**N. GREGORY MANKIW**

PRINCIPLES OF

# ECONOMICS
*Eight Edition*

CHAPTER

# 13

## The Costs of Production

Premium PowerPoint Slides by:
V. Andreea CHIRITESCU
Eastern Illinois University

**Modified by Joseph Tao-yi Wang**

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Active Learning 1          Brainstorming costs

You run Foxconn Electronics Inc.(鴻海富士康).
- List three different costs you have.
- List three different business decisions that are affected by your costs
- How would your answers change if you run 台北農產運銷公司 instead?

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## 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? 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"?

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## Total Revenue, Total Cost, Profit

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

**Profit = Total revenue − Total cost**

the amount a firm receives from the sale of its output

TR = P×Q

the market value of the inputs a firm uses in production

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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

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## Explicit vs. Implicit Costs: An Example

You need $1,000,000 to start your business. The interest rate is 5%.
- Case 1: borrow $1,000,000
  - explicit cost = $50,000 interest on loan
- Case 2: use $400,000 of your savings, borrow the other $600,000
  - explicit cost = $30,000 (5%) interest on the loan
  - implicit cost = $20,000 (5%) foregone interest you could have earned on your $400,000.

In both cases, total (exp + imp) costs are $50,000

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## 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 $5,000/month.

Determine the effects on accounting profit and economic profit if:

   a. you rent your office space

   b. you own your office space

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## Active Learning 2                    Answers

The rent on office space increases $5,000/month.

**a.** You rent your office space.
- Explicit costs increase $5,000/month.
- Accounting profit & economic profit each fall $5,000/month.

**b.** You own your office space.
- Explicit costs do not change, so accounting profit does not change.
- Implicit costs increase $5,000/month (opp. cost of using your space instead of renting it) so economic profit falls by $5,000/month.

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## Production Function

- Production function
   - Relationship between
      - Quantity of inputs used to make a good
      - And the quantity of output of that good
   - Gets flatter as production rises

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## EXAMPLE 1: Farmer Jack

Example 1:
- Farmer Jack grows rice.
- He has 5 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
   - Unit: picul (石) = a shoulder-load ≈ 60kg

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## EXAMPLE 1: Farmer Jack's Production Function

| L (no. of workers) | Q (piculs of rice) |
|---|---|
| 0 | 0 |
| 1 | 1000 |
| 2 | 1800 |
| 3 | 2400 |
| 4 | 2800 |
| 5 | 3000 |

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## Marginal Product

- Marginal product
  - Increase in output that arises from an additional unit of input
    - Other inputs constant
  - 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.

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### EXAMPLE 1: Total & Marginal Product

| L (no. of workers) | Q (piculs of rice) | | MPL |
|---|---|---|---|
| 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 |

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## 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

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### EXAMPLE 1: MPL = Slope of Prod Function

| L (no. of workers) | Q (piculs of rice) | MPL |
|---|---|---|
| 0 | 0 | |
| 1 | 1000 | 1000 |
| 2 | 1800 | 800 |
| 3 | 2400 | 600 |
| 4 | 2800 | 400 |
| 5 | 3000 | 200 |

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## 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.

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## 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.).

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## EXAMPLE 1: Farmer Jack's Costs

Farmer Jack must pay $10,000 per month for the land, regardless of how much rice he grows.

The market wage for a farm worker is $20,000 per month.

• So Farmer Jack's costs are related to how much rice he produces….

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## EXAMPLE 1: Farmer Jack's Costs

| L (no. of workers) | Q (piculs of rice) | Cost of land | Cost of labor | Total cost |
|---|---|---|---|---|
| 0 | 0 | $10,000 | $0 | $10,000 |
| 1 | 1000 | $10,000 | $20,000 | $30,000 |
| 2 | 1800 | $10,000 | $40,000 | $50,000 |
| 3 | 2400 | $10,000 | $60,000 | $70,000 |
| 4 | 2800 | $10,000 | $80,000 | $90,000 |
| 5 | 3000 | $10,000 | $100,000 | $110,000 |

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## EXAMPLE 1: Farmer Jack's Total Cost Curve

| Q (piculs of rice) | Total Cost |
|---|---|
| 0 | $10,000 |
| 1000 | $30,000 |
| 1800 | $50,000 |
| 2400 | $70,000 |
| 2800 | $90,000 |
| 3000 | $110,000 |

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## 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
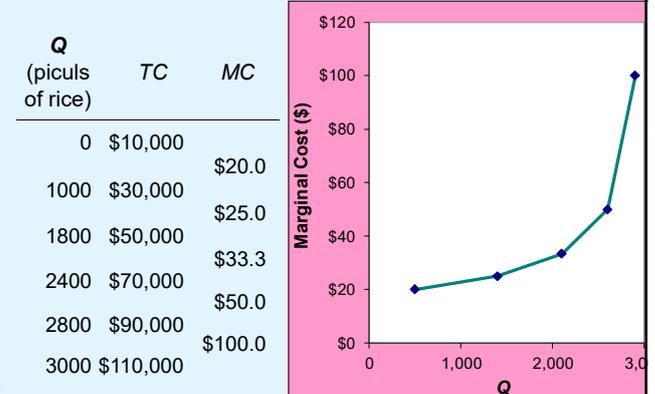    • From producing an additional unit of output

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## EXAMPLE 1: Total and Marginal Cost

| Q (piculs of rice) | Total Cost | | Marginal Cost (MC) |
|---|---|---|---|
| 0 | $10,000 | | |
| ΔQ = 1000 | | ΔTC = $20,000 | $20.0 |
| 1000 | $30,000 | | |
| ΔQ = 800 | | ΔTC = $20,000 | $25.0 |
| 1800 | $50,000 | | |
| ΔQ = 600 | | ΔTC = $20,000 | $33.3 |
| 2400 | $70,000 | | |
| ΔQ = 400 | | ΔTC = $20,000 | $50.0 |
| 2800 | $90,000 | | |
| ΔQ = 200 | | ΔTC = $20,000 | $100.0 |
| 3000 | $110,000 | | |

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## EXAMPLE 1: The Marginal Cost Curve

| Q (piculs of rice) | TC | MC |
|---|---|---|
| 0 | $10,000 | |
| | | $20.0 |
| 1000 | $30,000 | |
| | | $25.0 |
| 1800 | $50,000 | |
| | | $33.3 |
| 2400 | $70,000 | |
| | | $50.0 |
| 2800 | $90,000 | |
| | | $100.0 |
| 3000 | $110,000 | |

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## Why MC Is Important

- Farmer Jack is rational and wants to maximize his profit
  - To increase profit, should he produce more or less rice?
    - Farmer Jack needs to "think at the margin"
  - If the cost of additional rice (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 = $10,000 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 2: 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 2: 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 2: 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 | |

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

## EXAMPLE 2: 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 2: 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 |
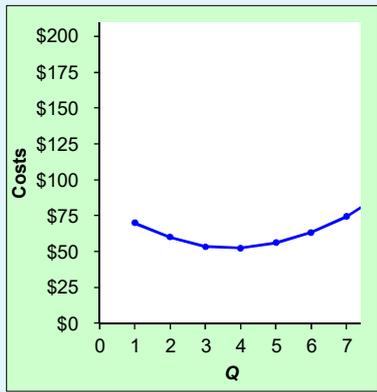
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## EXAMPLE 2: Average Total Cost

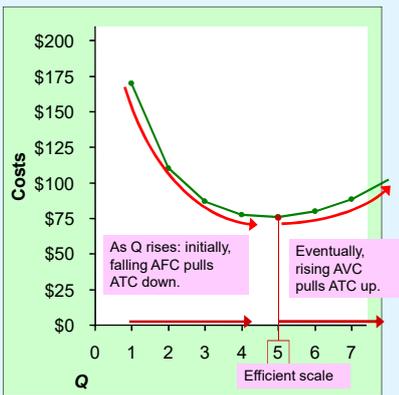| Q | TC | ATC | AFC | AVC |
|---|------|-------|-------|-------|
| 0 | $100 | n/a | n/a | n/a |
| 1 | 170 | $170 | $100 | $70 |
| 2 | 220 | 110 | 50 | 60 |
| 3 | 260 | 86.67 | 33.33 | 53.33 |
| 4 | 310 | 77.50 | 25 | 52.50 |
| 5 | 380 | 76 | 20 | 56.00 |
| 6 | 480 | 80 | 16.67 | 63.33 |
| 7 | 620 |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

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

$$ATC = TC/Q$$

Also,

$$ATC = AFC + AVC$$

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## EXAMPLE 2: 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 |



As Q rises: initially, falling AFC pulls ATC down.

Eventually, rising AVC pulls ATC up.

Efficient scale

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## EXAMPLE 2: The Various Cost Curves Together
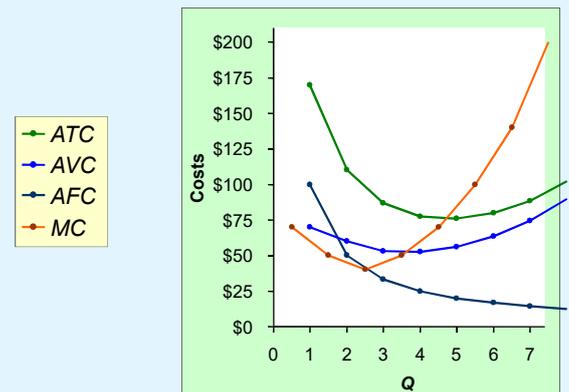


- ATC
- AVC
- AFC
- MC

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## 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.
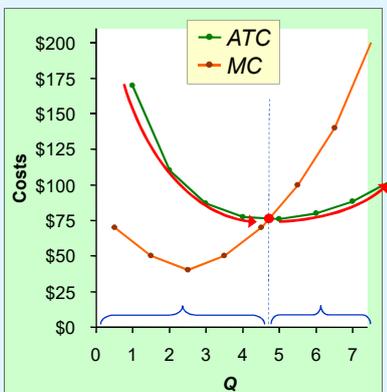


- ATC
- MC

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## 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 |      |
|   |     |      |       |      |        | $10 |
| 1 | 10 |      |       | $10 | $60.00 |      |
| 2 | 30 | 80 |       |      |        |      |
| 3 |     |      | 16.67 | 20 | 36.67 | 30 |
| 4 | 100 | 150 | 12.50 |      | 37.50 |      |
| 5 | 150 |      |       | 30 |        |      |
|   |     |      |       |      |        | 60 |
| 6 | 210 | 260 | 8.33 | 35 | 43.33 |      |

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## 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 | |
| | | | | | | $10 |
| 1 | 10 | 60 | $50.00 | $10 | $60.00 | |
| | | | | | | 20 |
| 2 | 30 | 80 | 25.00 | 15 | 40.00 | |
| | | | | | | 30 |
| 3 | 60 | 110 | 16.67 | 20 | 36.67 | |
| | | | | | | 40 |
| 4 | 100 | 150 | 12.50 | 25 | 37.50 | |
| | | | | | | 50 |
| 5 | 150 | 200 | 10.00 | 30 | 40.00 | |
| | | | | | | 60 |
| 6 | 210 | 260 | 8.33 | 35 | 43.33 | |

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## 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)
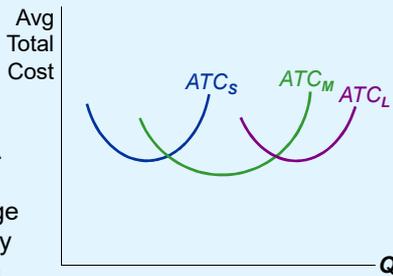
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## EXAMPLE 3: LRATC with 3 factory sizes

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

Each size has its own SRATC curve.

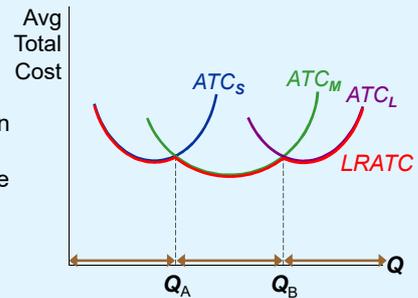The firm can change to a different factory size in the long run, but not in the short run.

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## 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.

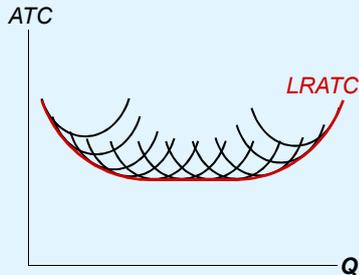To produce more than $Q_B$, firm will choose size L in the long run.

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## A Typical LRATC Curve

In the real world, factories come in many sizes, each with its own SRATC curve.
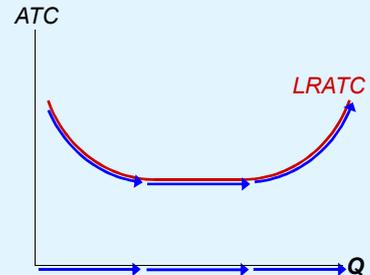
So a typical LRATC curve looks like this:

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## 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.

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## Costs in Short and Long Run

- Economies of scale
  - Long-run average total cost falls as the quantity of output increases
    - Increasing specialization among workers
    - More common when Q is low
- Constant returns to scale
  - Long-run average total cost stays the same as the quantity of output changes

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## Costs in Short and Long Run

- Diseconomies of scale
  - Long-run average total cost rises as the quantity of output increases
  - Increasing coordination problems in large organizations.
    - E.g., management becomes stretched, can't control costs.
    - More common when Q is high.

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## Summary

- The goal of firms is to maximize profit, which equals total revenue minus total cost.
- When analyzing a firm's behavior, it is important to include all the opportunity costs of production.
  - Explicit: wages a firm pays its workers
  - Implicit: wages the firm owner gives up by working at the firm rather than taking another job
- Economic profit takes both explicit and implicit costs into account, whereas accounting profit considers only explicit costs.

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## Summary

- A firm's costs reflect its production process.
  - Diminishing marginal product: production function gets flatter as Q of an input increases
  - Total-cost curve gets steeper as the quantity produced rises.
- Firm's total costs = fixed costs + variable costs.
  - Fixed costs: do not change when the firm alters the quantity of output produced.
  - Variable costs: change when the firm alters the quantity of output produced.

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## Summary

- Average total cost is total cost divided by the quantity of output.
- Marginal cost is the amount by which total cost rises if output increases by 1 unit.
- Graph average total cost and marginal cost.
  - Marginal cost rises with the quantity of output.
  - Average total cost first falls as output increases and then rises as output increases further.
  - The marginal-cost curve always crosses the average total-cost curve at the minimum of average total cost

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## Summary

- A firm's costs often depend on the time horizon considered.
  - In particular, many costs are fixed in the short run but variable in the long run.
  - As a result, when the firm changes its level of production, average total cost may rise more in the short run than in the long run.

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## Chapter 13: The Cost of Production

- ‣ Opportunity Cost (Explicit / Implicit)
  - ‣ Accounting Profit vs. Economic Profit
- ‣ Marginal Product
  - ‣ MC, TC = FC + VC, ATC = AFC+AVC
- ‣ Economies of Scale (for LR)

- ‣ Homework: Mankiw, Ch.13,
                    Problem 2, 4, 5, 7-9

## Chapter 13: The Cost of Production

- ‣ Challenge Questions (Past Finals)
  - ‣ 2007 - Part 1
  - ‣ 2008 - Essay C
  - ‣ 2012 - Part I
  - ‣ 2013 - Essay B
  - ‣ 2014 - Essay A1-4
  - ‣ 2015 - Essay B1-6
  - ‣ 2017 - Essay D5-D6