ECO2011 Basic Microeconomics

Mankiw Chapter 13 (Production and Costs)

Pindyck Chapter 6 (Production)

Pindyck Chapter 7 (Cost)

2023

Motivation

You are the boss of Huiyin Coffee

- What is your objective as the boss?
- What kind of decisions do you need to make?

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

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

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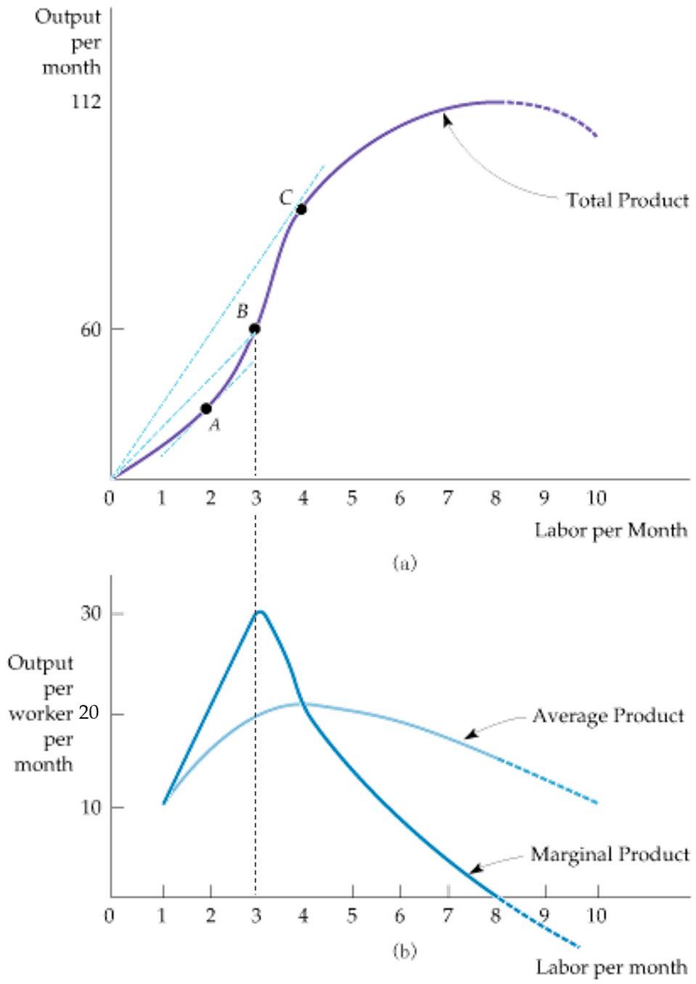
Production with One Variable Input (Labor)

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

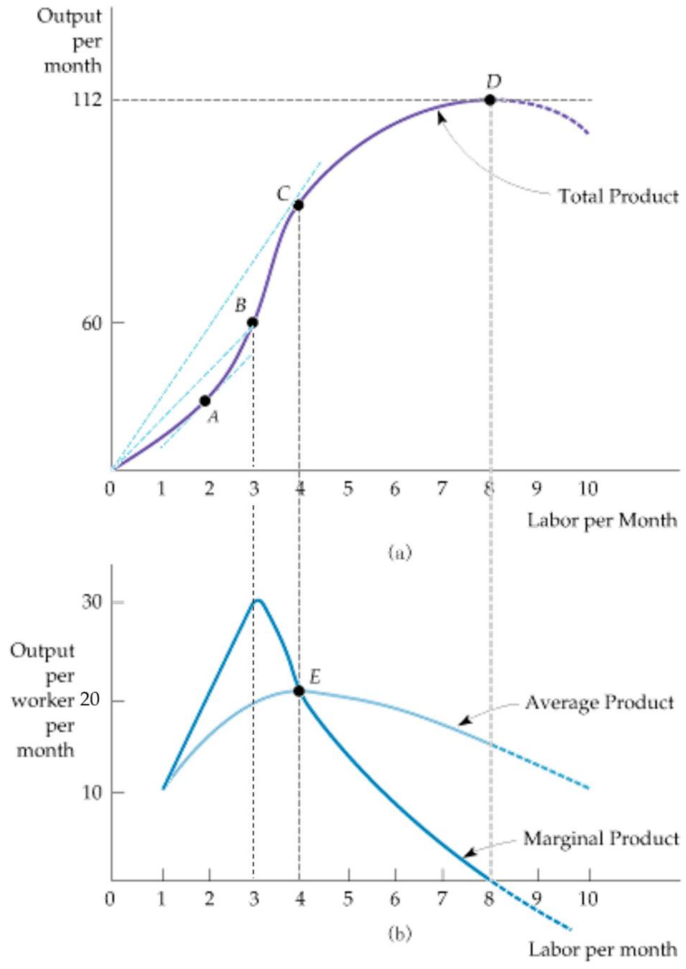
The Slopes of the Product Curve

- 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.

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 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.

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				
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

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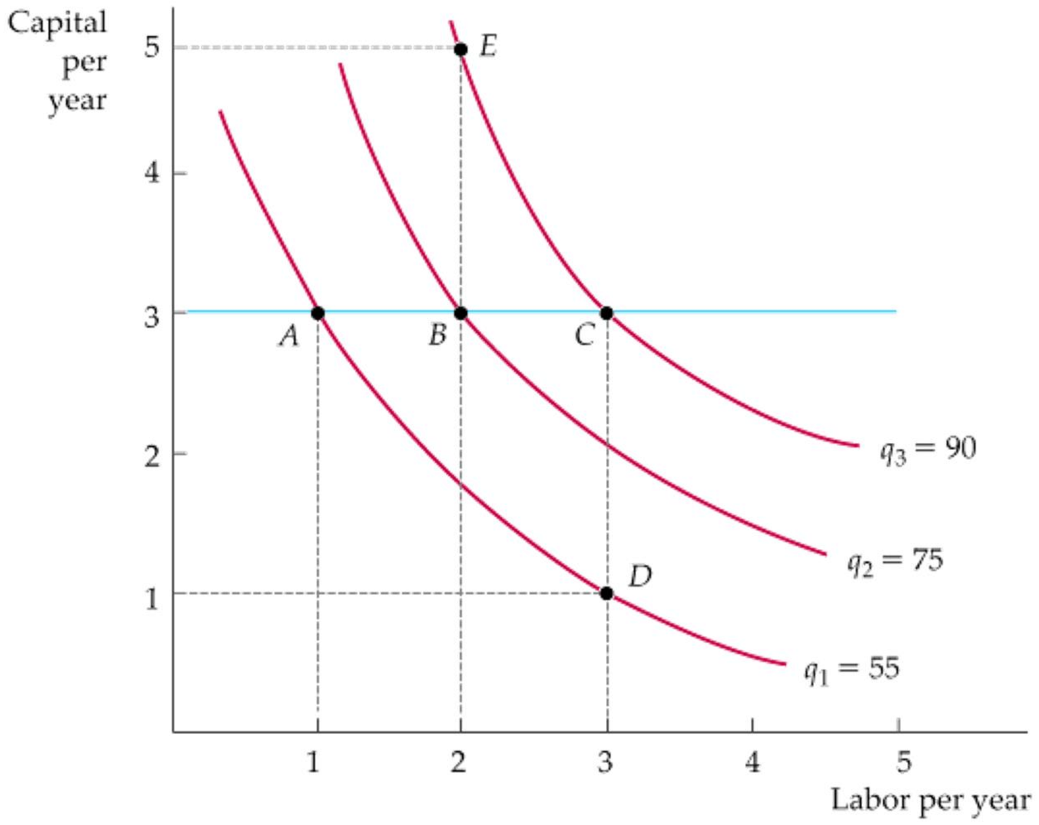
- Isoquants: curve showing all possible combinations of inputs that yield the same output.
- Isoquant map: graph combining a number of isoquants, used to describe a production function.

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 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).
- 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.

$$\text{MRTS} = -\text{Change in capital input/change in labor input}$$

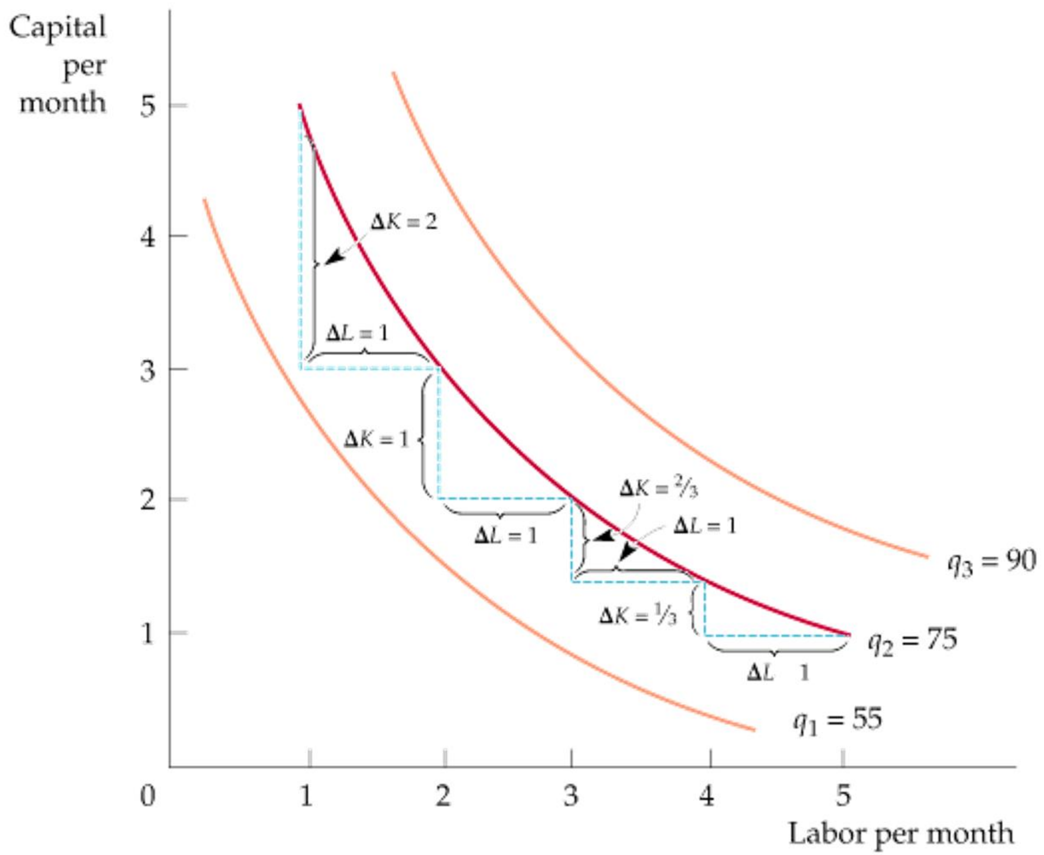
$$= -\Delta K/\Delta L \text{ (for a fixed level of } q\text{)}$$

Diminishing MRTS

- Additional output from increased use of labor = $(\mathrm{MP}_L)(\Delta L)$
- Reduction in output from decreased use of capital = $(\mathrm{MP}_K)(\Delta K)$
- Because we are keeping output constant by moving along an isoquant, the total change in output must be zero. Thus,
$$(\mathrm{MP}_L)(\Delta L) + (\mathrm{MP}_K)(\Delta K) = 0$$
- Now, by rearranging terms we see that
$$(\mathrm{MP}_L)(\mathrm{MP}_K) = -(\Delta K/\Delta L) = \mathrm{MRTS}$$

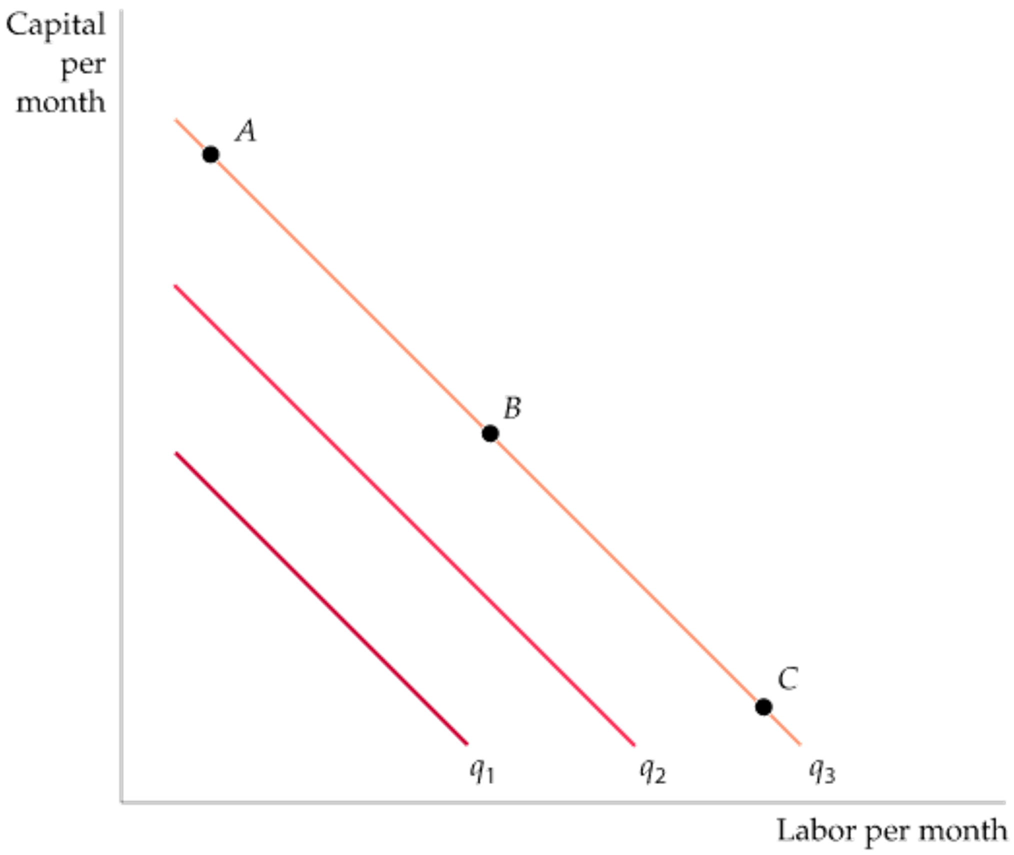
Diminishing MRTS

- 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 q2, the MRTS falls from 2 to 1 to 2/3 to 1/3.



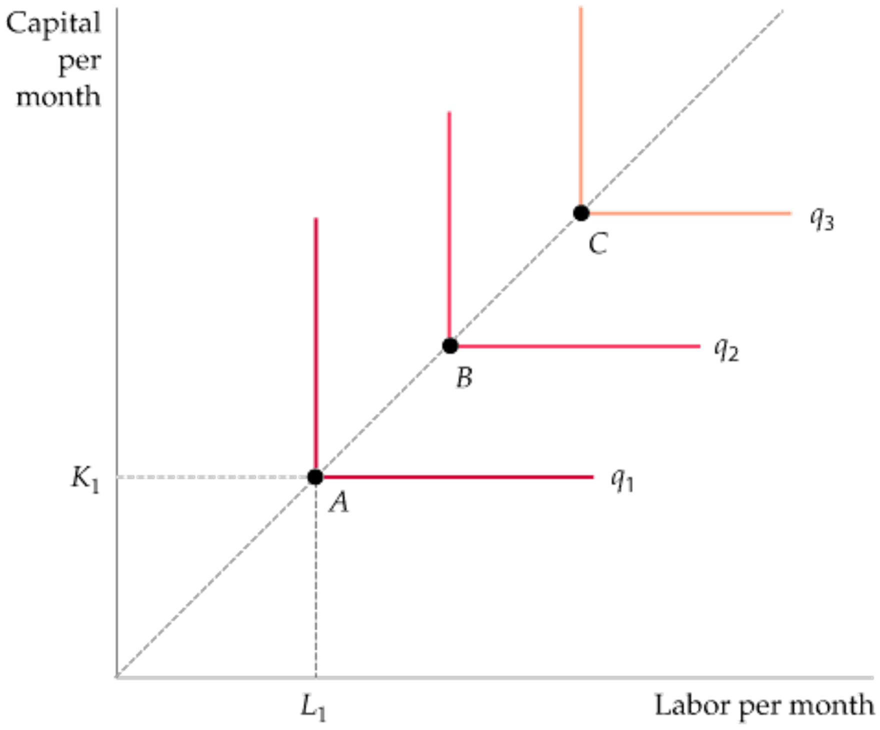
Production Functions—Two Special Cases

- **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 q3.



Production Functions—Two Special Cases

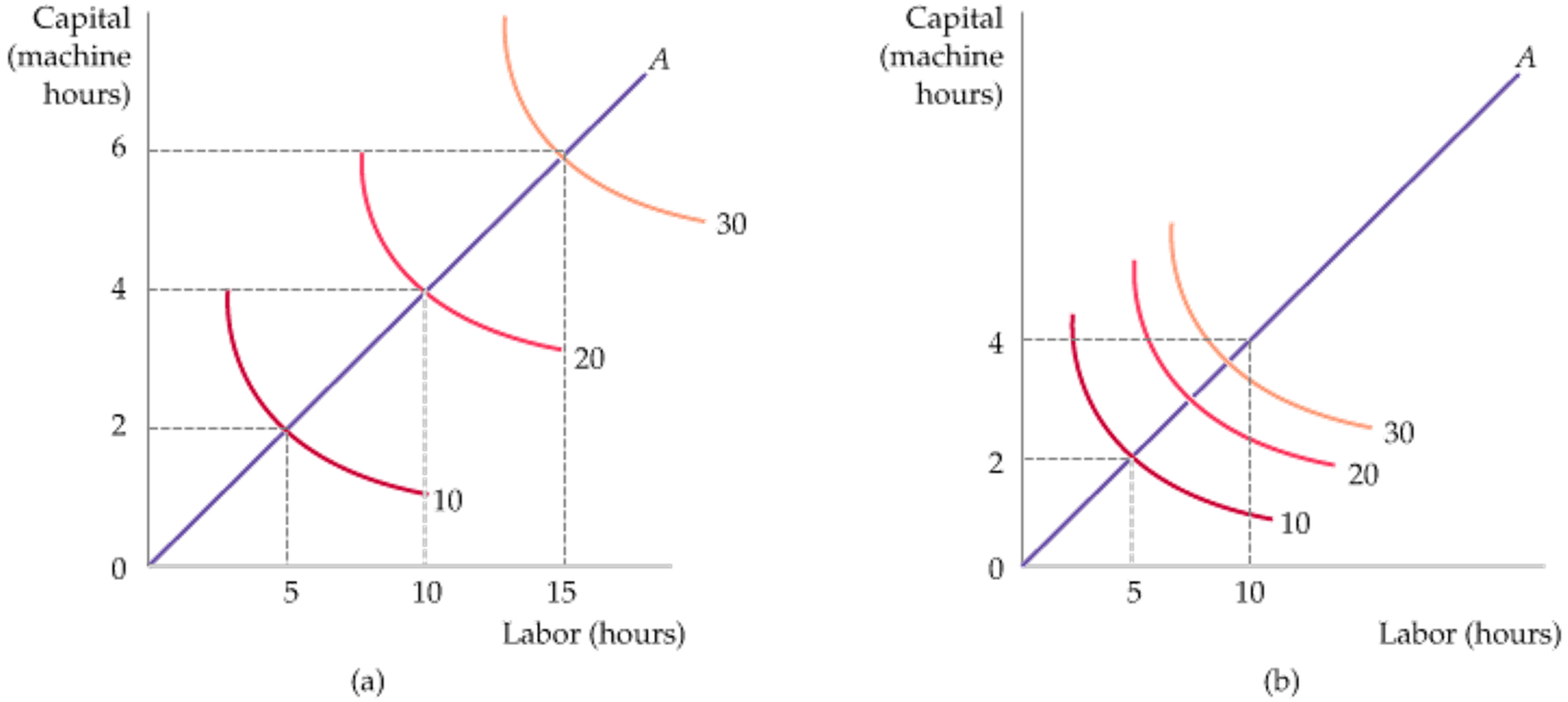
- **fixed-proportions production function** sometimes called a **Leonitief production function**: production function with L-shaped isoquants, so that only one combination of labor and capital can be used to produce each level of output. As at point A on isoquant q1, point B on isoquant q2, and point C on isoquant q3. 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



When a firm's production process exhibits constant returns to scale as shown by a movement along line 0*A* in part **(a),** the isoquants are equally spaced as output increases proportionally.

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.

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

Example: Explicit vs. Implicit Costs

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.

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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.

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: 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.

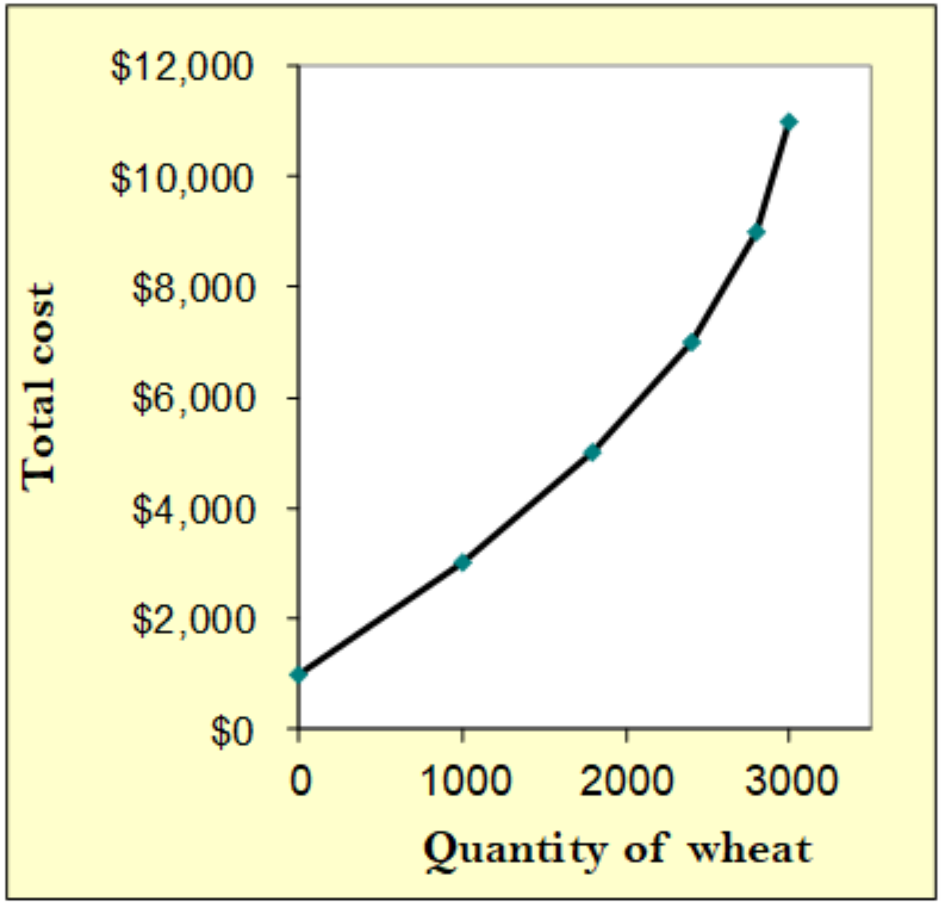
- So Farmer Jack's costs are related to how much wheat he produces….

Example: 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

Example: 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

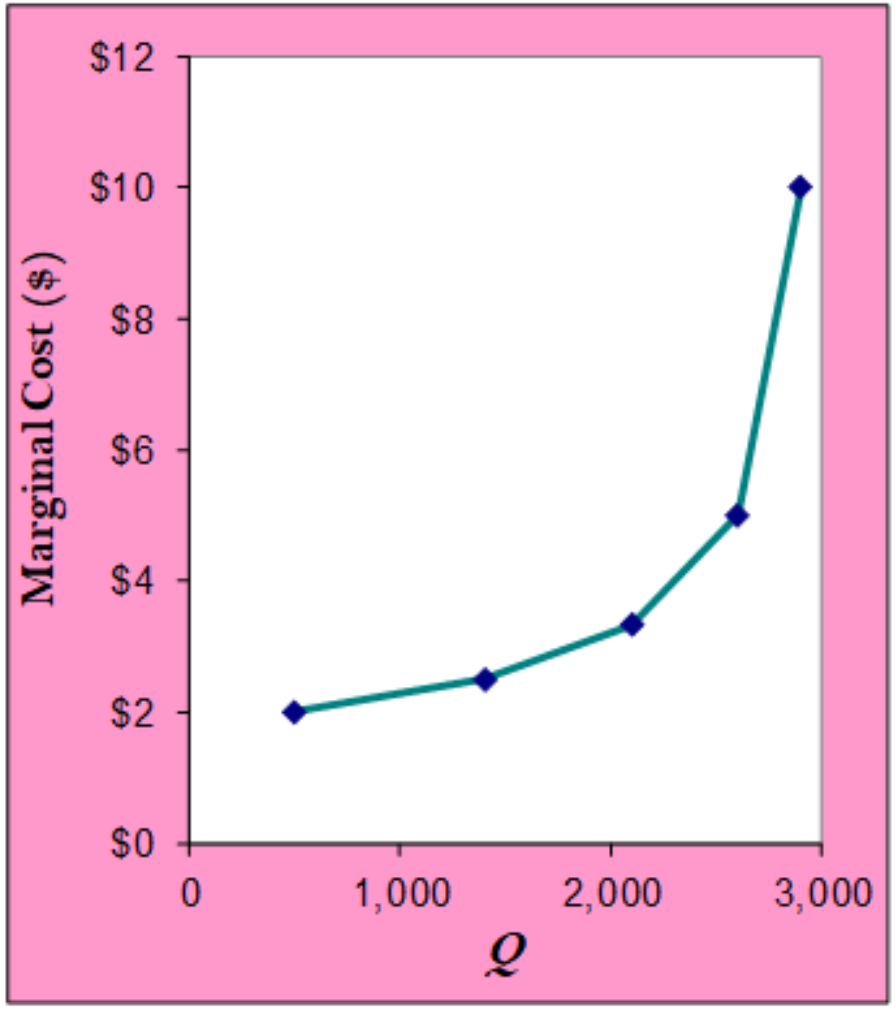
- Marginal cost, MC
  - Increase in total cost arising from an extra unit of production
  - Marginal cost = Change in total cost / Change in quantity
  - $MC = \Delta TC / \Delta Q$
  - Increase in total cost
    - From producing an additional unit of output

Example: Total and Marginal Cost

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

Example: The Marginal Cost Curve

Q (bushels of wheat)	*TC*	*MC*
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?
    - 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

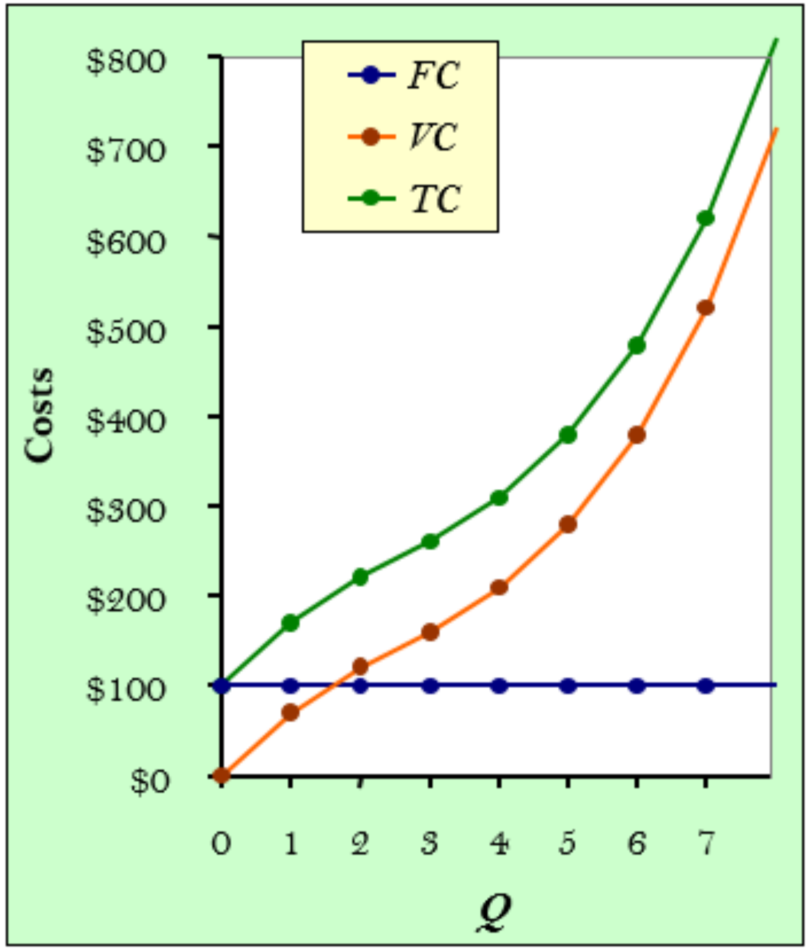
- Fixed costs, FC, do not vary with the quantity of output produced
  - For Farmer Jack, FC = $1000 for his land
  - Other examples: cost of equipment, loan payments, rent
- Variable costs, VC, vary with the quantity of output produced
  - For Farmer Jack, VC = wages he pays workers
  - Other example: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

Example: Production Costs

- Our second example is more general, applies to any type of firm producing any good with any types of inputs.
  - Calculate and graph TC knowing FC and VC
  - Calculate and graph marginal and average costs
  - Understand the relationship between marginal cost and average cost

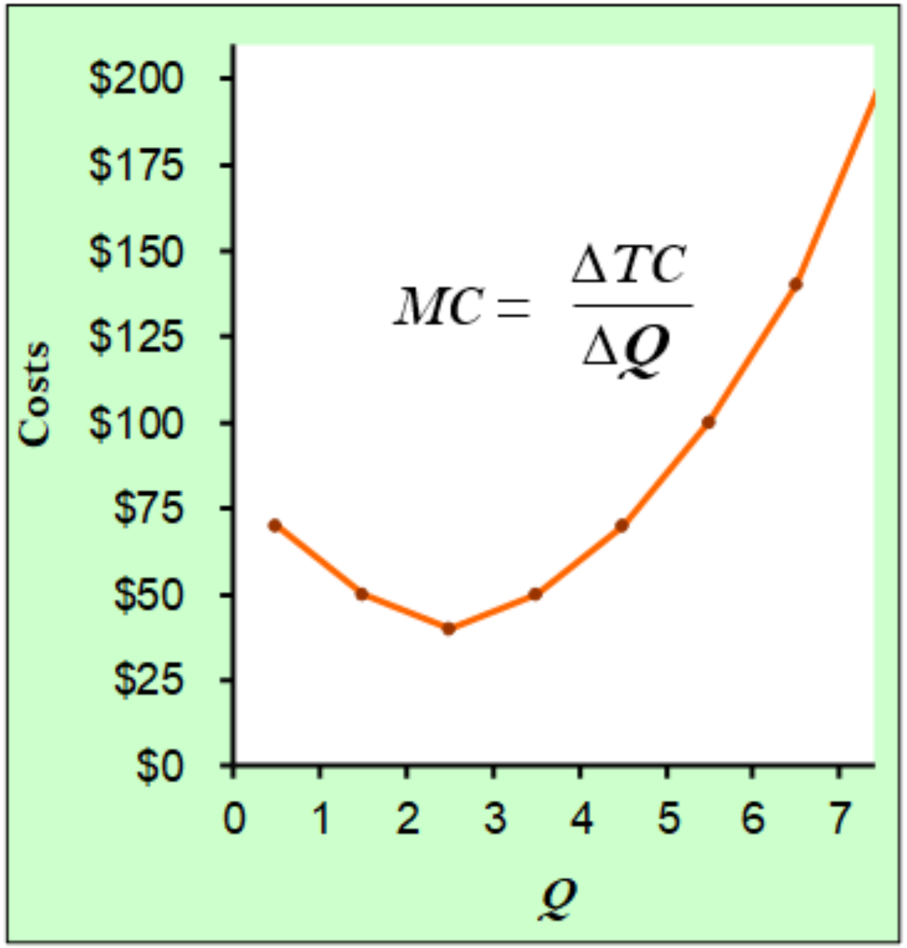
Example: Costs: TC = FC + VC

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



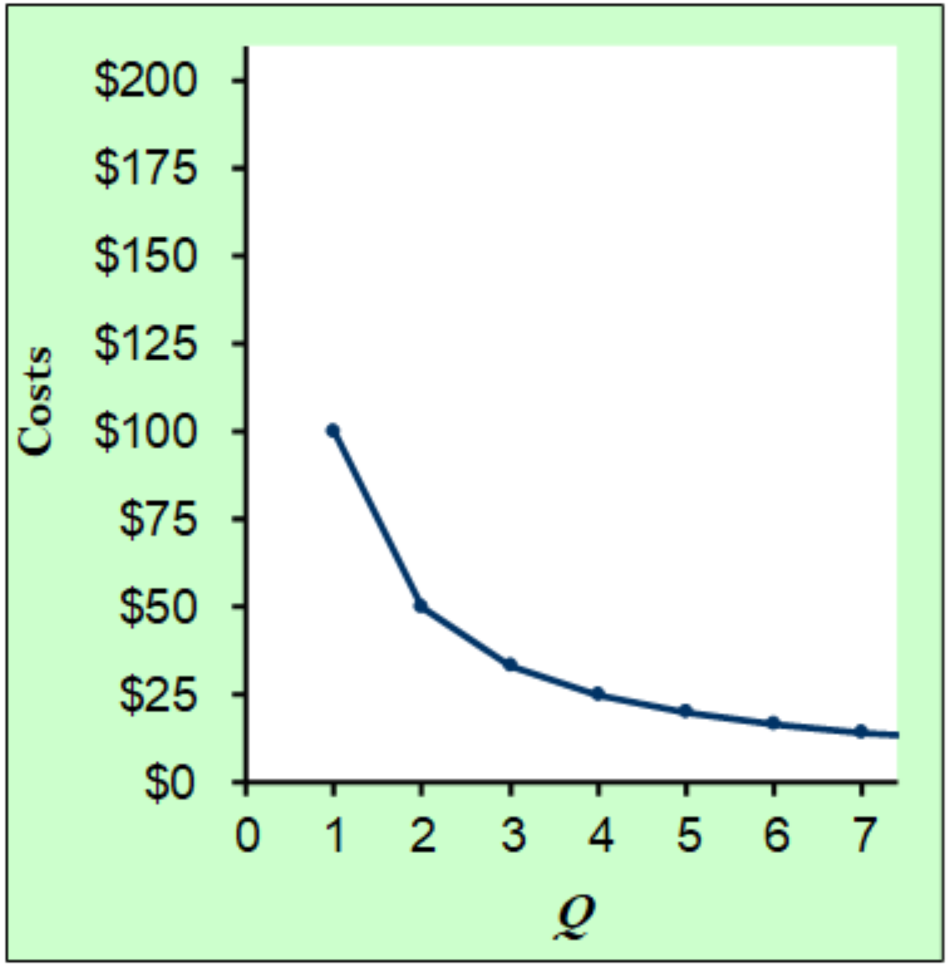
Example: Marginal Cost

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



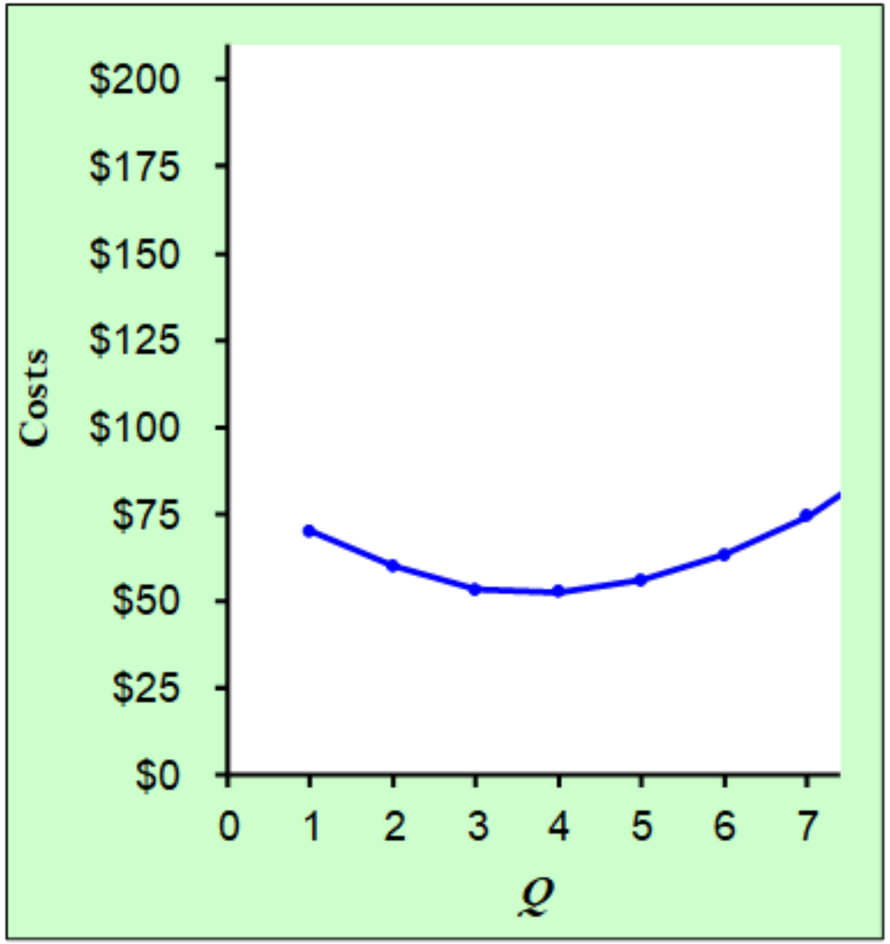
Example: Average Fixed Cost, AFC

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



Example: 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



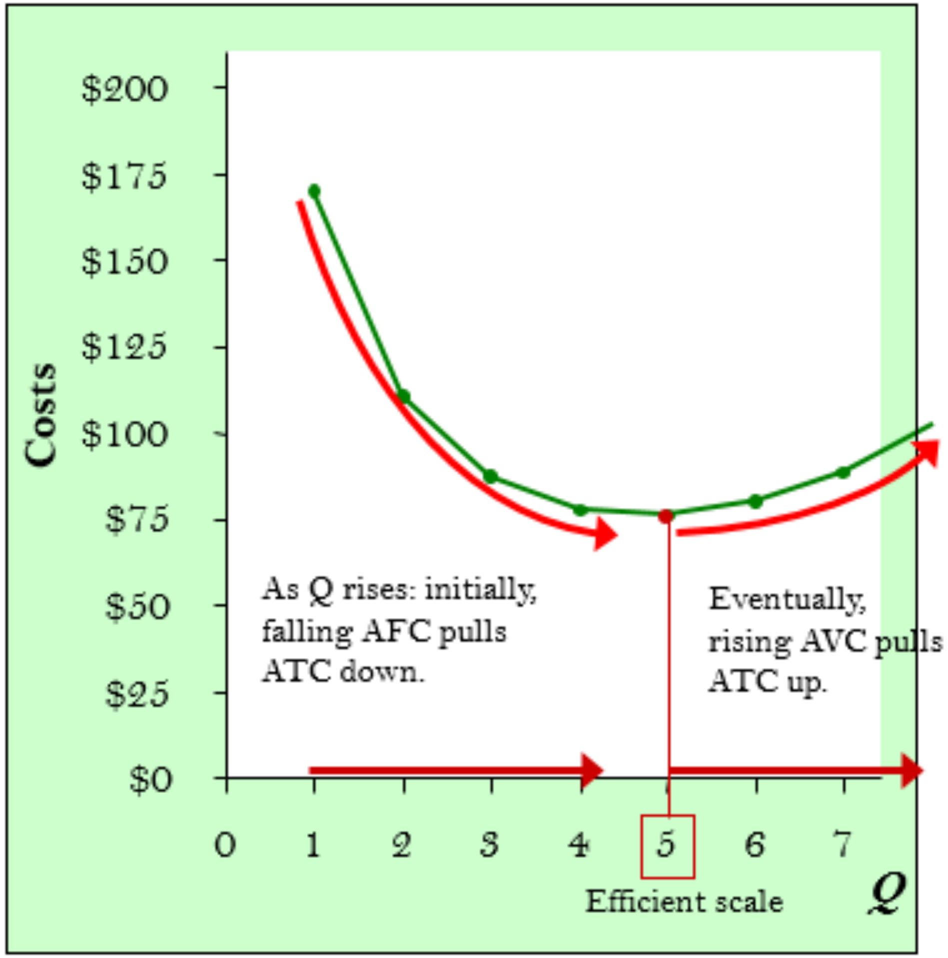
Example: Average Total Cost

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

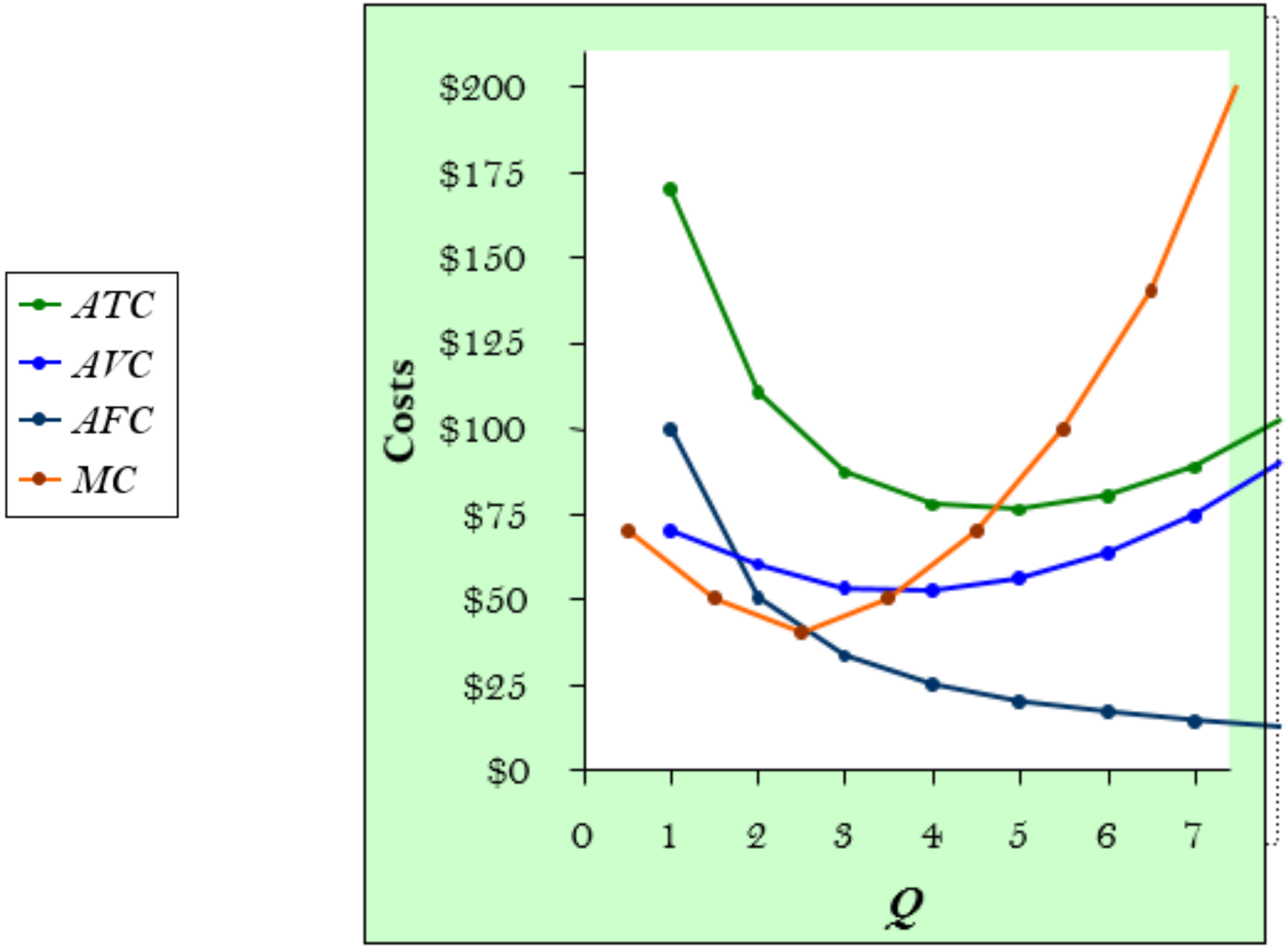
Q	TC	ATC	AFC	AVC
0	\$100	n/a	n/a	n/a
1	170	\$170	\$100	\$70
2	220	110	50	60
3	260	86.67	33.33	53.33
4	310	77.50	25	52.50
5	380	76	20	56.00
6	480	80	16.67	63.33
7	620	88.57	14.29	74.29

Example: 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



Example: The Various Cost Curves Together

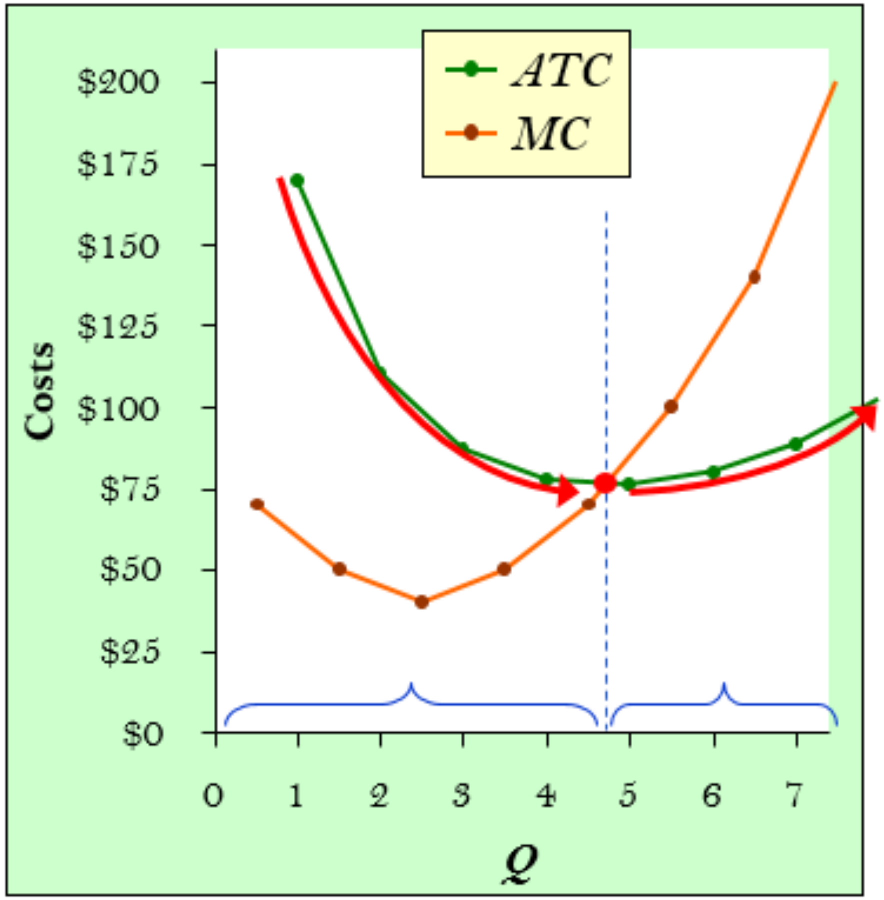


Example: ATC and MC

- 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.



Active Learning 3 Calculating costs

Fill in the blank spaces of this table.

Q	VC	TC	AFC	AVC	ATC	MC
0		$50	n/a	n/a	n/a	
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

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 a workers to produce and deliver pizzas.

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)

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

$$\text{MC} = \Delta\text{VC}/\Delta q = w\Delta L/\Delta q$$

- Derive the relationship between MC and MPL

$$\text{MC} = w/\text{MP}_L$$

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?

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.

$$\text{User Cost of Capital} = \text{Economic Depreciation} + (\text{InterestRate})(\text{Value of Capital})$$

- 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

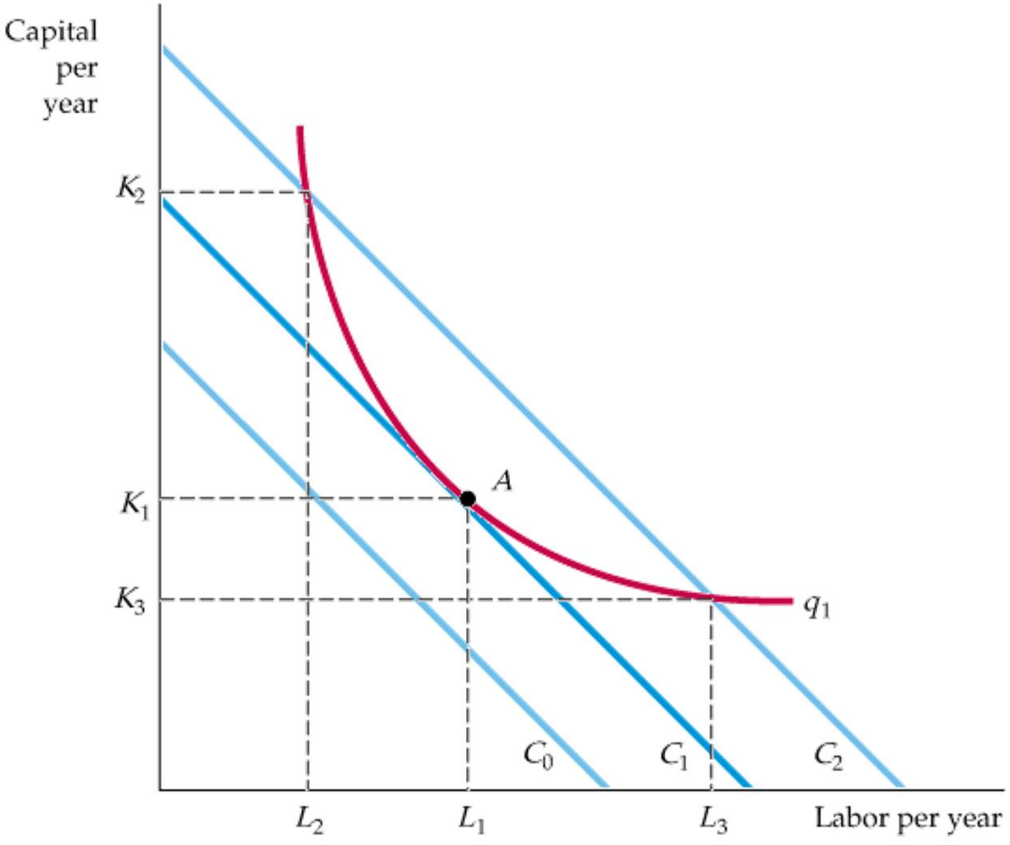
- isocost line: graph showing all possible combinations of labor and capital that can be purchased for a given total cost.
- To see what an isocost line looks like, recall that the total cost C of producing any particular output is given by the sum of the firm's labor cost wL and its capital cost rK:

$$C = wL + rK$$

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

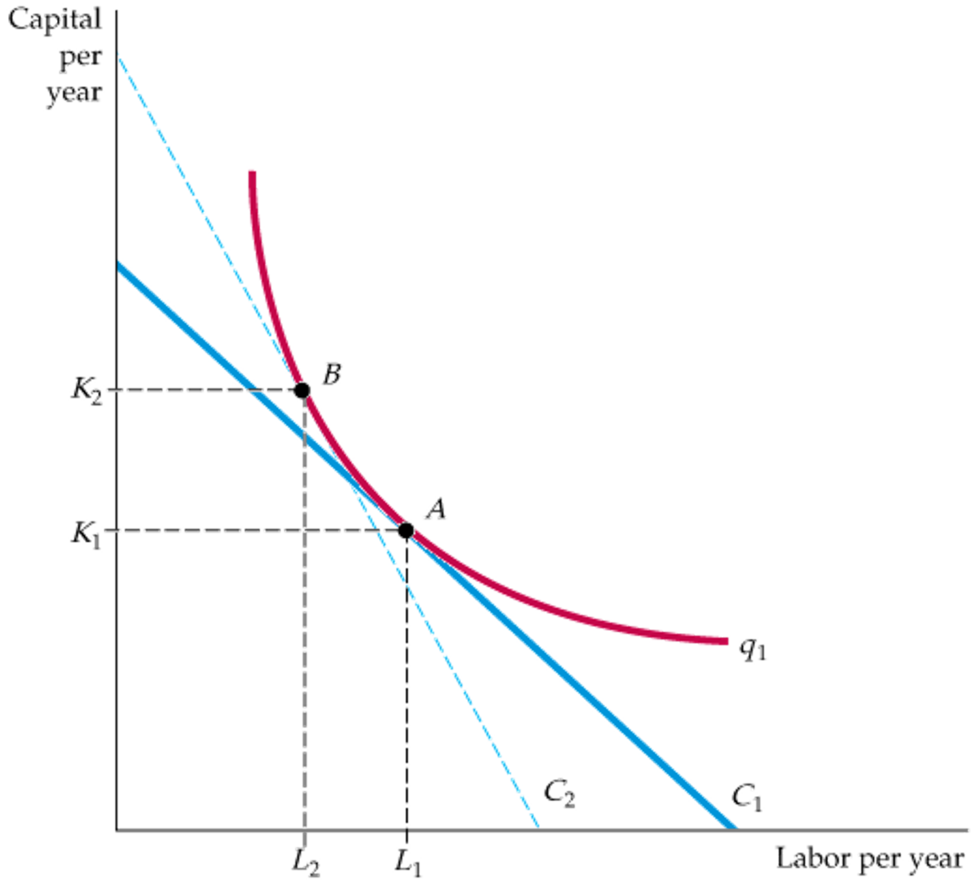
Choosing Inputs

- 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 C1, the firm produces output q1 at point A using L1 units of labor and K1 units of capital.
- When the price of labor increases, the isocost curves become steeper.
- Output q1 is now produced at point B on isocost curve C2 by using L2 units of labor and K2 units of capital.



Choosing Inputs

- Recall that $\text{MRTS} = -\Delta K/\Delta L = \text{MP}_L/\text{MP}_K$
- It follows that when a firm minimizes the cost of producing a particular output, the following condition holds:

$$\text{MP}_L/\text{MP}_K = w/r$$

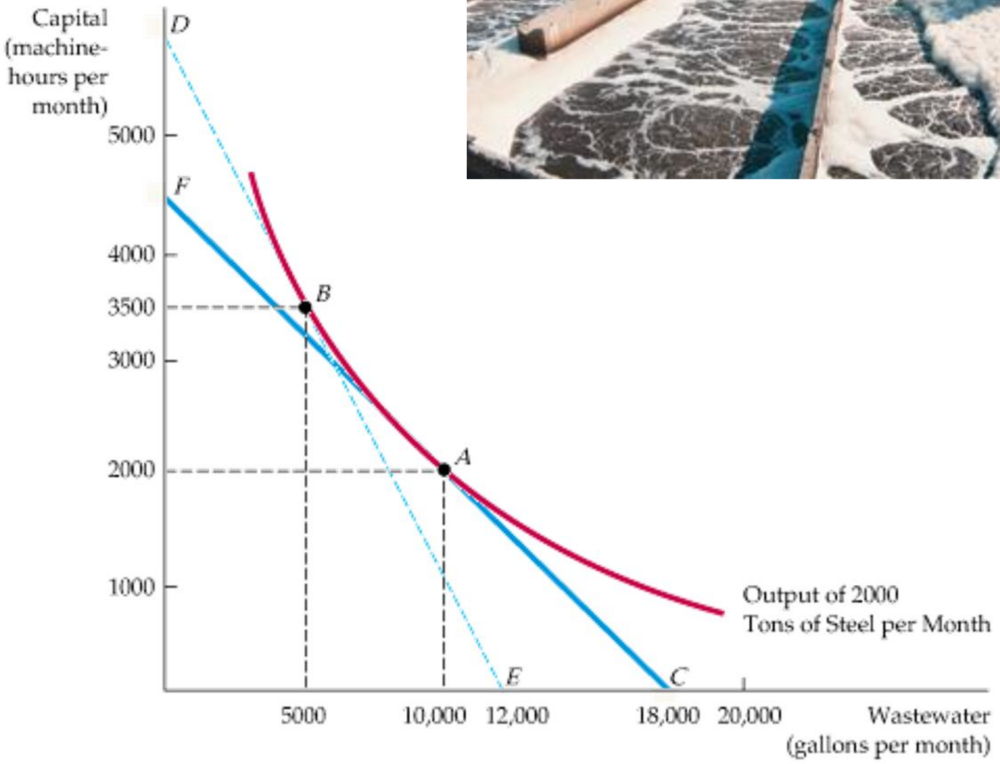
- We can rewrite this condition slightly as follows:

$$\text{MP}_L/w = \text{MP}_K/r$$

Question: What will firms do if $\text{MP}_L/w > \text{MP}_K/r$?

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?



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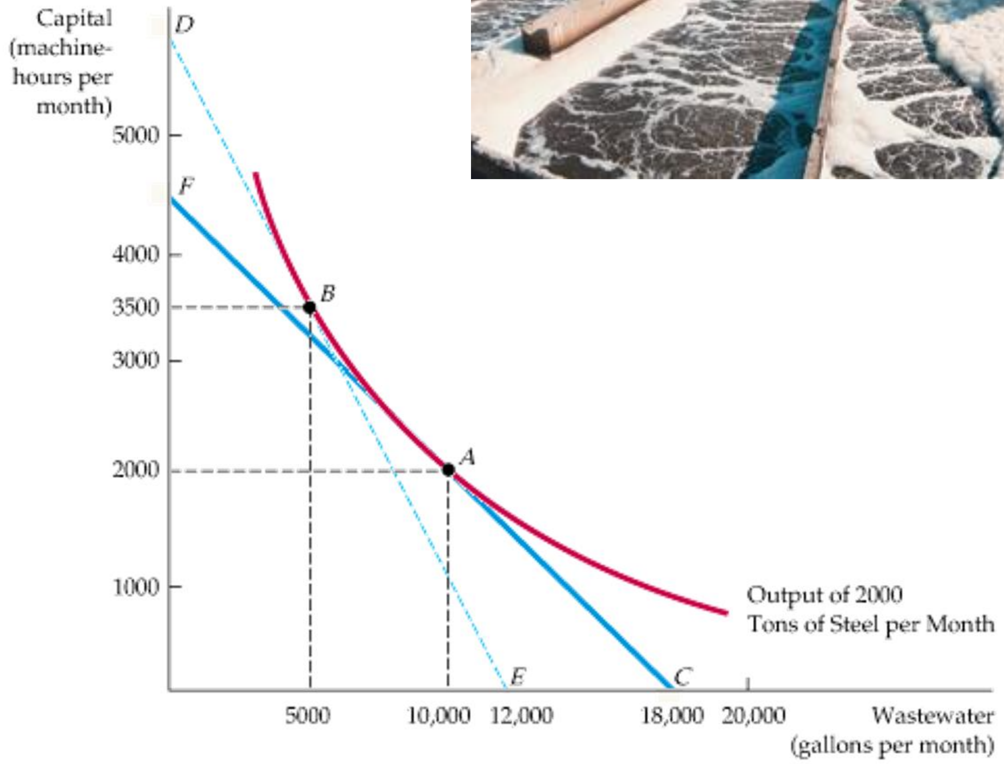

Can You Answer the Following Questions?

- 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