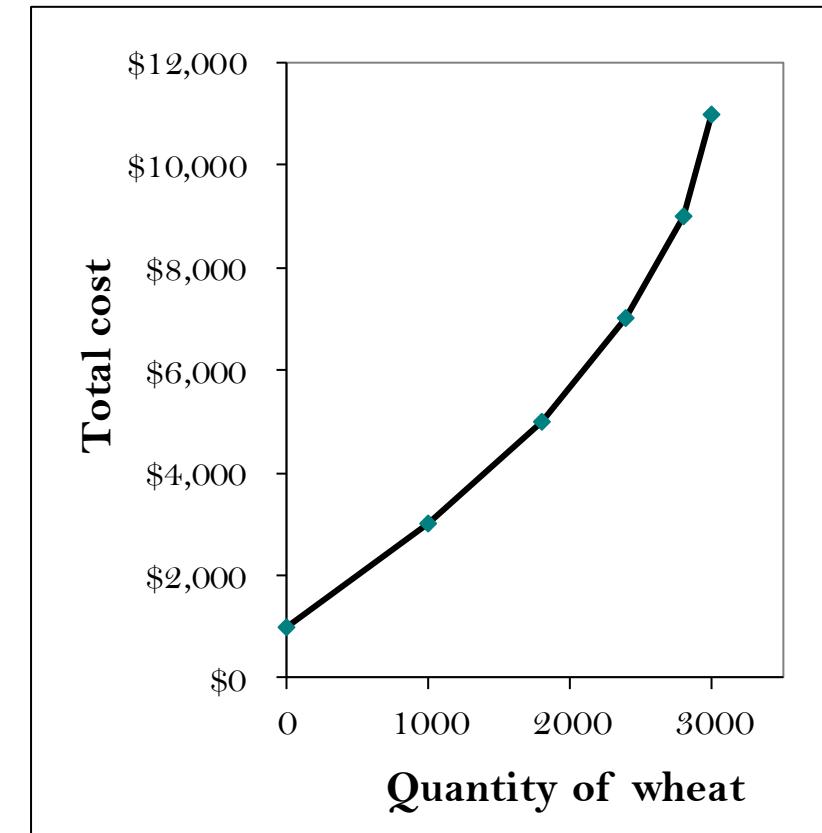
- So Farmer Jack's costs are related to how much wheat he produces....

Example 1: Farmer Jack's Costs

L (no. of workers)	Q (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

Farmer Jack's Total Cost Curve

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



Marginal Cost

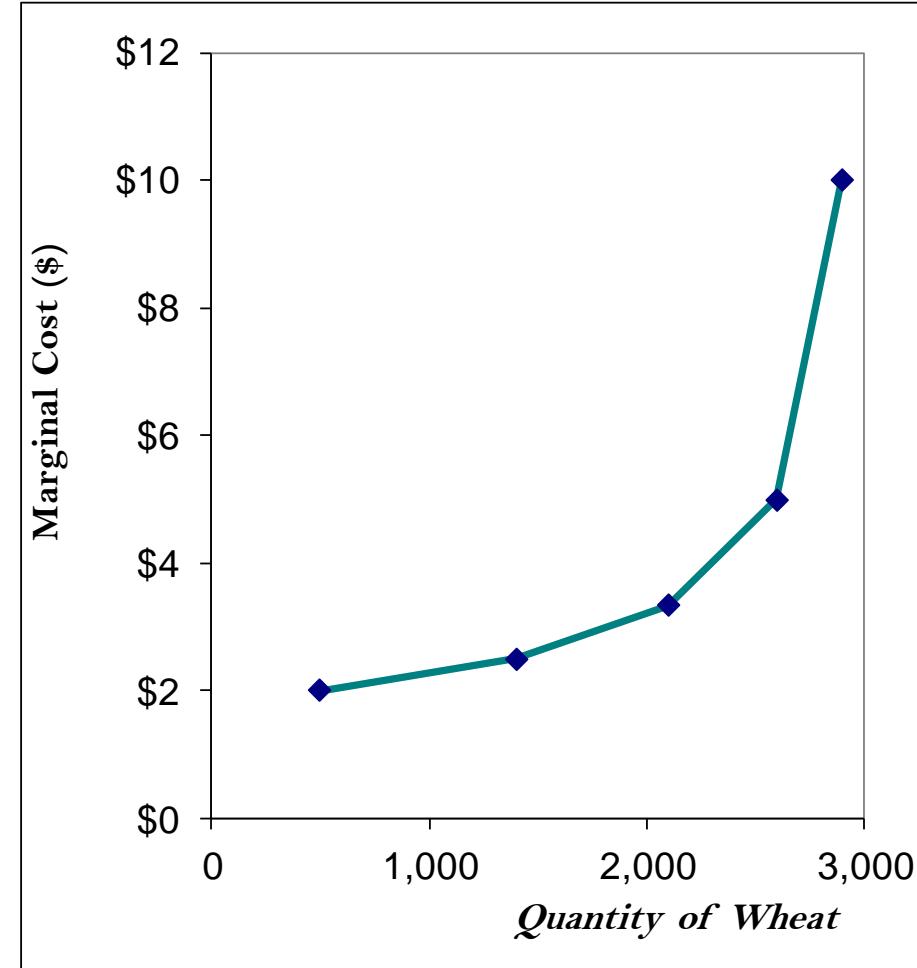
- Marginal cost, MC
 - Increase in total cost arising from an extra unit of production
 - Marginal cost = Change in total cost / Change in quantity
 - $MC = \Delta TC / \Delta Q$
 - Increase in total cost
 - From producing an additional unit of output

Total and Marginal Cost

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

The Marginal Cost Curve

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



Why MC Is Important

- Farmer Jack is rational and wants to maximize his profit
 - To increase profit, should he produce more or less wheat?
 - 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 of output produced
 - For Farmer Jack, $VC = \text{wages he pays workers}$
 - Other example: cost of materials
- Total cost = Fixed cost + Variable cost

Sunk Costs

- Sunk cost: expenditure that has been made and cannot be recovered.
- Because a sunk cost cannot be recovered, it should not influence the firm's decisions.
- For example, consider the purchase of specialized equipment for a plant. Suppose the equipment can be used to do only what it was originally designed for and cannot be converted for alternative use. The expenditure on this equipment is a sunk cost. Because it has no alternative use, its opportunity cost is zero. Thus it should not be included as part of the firm's economic costs.
- A prospective sunk cost is an investment. Here the firm must decide whether that investment in specialized equipment is economical.

Case Study: Sunk, Fixed, and Variable Costs: Computers, Software, and Pizzas

- It is important to understand the characteristics of production costs and to be able to identify which costs are fixed, which are variable, and which are sunk.
- Good examples include the personal computer industry (where most costs are variable), the computer software industry (where most costs are sunk), and the pizzeria business (where most costs are fixed).
- Because computers are very similar, competition is intense, and profitability depends on the ability to keep costs down. Most important are the cost of components and labor.
- A software firm will spend a large amount of money to develop a new application. The company can recoup its investment by selling as many copies of the program as possible.
- For the pizzeria, sunk costs are fairly low because equipment can be resold if the pizzeria goes out of business. Variable costs are low—mainly the ingredients for pizza and perhaps wages for workers to produce and deliver pizzas.

Costs in the Short Run vs. 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)

The Determinants of Short-Run Cost

- The change in variable cost is the per-unit cost of the extra labor w times the amount of extra labor needed to produce the extra output ΔL .
- Because $\Delta VC = w\Delta L$, it follows that

$$MC = \Delta TC / \Delta q = \Delta VC / \Delta q = w\Delta L / \Delta q$$

- Derive the relationship between MC and MPL

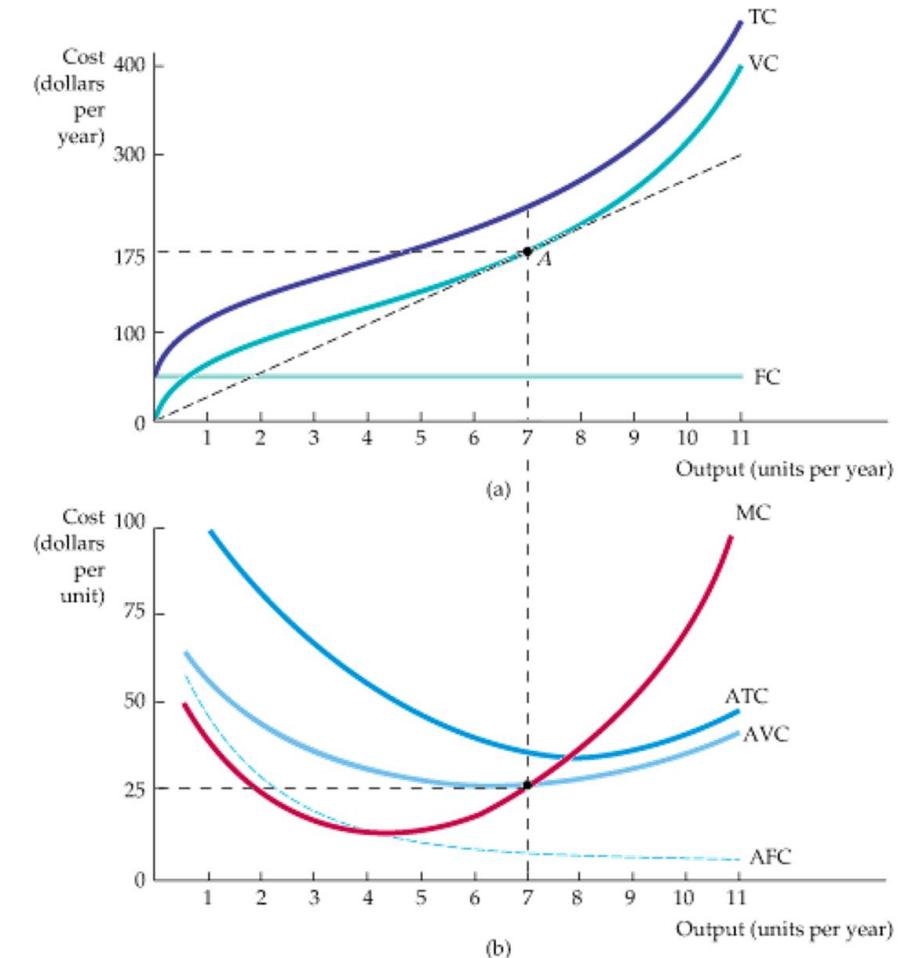
$$MC = w / MP_L$$

Diminishing Marginal Returns and Marginal Cost

- Diminishing marginal returns means that the marginal product of labor declines as the quantity of labor employed increases.
- How does it affect marginal costs?

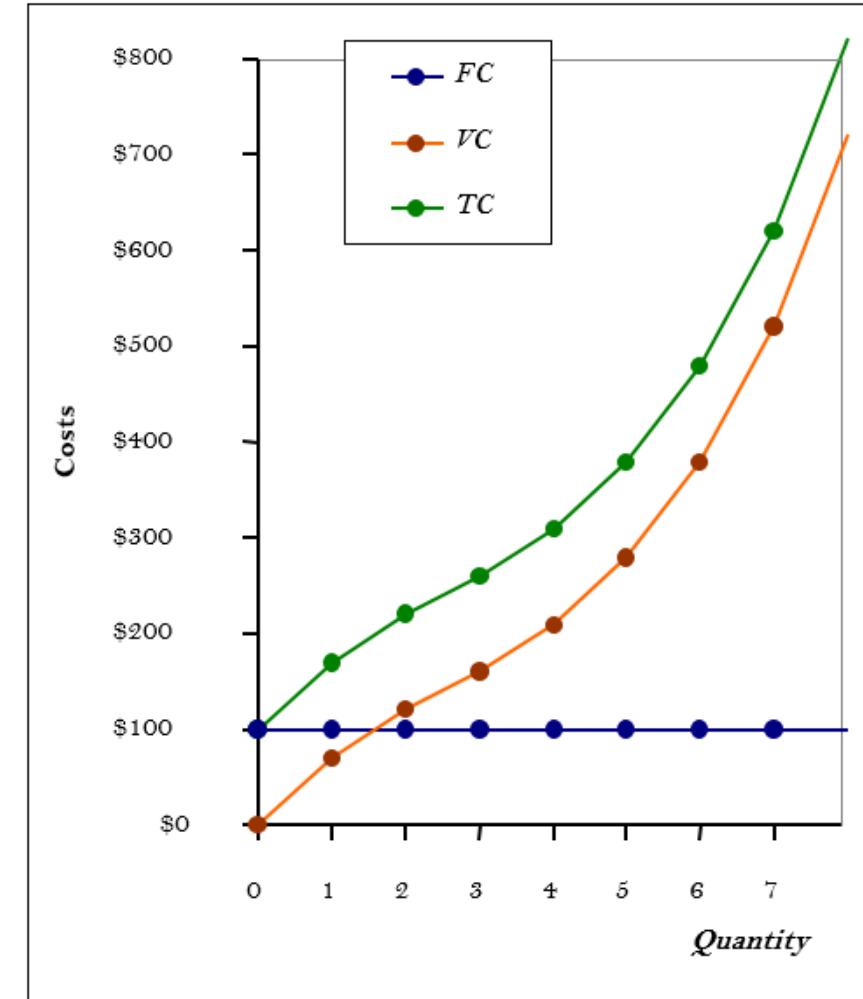
The Shapes of the Cost Curves

- In (a) total cost TC is the vertical sum of fixed cost FC and variable cost VC.
- In (b) average total cost ATC is the sum of average variable cost AVC and average fixed cost AFC.
- Marginal cost MC crosses the average variable cost and average total cost curves at their minimum points.



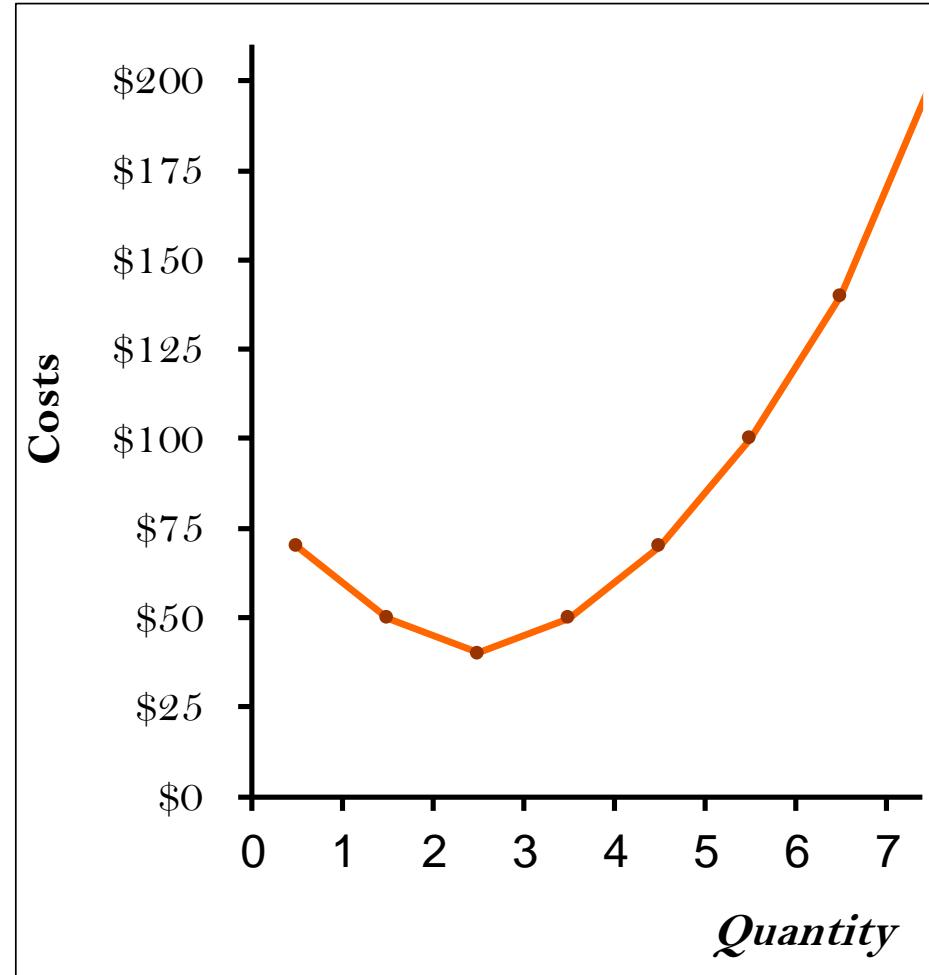
Another Example

<i>Q</i>	<i>FC</i>	<i>VC</i>	<i>TC</i>
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



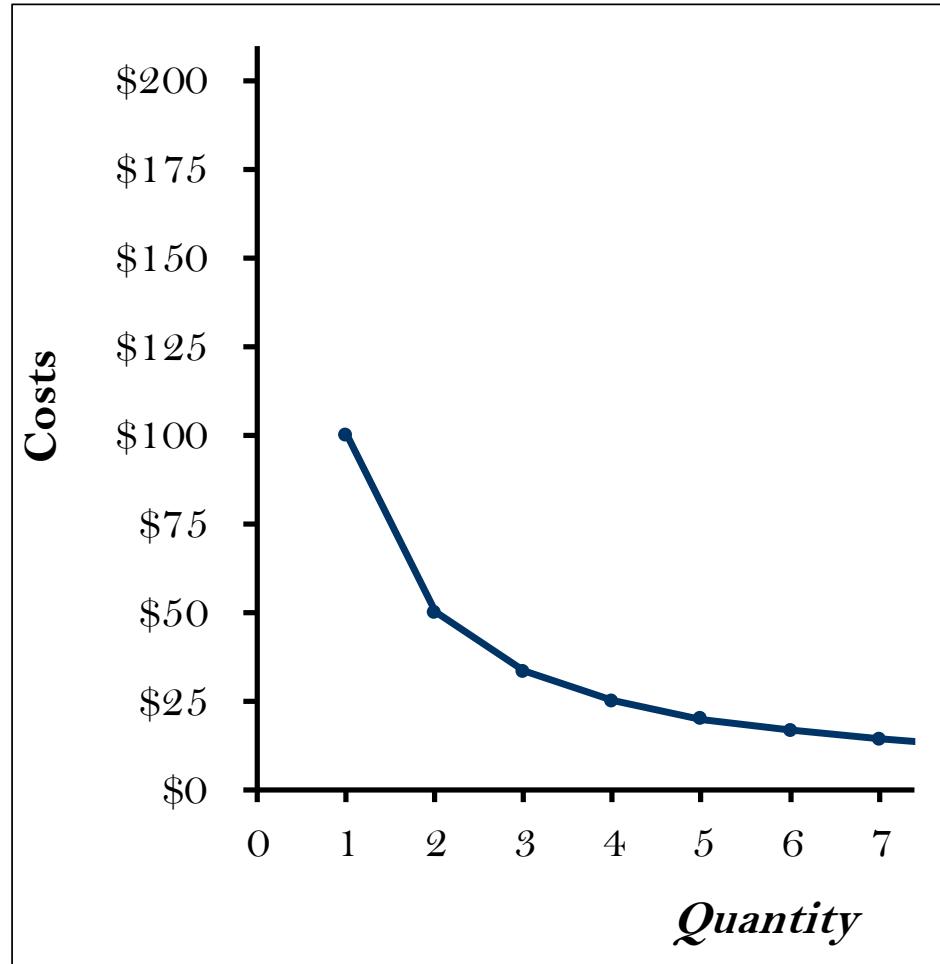
Marginal Cost

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



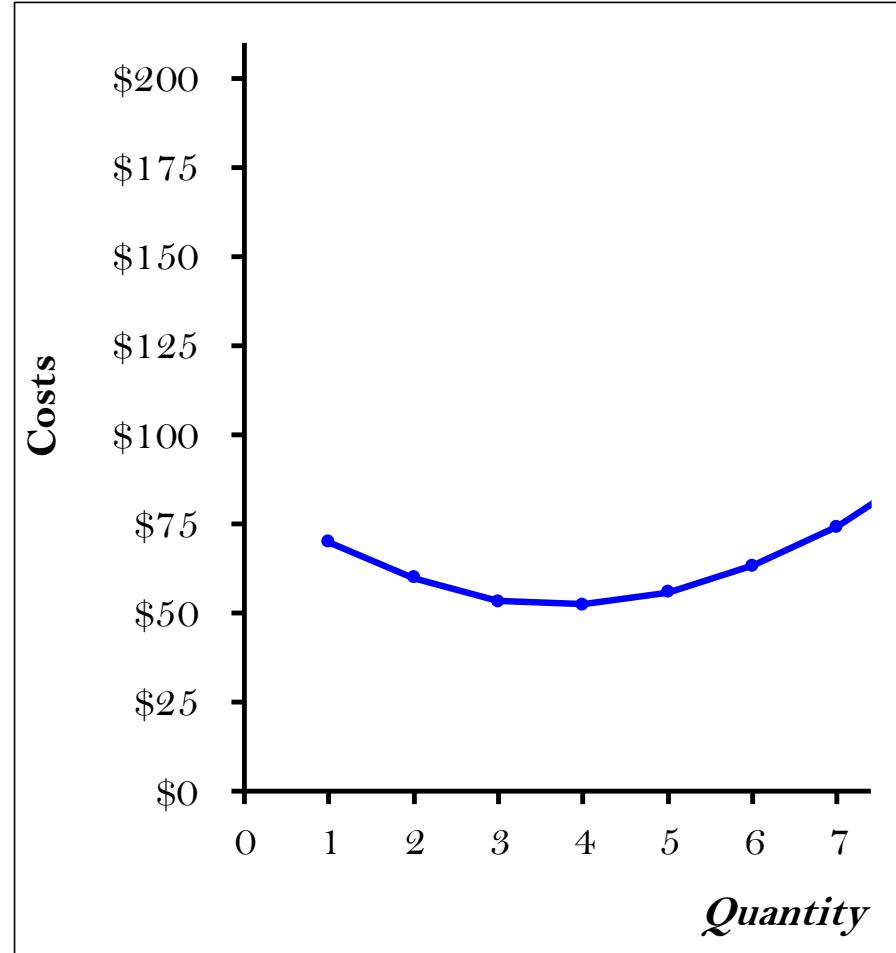
Average Fixed Cost, AFC

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



Average Variable Cost, AVC

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



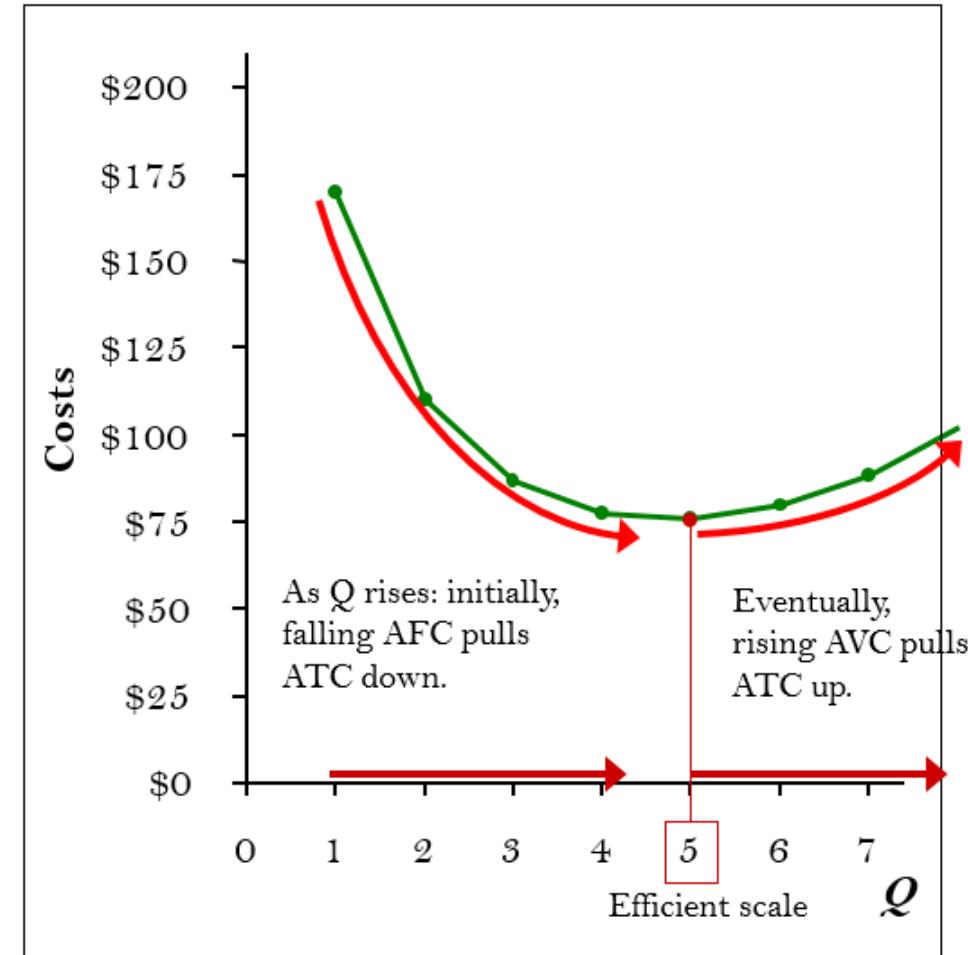
Average Total Cost

- Average total cost (ATC) equals total cost divided by the quantity of output:
- $ATC = TC/Q$
- Also, $ATC = AFC + AVC$

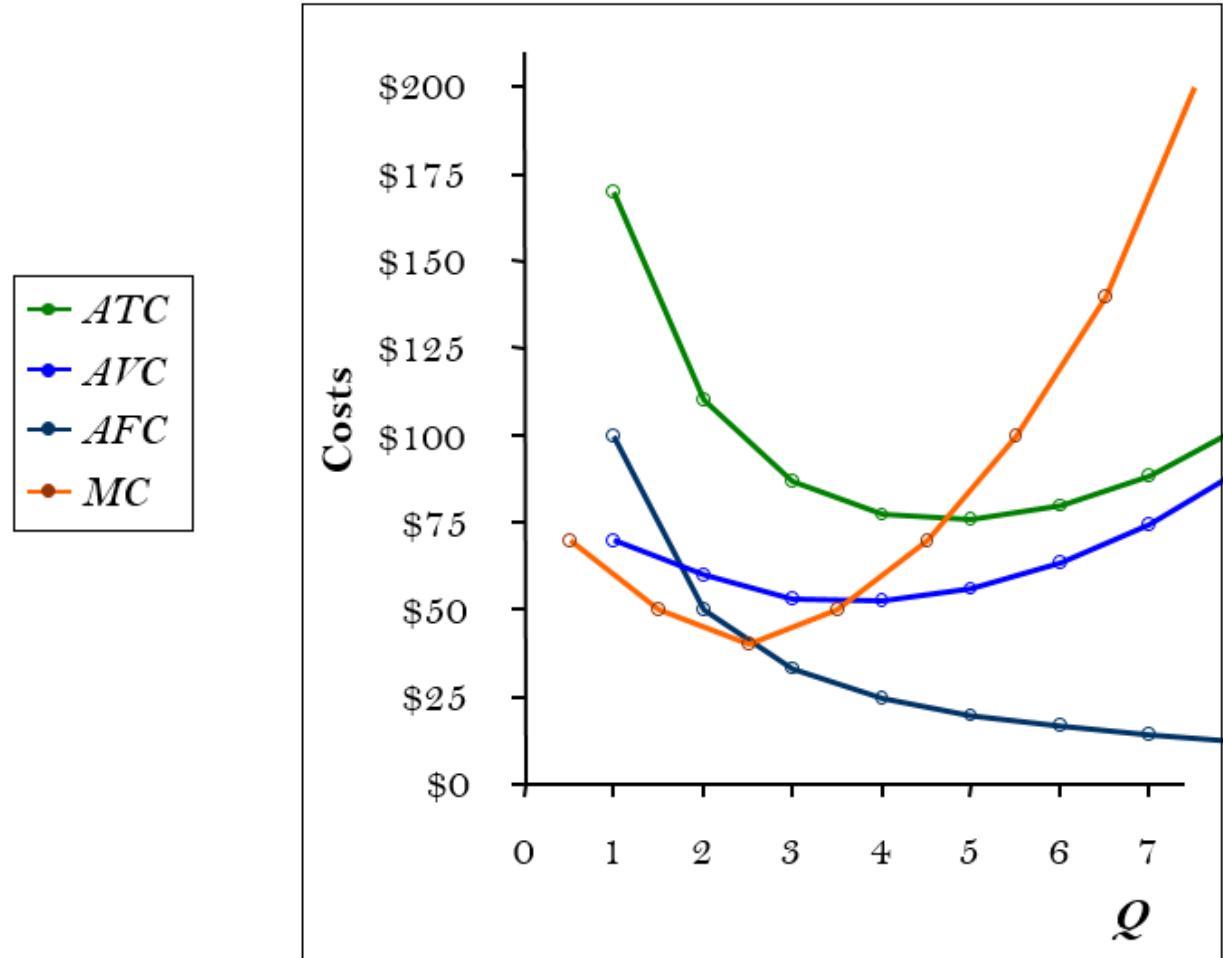
Q	TC	ATC	AFC	AVC
0	\$100	n/a	n/a	n/a
1	170	\$170	\$100	\$70
2	220	110	50	60
3	260	86.67	33.33	53.33
4	310	77.50	25	52.50
5	380	76	20	56.00
6	480	80	16.67	63.33
7	620	88.57	14.29	74.29

Average Total Cost, usually U-shaped

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

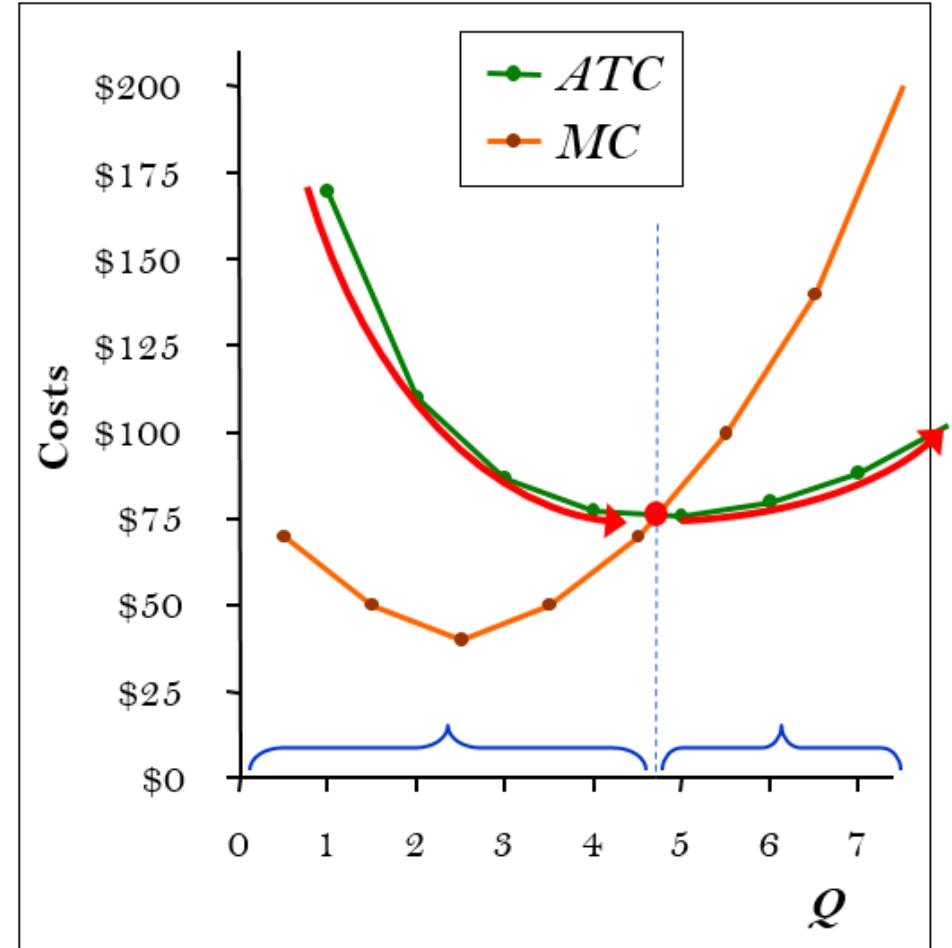


The Various Cost Curves Together



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, that is, at the efficient scale.
 - Efficient scale is the quantity that minimizes average total cost
- Similarly, Marginal cost MC crosses the average variable cost at the AVC curve's minimum.



Active Learning

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

Cost in the Long Run

- user cost of capital: annual cost of owning and using a capital asset, equal to economic depreciation plus forgone interest.
- The user cost of capital is given by the sum of the economic depreciation and the interest (i.e., the financial return) that could have been earned had the money been invested elsewhere.

User Cost of Capital = Economic Depreciation + (InterestRate)(Value of Capital)

- We can also express the user cost of capital as a rate per dollar of capital:

$$r = \text{Depreciation rate} + \text{Interest rate}$$

Cost in the Long Run

- The rental rate of capital: cost per year of renting one unit of capital.
- If the capital market is competitive, the rental rate should be equal to the user cost, r . Why?

The Cost-Minimizing Input Choice

- How to select inputs to produce a given output at minimum cost.
- For simplicity: labor (measured in hours of work per year) and capital (measured in hours of use of machinery per year).

The Cost-Minimizing Input Choice

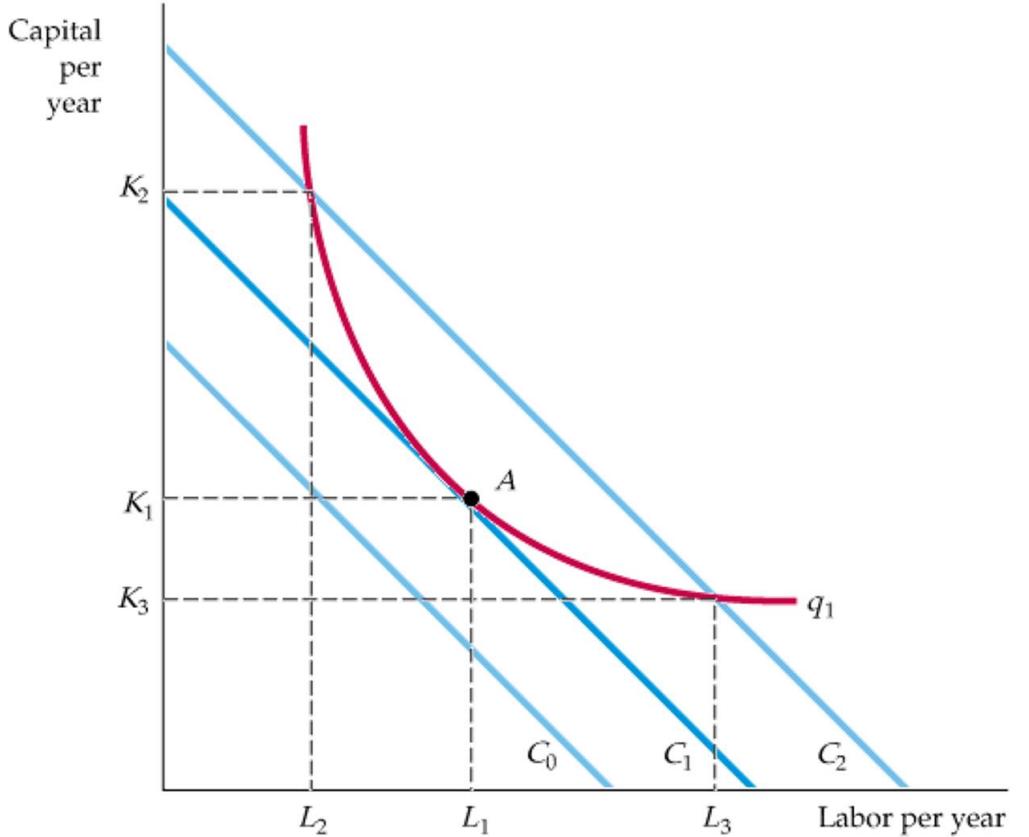
- isocost line: graph showing all possible combinations of labor and capital that can be purchased for a given total cost.
- To see what an isocost line looks like, recall that the total cost C of producing any particular output is given by the sum of the firm's labor cost wL and its capital cost rK :

$$C = wL + rK$$

- Draw the isocost line with capital on the y-axis. Calculate intercept and slope.

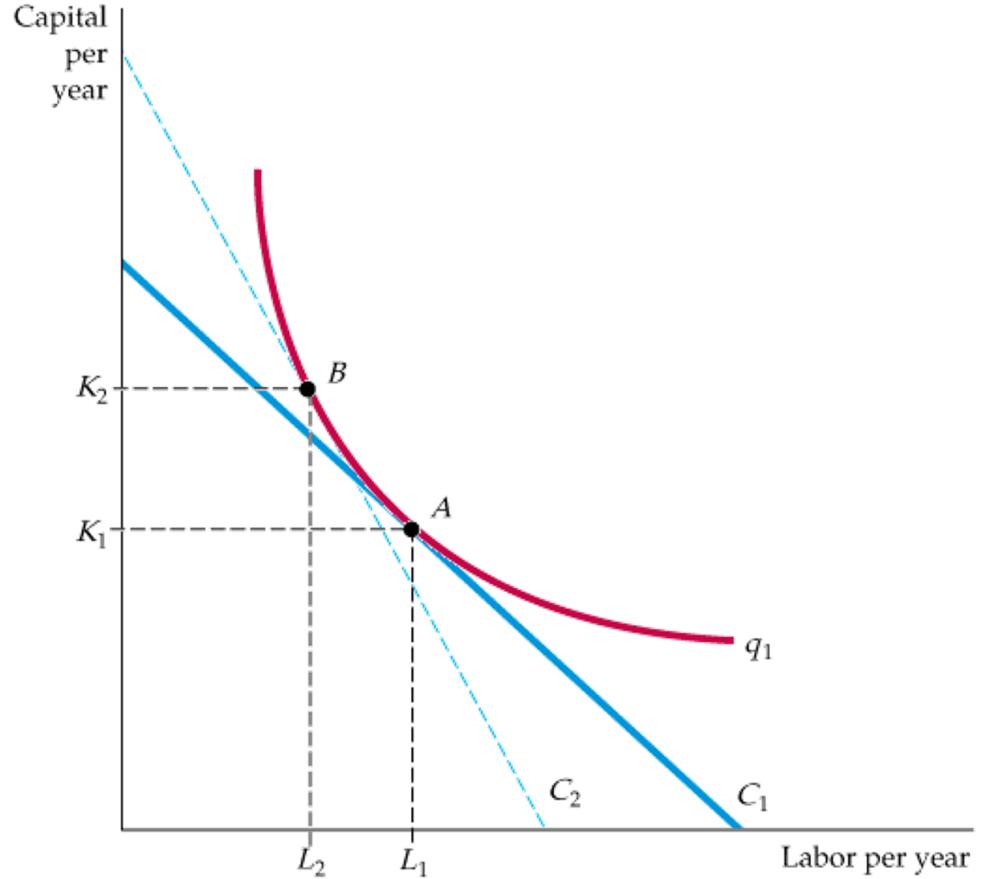
Choosing Inputs

- Which combinations can achieve the production goal?
- Which combinations have lowest cost?
- Which combination has lowest cost and can achieve the production goal? What is the condition?
- How is this related to consumer's choice?



Choosing Inputs

- Facing an isocost curve C_1 , the firm produces output q_1 at point A using L_1 units of labor and K_1 units of capital.
- When the price of labor increases, the isocost curves become steeper.
- Output q_1 is now produced at point B on isocost curve C_2 by using L_2 units of labor and K_2 units of capital.



Choosing Inputs

- Recall that $MRTS = -\Delta K / \Delta L = MP_L / MP_K$
- It follows that when a firm minimizes the cost of producing a particular output, the following condition holds:

$$MP_L / MP_K = w/r$$

- We can rewrite this condition slightly as follows:

$$MP_L / w = MP_K / r$$

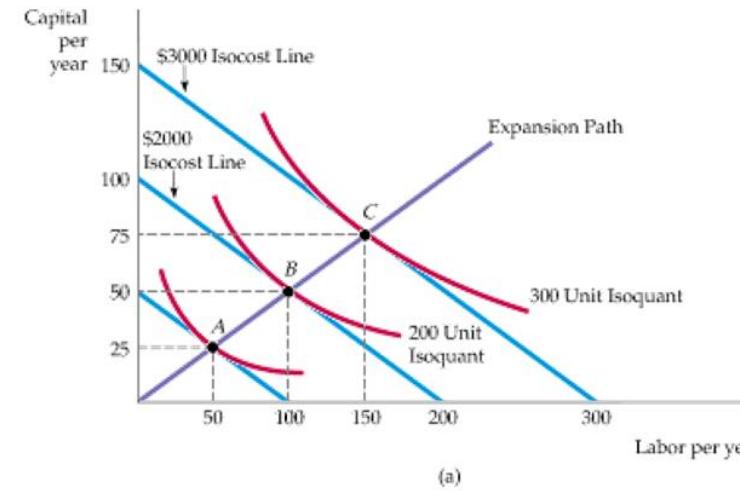
Question: What will firms do if $MP_L / w > MP_K / r$?

Cost Minimization with Varying Output Levels

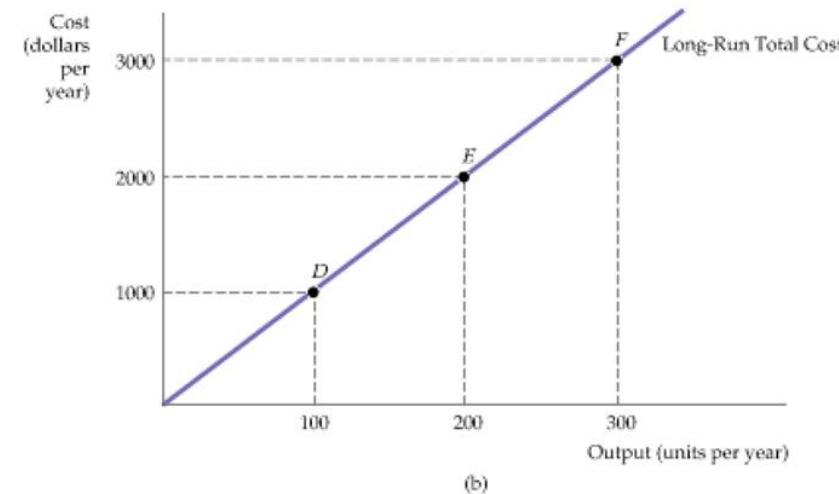
- Expansion path: Curve passing through points of tangency between a firm's isocost lines and its isoquants.
- The Expansion Path and Long-Run Costs
 - To move from the expansion path to the cost curve, we follow three steps:
 - 1. Choose an output level represented by an isoquant. Then find the point of tangency of that isoquant with an isocost line.
 - 2. From the chosen isocost line, determine the minimum cost of producing the output level that has been selected.
 - 3. Graph the output-cost combination.

Cost Minimization with Varying Output Levels

- In (a), the expansion path (from the origin through points A, B, and C) illustrates the lowest-cost combinations of labor and capital that can be used to produce each level of output in the long run— i.e., when both inputs to production can be varied.
- In (b), the corresponding long-run total cost curve (from the origin through points D, E, and F) measures the least cost of producing each level of output.



(a)



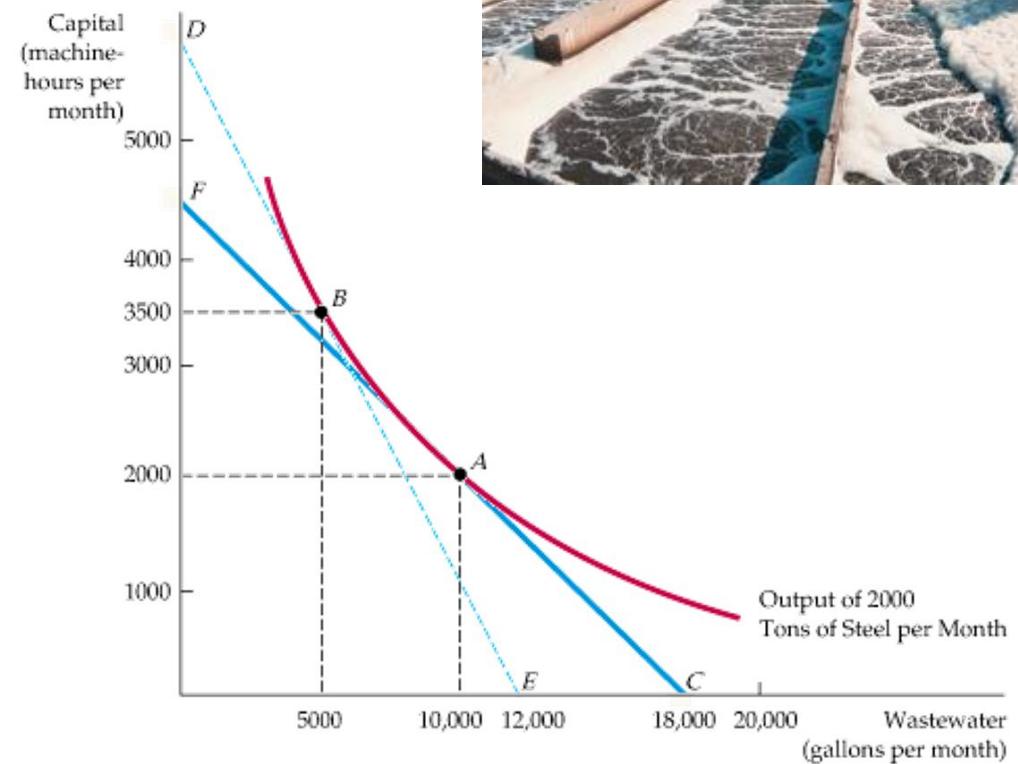
(b)

Cost in The Long Run

- 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)

Case Study: The Effect of Effluent Fees on Input Choices

- An effluent fee is a per-unit fee that the steel firm must pay for the effluent that goes into the river.
- Question: which point did firms choose after the effluent fee?



Can You Answer the Following Questions?

- What is a production function? What is marginal product? How are they related?
- What are the various costs? 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”?

End