1.2 — Technology and Cost

ECON 326 • Industrial Organization • Spring 2023

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Outline

Short Run Production Concepts

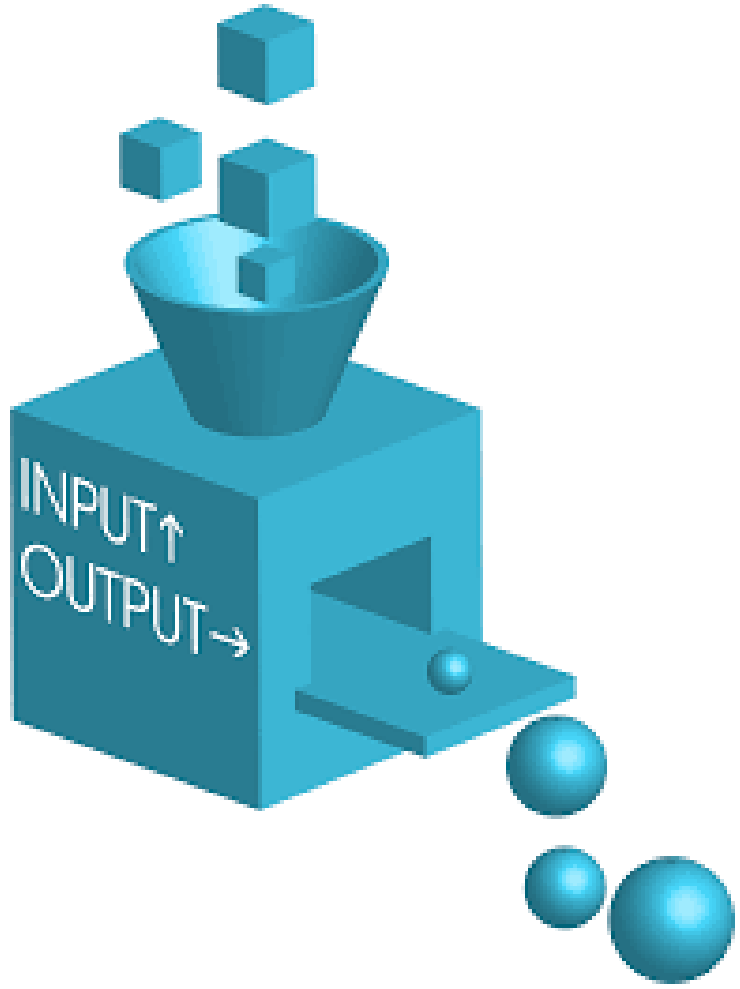
Costs in the Short Run

Costs in the Long Run

Revenues

This Black Box We Call "Firms"

- **Firm** is a mere **production process**:
  - a bundle of technology, physical assets, and individuals
- Synonymous with **production function**
- Fully replicable
- We'll explore (and explode) this much later



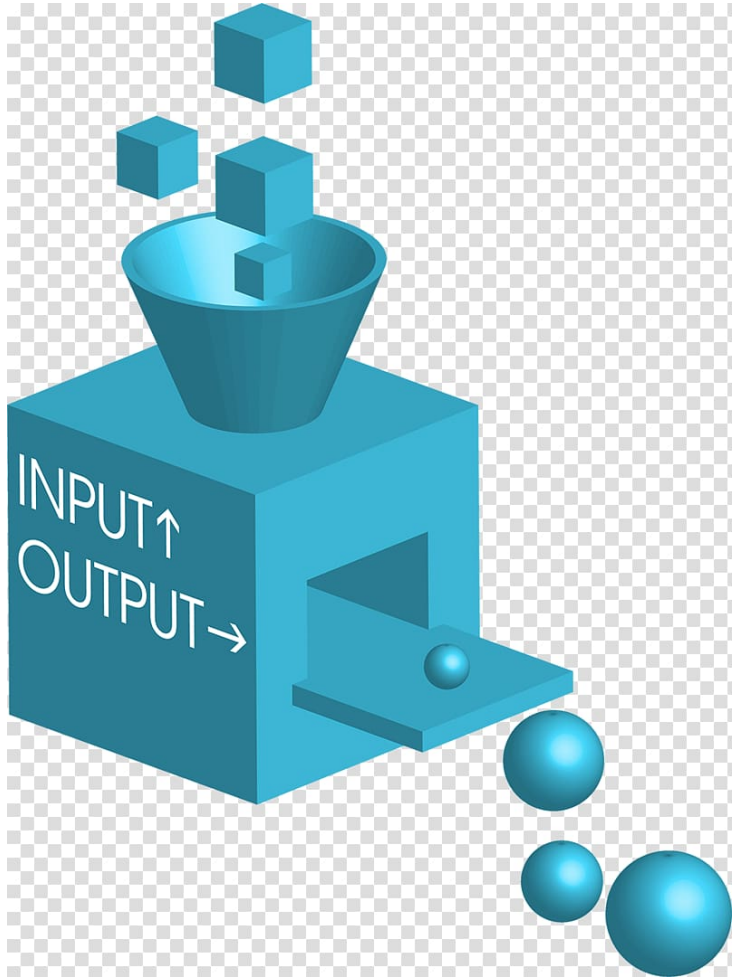
What Do Firms Do? I

- We'll assume “the firm” is the agent to model:
- So what do firms do?
- How would we set up an optimization model:

1. **Choose:** < some alternative >
2. **In order to maximize:** < some objective >
3. **Subject to:** < some constraints >

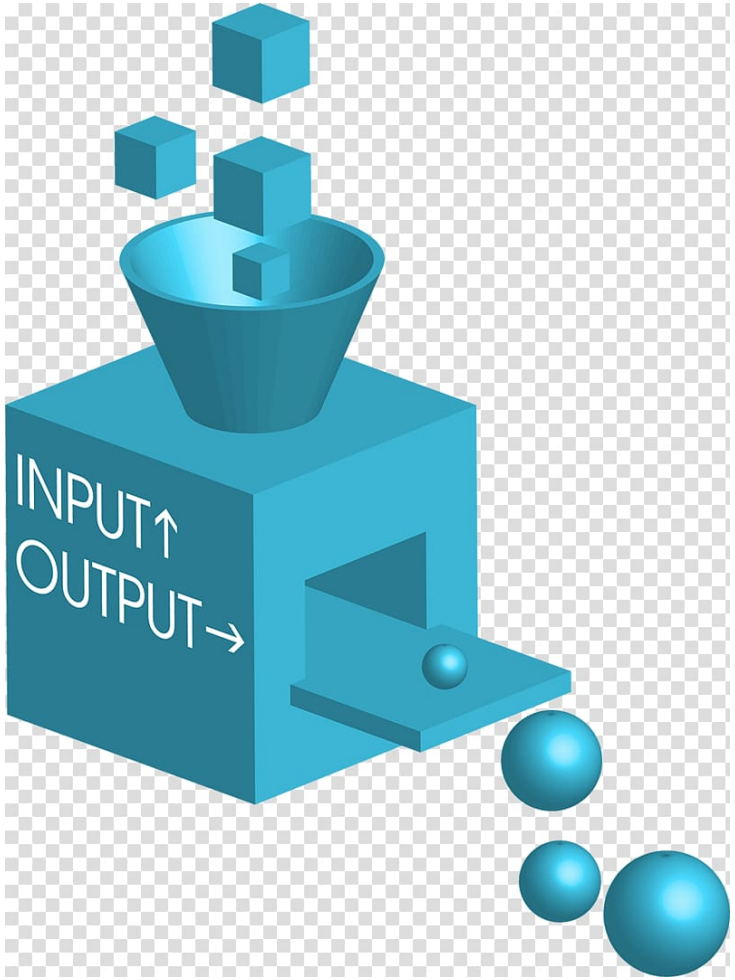
What Do Firms Do? II

- Firms convert some goods to other goods:



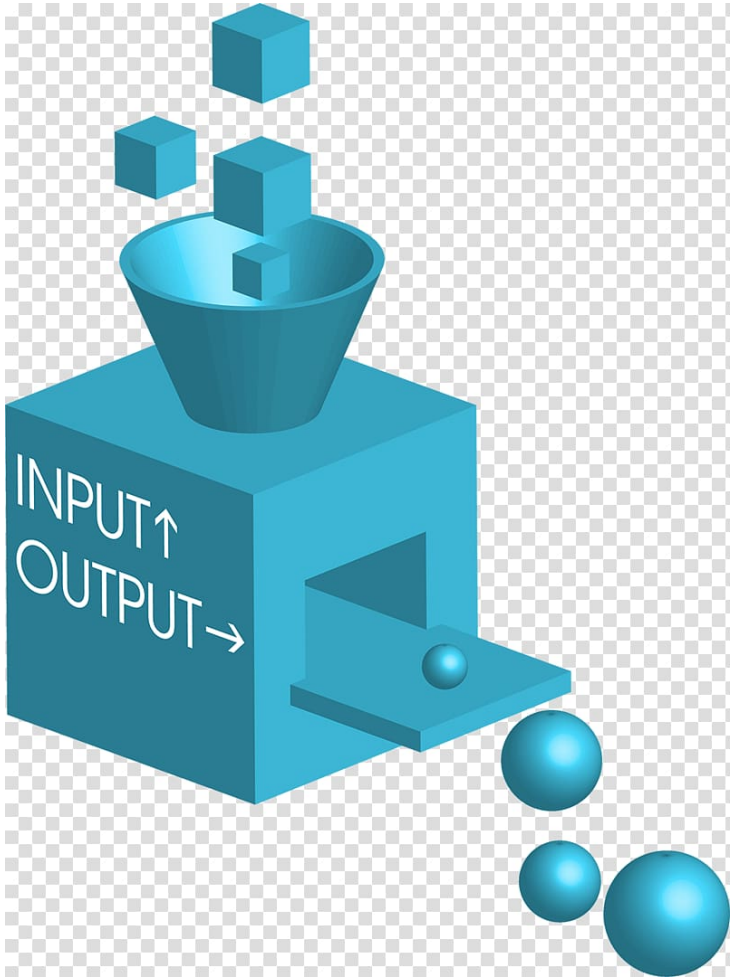
What Do Firms Do? II

- Firms convert some goods to other goods:
- **Inputs**: $x_1, x_2, \cdots, x_n$
    - **Examples**: worker efforts, warehouse space, electricity, loans, oil, cardboard, fertilizer, computers, software programs, etc



What Do Firms Do? II

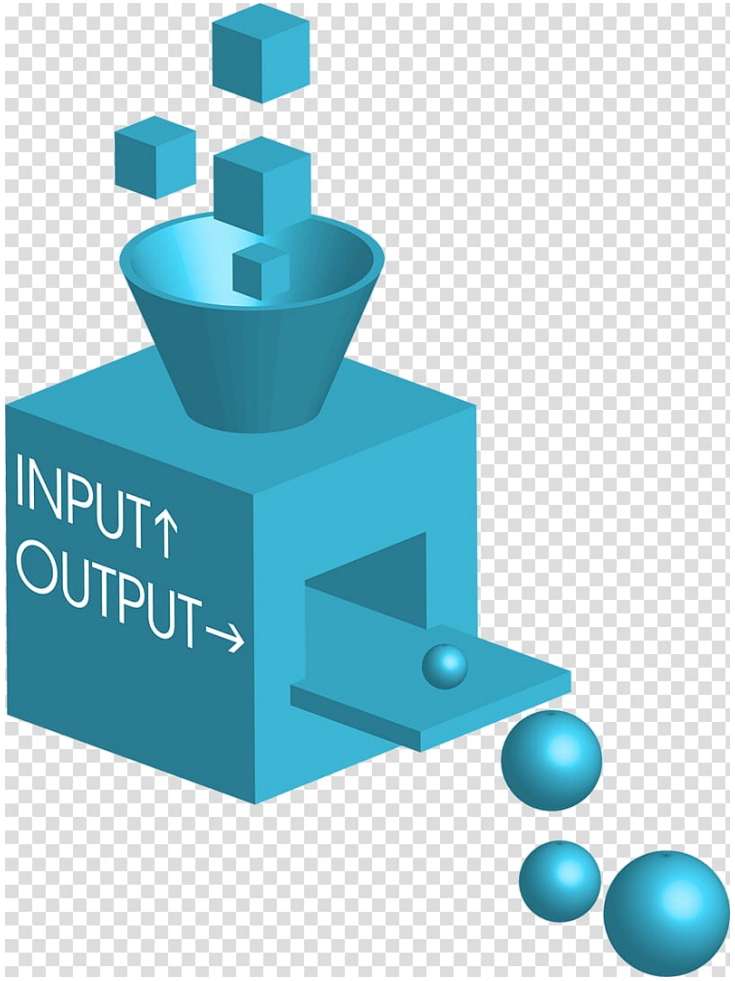
- Firms convert some goods to other goods:
- **Inputs**: $x_1, x_2, \cdots, x_n$
    - **Examples**: worker efforts, warehouse space, electricity, loans, oil, cardboard, fertilizer, computers, software programs, etc
- **Output**: q
    - **Examples**: gas, cars, legal services, mobile apps, vegetables, consulting advice, financial reports, etc



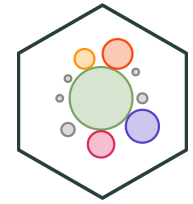
What Do Firms Do? III

- **Technology** or a **production function**: rate at which firm can convert specified **inputs** $(x_1, x_2, \cdots, x_n)$ into **output** (q)

$$q = f(x_1, x_2, \cdots, x_n)$$



Production Function as Recipe



The production function

READY IN: 1hr 20mins

YIELD: 2 loaves | UNITS: US

INGREDIENTS Nutrition

5	cups all-purpose white flour
2	tablespoons yeast (or 2 x 7g pkts)
2	teaspoons sugar
1	teaspoon salt
2	cups warm-hot water
¼	cup cooking oil

The production algorithm

DIRECTIONS

Put 4 cups of the flour, yeast, sugar and salt into large bowl.

Pour in hot water and oil and mix until combined- it will be sticky.

Add the remaining flour in increments until dough is no longer sticky.

Knead for about 5 minutes until dough is elastic and smooth.

Place dough back into bowl and cover with a damp teatowel and let it rise until double its size- about 1/2 hour.

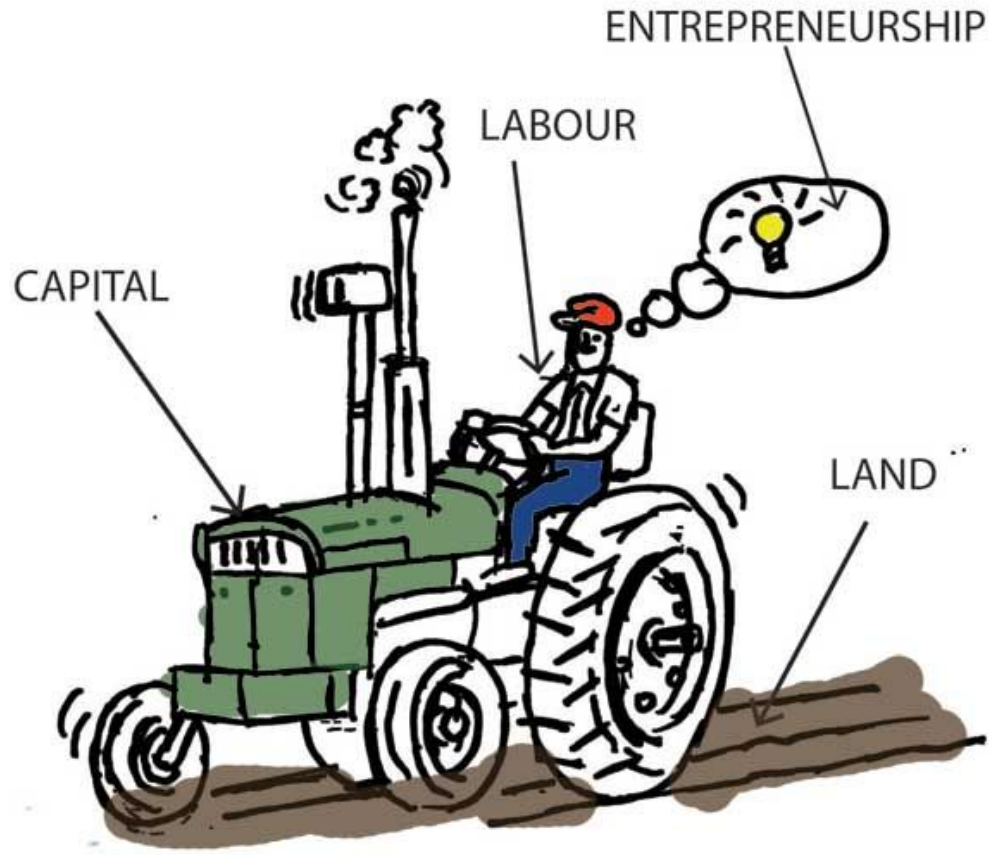
Factors of Production I

$$q = A\, f(t, l, k)$$

- Economists typically classify inputs, called the **"factors of production" (FOP)**:

Factor	Owned By	Earns
Land (t)	Landowners	Rent
Labor (l)	Laborers	Wages
Capital (k)	Capitalists	Interest

- A: **"total factor productivity"** (ideas/knowledge/institutions)

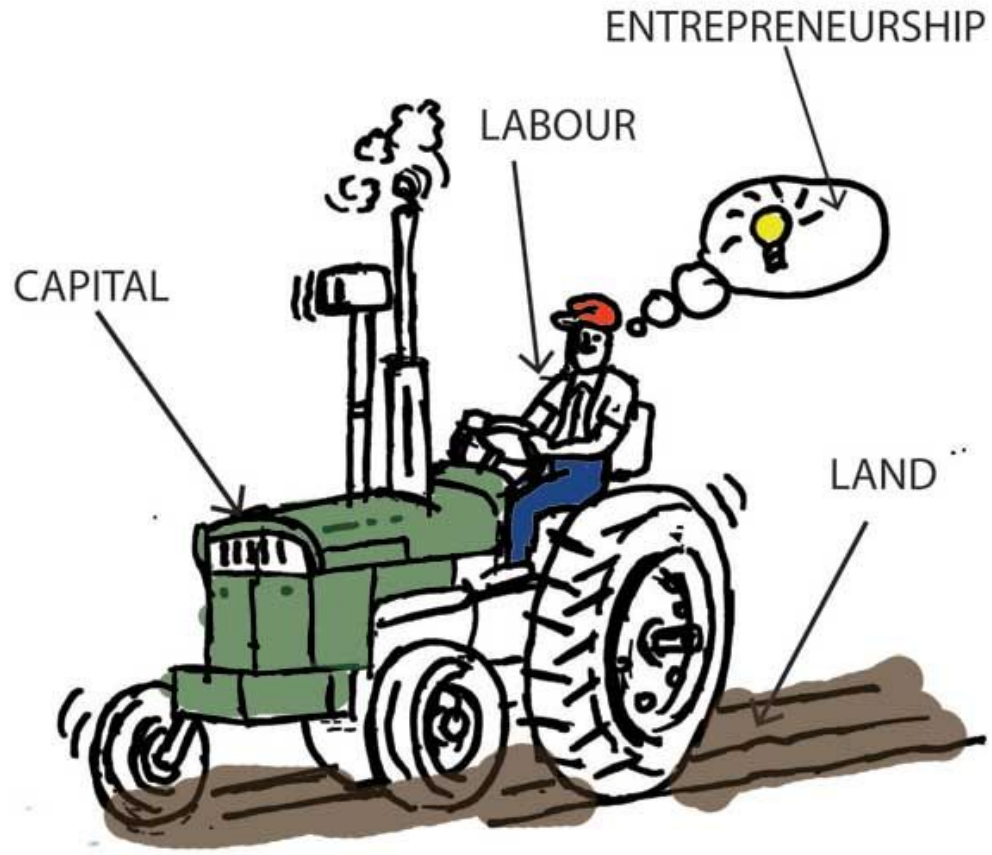


Factors of Production II

$$q = f(l, k)$$

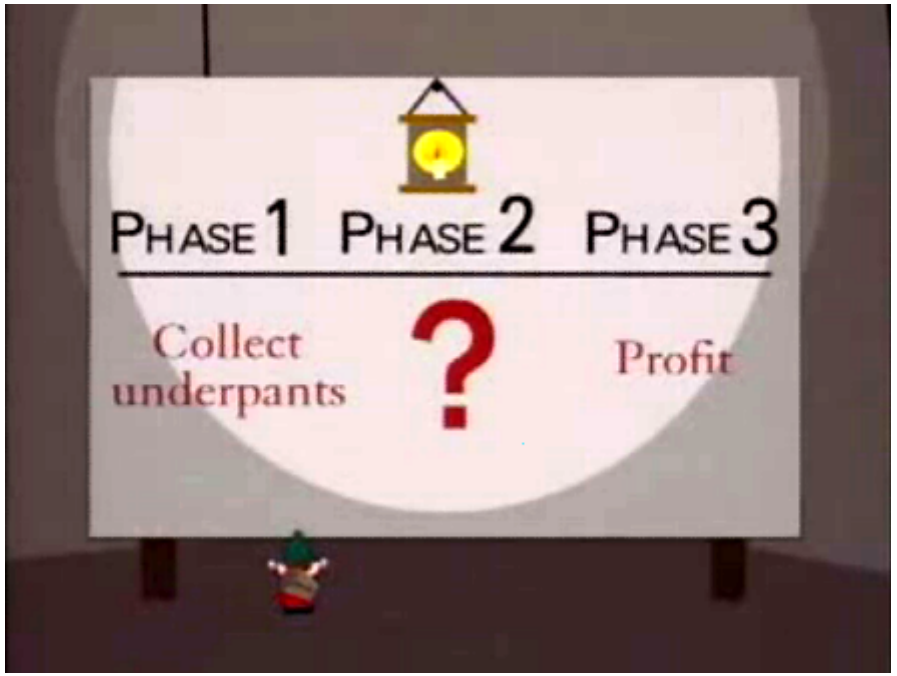
- We will assume just two inputs: labor l and capital k

Factor	Owned By	Earns
Labor (l)	Laborers	Wages
Capital (k)	Capitalists	Interest



What Does a Firm Maximize?

- We assume firms **maximize profit** (π)
- Not true for all firms
  - **Examples**: non-profits, charities, civic associations, government agencies, criminal organizations, etc
- Even profit-seeking firms may also want to maximize *additional* things
  - **Examples**: goodwill, sustainability, social responsibility, etc



Profits Have a Bad Rap These Days

What is Profit?

- In economics, **profit** is simply **benefits minus (opportunity) costs**

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- Suppose firm sells **output** q at price p
- It can buy each **input** x_i at an associated price p_i, i.e.
  - labor l at wage rate w
  - capital k at rental rate r

What is Profit?

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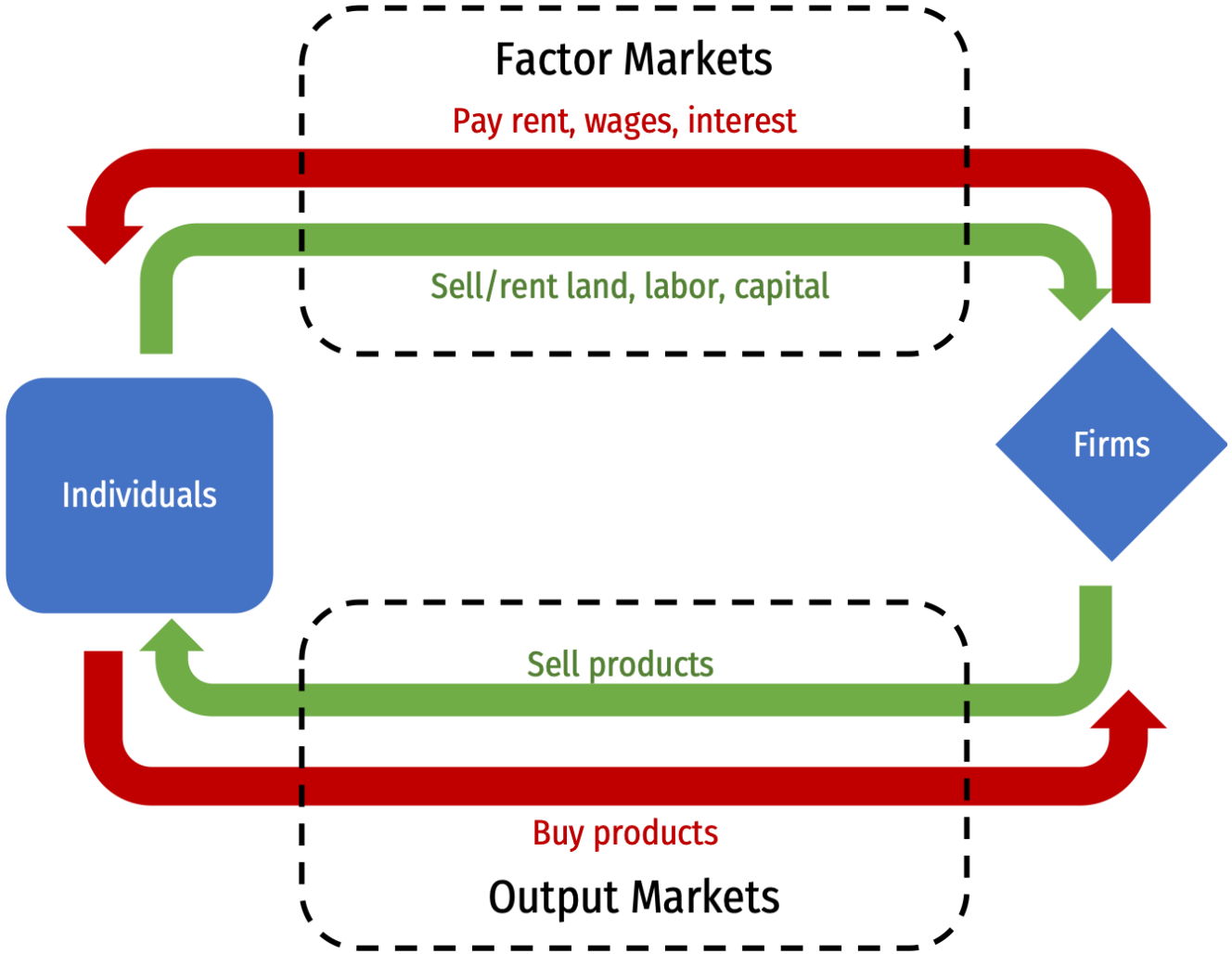
- Suppose firm sells **output** q at price p
- It can buy each **input** x_i at an associated price p_i, i.e.
  - labor l at wage rate w
  - capital k at rental rate r
- The profit of selling q units and using inputs l, k is:

Who Gets the Profits? I

$$\pi = \underbrace{pq}_{revenues} - \underbrace{(wl + rk)}_{costs}$$

Reminder from Macroeconomics: "The Circular Flow"



Who Gets the Profits? I

$$\pi = \underbrace{pq}_{revenues} - \underbrace{(wl + rk)}_{costs}$$

- **The firm's costs are all of the factor-owner's incomes!**
  - Landowners, laborers, creditors are all paid rent, wages, and interest, respectively

Who Gets the Profits? I

$$\pi = \underbrace{pq}_{revenues} - \underbrace{(wl + rk)}_{costs}$$

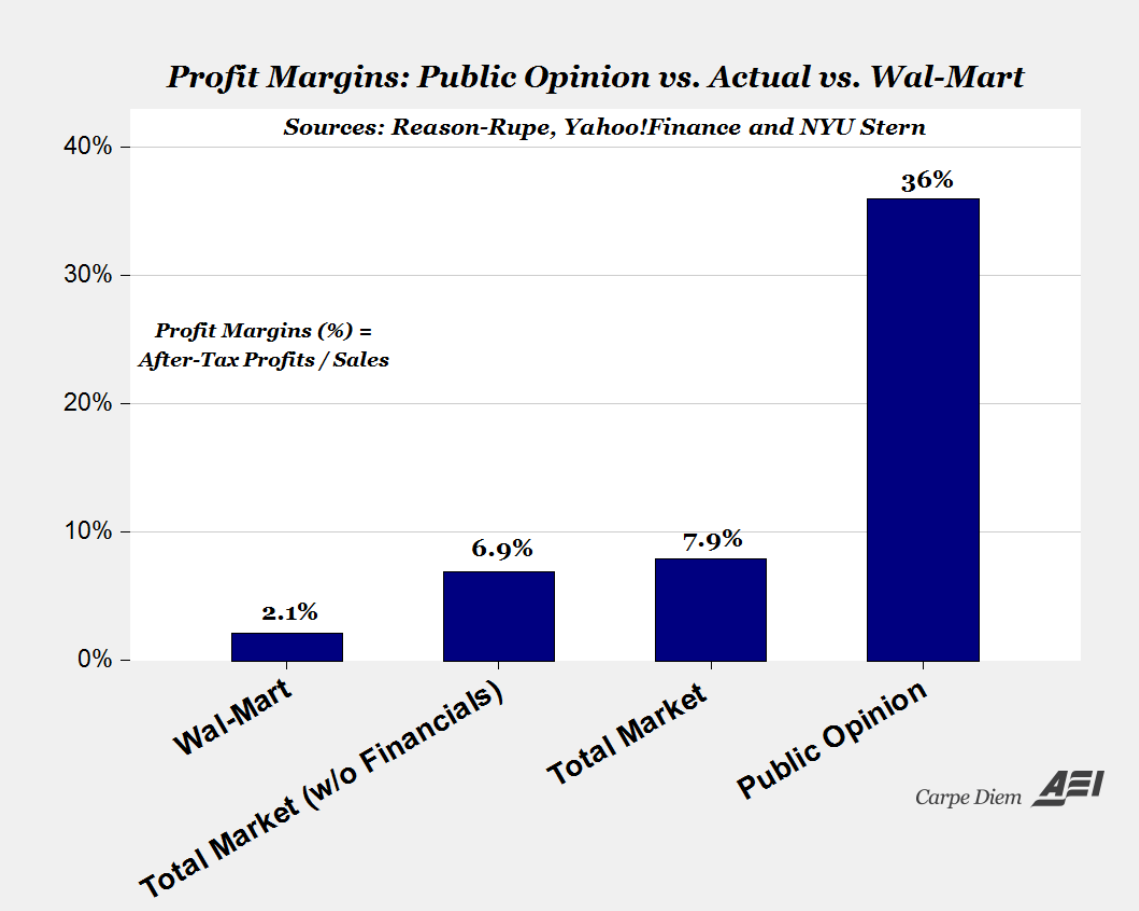
- Profits are the **residual value** leftover after paying all factors
- Profits are income for the **residual claimant(s)** of the production process (i.e. **owner(s)** of a firm):
  - Entrepreneurs
  - Shareholders

Who Gets the Profits? II

$$\pi = \underbrace{pq}_{revenues} - \underbrace{(wl + rk)}_{costs}$$

- Residual claimants have incentives to maximize firm's profits, as this *maximizes their own income*
- Entrepreneurs and shareholders are the only participants in production that are *not* guaranteed an income!
    - Starting and owning a firm is inherently **risky**!

People Overestimate Profits



Source: American Enterprise Institute

Profits and Entrepreneurship: A Preview

- In markets, production must face the **profit test**:
  - **Is consumer's willingness to pay > opportunity cost of inputs?**
- Profits are an indication that **value is being created for society**
- Losses are an indication that **value is being destroyed for society**
- Survival in markets *requires* firms continually create value & earn profits

The Firm's Optimization Problem I

- So what do firms do?

1. **Choose:** < some alternative >

2. **In order to maximize:** < profits >

3. **Subject to:** < technology >

- We've so far assumed they maximize profits and they are limited by their technology

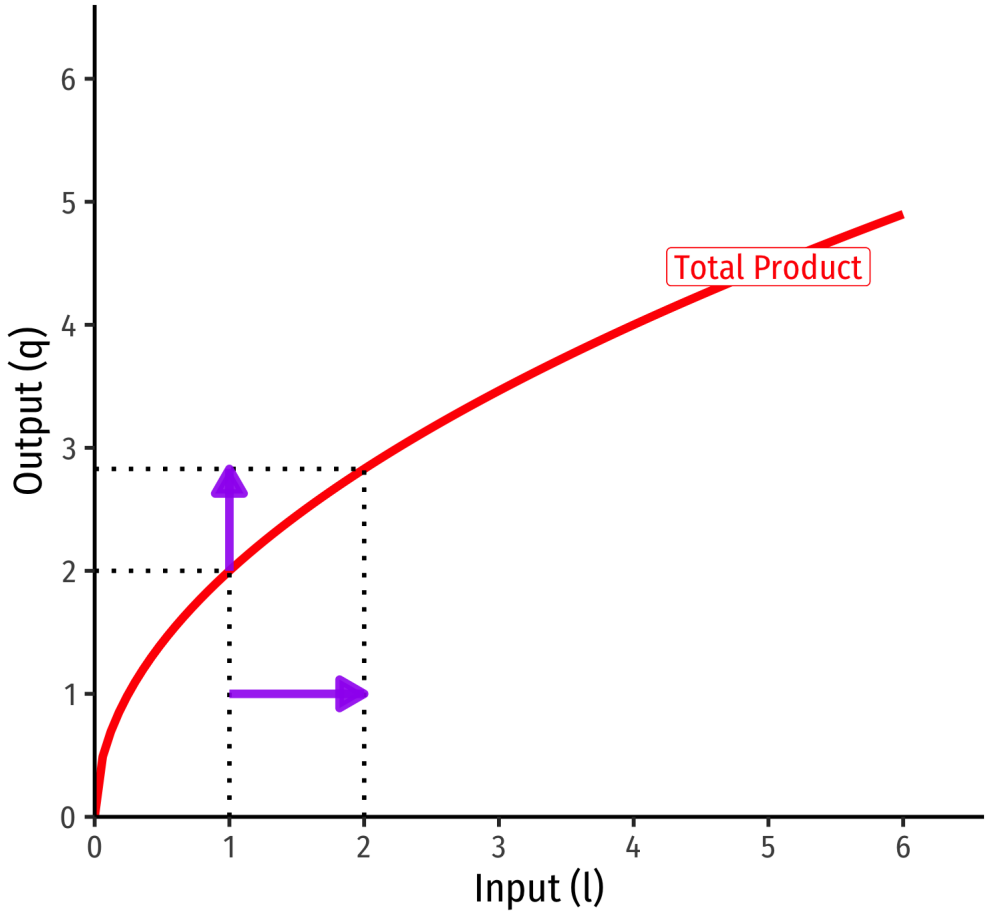
The Firm's Optimization Problem II

- What do firms **choose**? (Not an easy answer)
- Prices?
    - Depends on the market the firm is operating in!
    - Study of **industrial organization**
- Essential question: **how competitive is a market?** This will influence what firms (can) do

Short-Run Production Concepts

Marginal Products

- The **marginal product** of an input is the *additional* output produced by *one more unit* of that input (*holding all other inputs constant*)
- Like marginal utility
- Similar to marginal utilities, I will give you the marginal product equations



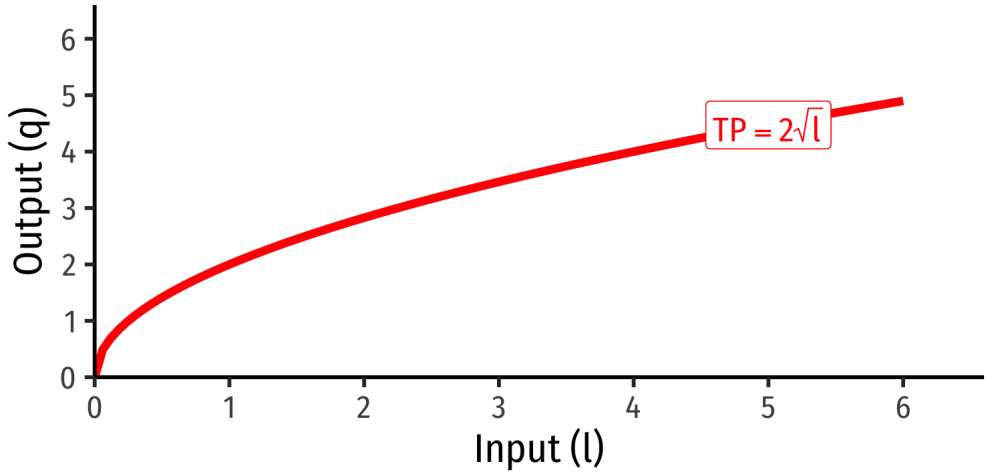
Technology: $q(l, \bar{k}) = 2\sqrt{l}$

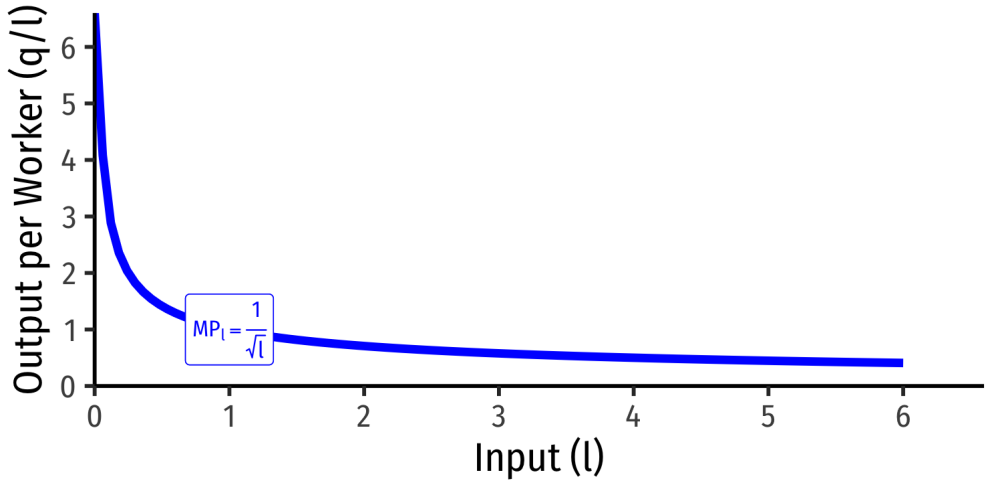
Marginal Product of Labor

- **Marginal product of labor** (MP_l): additional output produced by adding one more unit of labor (holding k constant)

$$MP_l = \frac{\Delta q}{\Delta l}$$

- MP_l is slope of TP at each value of l!
  - Note: via calculus: $\frac{\partial q}{\partial l}$



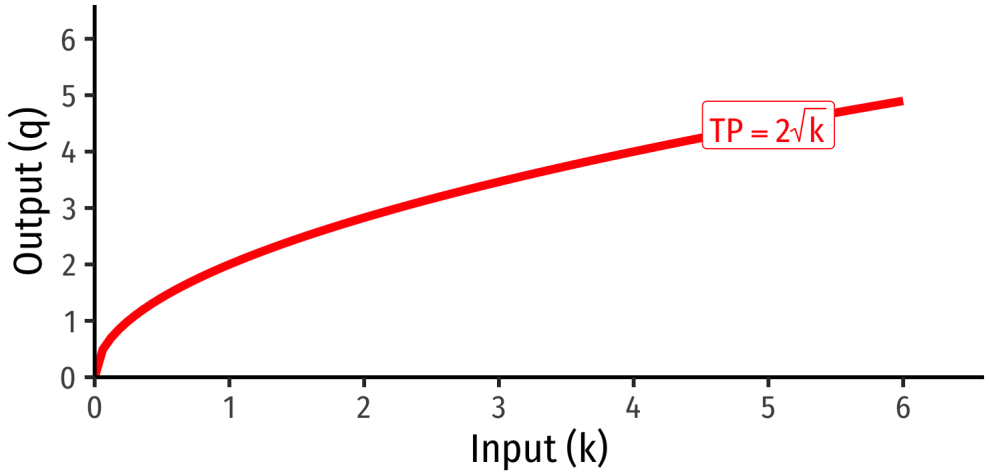


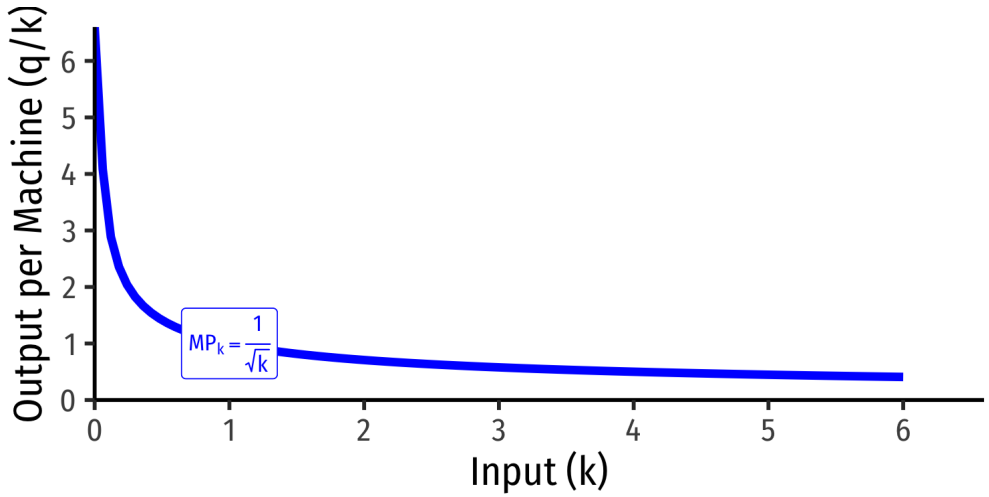
Marginal Product of Capital

- **Marginal product of capital** (MP_k): additional output produced by adding one more unit of capital (holding l constant)

$$MP_k = \frac{\Delta q}{\Delta k}$$

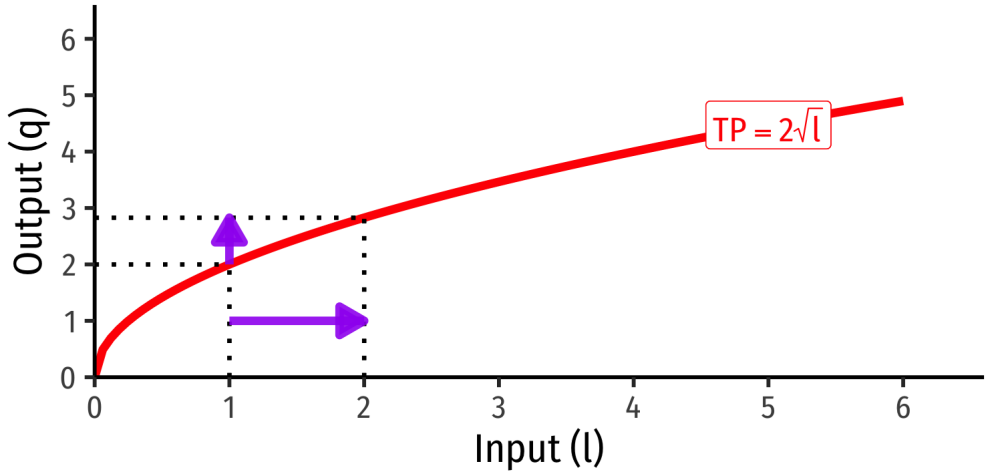
- MP_k is slope of TP at each value of k!
  - Note: via calculus: $\frac{\partial q}{\partial k}$
- Note we don't consider capital in the short run!

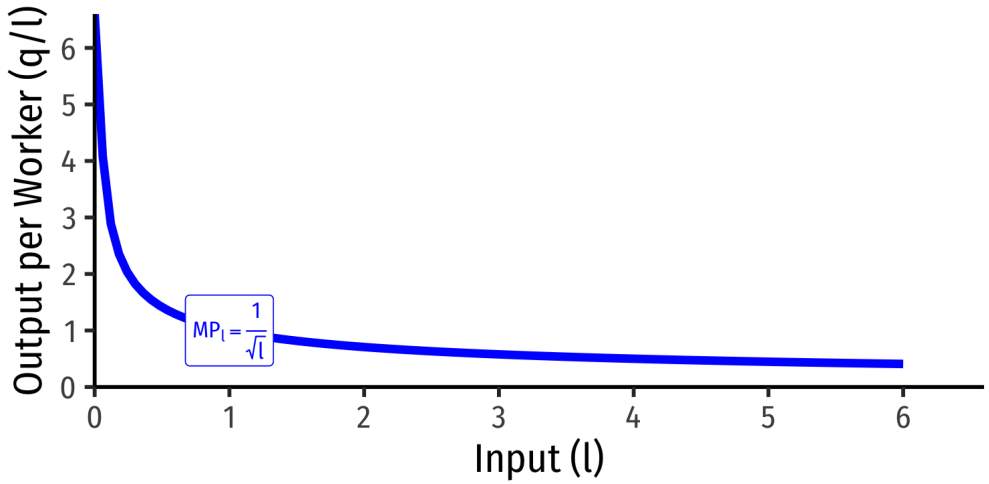




Diminishing Returns

- **Law of Diminishing Returns**: adding more of one factor of production **holding all others constant** will result in successively lower increases in output
- In order to increase output, firm will need to increase *all* factors!





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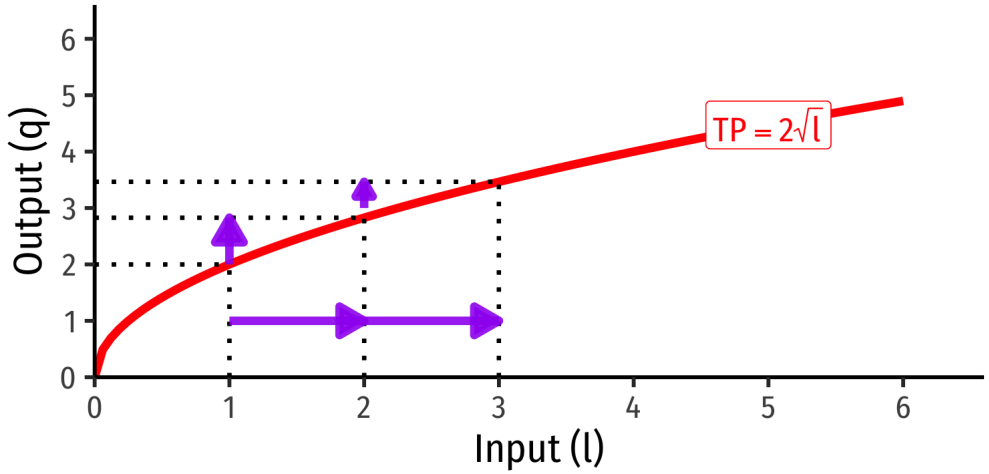
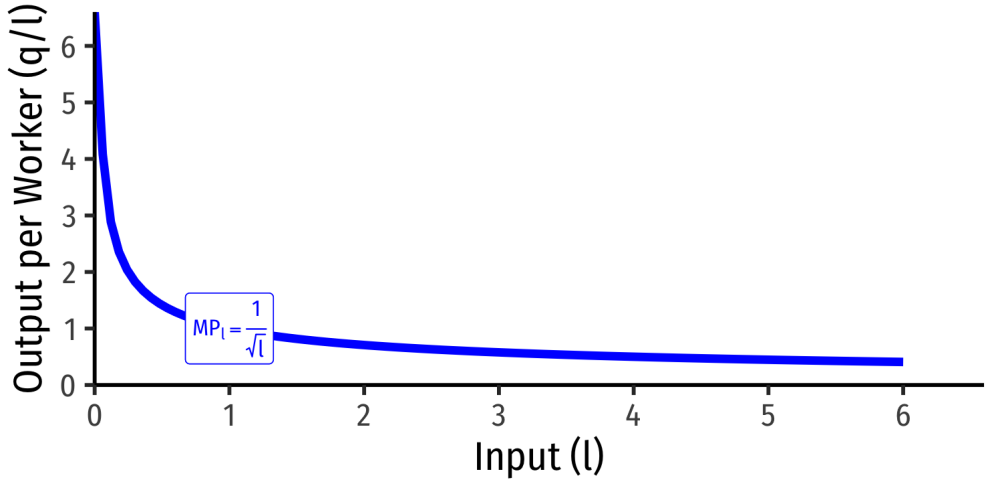




Average Product of Labor (and Capital)

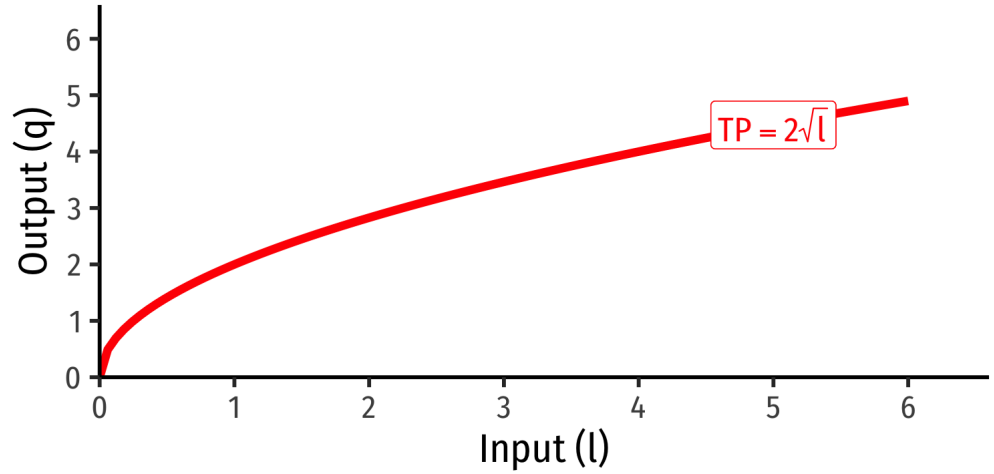
- **Average product of labor** (AP_l): total output per worker

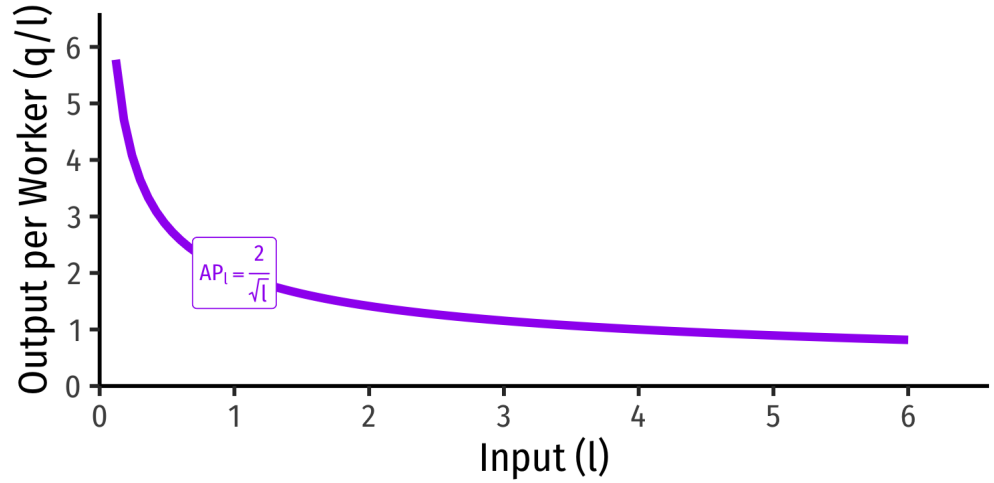
$$AP_l = \frac{q}{l}$$

- A measure of *labor productivity*

- **Average product of capital** (AP_k): total output per unit of capital

$$AP_k = \frac{q}{k}$$





The Firm's Problem: Long Run

The Long Run

- In the long run, *all* factors of production are **variable**

$$q = f(k, l)$$

- Can build more factories, open more storefronts, rent more space, invest in machines, etc.

- So the firm can choose both l *and* k

Production Costs are Opportunity Costs

- Remember, **economic costs** are broader than the common conception of “cost”
  - **Accounting cost**: monetary cost
  - **Economic cost**: value of next best alternative use of resources given up (i.e. **opportunity cost**)

Production Costs are Opportunity Costs

- This leads to the difference between:
  - **Accounting profit**: revenues minus accounting costs
  - **Economic profit**: revenues minus accounting + opportunity costs
- A really difficult concept to think about!

Production Costs are Opportunity Costs

- Another helpful perspective:
  - **Accounting cost**: what you **historically** paid for a resource
  - **Economic cost**: what you can **currently** get in the market for a selling a resource (it's value in *alternative* uses)

A Reminder: It's Demand all the Way Down!

- **Supply** is actually **Demand** in disguise!
- An **(opportunity) cost** to buy (scarce) inputs for production because **other people demand** those same inputs to consume or produce **other valuable things**!
    - Price necessary to **pull them out of other valuable productive uses** in the economy!

Production Costs are Opportunity Costs

- Because resources are scarce, and have rivalrous uses, **how do we know we are using resources efficiently??**
- In functioning markets, **the market price measures the opportunity cost of using a resource for an alternative use**
- Firms not only pay for direct use of a resource, but also indirectly compensate society for *"pulling the resource out"* of alternate uses in the economy!

Production Costs are Opportunity Costs

- Every choice incurs an opportunity cost

Examples:

- If you start a business, you may give up your salary at your current job
- If you invest in a factory, you give up other investment opportunities
- If you use an office building you own, you cannot rent it to other people
- If you hire a skilled worker, you must pay them a high enough salary to deter them from working for other firms

Opportunity Costs vs. Sunk Costs

- Opportunity cost is a *forward-looking* concept
- Choices made in the *past* with *non-recoverable* costs are called **sunk costs**
- Sunk costs *should not* enter into future decisions
- Many people have difficulty letting go of unchangeable past decisions: **sunk cost fallacy**

Common Sunk Costs in Business

- Licensing fees, long-term lease contracts
- Specific capital (with no alternative use): uniforms, menus, signs
- Research & Development spending
- Advertising spending

The Accounting vs. Economic Point of View I

- Helpful to consider two points of view:

1. **"Accounting point of view"**: are you taking in more cash than you are spending?

2. **"Economic point of view"**: is your product you making the *best social* use of your resources

    - i.e. are there higher-valued uses of your resources you are keeping them out of?

The Accounting vs. Economic Point of View II

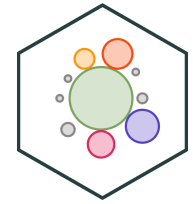
- **Implications for society**: are consumers *best* off with you using scarce resources (with alternative uses!) to produce your current product?

- Remember: **this is an *economics* course, not a *business* course**!

    - **Economists are pro-market, *not* pro-business!**
    - What might be good/bad for **one** business might have bad/good *consequences* for society!

Costs in the Short Run

Costs in the Short Run



- **Total cost function,** $C(q)$ relates output q to the total cost of production C[†]

$$C(q) = f + VC(q)$$

- Two kinds of short run costs:

1. Fixed costs, f are costs that do not vary with output

- Only true in the short run! (Consider this the cost of maintaining your capital)

2. Variable costs, $VC(q)$ are costs that vary with output (notice the variable in them!)

- Typically, the more production of q, the higher the cost
- e.g. firm is hiring *additional* labor

[†] Assuming that (i) firms are always choosing input combinations that minimize total cost and (ii) input prices are constant. See more in today's appendix.

Fixed vs. Variable costs: Examples

Example: Airlines

Fixed costs: the aircraft, regulatory approval

Variable costs: providing one more flight

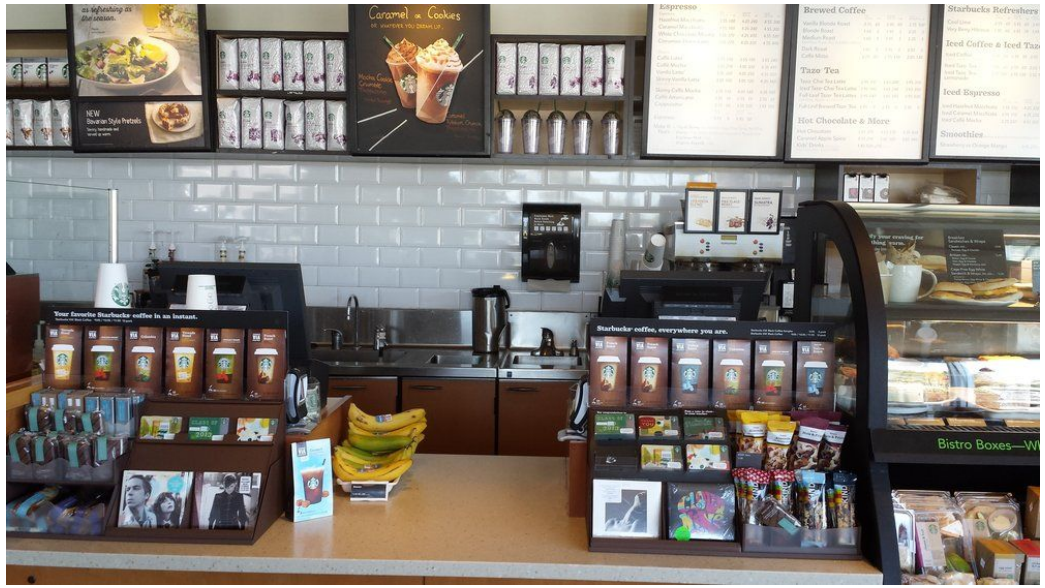
Fixed vs. Variable costs: Examples

Example: Car Factory

Fixed costs: the factory, machines in the factory

Variable costs: producing one more car

Fixed vs. Variable costs: Examples



Example: Starbucks

Fixed costs: the retail space, espresso machines

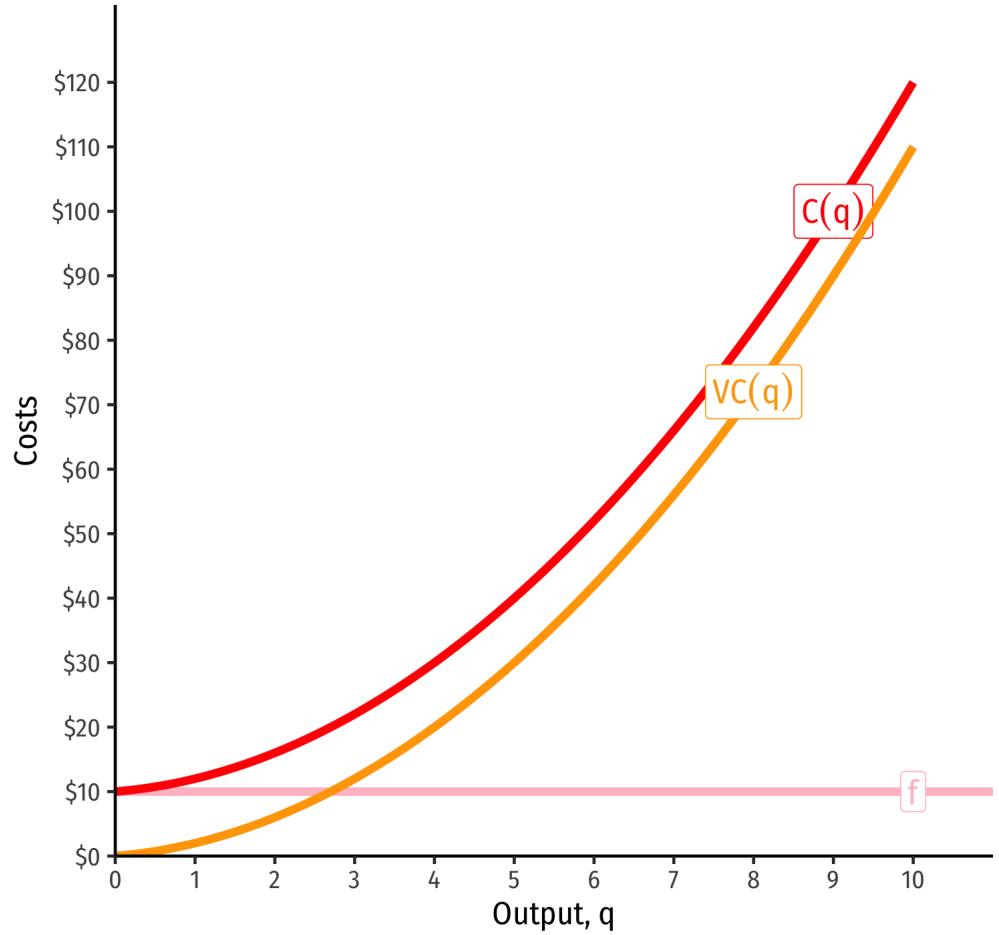
Variable costs: selling one more cup of coffee

Fixed vs. Sunk costs

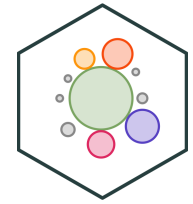
- Diff. between **fixed** vs. **sunk** costs?
- **Sunk costs** are a *type* of **fixed cost** that are *not* avoidable or recoverable
- Many **fixed costs** can be avoided or changed in the long run
- Common **fixed**, but *not* **sunk**, costs:
    - rent for office space, durable equipment, operating permits (that are renewed)
- When deciding to *stay* in business, **fixed costs** matter, **sunk costs** do not!

Cost Functions: Example, Visualized

q	f	$VC(q)$	$C(q)$
0	10	0	10
1	10	2	12
2	10	6	16
3	10	12	22
4	10	20	30
5	10	30	40
6	10	42	52
7	10	56	66
8	10	72	82
9	10	90	100
10	10	110	120



Average Costs



- **Average Fixed Cost**: fixed cost per unit of output:

$$AFC(q) = \frac{f}{q}$$

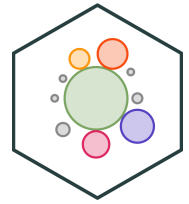
- **Average Variable Cost**: variable cost per unit of output:

$$AVC(q) = \frac{VC(q)}{q}$$

- **Average (Total) Cost**: (total) cost per unit of output:

$$AC(q) = \frac{C(q)}{q}$$

Marginal Cost



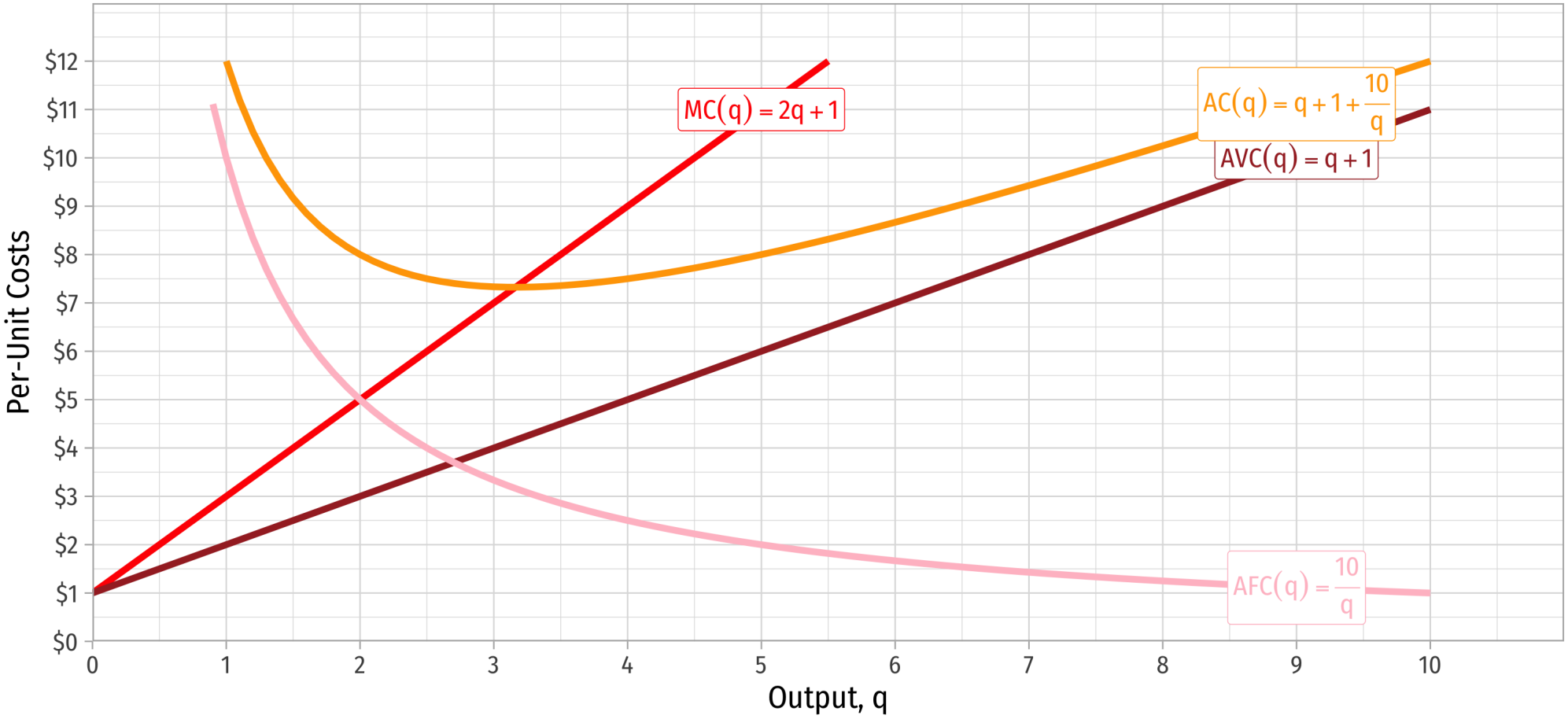
- **Marginal Cost** is the change in total cost for each additional unit of output produced:

$$MC(q) = \frac{\Delta C(q)}{\Delta q}$$

- Calculus: first derivative of the cost function

- **Marginal cost is the *primary* cost that matters in making decisions**
  - All other costs are driven by marginal costs
  - This is the main cost that firms can "see"

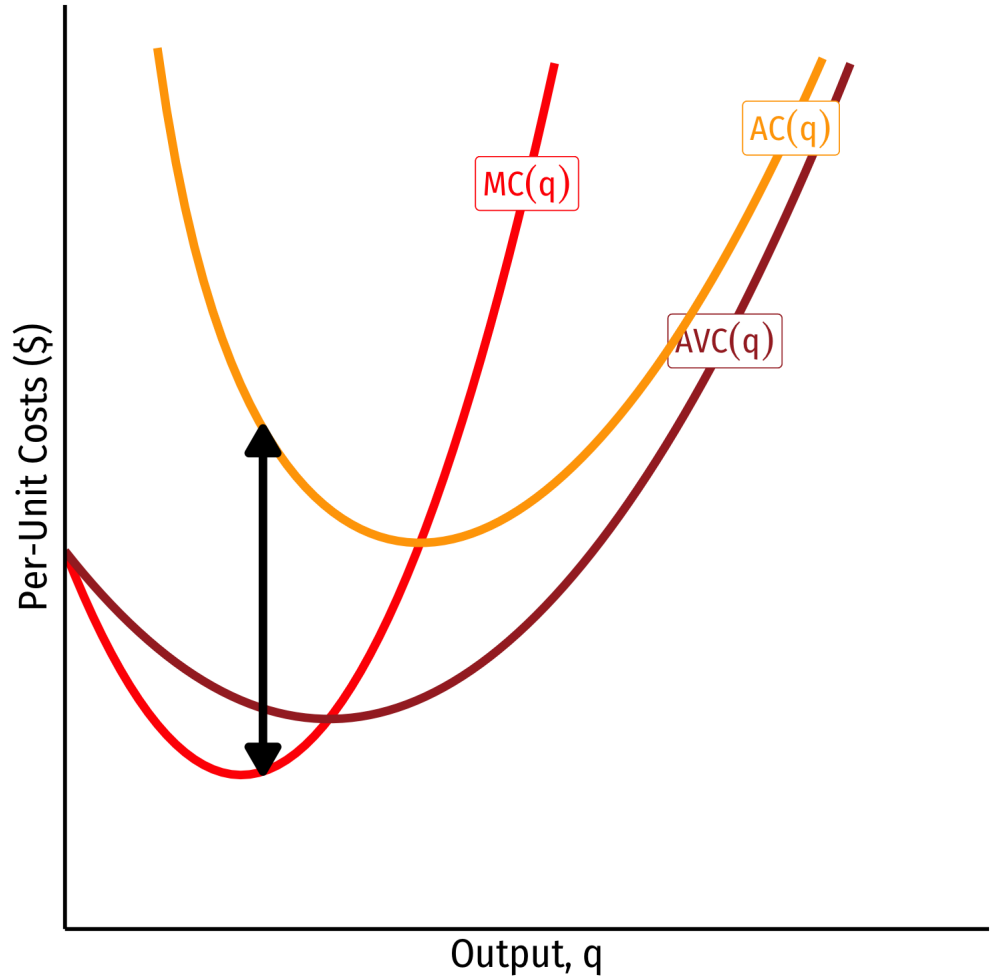
Average and Marginal Costs: Visualized



$C(q) = q^2 + q + 10$

Relationship Between Marginal and Average

- Mathematical relationship between a marginal & an average value
- If marginal $<$ average, then average $\downarrow$



Relationship Between Marginal and Average

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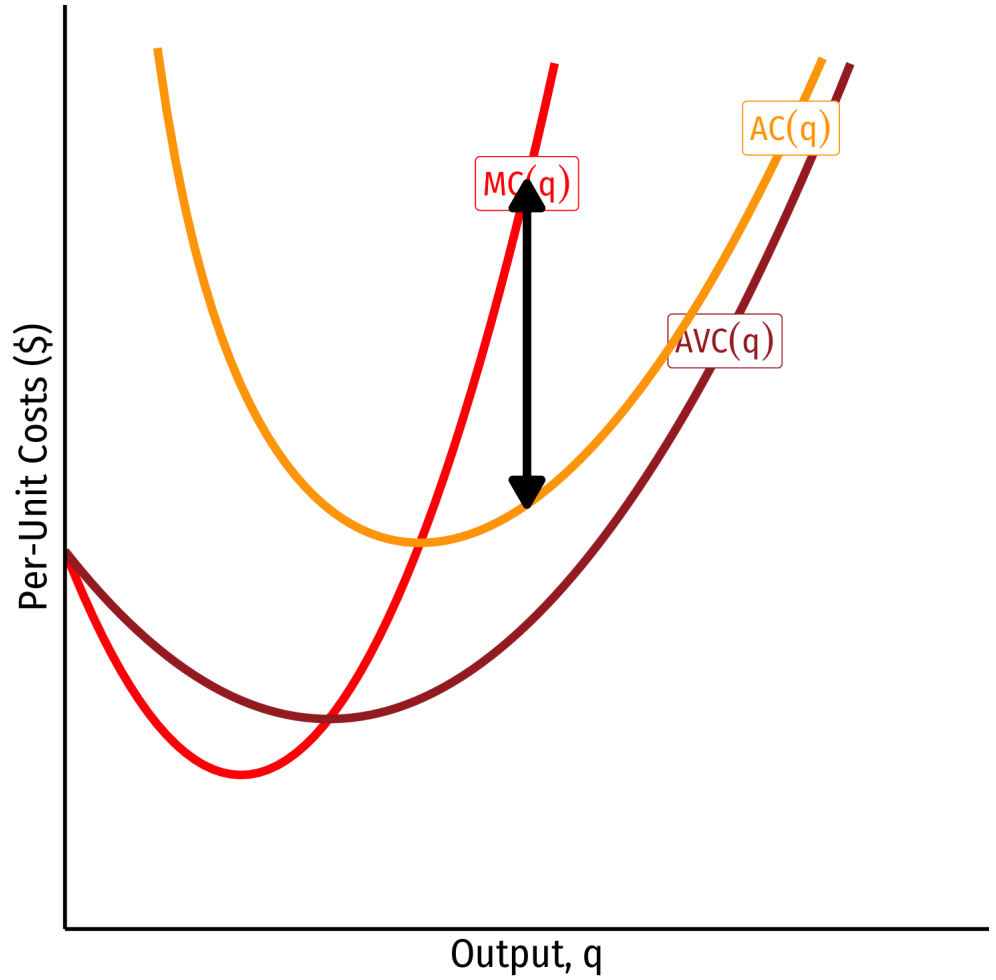
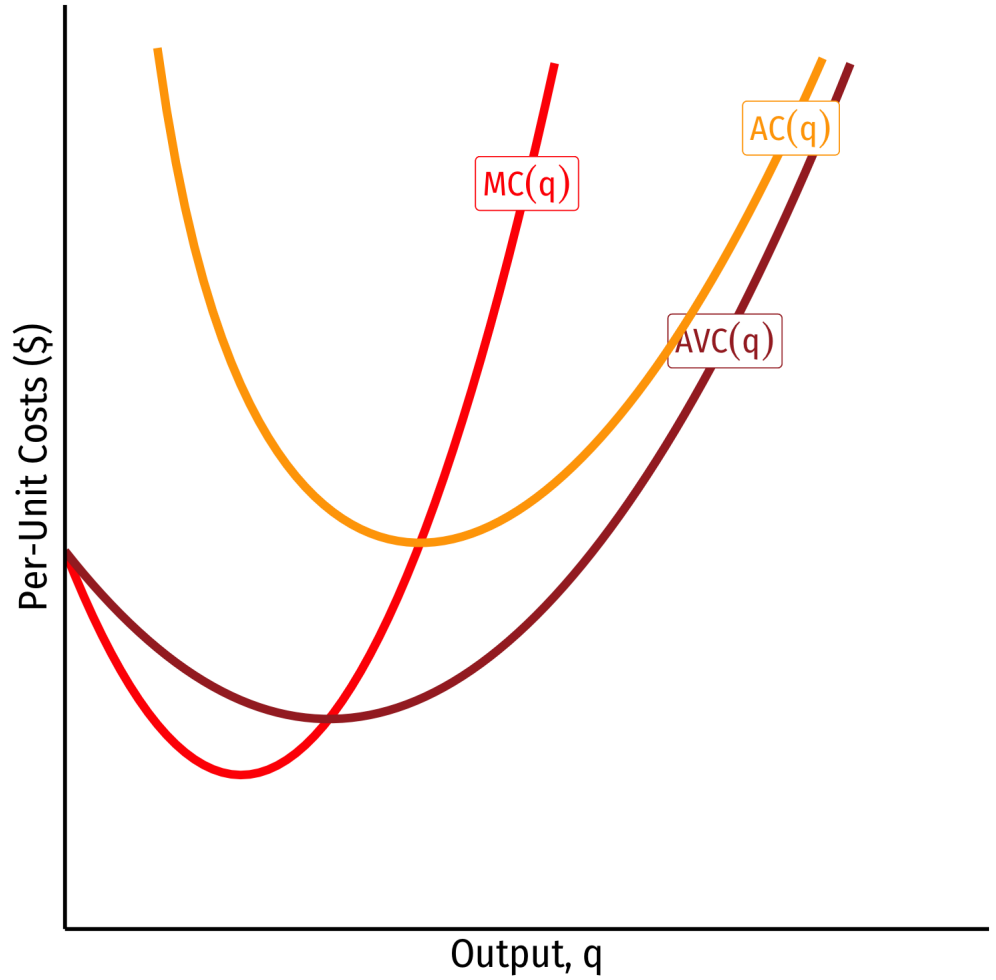


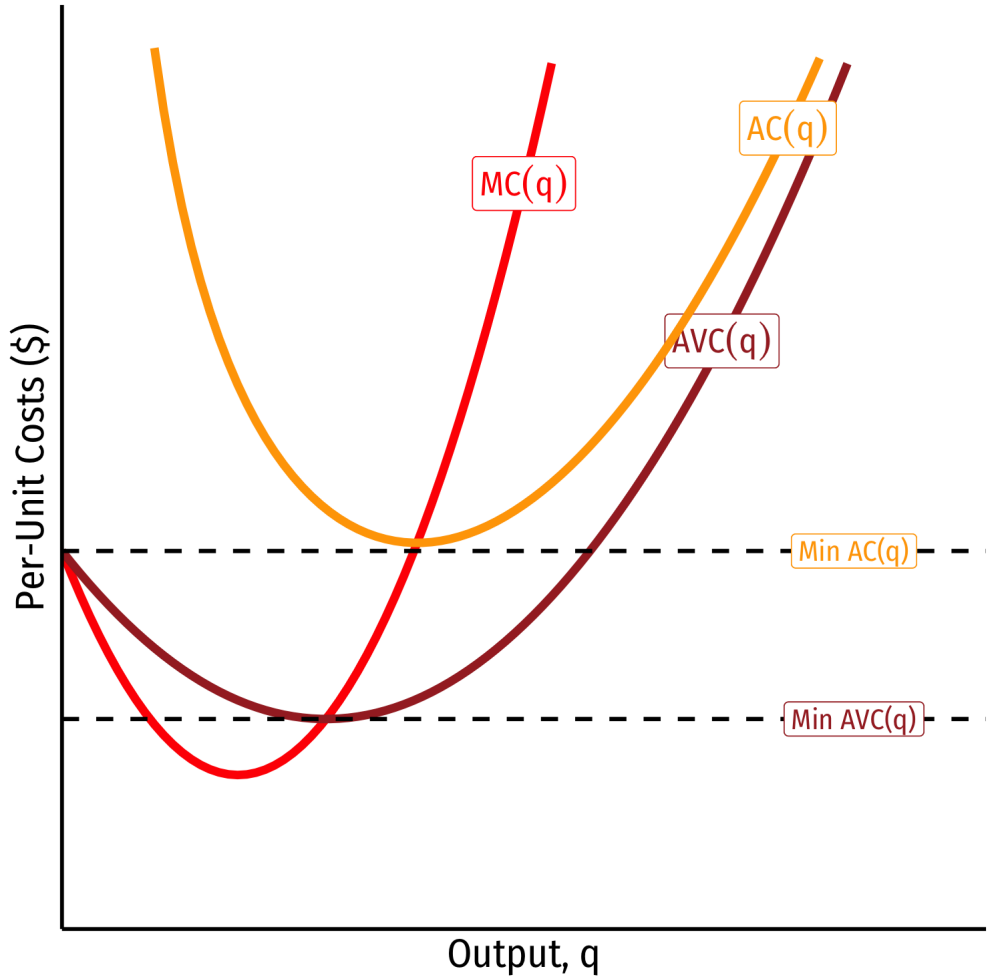
Relationship Between Marginal and Average

- Mathematical relationship between a marginal & an average value
- If marginal $<$ average, then average $\downarrow$
- If marginal $>$ average, then average $\uparrow$
- When marginal $=$ average, average is **maximized/minimized**



Relationship Between Marginal and Average

- Mathematical relationship between a marginal & an average value
- If marginal $<$ average, then average $\downarrow$
- If marginal $>$ average, then average $\uparrow$
- When marginal $=$ average, average is **maximized/minimized**
  - **When MC(q)=AC(q), AC(q) is at a *minimum*** (break-even price)
  - **When MC(q)=AVC(q), AVC(q) is at a *minimum*** (shut-down price)

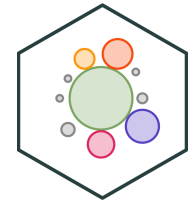


Costs in the Long Run

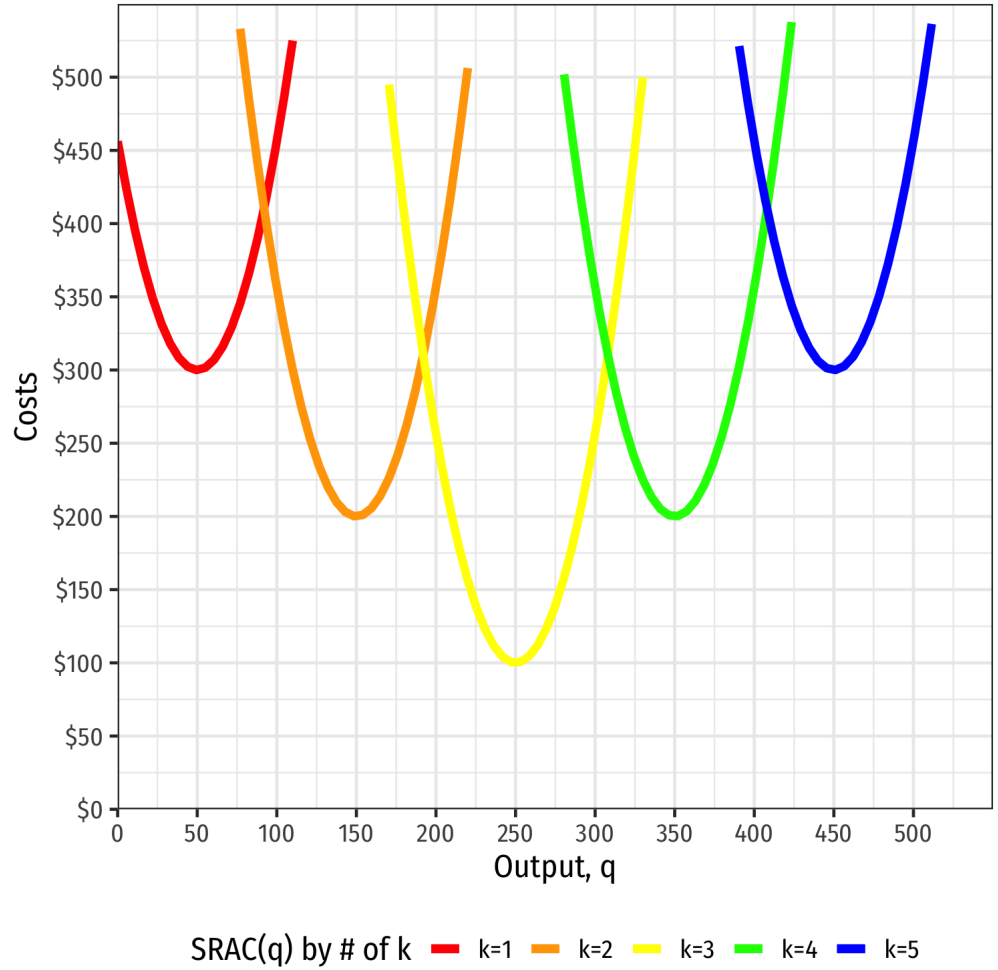
Costs in the Long Run

- **Long run**: firm can change all factors of production & vary scale of production
- **Long run average cost, LRAC(q)**: cost per unit of output when the firm can change *both* l and k to make more q
- **Long run marginal cost, LRMC(q)**: change in long run total cost as the firm produce an additional unit of q (by changing *both* l and/or k)

Average Cost in the Long Run



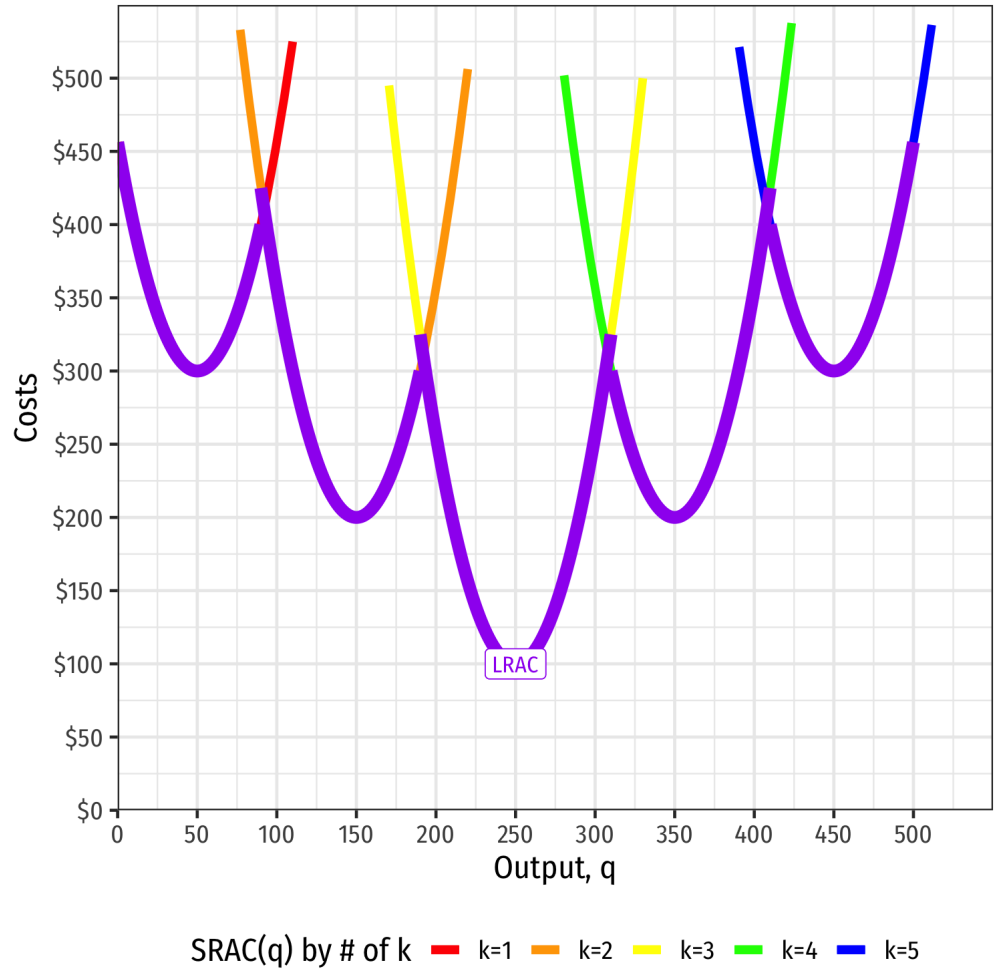
- **Long run**: firm can choose k (factories, locations, etc)
- Separate short run average cost (SRAC) curves for each amount of k potentially chosen



Average Cost in the Long Run

- **Long run**: firm can choose k (factories, locations, etc)
- Separate short run average cost (SRAC) curves for each amount of k potentially chosen
- **Long run average cost (LRAC)** curve "envelopes" the lowest (optimal) regions of all the SRAC curves!

> "Subject to producing the optimal amount of output, choose l and k to minimize cost"

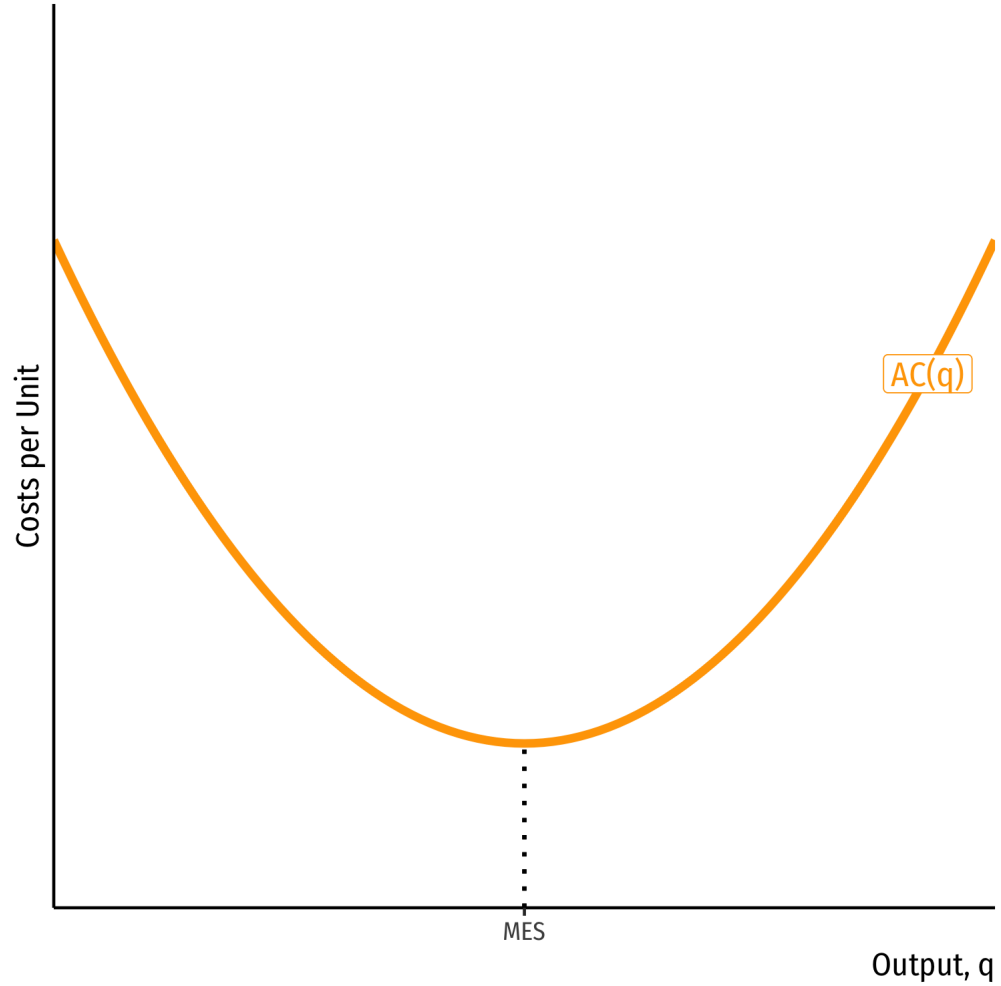


Long Run Costs & Scale Economies I

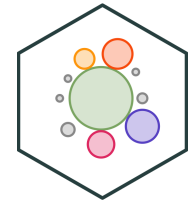
- Further important properties about costs based on **scale economies** of production: change in **average costs** when output is increased (scaled)
- **Economies of scale**: average costs **fall** with more output
  - High fixed costs $AFC > AVC(q)$ low variable costs
- **Diseconomies of scale**: average costs **rise** with more output
  - Low fixed costs $AFC < AVC(q)$ high variable costs
- **Constant economies of scale**: average costs **don't change** with more output
  - Firm at minimum average cost (optimal plant size), called **minimum efficient scale (MES)**

Long Run Costs & Scale Economies II

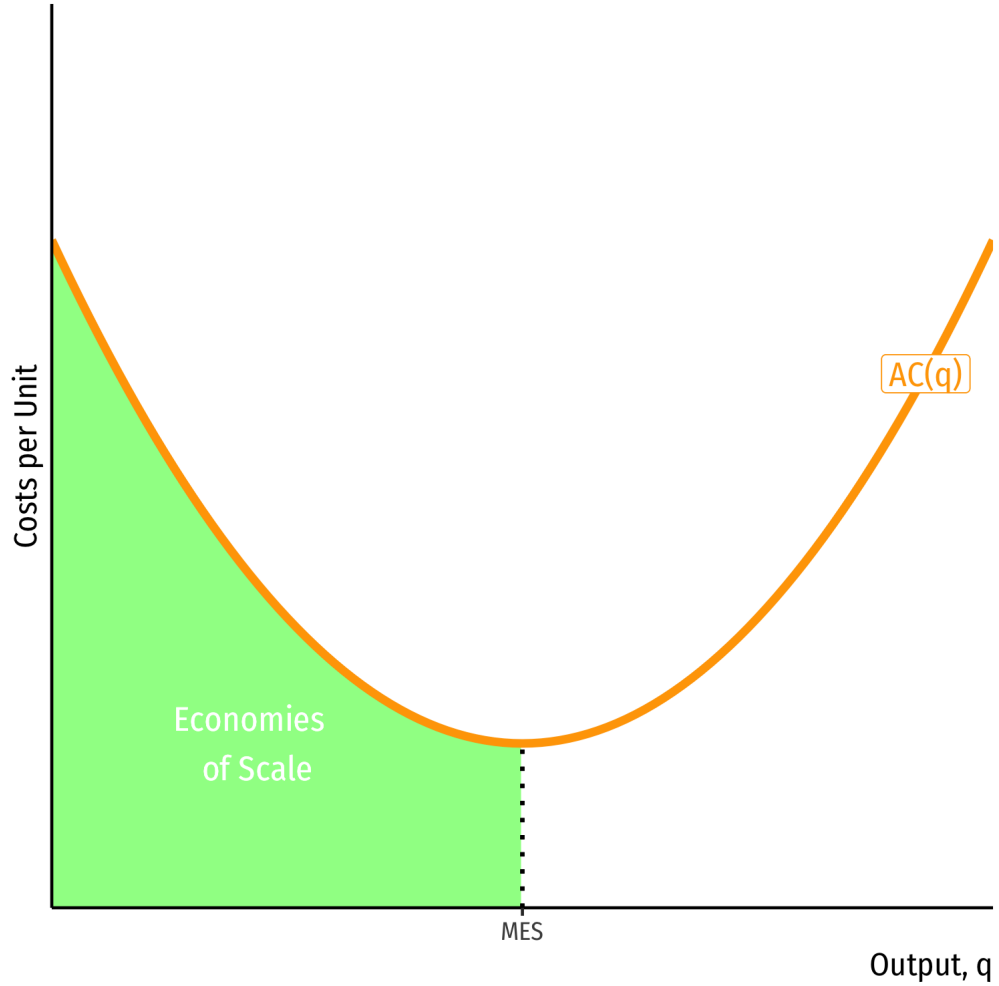
- **Minimum Efficient Scale**: q with the lowest $AC(q)$
  - "optimal firm size"



Long Run Costs & Scale Economies II

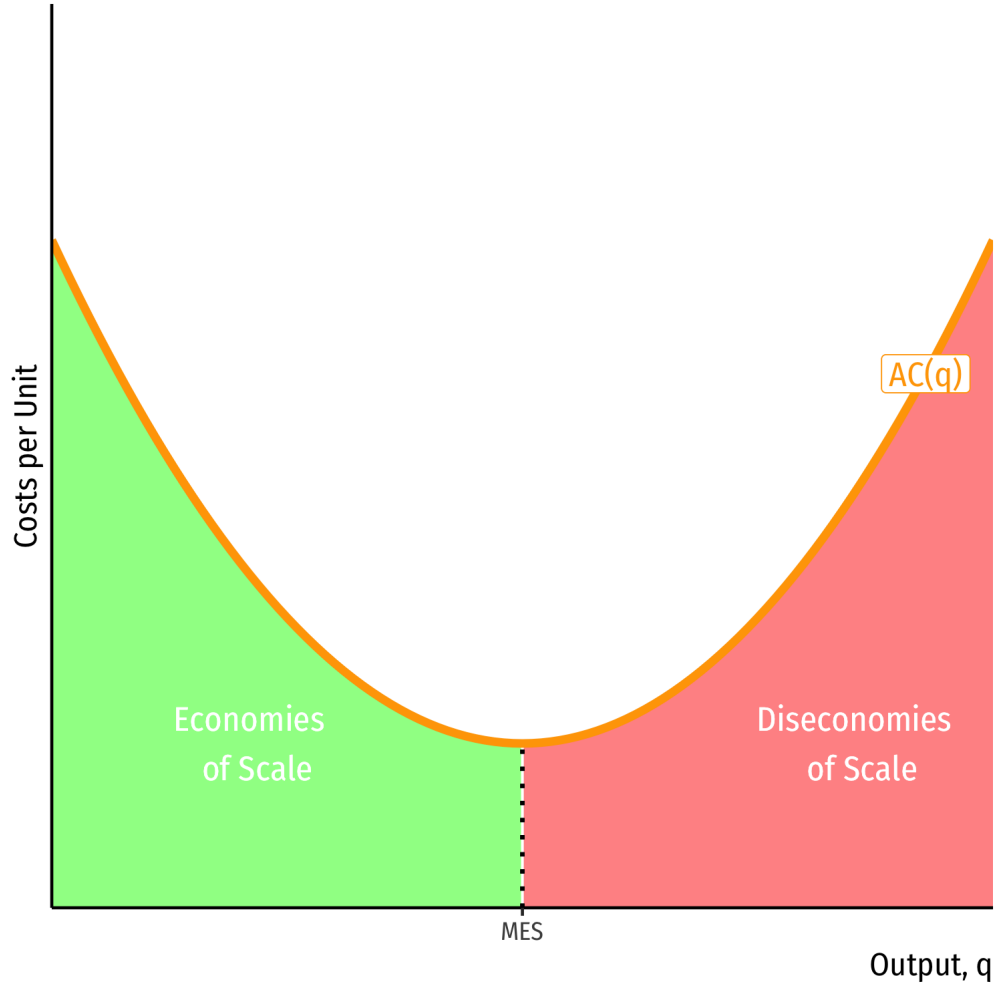


- **Minimum Efficient Scale**: q with the lowest $AC(q)$
  - "optimal firm size"
- **Economies of Scale**: $\uparrow q, \downarrow AC(q)$



Long Run Costs & Scale Economies II

- **Minimum Efficient Scale**: q with the lowest $AC(q)$
  - "optimal firm size"
- **Economies of Scale**: $\uparrow q, \downarrow AC(q)$
- **Diseconomies of Scale**: $\uparrow q, \uparrow AC(q)$

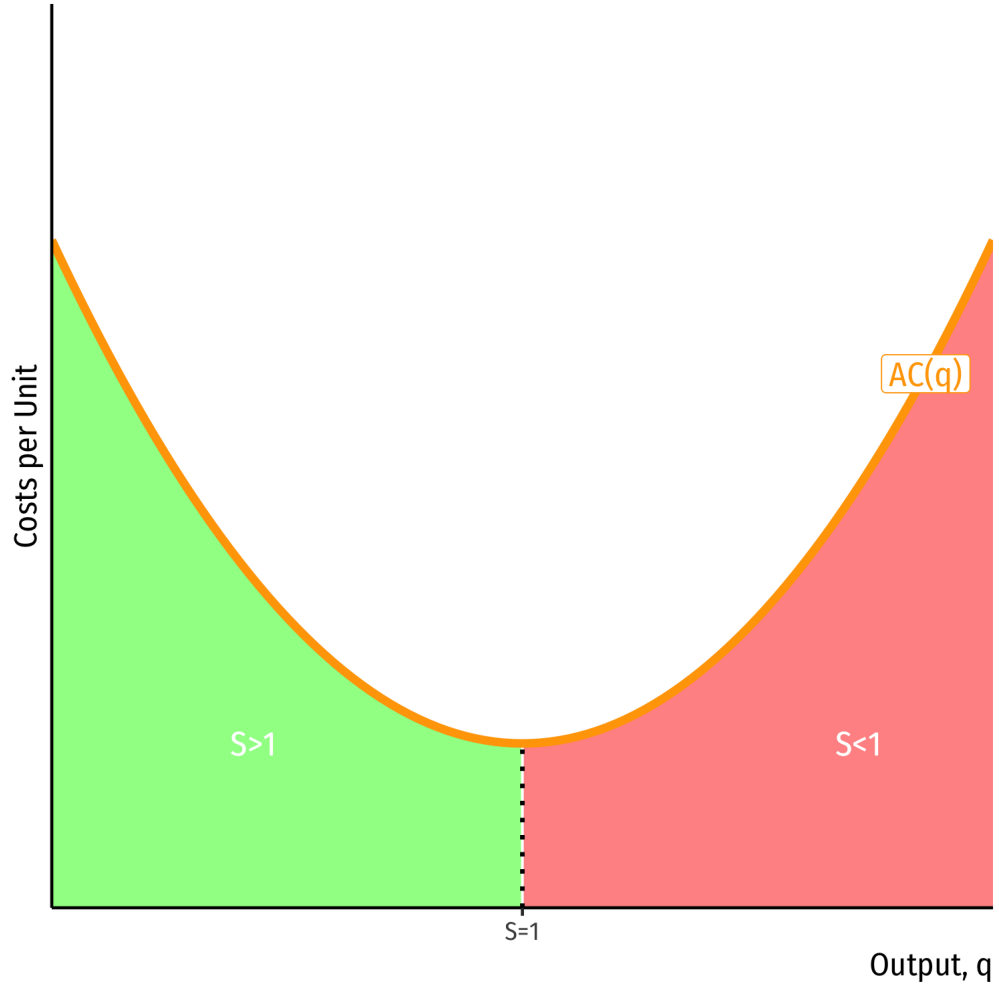


Long Run Costs & Scale Economies III

- Can measure economies of scale (S):

$$S(q) = \frac{AC(q)}{MC(q)}$$

- $S > 1$: economies of scale at q
- $S < 1$: diseconomies of scale at q
- $S = 1$: minimum efficient scale at q



Economies of Scope

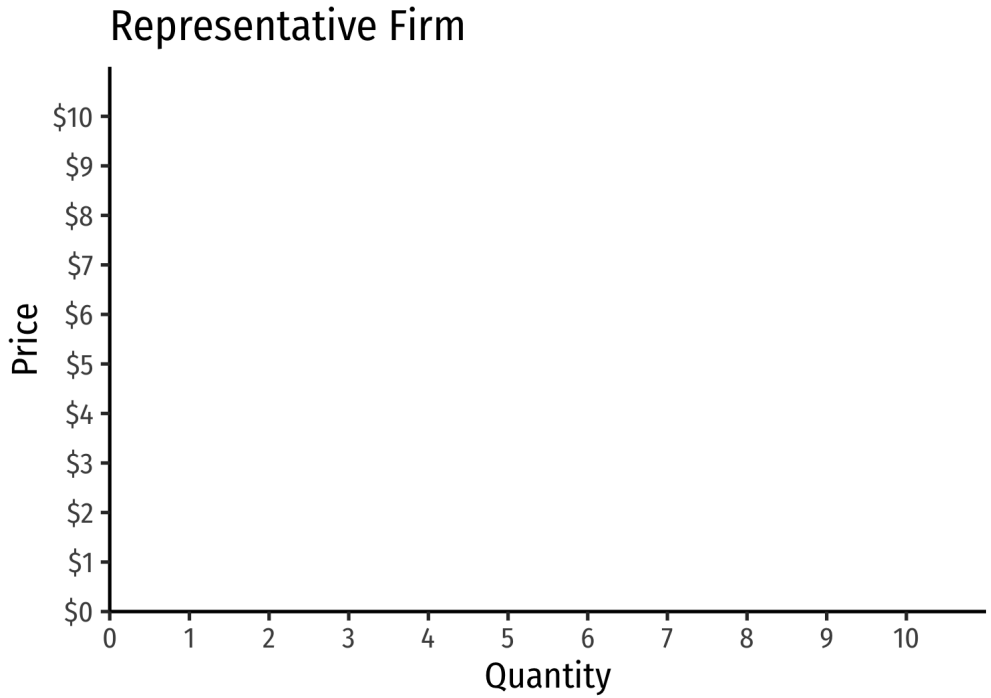
- We often assume **single-product plants/firms**, but in reality most firms/plants are **multi-product**

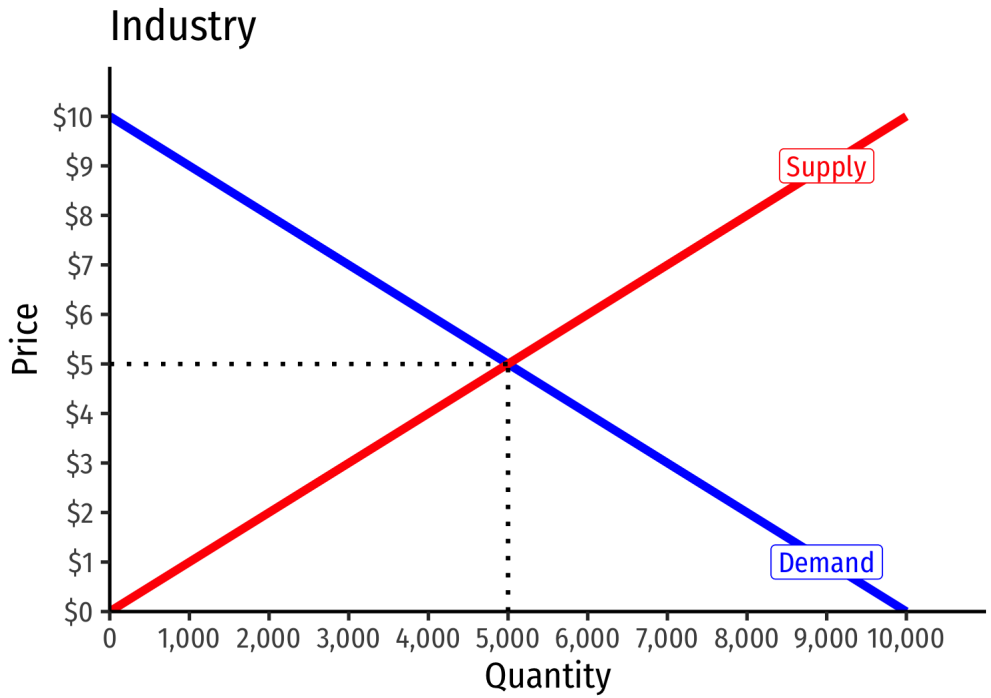
- **Economies of Scope**: cost of producing multiple products (e.g. q_1 and q_2) in a single plant exceeds costs of producing a single product in each plant

$$C(q_1, q_2) < C(q_1, 0) + C(0, q_2)$$

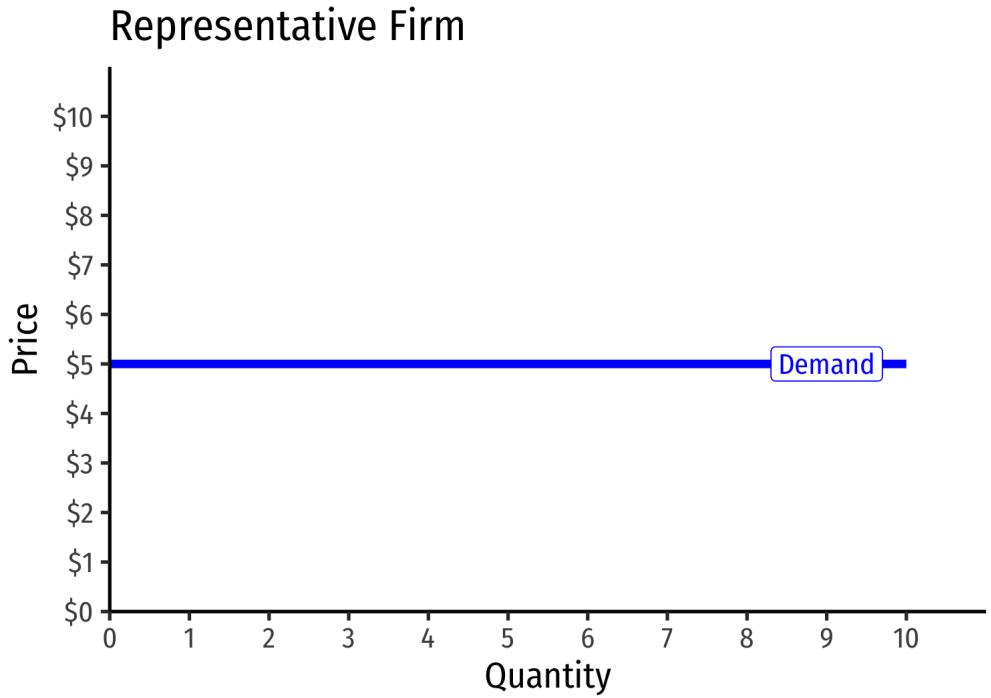
Revenues

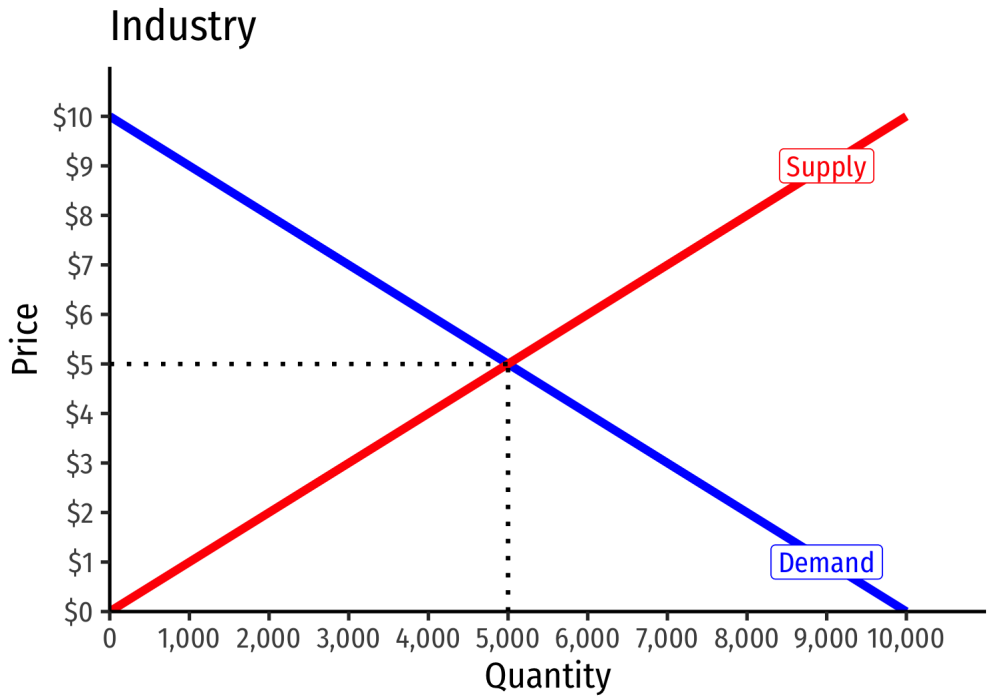
Revenues for Firms in *Competitive* Industries I





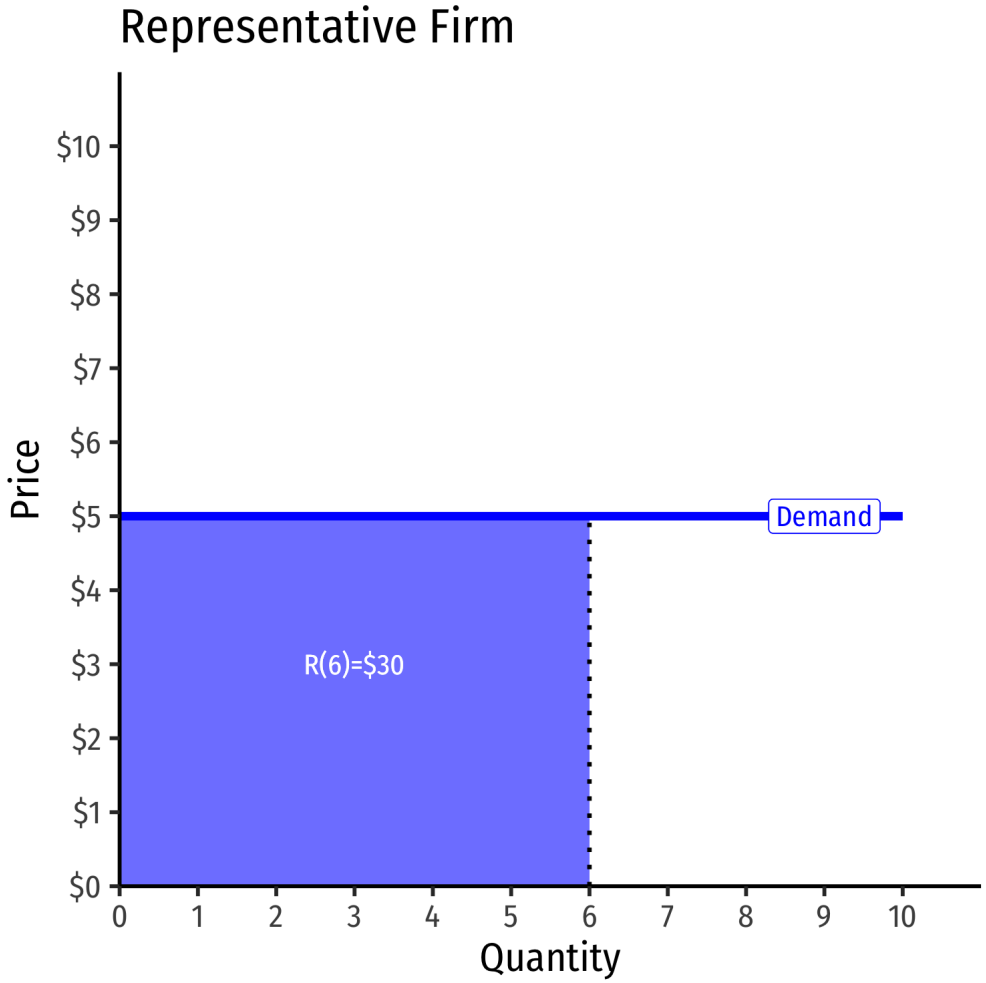
Revenues for Firms in *Competitive* Industries I





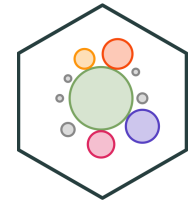
- Demand for a firm's product is **perfectly elastic** at the market price
- Where did the supply curve come from? You'll know today

Revenues for Firms in *Competitive* Industries II



- **Total Revenue** $R(q) = pq$

Average and Marginal Revenues



- **Average Revenue**: revenue per unit of output

$$AR(q) = \frac{R}{q}$$

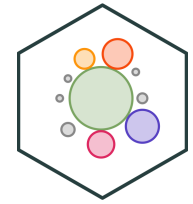
  - $AR(q)$ is **by definition** equal to the price! (Why?)

- **Marginal Revenue**: change in revenues for each additional unit of output sold:

$$MR(q) = \frac{\Delta R(q)}{\Delta q}$$

  - Calculus: first derivative of the revenues function
  - **For a *competitive* firm (only), MR(q) = p, i.e. the price!**

Average and Marginal Revenues: Example



Example: A firm sells bushels of wheat in a very competitive market. The current market price is $10/bushel.

For the 1st bushel sold:

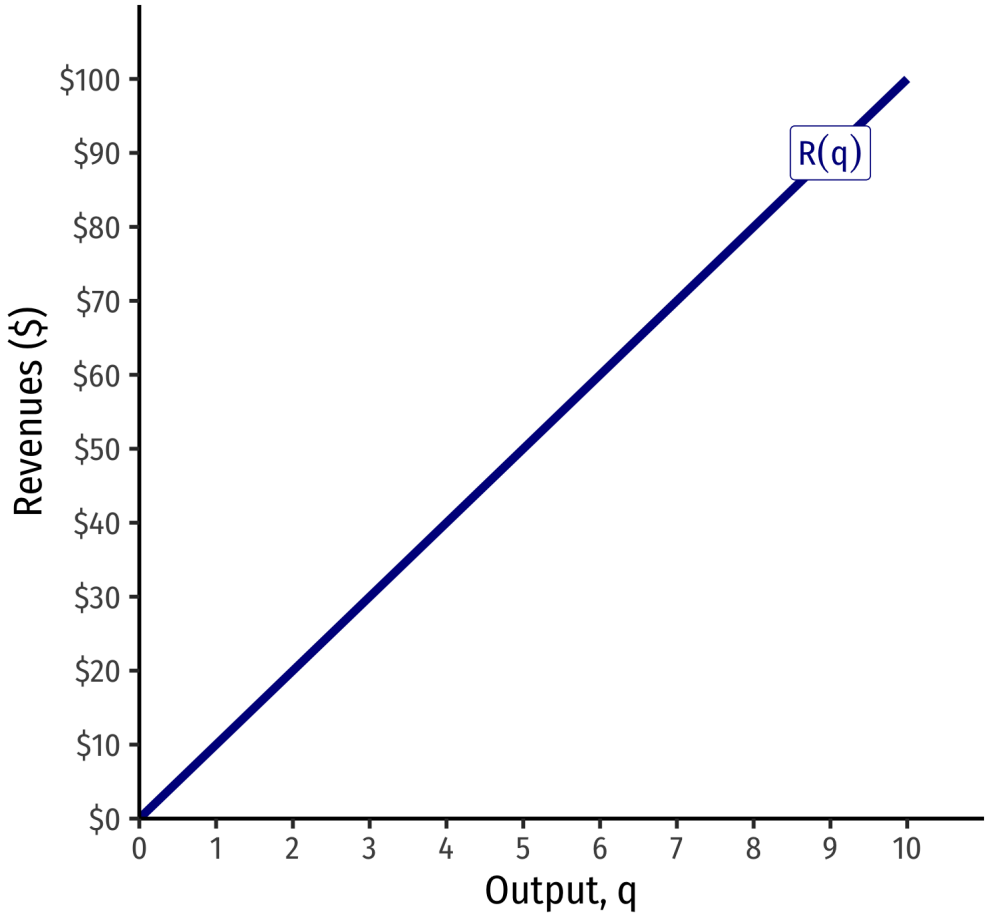
- What is the total revenue?
- What is the average revenue?

For the 2nd bushel sold:

- What is the total revenue?
- What is the average revenue?
- What is the marginal revenue?

Total Revenue, Example: Visualized

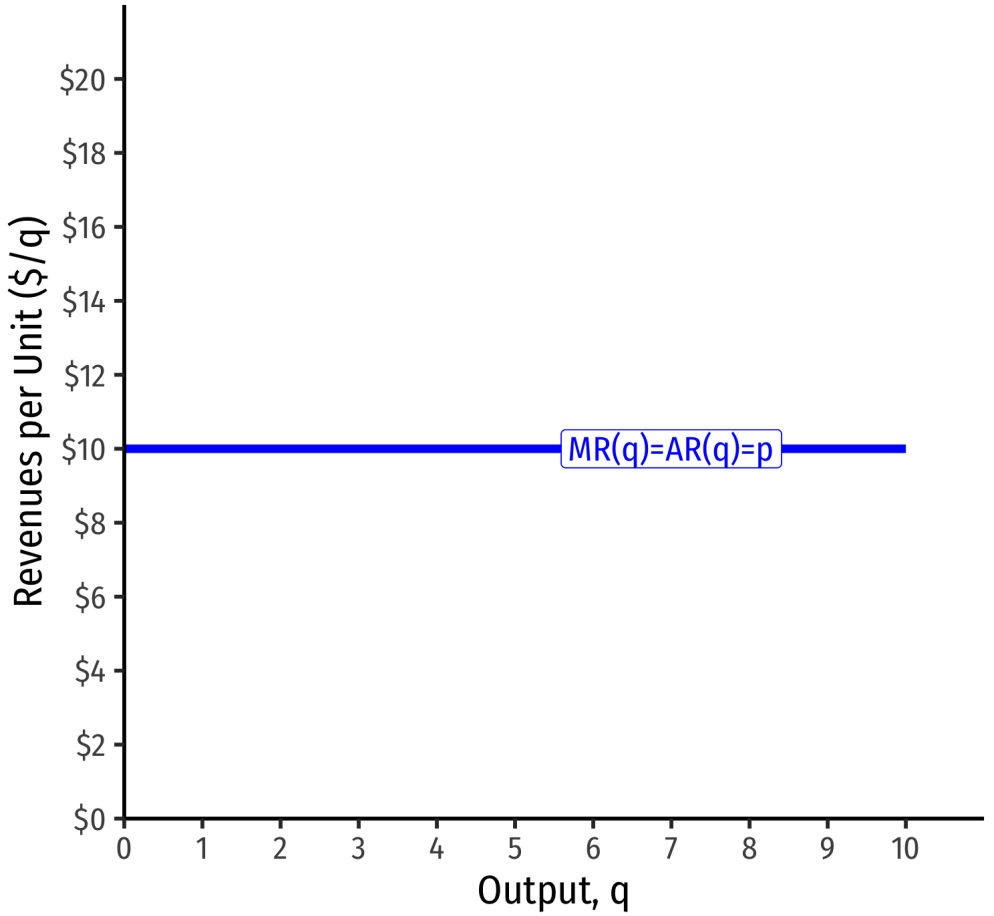
q	$R(q)$
0	0
1	10
2	20
3	30
4	40
5	50
6	60
7	70
8	80
9	90
10	100



$R(q) = 10q$

Average and Marginal Revenue, Example: Visualized

q	$R(q)$	$AR(q)$	$MR(q)$
0	0	–	–
1	10	10	10
2	20	10	10
3	30	10	10
4	40	10	10
5	50	10	10
6	60	10	10
7	70	10	10
8	80	10	10
9	90	10	10
10	100	10	10



R(q) = 10q