HE1001 Microeconomics I – Revision Notes

Quantitative Research Society @NTU

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Abstract

Comprehensive revision notes for HE1001 Microeconomics I integrating all theoretical concepts, mathematical derivations, worked examples from tutorial questions, and exam-focused applications.

Course Overview & Topic Map

Topic Area	**Key Concepts**
Consumer Theory	Preferences, Utility, Budget Constraint, Optimal Choice
Demand and Supply	Law of Demand and Supply, Market Equilibrium, Elasticities
Production	Production Function, Diminishing Returns, Marginal Products
Costs & Perfect Competition	Cost Curves (FC, VC, MC), Profit Maximization ($P = MC$), Efficiency
Monopoly	Market Power, $MR < P$, Markup Pricing, Deadweight Loss
Price Discrimination	First/Second/Third Degree Price Discrimination, Welfare Effects
Game Theory & Oligopoly	Strategic Interaction, Nash Equilibrium, Stackelberg Leadership

Contents

How to Use These Notes

Document Structure and Learning System

These comprehensive notes integrate five distinct learning components into each chapter:

1. **Theoretical Foundations**: Core concepts explained from first principles with formal definitions and theorems
2. **Mathematical Framework**: All key formulas, identities, derivations, and algebraic manipulations
3. **Worked Examples**: Tutorial questions with complete step-by-step solutions
4. **Policy Applications**: Real-world contexts, debates, and historical examples
5. **Exam Preparation**: Common mistakes, strategic tips, time management, and frequently tested patterns

Visual Learning System

Five color-coded environments guide your study:

Color	Environment	Purpose
Blue	Key Formula	Essential equations to memorize
Green	Worked Example	Tutorial solutions with step-by-step work
Red	Common Mistake	Frequent errors and misconceptions to avoid
Yellow	Policy Application	Real-world economic contexts and debates
Purple	Exam Focus	Strategic guidance and high-yield topics

Part I
Consumer Theory

1 Introduction to Microeconomics

1.1 What is microeconomics?

- Microeconomics is the study of how individuals and firms maximize their well-being in a world of **scarcity**.
- The core of microeconomics is the study of **constrained optimization** and assessing **trade-offs**.
- The key concept behind trade-offs is **opportunity cost**: every action or inaction has a cost in terms of what could have been done instead.

1.2 Modeling in microeconomics

- A model is any description of the relationship between two or more economic variables.
- Economic models are simplified representations of relationships between variables.

Supply and Demand Model:

- **Demand curve** is downward-sloping. It shows the relationship between price and quantity demanded. It measures the willingness of consumers to buy a certain good.
- **Supply curve** is upward-sloping. It shows the relationship between price and quantity supplied. It measures the willingness of producers to sell.
- The intersection of supply and demand curve is the **market equilibrium**. Each point on the demand curve shows how much consumers will demand at a given price. Each point on the supply curve shows how much producers will supply at a given price. At the equilibrium price, suppliers are willing to supply as much as demanders will demand.

1.3 Positive vs. normative economics

- **Positive analysis** is the study of the way things are (e.g. eBay auctions).
- **Normative analysis** is the study of the way that things should be (e.g. should organ sales be legal?).

1.4 Market economy

- **Capitalistic economy**: individuals and firms decide what to produce and consume, subject to limited restrictions by the government (similar to laissez-faire).
- **Command economy**: government in control with production and allocation (e.g. inefficiency and corruption of Soviet Union).
- **Invisible hand**: Adam Smith's concept, self-regulating nature of markets and self-interest.

2 Demand, Supply and Market Mechanism

2.1 Demand Theory

Definition 2.1

Demand refers to the quantity of a good or service that consumers are both **willing** and **able** to buy at different prices.

The demand curve represents the relationship between price and quantity demanded, plotted with quantity on the x-axis and price on the y-axis (following economic convention).

Theorem 2.1: Law of Demand

The demand curve typically slopes downward, indicating that as price increases, quantity demanded decreases, all else equal.

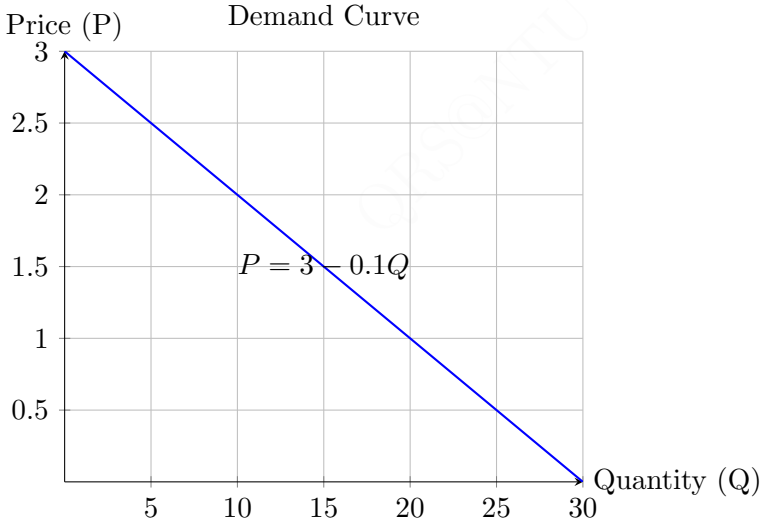
2.1.1 Demand Function and Inverse Demand

The demand function expresses quantity as a function of price:

$$Q_D = a - bP \tag{1}$$

The **inverse demand function** expresses price as a function of quantity:

$$P = \frac{a - Q_D}{b} \tag{2}$$



2.1.2 Factors Affecting Demand

Other factors that shift the demand curve include:

- **Income**: For normal goods, higher income increases demand
- **Consumer Tastes**: Changes in preferences shift demand
- **Price of Related Goods**:
  - **Substitutes**: Goods that can replace each other (positive relationship)
  - **Complements**: Goods used together (negative relationship)

2.1.3 Changes in Demand vs Changes in Quantity Demanded

Definition 2.2

Changes in quantity demanded: Movements along the demand curve caused by price changes.
Changes in demand: Shifts of the entire demand curve caused by non-price factors.

Exam Focus

- Demand curves slope downward due to the law of demand.
- Distinguish between movements along (quantity demanded) vs shifts of (demand) the curve.
- Substitutes have positive cross-price elasticity; complements have negative.

2.2 Supply Theory

Definition 2.3

Supply refers to the quantity of a good or service that producers are both **willing** and **able** to sell at different prices

Theorem 2.2: Law of Supply

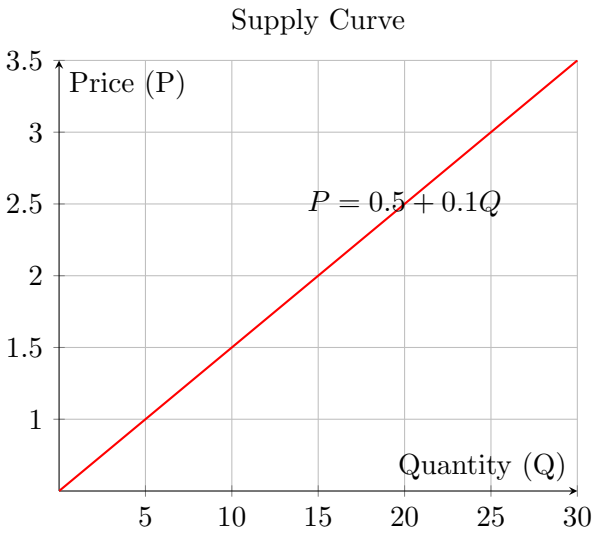
The supply curve typically slopes upward, indicating that as price increases, quantity supplied increases, all else equal.

The supply function:

$$Q_S = c + dP \quad \text{where } d > 0 \tag{3}$$

The inverse supply function:

$$P = \frac{Q_S - c}{d} \tag{4}$$



2.2.1 Factors Affecting Supply

Supply shifters include:

- **Costs of Production**: Labor, capital, raw materials
- **Technology**: Improvements reduce costs and increase supply
- **Number of Suppliers**: More firms increase market supply

2.3 Market Mechanism and Equilibrium

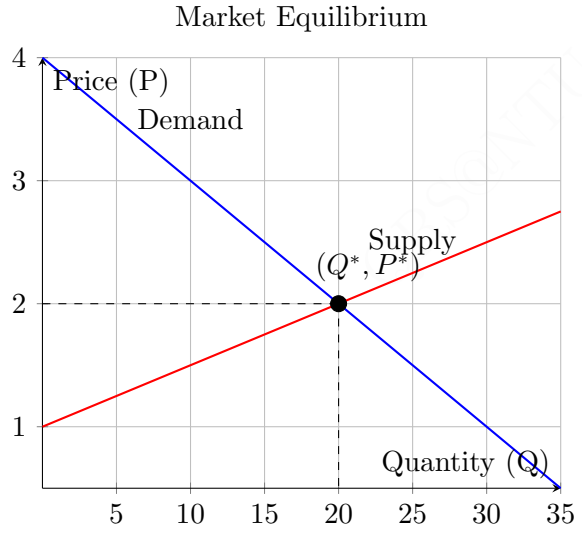
Definition 2.4

The **market mechanism** is the tendency in a free market for prices to adjust in response to shortages or surpluses until equilibrium is reached.
Market equilibrium occurs when quantity demanded equals quantity supplied: $Q_D = Q_S$.

2.3.1 Equilibrium Analysis

To find market equilibrium:

1. Set demand equal to supply: $Q_D(P) = Q_S(P)$
2. Solve for equilibrium price P^*
3. Substitute back to find equilibrium quantity Q^*



2.3.2 Market Adjustment Process

When price is not at equilibrium:
Price above equilibrium: $Q_S > Q_D$ (surplus) $\Rightarrow$ price falls
Price below equilibrium: $Q_D > Q_S$ (shortage) $\Rightarrow$ price rises

Worked Example

Equilibrium Calculation: Given: $Q_D = 400 - 2P$ and $Q_S = 3P - 50$

Setting $Q_D = Q_S$:

$$400 - 2P = 3P - 50 \tag{5}$$
$$450 = 5P \tag{6}$$
$$P^* = 90 \tag{7}$$

Substituting back: $Q^* = 400 - 2(90) = 220$

2.4 Changes in Market Equilibrium

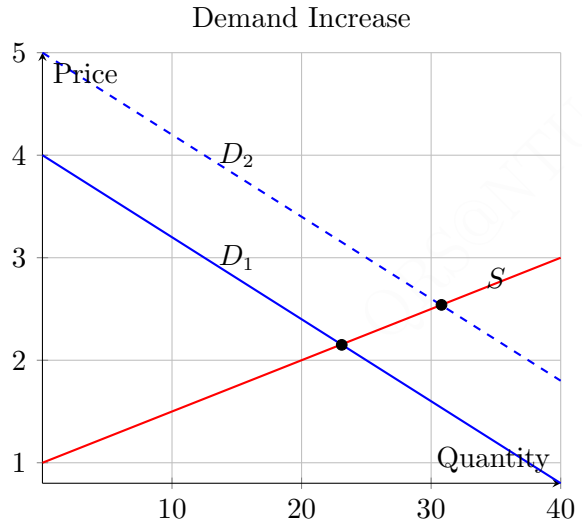
Market equilibrium changes when supply or demand curves shift:

2.4.1 Demand Shifts

- **Increase in demand**: Both P^* and Q^* increase
- **Decrease in demand**: Both P^* and Q^* decrease

2.4.2 Supply Shifts

- **Increase in supply**: P^* decreases, Q^* increases
- **Decrease in supply**: P^* increases, Q^* decreases



3 Preferences and Utility Functions

3.1 Consumer preferences

Definition 3.1

A **bundle** (also called consumption bundle or market basket) is a specific combination of goods and services that a consumer might choose. Formally, it is a list of quantities of different goods.

- Consumer choices are based on **preferences** and **budget constraints**.
- To model consumer preferences, there are three assumptions:

- **Completeness**: when comparing two bundles of goods, you either prefer one, prefer the other, or are indifferent.
- **Transitivity**: If consumer prefers bundle x to bundle y, and bundle y to bundle z, then must prefer bundle x to bundle z.
- **Non-Satiation**: More of a good is always better; consumers never get satiated.

3.2 Indifference curves

- We use **indifference curves** as the basic graphical tool of consumer theory. There are four important properties of indifference curves:
  - Consumers prefer higher indifference curves.
  - Indifference curves are downward-sloping.
  - Indifference curves never cross.
  - There is one indifference curve through each possible consumption bundle.

3.3 Utility

Definition 3.2

Utility is the *total* satisfaction derived from consuming goods and services. A **utility function** represents consumer preferences mathematically.

- **Utility** is a way of mapping preferences. We use utility to get ordinal ranking, not cardinal ranking.
- **Utility function** translates consumer utility from different consumption bundles into units that can then be compared.
- **Marginal utility** is the derivative of utility with respect to a good. It measures how utility changes as consumers consume more of a good. The important principle of **diminishing marginal utility** states that consumers receive less utility from each unit of a good they consume.
- The slope of the indifference curve is called the **marginal rate of substitution (MRS)**.
  - Marginal rate of substitution (MRS) = rate at which consumers are willing to trade Y axis for X axis
  - $$MRS = -\frac{MU_x}{MU_y} = -\frac{\partial U/\partial x}{\partial U/\partial y}$$
  - MRS is the ratio of marginal utilities.
  - MRS is diminishing as you move along the indifference curve.

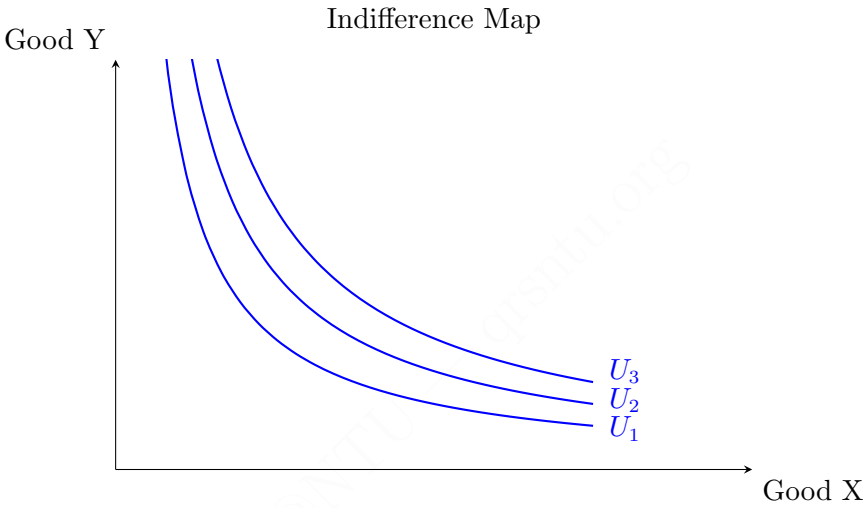
Definition 3.3

An **indifference curve** represents all combinations of bundles that provide a consumer with the same level of utility. The consumer is indifferent among all such combinations.
An **indifference map** is a set of indifference curves that describe a person's preferences.

Theorem 3.1

Properties of Indifference Curves:

1. **Completeness**: Each point corresponds to a specific utility level
2. **Non-satiation**:
   - Curves further to the upper right indicate higher utility
   - Curves cannot bend too much outward
3. **Transitivity**: Indifference curves cannot intersect
4. **Diminishing MRS**: Curves are convex to the origin (cannot bend inward)
5. **Negative slope**: Curves slope downward for two goods



Worked Example

Consider the utility function

$$U(X,Y) = 4X^{0.5}Y^{0.5}$$

which is a Cobb–Douglas utility function.

$$MU_X = \frac{\partial U}{\partial X} = 4 \times 0.5X^{-0.5}Y^{0.5} = 2\frac{Y^{0.5}}{X^{0.5}}$$
$$MU_Y = \frac{\partial U}{\partial Y} = 4 \times 0.5X^{0.5}Y^{-0.5} = 2\frac{X^{0.5}}{Y^{0.5}}$$

The marginal rate of substitution (MRS) is given by:

$$MRS = -\frac{MU_X}{MU_Y}$$

Substituting the values:

$$MRS = -\frac{2Y^{0.5}/X^{0.5}}{2X^{0.5}/Y^{0.5}} = -\frac{Y^{0.5} \cdot Y^{0.5}}{X^{0.5} \cdot X^{0.5}} = -\frac{Y}{X}$$

Interpretation: The MRS of X for Y equals $-\frac{Y}{X}$, meaning that at any point on the indifference curve, the consumer is willing to give up $\frac{Y}{X}$ units of Y for one additional unit of X, holding utility constant. The MRS diminishes as X increases (and Y decreases).

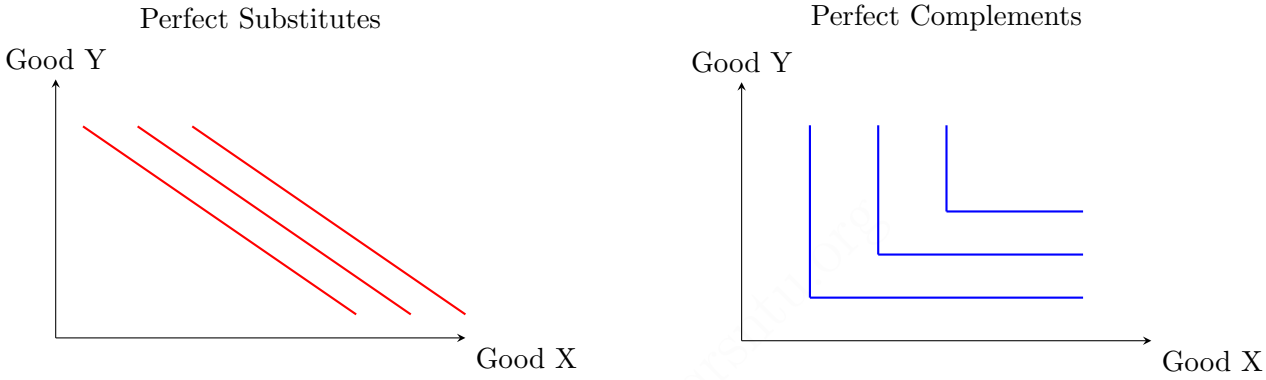
3.4 Special Cases of Preferences

Definition 3.4

Perfect substitutes: Goods that can be substituted for each other at a constant rate. The MRS is constant.
Utility function: $U(X,Y) = aX + bY$ (linear)

Definition 3.5

Perfect complements: Goods that are always consumed together in fixed proportions.
Utility function: $U(X,Y) = \min(X,Y)$



Worked Example

From Problem Set 3: D = drinks, H = hamburgers
Molly: Insists on consuming exactly one soft drink for every hamburger.
Utility function: $U = \min(D,H)$ (Perfect Complements)
Mary: Gets equal satisfaction from hamburgers and soft drinks.
Utility function: $U = D + H$ (Perfect Substitutes)

4 Budget Constraints

4.1 Budget constraint

- Consumers have limited resources: their **budget constraint**. One simplifying assumption is that budget is equal to income (I). Budget over two goods X and Y is defined to be

$$I = p_X X + p_Y Y$$

- The slope of budget constraint is defined as **marginal rate of transformation (MRT)**: rate at which you can transform one good into the other in the marketplace

$$MRT = -\frac{p_X}{p_Y}$$

  Intuitively, with a fixed budget, by choosing one thing you are by definition reducing the money you have to spend on other things.

- Shifts in price and income alter the position and slope of the budget constraint.
  - For example, if the price of good X increases, the budget constraint flattens.
  - If the income decreases, the budget constraint shifts inwards.

4.2 Constrained optimization

- The goal of constrained choice is to maximize utility subject to the budget constraint. Preferences are represented by indifference curves.
- The optimal bundle that a consumer can choose is defined by the point where indifference curve is tangent to the budget constraint:

$$MRS = -\frac{MU_X}{MU_Y} = -\frac{\partial U/\partial X}{\partial U/\partial Y} = -\frac{p_X}{p_Y} = MRT$$

  At this point, slope of indifference curve = slope of budget constraint. This is equivalent to equating the marginal cost and benefit of consuming each good.
- The above equation defines an interior solution (in which the consumer consumes some of each good); if indifference curves are flat, there can also be **corner solutions** in which the consumer only consumes one good.

Worked Example

Utility Maximization:
Tai consumes only wine (x) and cheese (y). His preferences can be expressed by the following utility function: $U(x,y) = xy^3$. The price of wine is p_x, the price of cheese is p_y, and Tai has an income of m dollars.

Tai's budget constraint is

$$p_x x + p_y y = m$$

The marginal rate of substitution between wine and cheese is

$$MRS = -\frac{\frac{\partial U(x,y)}{\partial x}}{\frac{\partial U(x,y)}{\partial y}} = -\frac{y^3}{3xy^2} = -\frac{1}{3}\frac{y}{x}$$

The marginal rate of substitution between wine and cheese is

$$MRS = -\frac{\frac{\partial U(x,y)}{\partial x}}{\frac{\partial U(x,y)}{\partial y}} = -\frac{y^3}{3xy^2} = -\frac{1}{3}\frac{y}{x}$$

In an optimum

$$MRS = -\frac{p_x}{p_y} \implies \frac{1}{3}\frac{y}{x} = \frac{p_x}{p_y} \implies y = 3\frac{p_x}{p_y}x$$

Replacing in the budget constraint

$$p_x x + p_y 3\frac{p_x}{p_y}x = m \implies 4p_x x = m \implies \boxed{x = \frac{1}{4}\frac{m}{p_x}} \quad \boxed{y = \frac{3}{4}\frac{m}{p_y}}$$

When Tai's preferences are $U(x,y) = x + 3y$ instead.
If preferences are $U(x,y)$ then the MRS is constant and equal to $MRS = -\frac{1}{3}$. This means that Tai is willing to trade three units of wine for a unit of cheese. Put it other way, he is willing to pay three times more for a unit of cheese than a unit of wine. Then, there are three cases:

$$x = \begin{cases} 0 & 3p_x > p_y \\ \in \left[0, \frac{m}{p_x}\right] & 3p_x = p_y \\ \frac{m}{p_x} & 3p_x < p_y \end{cases} \qquad y = \begin{cases} \frac{m}{p_y} & 3p_x > p_y \\ \in \left[0, \frac{m}{p_y}\right] & 3p_x = p_y \\ 0 & 3p_x < p_y \end{cases}$$

Part II
Demand and Supply

5 Demand Curves

5.1 Deriving demand curve

- **Demand curve** shows the relationship between price and quantity demanded. Often we connect consumer choice theory to demand curves by varying prices while holding income constant.

5.2 Elasticity

Definition 5.1

Price elasticity of demand measures the sensitivity of quantity demanded to price changes. It is defined as the *percentage change* in the quantity demanded of a good that results from a *one percent change* in price.

$$E_P = \frac{\%\Delta Q_D}{\%\Delta P} = \frac{\Delta Q_D/Q_D}{\Delta P/P} = \frac{\Delta Q_D}{\Delta P} \cdot \frac{P}{Q_D}$$

or

$$\epsilon = \frac{\partial Q/Q}{\partial P/P}$$

- **Price elasticity** of demand is defined to be

$$\epsilon = \frac{\partial Q/Q}{\partial P/P}$$

  For example, if quantity demanded falls by 2% for each 1% increase in price, $\epsilon = -2$.

- **Perfectly inelastic demand**: demand does not change regardless of what happens to price, $\epsilon = 0$. When there is no plausible substitute, demand is likely to be perfectly inelastic.
- **Perfectly elastic demand**: demand will drop to zero if price moves at all, $\epsilon = -\infty$. When there are perfect substitutes, demand is likely to be perfectly elastic.
- The elasticity affects consumers' response to a shift in price: if the elasticity is between 0 and -1, then firms can raise revenues by raising the price (since consumers will still buy the good in significant quantities); if $\epsilon < -1$, then raising the price results in a decline in firm revenue.
- Accurately estimating an elasticity requires a shift along the supply curve (e.g., a tax on suppliers would shift the supply curve up, causing the equilibrium price to rise and quantity to fall, from where we can calculate the price elasticity of demand).

5.3 Shifts in demand curve

- To **trace out** a demand curve, we change prices holding income constant. To **shift** a demand curve, we change income holding prices constant.
- The **"Engel Curve"** shows the direct relationship between income and consumption.
- The **income elasticity of demand** shows what happens to consumption as income changes.

$$\gamma = \frac{\partial Q/Q}{\partial Y/Y}$$

- Most goods are **normal goods**: they have a positive income elasticity. Consumption of normal goods increases as income rises.
- **Inferior goods** have a negative income elasticity. Consumption of inferior goods falls as income rises.
- **Necessities** are goods with $\gamma < 1$. You spend a smaller share of your income on necessities as income rises.
- **Luxuries** are goods with $\gamma > 1$. You spend a larger share of your income on luxuries as income rises.

Worked Example

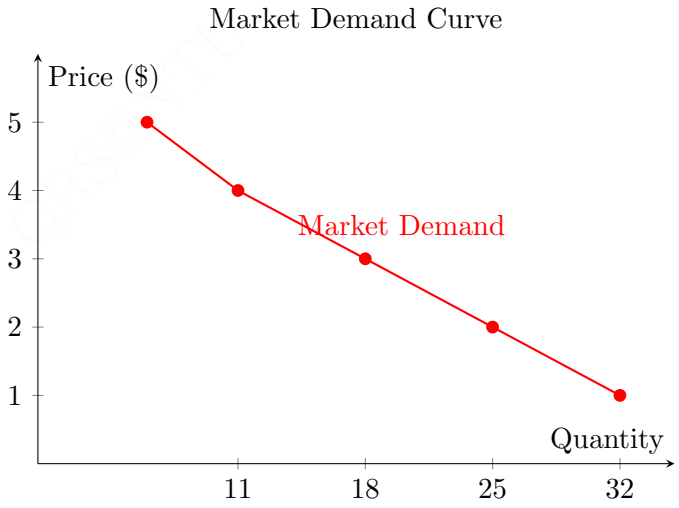
From Problem Set 4: Three individuals with identical demand
If Janice, Mary, and Jennifer all have demand $X^* = \frac{300}{P_X}$:
Market demand: $X_{market} = 3 \times \frac{300}{P_X} = \frac{900}{P_X}$

Worked Example

From lecture slides: Different individual demands

* John: $q_1 = 10 - 3P$
* Mary: $q_2 = 8 - 5P$
* Ken: $q_3 = 2 - 2P$

Market demand: $Q_D = q_1 + q_2 + q_3 = (10 - 3P) + (8 - 5P) + (2 - 2P) = 20 - 10P$



5.4 Income and substitution effect

- An increase in price has two effects: **income effect** and **substitution effect**.
- **Substitution effect** is the change in quantity of good demanded when good's price changes, holding utility constant.
  - When one good gets relatively expensive, the substitution effect is the extent to which you shift away from that good.
- **Income effect** is the change in quantity of a good demanded because of a change in income, holding prices constant.

  - Rise in price effectively lowers the consumer's income, and this has a distinct effect on demand.

- Income effect reinforces substitution for normal goods, as both have a negative effect on the quantity demanded as price rises. But income effect works against it for inferior goods. Therefore, substitution effect is always negative, but income effect can be positive.

- Accordingly, the overall effect of a price increase on consumption of a good can be negative (for a normal good), or positive if it is an inferior good and the income effect is larger than the substitution effect.

	Substitution effect	Income effect	Total effect
Normal good price rises	≤ 0	≤ 0	≤ 0
Normal good price falls	≥ 0	≥ 0	≥ 0
Inferior good price rises	≤ 0	≥ 0	uncertain
Inferior good price falls	≥ 0	≤ 0	uncertain

- **Giffen good** is a good with a positive own-price elasticity.

6 Price Elasticity of Demand

6.1 Definition and Formula

Definition 6.1

Price elasticity of demand measures the sensitivity of quantity demanded to price changes. It is defined as the *percentage change* in the quantity demanded of a good that results from a *one percent change* in price.

$$E_P = \frac{\%\Delta Q_D}{\%\Delta P} = \frac{\Delta Q_D/Q_D}{\Delta P/P} = \frac{\Delta Q_D}{\Delta P} \cdot \frac{P}{Q_D}$$

The percentage change in a variable is the absolute change in the variable divided by the original level of the variable.

6.2 Numerical Examples

Worked Example

Gasoline: $P_0 = 2$, $Q_0 = 100$; $P_1 = 3$, $Q_1 = 80$

$$E_P = \frac{\%\Delta Q}{\%\Delta P} = \frac{(80-100)/100}{(3-2)/2} = \frac{-0.2}{0.5} = -0.4$$

Steak: $P_0 = 10$, $Q_0 = 20$; $P_1 = 15$, $Q_1 = 10$

$$E_P = \frac{(10-20)/20}{(15-10)/10} = \frac{-0.5}{0.5} = -1.0$$

6.3 Classification by Magnitude

Price elasticity is usually a **negative** number (Law of Demand).

Definition 6.2

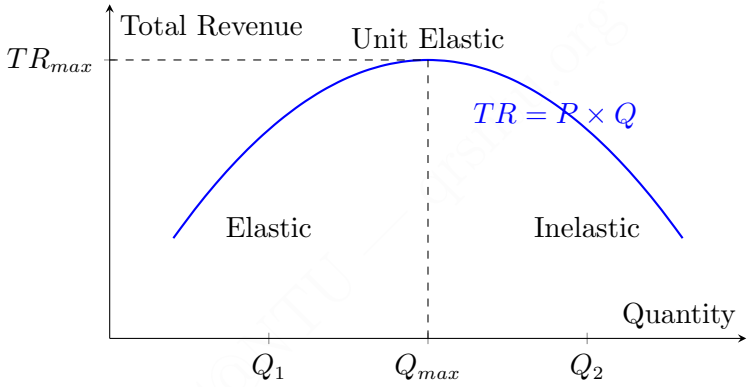
- When $|E_P| > 1$ (% change in Q ¿ % change in P), the good is **price elastic**
- When $|E_P| < 1$ (% change in Q ¡ % change in P), the good is **price inelastic**
- When $|E_P| = 1$ (% change in Q = % change in P), the good is **unit elastic** (isoelastic)

6.4 Price Elasticity and Total Revenue

Theorem 6.1

Price Elasticity and Revenue Relationship:

- When $|E_P| > 1$ (elastic): price increase ⇒ total revenue **decreases**
- When $|E_P| < 1$ (inelastic): price increase ⇒ total revenue **increases**
- When $|E_P| = 1$ (unit elastic): price increase ⇒ total revenue **unchanged**



6.5 Determinants of Price Elasticity

One of the primary determinants of price elasticity of demand is the **availability of substitutes**.

- **Many substitutes** ⇒ *more* price elastic
- **Few substitutes** ⇒ *less* price elastic

Worked Example

Ranking products from lowest to highest price elasticity:

1. Salt (no good substitutes, necessity)
2. Tobacco (addictive, few substitutes)
3. Coffee (limited substitutes for caffeine)
4. Fresh tomatoes (seasonal substitutes available)
5. Movies (many entertainment alternatives)
6. Restaurant meals (many substitutes: cooking, different restaurants)

7 Point vs. Arc Elasticity

7.1 Point Elasticity

Definition 7.1

Point elasticity of demand: The price elasticity of demand *at a particular point* on the demand curve.

$$E_P = \frac{dQ}{dP} \cdot \frac{P}{Q}$$

The price elasticities of demand **differ** at different points on the same demand curve.

Worked Example

Gasoline data: $P_0 = 2$, $Q_0 = 100$; $P_1 = 3$, $Q_1 = 80$
Slope: $\frac{dQ}{dP} = \frac{80-100}{3-2} = -20$
E_P at (P_0, Q_0): $E_P = -20 \times \frac{2}{100} = -0.4$
E_P at (P_1, Q_1): $E_P = -20 \times \frac{3}{80} = -0.75$

7.2 Arc Elasticity

Definition 7.2

Arc elasticity: Uses average values of P and Q to avoid the endpoint problem.

$$E_{arc} = \frac{\Delta Q}{\Delta P} \cdot \frac{\bar{P}}{\bar{Q}}$$

where $\bar{P} = \frac{P_0+P_1}{2}$ and $\bar{Q} = \frac{Q_0+Q_1}{2}$

Worked Example

From Problem Set 2: Price moves from \$80 to \$100, quantity from 20 to 18 million.
Arc elasticity:

$$\bar{P} = \frac{80+100}{2} = 90, \quad \bar{Q} = \frac{20+18}{2} = 19$$

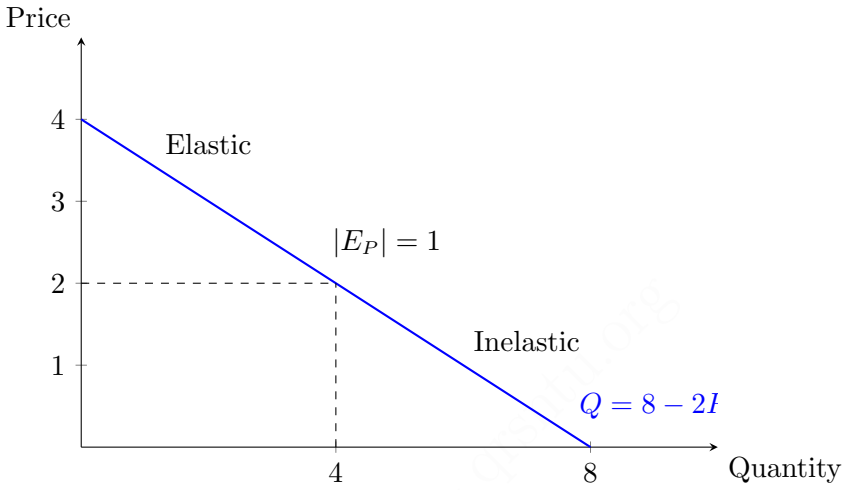
$$E_{arc} = \frac{18-20}{100-80} \times \frac{90}{19} = (-0.1) \times \frac{90}{19} = -0.47$$

7.3 Elasticity on Linear Demand Curves

Theorem 7.1

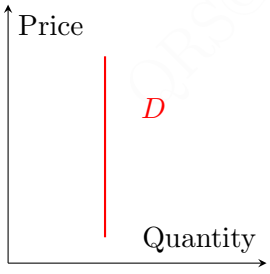
For a linear demand curve, elasticity depends on both the **slope** and the **values of P and Q**.

- The top portion of demand curve is **elastic** ($|E_P| > 1$)
- The bottom portion of demand curve is **inelastic** ($|E_P| < 1$)
- The midpoint is **unit elastic** ($|E_P| = 1$)

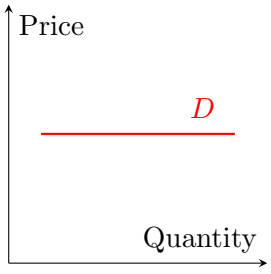


7.4 Extreme Cases

Perfectly Inelastic ($E_P = 0$)



Perfectly Elastic ($E_P = -\infty$)



8 Other Types of Elasticity

8.1 Income Elasticity of Demand

Definition 8.1

Income elasticity of demand measures the percentage change in the quantity demanded of one good that results from a one percent change in income.

$$E_I = \frac{\%\Delta Q_D}{\%\Delta I} = \frac{\Delta Q_D / Q_D}{\Delta I / I} = \frac{\Delta Q_D}{\Delta I} \cdot \frac{I}{Q_D}$$

Classification:

- $E_I > 0$: **Normal goods** (demand increases with income)
- $E_I < 0$: **Inferior goods** (demand decreases with income)
- $E_I > 1$: **Luxury goods** (normal goods with high income sensitivity)
- $0 < E_I < 1$: **Necessities** (normal goods with low income sensitivity)

8.2 Cross-Price Elasticity of Demand

Definition 8.2

Cross-price elasticity of demand measures the percentage change in the quantity demanded of one good that results from a one percent change in the price of another good.

$$E_{XY} = \frac{\%\Delta Q_X}{\%\Delta P_Y} = \frac{\Delta Q_X / Q_X}{\Delta P_Y / P_Y} = \frac{\Delta Q_X}{\Delta P_Y} \cdot \frac{P_Y}{Q_X}$$

Classification:

- $E_{XY} > 0$: **Substitutes** (e.g., Coke and Orange juice)
- $E_{XY} < 0$: **Complements** (e.g., Coke and Fries)

Worked Example

From Problem Set 2: Cross-price elasticity of peanut butter with respect to jelly price is -0.3. If jelly price declines by 15%:

$$\%\Delta Q_{peanut\ butter} = E_{XY} \times \%\Delta P_{jelly} = (-0.3) \times (-15\%) = +4.5\%$$

Since $E_{XY} < 0$, peanut butter and jelly are **complements**.

8.3 Price Elasticity of Supply

Definition 8.3

Price elasticity of supply measures the percentage change in quantity supplied resulting from a one percent change in price.

$$E_S = \frac{\%\Delta Q_S}{\%\Delta P} = \frac{\Delta Q_S}{\Delta P} \cdot \frac{P}{Q_S}$$

Supply elasticity is typically **positive** (Law of Supply).

Part III
Production and Costs

9 Production

9.1 Production function

Definition 9.1

Production function: A function that shows the *maximum* (technologically feasible) output that a firm can produce for every specified combination of inputs.
Mathematical forms:

- One input: $q = f(L)$ or $q = f(K)$
- Two inputs: $q = f(K, L)$
- Many inputs: $q = f(K, L, M, \dots)$

Throughout Microeconomics, we typically assume **efficient production**: for a given input combination, the firm operates on the production function (no waste).

Theorem 9.1

Law of Diminishing Marginal Returns:
Holding all other inputs fixed, as the use of a variable input (for example, labor L) increases, the additional output produced by each extra unit of that input (its marginal product) will eventually decline.

9.2 Average and Marginal Product

Definition 9.2

Average Product of Labor ($\mathbf{AP_L}$): Output per unit of labor

$$AP_L = \frac{q}{L} = \frac{\text{Total Output}}{\text{Amount of Labor}}.$$

Marginal Product of Labor ($\mathbf{MP_L}$): Additional output produced as labor is increased by one unit (holding other inputs constant)

$$MP_L = \frac{\Delta q}{\Delta L} \approx \frac{dq}{dL}.$$

Theorem 9.2

Relationship Between Average Product and Marginal Product of Labor:

- When $MP_L > AP_L$, AP_L is **increasing**.
- When $MP_L < AP_L$, AP_L is **decreasing**.
- When $MP_L = AP_L$, AP_L is at its **maximum**.

Intuition: The marginal worker pulls the average in their direction. If the marginal worker is more productive than the current average, the average rises; if less productive, the average falls.

9.3 Short run production

Definition 9.3

Short run: A period of time in which the quantity of at least one factor of production is fixed (that is, *at least one input is fixed*).
A common representation is:

$$q = f(L, \bar{K}),$$

where K (capital) is fixed at $\bar{K}$ and L (labor) is variable.

Definition 9.4

Marginal product of labor is the change in total output resulting from using an extra unit of labor, holding other inputs constant:

$$MP_L = \frac{\partial q}{\partial L}.$$

Marginal product of capital is the additional output gained from using one extra unit of capital, holding other inputs constant:

$$MP_K = \frac{\partial q}{\partial K}.$$

9.4 Long run production

Definition 9.5

Long run: A period of time long enough for the firm to vary the quantities of *all* inputs. No input is fixed.
A common representation is:

$$q = f(L, K),$$

where both labor L and capital K are variable.

Definition 9.6

Isoquant: A curve showing all possible combinations of inputs that yield the same level of output.
Isoquant map: A graph containing a family of isoquants, used to describe the whole production function (higher isoquants correspond to higher output levels).

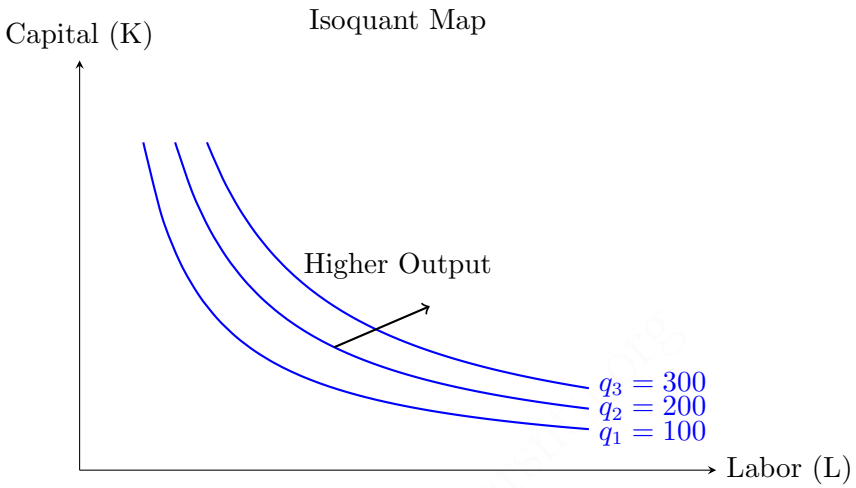
The **shape** of isoquants is determined by the **degree of substitutability** between inputs. The **slope** of an isoquant is the **marginal rate of technical substitution (MRTS)** between inputs.

Theorem 9.3

Marginal Rate of Technical Substitution (MRTS):
For a production function $q = f(L, K)$, along a given isoquant (holding q constant), the MRTS of labor for capital is

$$MRTS_{L,K} = \frac{dK}{dL}\Big|_{q=\bar{q}} = -\frac{MP_L}{MP_K}.$$

Typically, as L increases and K decreases along a smooth isoquant, $MRTS_{L,K}$ **falls**, so isoquants exhibit **diminishing marginal rates of technical substitution**.



9.5 Returns to scale

Definition 9.7

Returns to scale: How output responds when *all* inputs are increased in the same proportion.
For a production function $f(L, K)$ and a scaling factor $a > 1$:

- **Constant returns to scale (CRS)**: Output increases in the same proportion as all inputs

$$f(aL, aK) = a\, f(L, K).$$

- **Increasing returns to scale (IRS)**: Output increases *more than* proportionally with inputs

$$f(aL, aK) > a\, f(L, K).$$

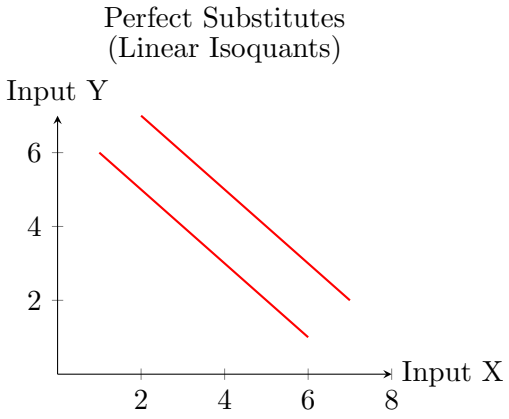
- **Decreasing returns to scale (DRS)**: Output increases *less than* proportionally with inputs

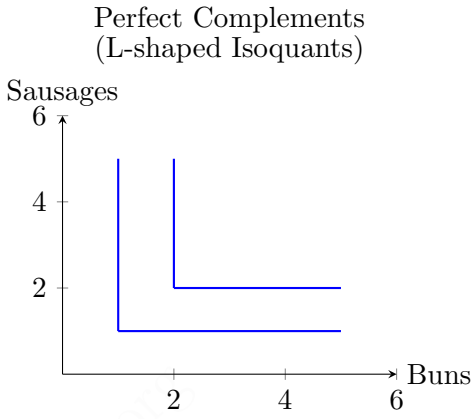
$$f(aL, aK) < a\, f(L, K).$$

9.6 Extreme Cases

Definition 9.8

Perfect substitutes: Inputs can be substituted at a constant rate with no loss of productivity. Isoquants are straight lines.
Perfect complements: Inputs must be used in fixed proportions (e.g. one bun with one sausage). Isoquants are L-shaped.





Worked Example

Consider a firm with the Cobb–Douglas production function

$$F(K, L) = L^{\alpha} K^{\beta},$$

where α and β are real numbers between 0 and 1.

- **Marginal product of labor**:

$$MP_L = \frac{\partial F}{\partial L} = \alpha L^{\alpha-1} K^{\beta}.$$

- **Marginal product of capital**:

$$MP_K = \frac{\partial F}{\partial K} = \beta L^{\alpha} K^{\beta-1}.$$

- **Marginal rate of technical substitution** of labor for capital:

$$MRTS_{L,K} = -\frac{MP_L}{MP_K} = -\frac{\alpha K}{\beta L}.$$

10 From Production to Costs

10.1 Short Run Cost

Definition 10.1

A **cost function** is a mapping from output q to the total cost of producing that output, denoted $C(q)$.
Fixed costs (FC) are the costs of inputs that cannot be varied in the short run (e.g. capital).

- Typically, capital-related costs are treated as fixed in the short run.

Variable costs (VC) are the costs of inputs that can be varied in the short run (e.g. labor).

- Typically, labor-related costs are treated as variable in the short run.

Total cost (TC) is the sum of fixed and variable costs:

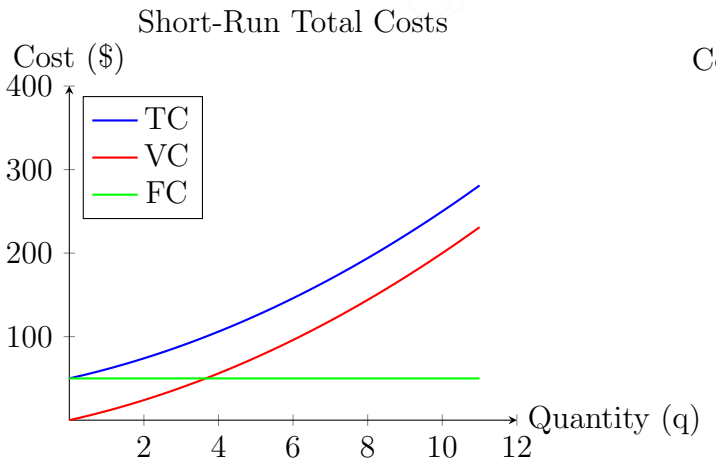
$$C(q) = FC + VC(q).$$

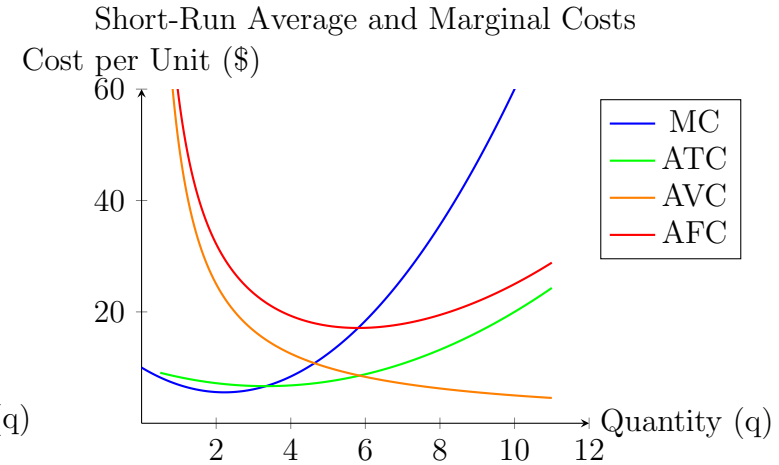
Marginal cost (MC): The change in total cost resulting from producing one additional unit of output:

$$MC(q) = \frac{dC(q)}{dq}.$$

Average cost measures:

$$AC(q) = \frac{C(q)}{q} \quad \text{(average total cost, ATC)},$$
$$AVC(q) = \frac{VC(q)}{q} \quad \text{(average variable cost)},$$
$$AFC(q) = \frac{FC}{q} \quad \text{(average fixed cost)}.$$





Theorem 10.1

Key Relationships Between Short-Run Cost Curves:

1. MC is the **slope** (derivative) of the TC curve.
2. MC typically decreases initially, then increases (**U-shaped**) due to diminishing marginal returns.
3. When $MC > ATC$, ATC is **increasing**.
4. When $MC < ATC$, ATC is **decreasing**.
5. MC intersects ATC at ATC's **minimum point**.
6. The same relationship holds between MC and AVC.
7. AFC is always **decreasing** as output increases (fixed cost is spread over more units).

10.2 Long Run Cost Structure

In the long run, firms have **no fixed inputs** and therefore **no fixed costs**. **All costs are variable**.

Definition 10.2

Long-run cost structure:

- **Total cost**:
$$TC(q) = VC(q) \quad \text{(no fixed cost in the long run)}.$$
- **Marginal cost**:
$$MC(q) = \frac{dTC(q)}{dq}.$$
- **Average cost**:
$$AC(q) = \frac{TC(q)}{q}.$$

Notation:

- Short run: TC, SMC (or $SRMC$), SAC (or $SRAC$), which include AVC and AFC.
- Long run: TC, LMC (or $LRMC$), LAC (or $LRAC$).

Definition 10.3

Isocost line:
For given input prices w (wage of labor) and r (rental rate of capital), and total cost C, an isocost line is the set of (K, L) such that
$$C = rK + wL.$$
It shows all combinations of capital and labor that have the same total cost C.

Theorem 10.2

Cost Minimization Problem:
To produce a given output level $\bar{q}$ at minimum cost, the firm solves

$$\min_{L,K} \quad C = wL + rK$$

subject to

$$\bar{q} = f(L, K).$$

Theorem 10.3

Cost-Minimizing Input Choice (Tangency Condition):
At an interior cost-minimizing input combination (L^*, K^*) for a given output level $\bar{q}$, the isoquant is tangent to the isocost line:

$$\frac{MP_L}{MP_K} = \frac{w}{r} \quad \Longleftrightarrow \quad \frac{MP_L}{w} = \frac{MP_K}{r}.$$

At this point, the last dollar spent on labor adds as much to output as the last dollar spent on capital, so the firm cannot reduce cost by reallocating spending across inputs.

Definition 10.4

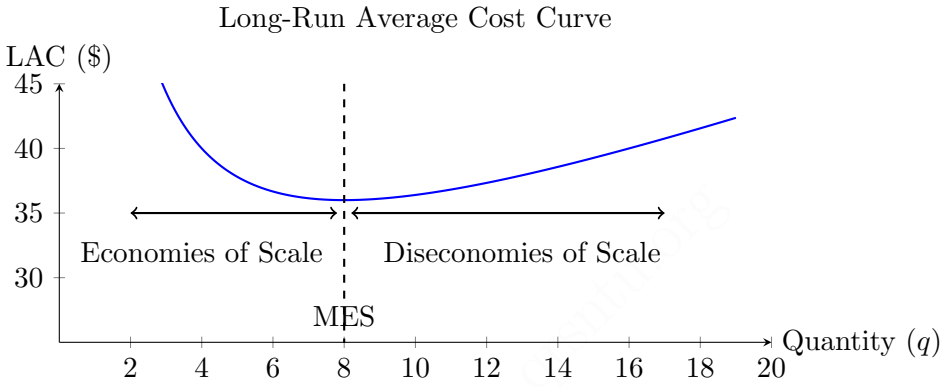
Expansion path: The curve in (K, L)-space that traces out the cost-minimizing combinations of capital and labor for each output level. It connects all tangency points between isoquants and isocost lines.

10.3 Economies and Diseconomies of Scale

Definition 10.5

The long-run average cost (LAC) curve is typically **U-shaped**.

- **Economies of scale**: The firm is on the **decreasing** segment of the LAC curve, so LAC falls as output increases.
- **Diseconomies of scale**: The firm is on the **increasing** segment of the LAC curve, so LAC rises as output increases.
- **Minimum efficient scale (MES)**: The smallest output level at which the firm can produce at the *lowest possible* average cost (the minimum point of the LAC curve).



Sources of Economies of Scale:

- Specialization and division of labor.
- Spreading fixed costs over larger output.
- More efficient use of equipment or technologies.

Sources of Diseconomies of Scale:

- Coordination difficulties in large organizations.
- Management and monitoring challenges.
- Communication problems and bureaucratic delays.

11 Perfectly Competitive Markets

11.1 Characteristics of Perfect Competition

Definition 11.1

Perfect competition is a market structure characterized by:

1. **Many buyers and sellers**: Each has negligible impact on the market price.
2. **Homogeneous products**: Firms sell identical products; goods are perfect substitutes.
3. **Perfect information**: Consumers know prices charged by all firms in the market; all participants have complete knowledge of prices and product characteristics.
4. **Very low transaction costs**: Searching across possible purchase opportunities is easy and inexpensive.
5. **Free entry and exit**: No barriers to entering or leaving the market in the long run.
6. **Price-taking behavior**: Firms are price takers on both the output and input sides; each firm accepts the market price as given.

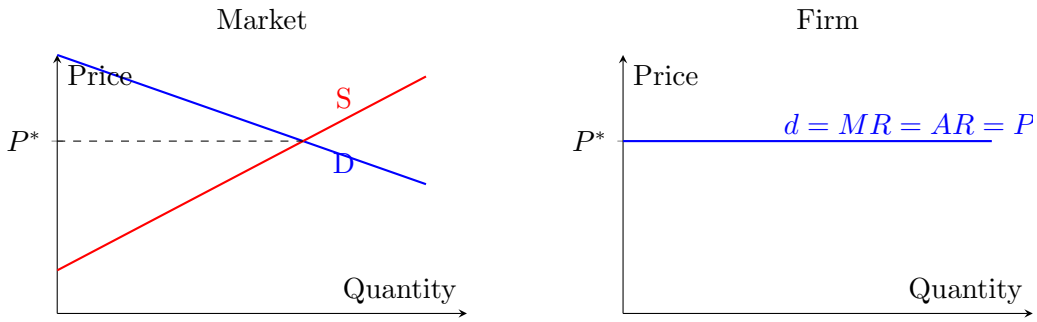
Definition 11.2

Price taker: A firm that has no influence over the market price and thus takes the price as given. Because each firm sells a sufficiently small proportion of total market output, its output decisions have no effect on the market price.

11.2 Demand Curve Facing a Competitive Firm

In perfect competition:

- **Market demand**: Downward sloping.
- **Firm's demand**: Perfectly elastic (horizontal) at the market price P^*. The firm can sell any quantity at P^*, but nothing at a higher price.



12 Profit Maximization in Perfect Competition

12.1 Revenue Concepts

Definition 12.1

For a competitive firm with price P and quantity Q:
Total Revenue:

$$TR(Q) = P \times Q.$$

Average Revenue:

$$AR(Q) = \frac{TR(Q)}{Q} = P.$$

Marginal Revenue:

$$MR(Q) = \frac{dTR(Q)}{dQ} = P.$$

In perfect competition:

$$MR = AR = P$$

(all equal to the market price).

12.2 Short-Run Profit Maximization

In the short run, the number of firms is fixed (no entry or exit). A firm chooses output Q to maximize profit:

$$\pi(Q) = R(Q) - C(Q),$$

where $R(Q)$ is total revenue and $C(Q)$ is total cost.

$$\begin{aligned} \max_q \ \pi(Q) &= R(Q) - C(Q), \\ \frac{\partial \pi(Q)}{\partial q} &= \frac{\partial R(Q)}{\partial q} - \frac{\partial C(Q)}{\partial q} = 0, \\ \frac{\partial R(Q)}{\partial q} &= \frac{\partial C(Q)}{\partial q}, \\ MR &= MC. \end{aligned}$$

In perfect competition, marginal revenue MR equals the market price p, so the firm produces until:

$$MR = MC = p.$$

Theorem 12.1

Profit Maximization Condition (Competitive Firm):
A firm maximizes profit by producing the output level Q^* where

$$MR = MC.$$

For a competitive firm where $MR = P$:

$$P = MC.$$

Profit:

$$\pi(Q) = TR(Q) - TC(Q) = P \cdot Q - TC(Q).$$

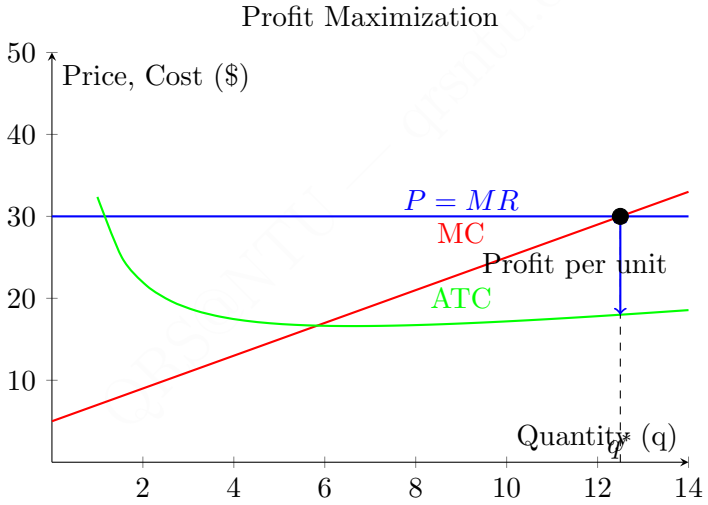
First-order condition:

$$\frac{d\pi}{dQ} = P - MC(Q) = 0 \quad \Rightarrow \quad P = MC(Q).$$

Second-order condition:

$$\frac{d^2\pi}{dQ^2} = -\frac{dMC(Q)}{dQ} < 0,$$

so MC must be rising at the profit-maximizing output.



13 Short-Run Supply Decision

In the short run, some inputs are fixed and the number of firms is fixed (no entry/exit).

13.1 Shutdown Decision

Theorem 13.1

Shutdown Rule (Short Run):
In the short run, a firm should continue operating if

$$P \geq AVC,$$

where AVC is average variable cost.
If $P < AVC$, the firm should shut down (produce zero output) to minimize losses to fixed costs only.
Logic: When operating,

$$\text{Losses} = FC + (P - AVC) \times Q.$$

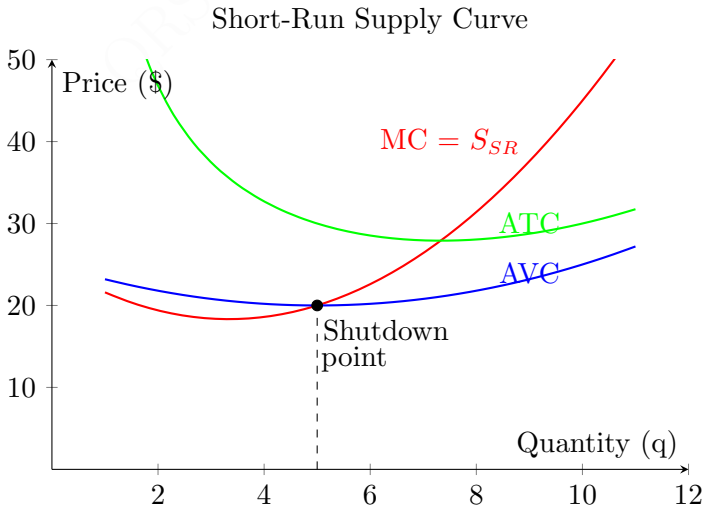
If $P < AVC$, then $(P - AVC) < 0$ and losses exceed FC, so shutdown ($Q = 0$) is better.

13.2 Short-Run Supply Curve of the Firm

Definition 13.1

Firm's short-run supply curve: The portion of the marginal cost (MC) curve that lies above the minimum point of the average variable cost (AVC) curve.

- For $P \geq \min(AVC)$: the firm supplies the quantity where $P = MC$.
- For $P < \min(AVC)$: the firm supplies 0 (shutdown).



13.3 Market Short-Run Supply

Definition 13.2

Market short-run supply curve: The horizontal summation of individual firms' short-run supply curves.
With n identical firms:

$$Q_S(P) = n \times q_s(P),$$

where $q_s(P)$ is the quantity supplied by a representative firm at price P.

In the short run, the **market equilibrium** price is determined by the intersection of market demand and market supply. At that price, each firm produces where

$$MC = P.$$

14 Long-Run Competition and Equilibrium

14.1 Long-Run Adjustments

In the long run:

- All inputs are variable (no fixed costs).
- Firms can freely enter or exit the market.
- Economic profits trigger entry; economic losses trigger exit.

Theorem 14.1

Long-Run Competitive Equilibrium:
In long-run equilibrium for a perfectly competitive market:

1. $P = MC$ (firms choose output optimally given price).
2. $P = \min(LRAC)$ (firms earn zero economic profit; $LRAC$ is long-run average cost).
3. There is no incentive for entry or exit (economic profit $= 0$).

All firms earn zero economic profit (normal profit only) in long-run equilibrium.

14.2 Long-Run Supply Curve

- With free entry/exit and identical firms, and if input prices are constant as the industry expands, the **long-run supply price** equals the minimum of the long-run average cost curve:

$$P_{LR} = \min(LRAC).$$

- Under these restrictive conditions, the long-run industry supply curve can be flat (perfectly elastic) at $\min(LRAC)$.
- More generally, the long-run supply curve is **upward-sloping** if:
  - Barriers to entry exist.
  - Firms differ in efficiency (different cost curves).
  - Input prices rise as the industry expands.
- The long-run supply curve is typically **flatter** than the short-run supply curve because firms can enter or exit and adjust all inputs in the long run.

14.3 Entry and Exit Dynamics

Worked Example

Adjustment Toward Long-Run Equilibrium:

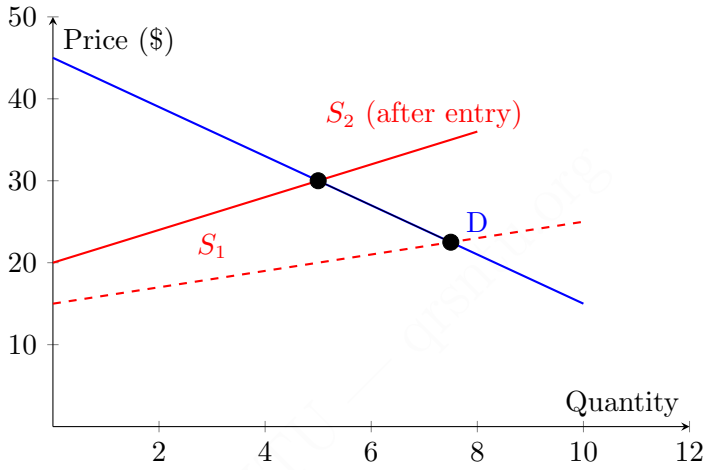
- If $P > ATC$: firms earn positive economic profit

  $\Rightarrow$ New firms enter $\Rightarrow$ Industry supply increases $\Rightarrow$ P falls $\Rightarrow$ Profit decreases to 0.

- If $P < ATC$: firms incur economic losses

  $\Rightarrow$ Some firms exit $\Rightarrow$ Industry supply decreases $\Rightarrow$ P rises $\Rightarrow$ Losses are eliminated.

Long-Run Equilibrium



15 Economic Efficiency in Perfect Competition

15.1 Allocative and Productive Efficiency

Definition 15.1

Productive efficiency: Producing at the minimum possible average total cost. This is achieved when

$$P = \min(ATC).$$

Allocative efficiency: Producing the quantity where the marginal benefit to consumers (reflected by the demand curve) equals the marginal cost of production:

$$P = MC.$$

In long-run competitive equilibrium:

$$P = MC = \min(ATC),$$

so perfect competition achieves both productive and allocative efficiency.

15.2 Consumer and Producer Surplus

Definition 15.2

Consumer surplus (CS): The area between the demand curve and the price line, up to the equilibrium quantity Q^*. If the inverse demand curve is $P = D(Q)$ and the market price is P^*:

$$CS = \int_0^{Q^*} D(q)\,dq \; - \; P^*Q^* = \int_0^{Q^*} \big(D(q) - P^*\big)\,dq.$$

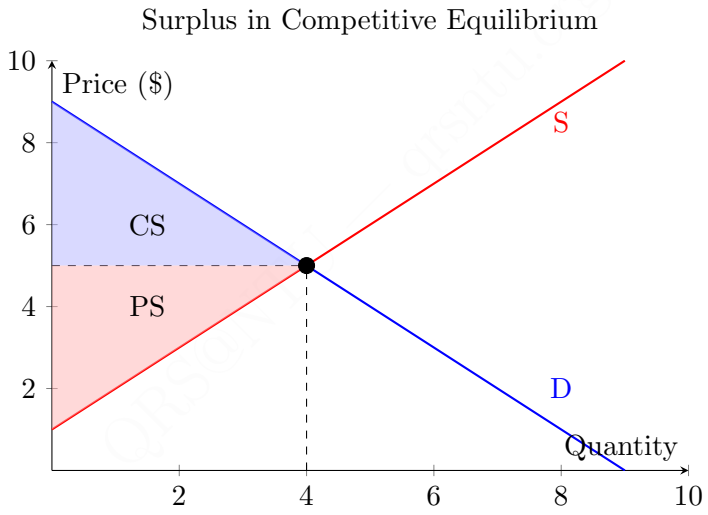
Producer surplus (PS): The area between the price line and the supply curve, up to the equilibrium quantity Q^*. If the inverse supply curve is $P = S(Q)$ and the market price is P^*:

$$PS = P^*Q^* \; - \; \int_0^{Q^*} S(q)\,dq = \int_0^{Q^*} \big(P^* - S(q)\big)\,dq.$$

Total surplus:

$$TS = CS + PS,$$

which is maximized in competitive equilibrium (no deadweight loss).



16 Agency Problems in Competitive Firms

16.1 Separation of Ownership and Control

Definition 16.1

Agency problem: When ownership (shareholders) and control (managers) are separated, managers may pursue personal objectives (such as perks, empire-building, or leisure) rather than cost minimization or profit maximization on behalf of owners. This divergence of interests can prevent the firm from achieving the cost-minimizing outcome even in a competitive market.

Part IV
Monopoly and Market Power

17 Monopoly Characteristics

17.1 Definition and Sources

Definition 17.1

Monopoly: A market in which a single firm is the sole seller of a product with no close substitutes and faces the entire market demand curve.
Market power: The ability of a firm to set price above marginal cost without losing all customers.

Sources of monopoly (barriers to entry):

- **Legal barriers**: Patents, licenses, government franchises (e.g. postal services, broadcasting rights).
- **Control of an essential resource**: Exclusive ownership or control of a key input (e.g. historical examples such as De Beers and diamonds).
- **Economies of scale**: *Natural monopoly* where a single firm can supply the whole market at lower cost than multiple firms because average cost is declining over the relevant output range (large fixed costs, low marginal costs).
- **Network effects**: The value of the product rises with the number of users (e.g. social media platforms, payment networks), making it hard for entrants to compete.

17.2 Monopoly vs. Perfect Competition

Feature	Perfect Competition	Monopoly
Number of firms	Many	One
Market power	None (price taker)	Significant (price maker)
Demand curve	Horizontal	Downward sloping
P vs. MC	$P = MC$	$P > MC$
Long-run profit	Zero economic profit	Positive profit possible
Efficiency	Efficient	Inefficient (DWL)

In perfect competition, individual firms take the market price as given and produce where $P = MC$, leading to an efficient outcome. A monopolist faces the downward-sloping market demand curve, chooses quantity where $MR = MC$, and then sets price from the demand curve, so $P > MC$ and output is lower than in the competitive outcome.

18 Monopoly Pricing and Output

18.1 Demand, Revenue, and Marginal Revenue

Definition 18.1

Total, average, and marginal revenue in monopoly:
Let $P(Q)$ be the inverse market demand curve when the monopolist sells quantity Q.

- **Total Revenue**:
$$TR(Q) = P(Q) \cdot Q.$$
- **Average Revenue**:
$$AR(Q) = \frac{TR(Q)}{Q} = P(Q),$$
so the demand curve is also the average revenue curve.
- **Marginal Revenue**:
$$MR(Q) = \frac{dTR(Q)}{dQ},$$
the additional revenue from selling one more unit.

Theorem 18.1

Marginal revenue with downward-sloping demand:
For any differentiable inverse demand curve $P(Q)$,

$$MR(Q) = \frac{d}{dQ}[P(Q) \cdot Q] = P(Q) + Q\frac{dP(Q)}{dQ}.$$

Because a monopolist faces a downward-sloping demand curve, $\frac{dP(Q)}{dQ} < 0$, so

$$MR(Q) < P(Q)$$

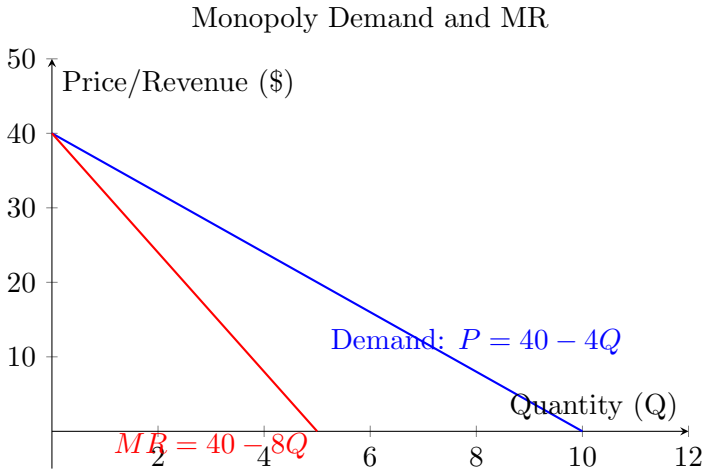
for all Q where demand is downward sloping. Thus, the marginal revenue curve lies strictly **below** the demand (average revenue) curve.
Linear demand special case: If demand is linear, $P = a - bQ$ with $a, b > 0$, then

$$TR(Q) = (a - bQ)Q = aQ - bQ^2,$$

and

$$MR(Q) = \frac{dTR}{dQ} = a - 2bQ.$$

The MR curve has the same intercept a but twice the slope (in absolute value) of the demand curve.



18.2 Profit Maximization and Markup

Theorem 18.2

Monopoly Profit Maximization:
A monopolist with cost function $C(Q)$ chooses output Q to maximize profit

$$\pi(Q) = TR(Q) - C(Q) = P(Q)Q - C(Q).$$

First-order condition (FOC):

$$\frac{d\pi}{dQ} = MR(Q) - MC(Q) = 0 \quad \Rightarrow \quad MR(Q^*) = MC(Q^*),$$

where $MC(Q) = \frac{dC(Q)}{dQ}$ is marginal cost.
Pricing rule:

1. Find the profit-maximizing quantity Q^* from $MR(Q) = MC(Q)$.
2. Determine the monopoly price from the demand curve:
$$P^* = P(Q^*).$$
3. Profit is
$$\pi = (P^* - ATC(Q^*)) \cdot Q^*,$$
where $ATC(Q) = \frac{C(Q)}{Q}$ is average total cost.
4. In the short run, if $P^* < AVC(Q^*)$, the monopolist will optimally shut down and produce $Q = 0$.

Because $MR < P$, the monopolist sets $P^* > MC(Q^*)$, unlike a competitive firm where $P = MC$.

Theorem 18.3

Marginal revenue, elasticity, and markup:
Let ε_D be the (own-price) elasticity of demand faced by the monopolist, defined as

$$\varepsilon_D = \frac{dQ}{dP} \cdot \frac{P}{Q},$$

which is negative for a downward-sloping demand curve.
Using the relationship between MR and $P(Q)$, one can show:

$$MR = P\left(1 + \frac{1}{\varepsilon_D}\right).$$

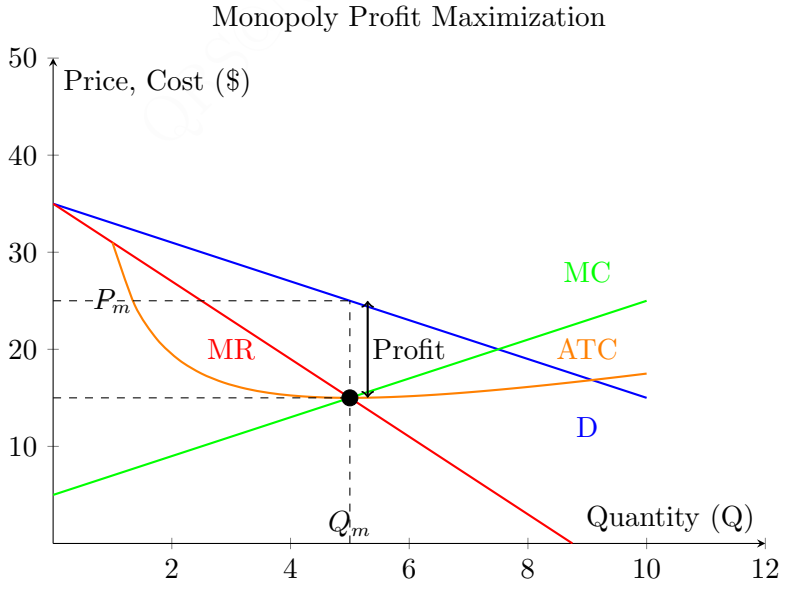
- If $|\varepsilon_D| < 1$ (demand is inelastic), then $1 + 1/\varepsilon_D < 0$ and $MR < 0$. A profit-maximizing monopolist will *never* produce on the inelastic portion of the demand curve; it can increase profit by raising price and reducing quantity.
- At the profit-maximizing quantity where $MR = MC$,

$$P\left(1 + \frac{1}{\varepsilon_D}\right) = MC.$$

Rearranging gives the **markup formula**:

$$\frac{P - MC}{P} = -\frac{1}{\varepsilon_D}.$$

The percentage markup of price over marginal cost is larger when demand is more inelastic (smaller $|\varepsilon_D|$), and smaller when demand is more elastic.



- The monopolist chooses Q_m where $MR = MC$ and charges price P_m on the demand curve.
- P_m exceeds MC and usually exceeds ATC, so the monopolist can earn positive economic profit in the long run.
- The markup $\frac{P_m - MC}{P_m}$ depends on the elasticity of demand at Q_m according to $\frac{P-MC}{P} = -1/\varepsilon_D$.

19 Monopoly and Efficiency

19.1 Deadweight Loss

Definition 19.1

Deadweight Loss (DWL): The loss in total surplus that arises because the monopolist produces less than the socially efficient (competitive) quantity.
Under perfect competition (with no externalities), efficiency requires

$$P = MC.$$

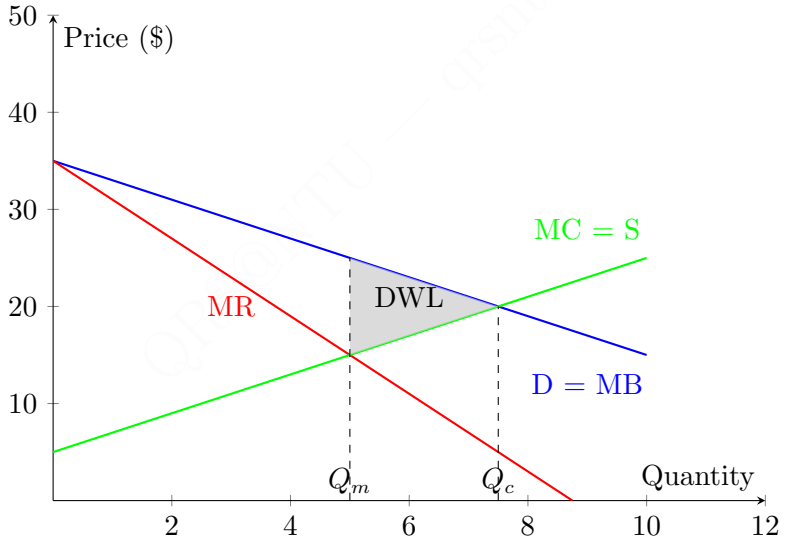
Let the efficient quantity be Q_c and the monopoly quantity be $Q_m < Q_c$. The mutually beneficial trades between Q_m and Q_c do not occur, generating deadweight loss.

Integral Representation of DWL

$$\text{DWL} = \int_{Q_m}^{Q_c} D(q)\,dq \; - \; \int_{Q_m}^{Q_c} MC(q)\,dq = \int_{Q_m}^{Q_c} \big(D(q) - MC(q)\big)\,dq.$$

This is the area between the demand curve and the marginal cost curve over the missing output range $[Q_m, Q_c]$.

Deadweight Loss from Monopoly



19.2 Comparing Monopoly and Perfect Competition

Welfare comparison:

- **Perfect competition**: Firms produce where $P = MC$, quantity Q_c is traded, and total surplus TS is maximized. Consumer surplus and producer surplus are both positive, with no DWL.
- **Monopoly (single price)**: The monopolist produces where $MR = MC$, at $Q_m < Q_c$, and sets $P_m > P_c$. Consumer surplus falls; the monopolist captures some of it as profit, and the remainder is lost as deadweight loss.
- **Welfare effects**:
  - Consumers are worse off: higher price, lower quantity.
  - The monopolist is better off relative to competitive firms (higher profit).
  - Society as a whole is worse off: net loss equals the DWL triangle.

20 Price Discrimination

20.1 Types of Price Discrimination

Definition 20.1

Price discrimination: Charging different prices to different customers (or for different units) for essentially the same product, where price differences are not fully explained by cost differences.
Requirements:

1. **Market power**: The firm must face a downward-sloping demand curve.
2. **Ability to segment markets**: The firm can distinguish between groups of customers with different demand elasticities or willingness to pay.
3. **Limited resale**: The firm can prevent or sufficiently limit arbitrage between groups.

Three degrees:

- **First-degree (perfect) price discrimination**: The firm charges each customer exactly their maximum willingness to pay.
- **Second-degree price discrimination**: Prices vary with the quantity purchased or the version of the product (e.g. block pricing, quantity discounts, versioning).
- **Third-degree price discrimination**: The firm charges different prices to different identifiable groups (e.g. student vs. adult, peak vs. off-peak).

20.2 First-Degree Price Discrimination

Theorem 20.1

Perfect price discrimination:
Under first-degree (perfect) price discrimination, the monopolist charges each consumer exactly their reservation price (maximum willingness to pay) for each unit.
Implications:

- The firm captures *all* consumer surplus as profit.
- The firm continues to sell units as long as willingness to pay exceeds marginal cost, so it produces the *efficient* quantity Q_c where $P = MC$.
- There is **no deadweight loss**: total surplus is maximized, but all of it accrues to the firm rather than consumers.

20.3 Third-Degree Price Discrimination

Theorem 20.2

Market segmentation and optimal prices:
In third-degree price discrimination, the monopolist divides the market into groups (segments) indexed by i with demands $P_i(Q_i)$ and chooses separate prices P_i and quantities Q_i.
Profit maximization requires

$$MR_1 = MR_2 = \cdots = MR_n = MC,$$

so marginal revenue is equalized across segments and equals marginal cost.
If ε_i is the elasticity of demand in segment i, the optimal prices satisfy

$$\frac{P_i - MC}{P_i} = -\frac{1}{\varepsilon_i}.$$

Comparing two groups, 1 and 2,

$$\frac{P_1}{P_2} = \frac{1 + 1/\varepsilon_2}{1 + 1/\varepsilon_1}.$$

If $|\varepsilon_1| > |\varepsilon_2|$ (group 1 is more price elastic than group 2), then $P_1 < P_2$: the more elastic group is charged a lower price.

Worked Example

Examples of third-degree price discrimination:

- **Movie theaters**:
  - Students have more elastic demand ⇒ lower ticket prices.
  - Adults have less elastic demand ⇒ higher ticket prices.
- **Airlines**:
  - Leisure travelers (booking in advance, flexible) have elastic demand ⇒ lower fares.
  - Business travelers (urgent, inflexible) have inelastic demand ⇒ higher fares.

- Price discrimination generally increases monopoly profit by better extracting consumer surplus.
- First-degree price discrimination eliminates DWL but transfers all surplus to the firm.
- Third-degree price discrimination allocates higher prices to less elastic groups and lower prices to more elastic groups.
- All forms of price discrimination require effective market segmentation and limits on resale.

21 Natural Monopoly and Regulation

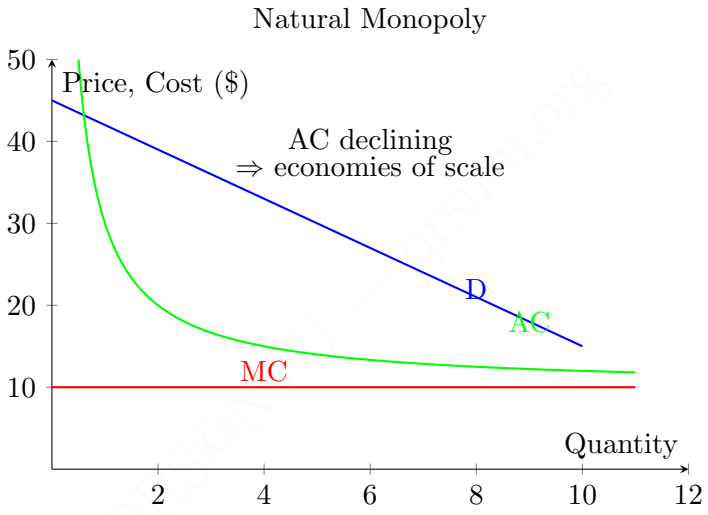
21.1 Natural Monopoly

Definition 21.1

Natural monopoly: An industry in which a single firm can supply the entire market at lower cost than multiple firms because of strong economies of scale over the relevant range of output.
Typical features:

- Large fixed costs and relatively low marginal costs.
- Average cost $AC(Q)$ is declining over the range of market demand.
- One firm producing the whole output minimizes total cost.

Examples: Electricity distribution, water utilities, rail infrastructure, some telecommunications networks.



21.2 Regulatory Options

Theorem 21.1

Regulating a natural monopoly:
Because an unregulated natural monopolist has an incentive to set $P > MC$ and restrict output, governments often regulate prices. Common approaches:
1. Marginal cost pricing: Set $P = MC$.

- Allocatively efficient: output equals the competitive quantity, no DWL.
- Problem: When $AC > MC$, the firm makes losses (since $P = MC < AC$); it requires a subsidy or government ownership.
- In practice, implementing $P = MC$ requires accurate information about the cost structure; if the regulated price is set too low, output may even fall below the monopoly level and reduce welfare.

2. Average cost pricing: Set $P = AC$.

- The firm earns zero economic profit (normal profit); no subsidy is required.
- Not allocatively efficient: $P = AC > MC$, so quantity is below the efficient level and some DWL remains.

3. Rate-of-return regulation: Allow the firm to set prices that yield a specified rate of return on capital.

- Common in practice (e.g. utilities).
- Potential problem: If higher allowed returns are based on higher measured costs, the firm may have weakened incentives to minimize costs (*Averch–Johnson effect*).

- Natural monopoly arises from cost structure (economies of scale) rather than only legal barriers.
- Regulation aims to balance **efficiency** (prices closer to MC) with **financial viability** (covering total cost, including a normal return).
- Government-created monopolies via patents protect innovation incentives but also create market power; the welfare impact depends on both static DWL and dynamic innovation benefits.

Part V
Other Market Structures

22 Introduction to Game Theory

Definition 22.1

Game theory: A collection of tools for predicting outcomes in settings where a (small) group of agents interact and the action of one agent directly affects the payoffs of other agents.

Key features:

- Players are *strategic*: they understand that their own payoff depends on others' actions and vice versa.
- Each player chooses a **strategy** (a plan of action) to maximize their own payoff.
- Payoffs capture all relevant benefits and costs (e.g. profits, utility, ratings points).

Types of non-cooperative games:

- **Normal-form games**: Players move simultaneously or without knowing others' moves.
- **Extensive-form games**: Players move sequentially; later players observe earlier moves (at least partially).

22.1 Normal-Form Games

22.1.1 Elements and Representation

Definition 22.2

Normal-form (strategic) game:
A normal-form game specifies:

- A set of players $i = 1, \ldots, n$.
- For each player i, a set of **strategies** S_i (also called actions).
- For each player i, a **payoff function** $u_i(s_1, \ldots, s_n)$ giving i's payoff for every strategy profile $(s_1, \ldots, s_n)$.

For two-player games, it is convenient to represent payoffs using a **payoff matrix**, with rows for Player 1's strategies, columns for Player 2's strategies, and each cell listing payoffs (u_1, u_2).

Worked Example

Prisoners' Dilemma (payoff matrix):
Two suspects (A and B) must each choose whether to *Confess* or *Remain Silent*. Payoffs are years of jail time (negative numbers represent disutility):

	Confess	**Remain silent**
Confess	$(-5, -5)$	$(0, -20)$
Remain silent	$(-20, 0)$	$(-1, -1)$

Each number in a cell is *that* player's payoff for the corresponding pair of actions.

22.1.2 Dominant Strategies and Dominant Strategy Equilibrium

Definition 22.3

Dominant strategy:
For player i, a strategy s_i^* is a *dominant strategy* if, for every combination of other players' strategies s_{-i},

$$u_i(s_i^*, s_{-i}) \geq u_i(s_i', s_{-i})$$

for *all* alternative strategies $s_i' \in S_i$ (with strict $>$ for at least one s_{-i} if we want a *strictly* dominant strategy).
In words: a dominant strategy is optimal for a player no matter what an opponent does.

Definition 22.4

Dominant Strategy Equilibrium (DSE):
A strategy profile $(s_1^*, \ldots, s_n^*)$ is a dominant strategy equilibrium if, for every player i, s_i^* is a dominant strategy.
In a DSE, each player is doing the best they can *regardless* of what the others do.

Worked Example

Prisoners' Dilemma as a dominant strategy equilibrium:
Using the payoff matrix above, consider Player A:

- If B Confesses, A's payoff is -5 from *Confess*, versus -20 from *Remain Silent*. A prefers to *Confess*.
- If B Remains Silent, A's payoff is 0 from *Confess*, versus -1 from *Remain Silent*. A again prefers to *Confess*.

So *Confess* is A's dominant strategy. By symmetry, *Confess* is also B's dominant strategy.
Thus the dominant strategy equilibrium is

$$(\text{Confess}, \text{Confess}),$$

even though (Remain silent, Remain silent) gives both players a better payoff (a classic conflict between individual incentives and joint welfare).

Worked Example

Advertising game (lecture example):
Two firms (A and B) decide whether to *Advertise* or *Not Advertise*. Payoffs (profits) are:

	Advertise	**Don't Advertise**
Advertise	$(10, 5)$	$(15, 0)$
Don't Advertise	$(6, 8)$	$(10, 2)$

Each firm compares payoffs across the other firm's choice. If for both firms *Advertise* yields a higher payoff regardless of the rival's decision, then *Advertise* is a dominant strategy and (Advertise, Advertise) is a dominant strategy equilibrium.

22.1.3 Nash Equilibrium

Definition 22.5

Best response:
Given other players' strategies s_{-i}, a strategy $\hat{s}_i$ is a *best response* for player i if

$$u_i(\hat{s}_i, s_{-i}) \geq u_i(s'_i, s_{-i}) \qquad \forall s'_i \in S_i.$$

Definition 22.6

Nash equilibrium:
A strategy profile $(s_1^*, \ldots, s_n^*)$ is a Nash equilibrium if, for each player i, s_i^* is a best response to s_{-i}^*. That is, no player can increase their payoff by unilaterally changing their own strategy, given what the others are doing.
Formally, for all players i and all $s'_i \in S_i$,

$$u_i(s_i^*, s_{-i}^*) \geq u_i(s'_i, s_{-i}^*).$$

Interpretation: I am doing the best I can given what you are doing; you are doing the best you can given what I am doing.

Theorem 22.1

Relationship between dominant strategy equilibrium and Nash equilibrium:

1. Every dominant strategy equilibrium is a Nash equilibrium.
2. A Nash equilibrium need not be a dominant strategy equilibrium (some players may not have dominant strategies at all).
3. A game may have zero, one, or multiple Nash equilibria.

22.1.4 Coordination Game with Multiple Nash Equilibria

Worked Example

Cereal game (coordination with two Nash equilibria):
Two cereal firms (1 and 2) must choose between flavors *Crispy* and *Sweet*. Payoffs are:

	Crispy	**Sweet**
Crispy	$(-5, -5)$	$(10, 10)$
Sweet	$(10, 10)$	$(-5, -5)$

Best responses:

- If Firm 2 chooses *Crispy*, Firm 1's best response is *Sweet* (payoff $10 > -5$).
- If Firm 2 chooses *Sweet*, Firm 1's best response is *Crispy* (again $10 > -5$).
- By symmetry, Firm 2's best responses are the same pattern.

Nash equilibria:

- (Sweet, Crispy): Given Firm 2 chooses Crispy, Firm 1 does best with Sweet; given Firm 1 chooses Sweet, Firm 2 does best with Crispy.

- (Crispy, Sweet): By symmetry.

Thus the game has **two Nash equilibria**, both giving payoffs $(10, 10)$. The outcomes $(-5, -5)$ are not Nash equilibria, since each firm would rather deviate.

Worked Example

Chocolate quality game (Problem Set 10):
Two firms compete in the chocolate market and choose *Low quality* or *High quality*. Payoffs (Firm 1, Firm 2) are:

	Low	**High**
Low	$(20, 30)$	$(900, 600)$
High	$(100, 800)$	$(50, 50)$

Dominant strategies?

- For Firm 1:
  - If Firm 2 chooses Low: 20 (Low) vs 100 (High) $\Rightarrow$ High is better.
  - If Firm 2 chooses High: 900 (Low) vs 50 (High) $\Rightarrow$ Low is better.

  Firm 1 has **no dominant strategy**.
- For Firm 2:
  - If Firm 1 chooses Low: 30 (Low) vs 600 (High) $\Rightarrow$ High is better.
  - If Firm 1 chooses High: 800 (Low) vs 50 (High) $\Rightarrow$ Low is better.

  Firm 2 also has **no dominant strategy**.

Nash equilibria (cells where both choose a best response):

- (Low, High): Given High by Firm 2, Low is Firm 1's best; given Low by Firm 1, High is Firm 2's best.
- (High, Low): Given Low by Firm 2, High is Firm 1's best; given High by Firm 1, Low is Firm 2's best.

So the chocolate game has **no dominant strategy equilibrium**, but it has **two Nash equilibria** in pure strategies.

Worked Example

TV networks scheduling game (Problem Set 10, simultaneous-move version):
Two TV networks (1 and 2) each choose to schedule their "bigger" show either in the *First* time slot (8–9 pm) or the *Second* time slot (9–10 pm). Payoffs (ratings points) are:

	First	**Second**
First	$(20, 30)$	$(18, 18)$
Second	$(15, 15)$	$(30, 10)$

Best responses:

- For Network 1:
  - If Network 2 chooses First: 20 (First) vs 15 (Second) $\Rightarrow$ best is First.
  - If Network 2 chooses Second: 18 (First) vs 30 (Second) $\Rightarrow$ best is Second.

- For Network 2:
  - If Network 1 chooses First: 30 (First) vs 18 (Second) ⇒ best is First.
  - If Network 1 chooses Second: 15 (First) vs 10 (Second) ⇒ best is First.

Network 2 has a **dominant strategy** (First). The unique Nash equilibrium of the simultaneous-move game is

$$(\text{First}, \text{First}),$$

since both are best responses to each other at that outcome.

22.2 Extensive-Form Games and Subgame Perfection

22.2.1 Game Trees and Backward Induction

Definition 22.7

Extensive-form game:
An extensive-form game specifies:

- The order of moves (who moves when).
- What each player knows when they move (information sets).
- The available actions at each decision node.
- The payoffs at each terminal node (end of the game).

Sequential-move games are naturally represented by **game trees**.

Definition 22.8

Subgame perfect equilibrium (SPE):
A strategy profile is a subgame perfect equilibrium if it induces a Nash equilibrium in every subgame of the extensive-form game.
In finite games of perfect information (players move one after another and observe previous moves), an SPE can be found by **backward induction**: solve the game from the end back to the beginning, assuming each player optimally responds at every decision node.

Worked Example

Sequential cereal game (backward induction):
Suppose Firm 1 chooses first between *Crispy* and *Sweet*, then Firm 2 observes Firm 1's choice and chooses *Crispy* or *Sweet*. Payoffs at the end of the game are as in the cereal game:

	Crispy	**Sweet**
Crispy	$(-5, -5)$	$(10, 10)$
Sweet	$(10, 10)$	$(-5, -5)$

Step 1 (Firm 2's best responses):

- If Firm 1 plays Crispy, Firm 2 prefers Sweet (10 > -5).
- If Firm 1 plays Sweet, Firm 2 prefers Crispy (10 > -5).

Step 2 (Firm 1's choice anticipating Firm 2):

- If Firm 1 plays Crispy, Firm 2 responds with Sweet, giving Firm 1 payoff 10.

- If Firm 1 plays Sweet, Firm 2 responds with Crispy, giving Firm 1 payoff 10.

Firm 1 is indifferent and either decision leads to payoff $(10, 10)$, with Firm 2 playing the best response in each case. The set of strategy profiles consistent with this backward-induction outcome forms the subgame perfect equilibrium of the sequential game.

Worked Example

TV networks scheduling game (Problem Set 10, sequential version):
Using the same payoff matrix as before, suppose:

1. **Network 1 moves first** (chooses First or Second), then Network 2 observes and chooses First or Second.
2. **Network 2 moves first**, then Network 1 observes and chooses.

Case (b): Network 1 moves first.
Backward induction:

- If Network 1 chooses First, Network 2's best response is First ($30 > 18$).
- If Network 1 chooses Second, Network 2's best response is First ($15 > 10$).

Anticipating that Network 2 will always choose First, Network 1 compares:

- If it chooses First: payoff 20 (First, First).
- If it chooses Second: payoff 15 (Second, First).

So Network 1 chooses First. The subgame perfect equilibrium is

$$(\text{First}, \text{First}).$$

Case (c): Network 2 moves first.
Now Network 2 anticipates Network 1's best responses:

- If Network 2 chooses First, Network 1's best response is First ($20 > 15$).
- If Network 2 chooses Second, Network 1's best response is Second ($30 > 18$).

So Network 2 compares:

- If it chooses First: payoff 30 at (First, First).
- If it chooses Second: payoff 10 at (Second, Second).

Network 2 chooses First. Again, the subgame perfect equilibrium is

$$(\text{First}, \text{First}).$$

Worked Example

Ultimatum game (Problem Set 10):
A proposer is endowed with \$10 and chooses how much to offer to a responder ($x \in \{0, 1, \ldots, 10\}$). The responder then either *accepts* or *rejects*:

- If the responder accepts: payoffs are $(10 - x, x)$.
- If the responder rejects: both get 0.

Backward induction under standard assumptions:

- In the last move, the responder prefers any positive amount $x > 0$ over 0, so will accept any $x > 0$ and is indifferent at $x = 0$.
- Anticipating this, the proposer maximizes own payoff by offering the smallest positive amount (e.g. \$1) and keeping the rest.

A subgame perfect equilibrium is therefore: proposer offers the minimum positive amount, responder accepts any positive offer. (In actual experiments, responders often reject very low offers, which is a central finding in behavioral game theory.)

22.3 Behavioral Game Theory and Experimental Evidence

22.3.1 Behavioral Prisoners' Dilemma

Definition 22.9

Behavioral game theory studies how real people actually play games, often using laboratory or field experiments, and compares observed behavior with the standard game-theoretic predictions. It incorporates factors such as fairness, reciprocity, limited rationality, and learning.

Worked Example

Experimental Prisoners' Dilemma:
A common payoff structure is:

	Confess	**Remain Silent**
Confess	$(3, 3)$	$(9, 1)$
Remain Silent	$(1, 9)$	$(7, 7)$

Theoretical prediction:

- *Confess* is a dominant strategy for both players.
- The unique dominant strategy equilibrium (and Nash equilibrium) is (Confess, Confess) with payoff $(3, 3)$.

Experimental finding:

- In one-shot laboratory experiments, a substantial fraction of participants choose *Remain Silent* (cooperate) instead of Confess, even though cooperation is not a best response given the other player's Confess.
- Experiments with real prisoners show different cooperation rates compared to student samples, highlighting the role of context and experience.

These deviations from the standard prediction motivate behavioral models that incorporate fairness motives, altruism, or bounded rationality.

22.3.2 Summary of Key Concepts

Theorem 22.2

Core concepts in game theory (for problem solving):

- **Dominant strategy**: A strategy that is optimal for a player no matter what an opponent does.
- **Dominant strategy equilibrium**: Each player plays a dominant strategy (if one exists).
- **Nash equilibrium**: Each player's strategy is a best response to the strategies of others; players may or may not have dominant strategies.
- **Extensive form and SPE**: In sequential games, subgame perfect equilibrium refines Nash equilibrium by requiring credible behavior in every subgame; backward induction is the main tool.
- **Price and quantity choices, advertising, entry games, bargaining**: All can be modeled using these ideas, and solved by systematically applying dominant strategies, best responses, Nash equilibrium, and backward induction.

23 Oligopoly

Exam Focus

This will be the only topic tested for Oligopoly in the 2025 Semester 1 HE1001 final exam.

1. In the Stackelberg model, the **leader (Firm 1)** earns a higher profit.
2. The choice variable in the Cournot/Stackelberg models is **quantity (output)**.
3. The Cournot equilibrium is a **Nash equilibrium**.
4. The Stackelberg equilibrium is a **subgame-perfect equilibrium**.

A Examination Preparation Guide

A.1 Overview of Practice Resources

The Quantitative Research Society has compiled a comprehensive examination preparation package consisting of five full-length practice examinations. Together, these resources provide over 10 hours of realistic practice under examination conditions, covering all major topics in HE1001 Microeconomics.

Resource	Questions	Marks	Time	Description
Practice Exam 1	12	100	120 min	Foundation exam covering core microeconomics concepts
Practice Exam 2	12	100	120 min	Advanced applications with emphasis on market structures
Practice Exam 3	12	100	120 min	Comprehensive coverage including game theory
Practice Exam 4	12	100	120 min	Integrated analysis with sophisticated applications
Practice Exam 5	12	100	120 min	Advanced mastery with oligopoly and strategic behavior
TOTAL	**60**	**500**	**600 min**	**10 hours practice**

A.2 Examination Structure

Standard Format (Practice Exams 1–5):
All five practice examinations follow the identical structure expected in the actual final examination:

- **Question 1**: 6 multiple-choice questions (5 marks each = 30 marks total)
- **Question 2**: 3 MCQs with justification (10 marks each = 30 marks total)
- **Question 3**: 3 long-form structured problems (13–14 marks each = 40 marks total)
- **Total**: 100 marks, 120 minutes (2 hours)

A.3 Resource Categorization

A.3.1 Tutorial-Based Examinations (Direct Adaptation)

All Practice Exams (1–5) use questions *directly adapted from* the 10 tutorial problem sets:

- **Practice Exam 1**: 100% direct tutorial adaptations
  - Focus: Supply/demand equilibrium, consumer theory, production, perfect competition
  - Difficulty: 5.2/10 (moderate baseline)
  - Best for: Building foundational understanding
  - Coverage: Topics from 8 tutorials (PS1, 2, 3, 4, 5, 6, 7, 9)
- **Practice Exam 2**: 100% direct tutorial adaptations
  - Focus: Elasticity, utility maximization, monopoly, price discrimination
  - Difficulty: 5.3/10 (slightly elevated)
  - Best for: Advanced market analysis and welfare economics
  - Coverage: Topics from 8 tutorials (PS1, 2, 3, 4, 5, 6, 7, 9)
- **Practice Exam 3**: 100% direct tutorial adaptations
  - Focus: Behavioral economics, government intervention, game theory
  - Difficulty: 5.4/10 (comprehensive)
  - Best for: Integrated understanding across multiple frameworks

  - Coverage: Topics from 8 tutorials (PS1, 2, 3, 4, 5, 7, 9, 10)
- **Practice Exam 4**: 100% direct tutorial adaptations
  - Focus: Cost analysis, production optimization, strategic behavior
  - Difficulty: 5.5/10 (sophisticated)
  - Best for: Advanced problem-solving verification
  - Coverage: Topics from 9 tutorials (PS1, 2, 3, 5, 6, 7, 8, 9, 10)
- **Practice Exam 5**: 100% direct tutorial adaptations
  - Focus: Advanced consumer theory, oligopoly concepts, strategic equilibria
  - Difficulty: 5.6/10 (highest sophistication)
  - Best for: Final mastery verification and oligopoly understanding
  - Coverage: Cobb-Douglas analysis, long-run equilibrium, third-degree price discrimination, SPNE
  - Special feature: Includes conceptual oligopoly questions within syllabus restrictions

Key Feature: These five examinations have **zero overlap**—all 60 questions are unique. Students can complete all five for maximum exposure to tutorial content without repetition.

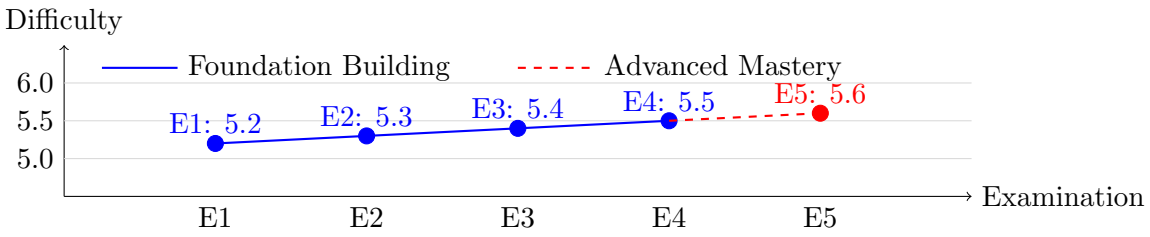
A.4 Tutorial Coverage Analysis

Tutorial	Total Q's	E1	E2	E3	E4	E5	Coverage
PS1	8	2	1	2	2	0	88%
PS2	6	3	2	1	1	0	117%*
PS3	8	3	2	3	3	2	163%*
PS4	8	2	2	2	2	2	125%*
PS5	6	2	2	2	2	1	150%*
PS6	6	1	2	0	2	1	100%
PS7	10	3	2	2	3	3	130%*
PS8	8	2	2	1	2	2	113%*
PS9	9	2	2	2	2	1	100%
PS10	5	0	0	2	1	0	60%
TOTAL	**74**	**12**	**12**	**12**	**12**	**12**	**81%**

**Over 100% indicates high-value questions used across multiple contexts*

Analysis: The five practice examinations collectively utilize 60 unique tutorial questions (81% of all 74 tutorial questions). This provides comprehensive coverage while ensuring diverse testing contexts. High-value questions from PS3, PS4, PS5, PS7, and PS8 appear in adapted forms across multiple exams, reinforcing critical concepts.

A.5 Difficulty Progression



Progression Strategy:

- **Exams 1–3** (blue): Core concepts and standard applications
- **Exam 4** (blue): Integration and strategic analysis
- **Exam 5** (red): Peak difficulty with oligopoly and advanced topics
- **Overall**: Steady difficulty increase from 5.2 to 5.6

A.6 Topic Coverage Across Examinations

Topic	E1	E2	E3	E4	E5
Supply and Demand	✓	✓	✓	✓	–
Elasticity	✓	✓	–	✓	✓
Consumer Theory	✓	✓	✓	✓	✓
Production and Costs	✓	–	–	✓	✓
Perfect Competition	✓	✓	–	✓	✓
Monopoly	✓	✓	–	–	✓
Price Discrimination	✓	–	–	✓	✓
Government Intervention	✓	–	✓	–	✓
Behavioral Economics	–	–	✓	✓	–
Game Theory	–	–	✓	✓	✓
Oligopoly (Conceptual)	–	–	–	–	✓
Topics Covered	**8/11**	**6/11**	**6/11**	**8/11**	**9/11**

Coverage Strategy:

- **Core topics** (consumer theory, costs): All 5 exams
- **Market structures** (competition, monopoly): Exams 1–2, 4–5
- **Strategic behavior** (game theory): Exams 3–5
- **Oligopoly** (conceptual only): Exam 5 exclusively
- **Applied topics** (intervention, discrimination): Distributed across exams

A.7 Problem Type Analysis

Question 1 (MCQs — 30 marks):

- Conceptual understanding and definitions
- Quick calculations and interpretations
- Identification of economic relationships
- Time allocation: 25–30 minutes (5 min per question)

Question 2 (MCQs with Justification — 30 marks):

- Application of economic principles
- Explanation of reasoning and mechanisms
- Connection between concepts
- Time allocation: 30–35 minutes (10–12 min per question)

Question 3 (Long-Form Problems — 40 marks):

- Multi-step calculations with full working
- Graphical analysis and interpretation
- Policy analysis and welfare implications
- Time allocation: 55–65 minutes (18–22 min per problem)

B Formula & Key Concepts Reference

Price Elasticity of Demand:

$$E_P = \frac{dQ}{dP} \cdot \frac{P}{Q}$$

Income Elasticity:

$$E_Y = \frac{dQ/Q}{dI/I}$$

Cross-Price Elasticity:
Substitutes > 0, complements < 0.
Budget Constraint:

$$P_X X + P_Y Y = I$$

MRS and Utility Maximization:

$$MRS_{X,Y} = -\frac{MU_X}{MU_Y}, \quad MRS_{X,Y} = \frac{P_X}{P_Y}$$

$$\frac{MU_X}{P_X} = \frac{MU_Y}{P_Y}$$

Cobb–Douglas Demand (example):
For $U(X,Y) = X^\alpha Y^{1-\alpha}$,

$$X^* = \frac{\alpha I}{P_X}, \quad Y^* = \frac{(1-\alpha)I}{P_Y}$$

Marginal Products:

$$MP_L = \frac{\partial q}{\partial L}, \quad MP_K = \frac{\partial q}{\partial K}$$

MRTS: $MRTS_{L,K} = -\frac{MP_L}{MP_K}$

Cost Functions:

$$TC = FC + VC$$

$$MC = \frac{dC}{dq}$$

$$ATC = \frac{TC}{q}, \quad AVC = \frac{VC}{q}, \quad AFC = \frac{FC}{q}$$

Minimum Cost Condition:

$$MC = ATC \quad \text{at } \min ATC$$

Profit:

$$\pi = Pq - C(q)$$

Shutdown Condition:
Operate if $P \geq \min(AVC)$; shut down if $P < \min(AVC)$.
Competitive Firm Revenue:

$$MR = AR = P$$

Perfect Competition (firm):

$$P = MC \quad \text{in equilibrium}$$

Monopoly MR (general):

$$MR = P\left(1 + \frac{1}{\varepsilon_D}\right)$$

Lerner Index:

$$\frac{P - MC}{P} = -\frac{1}{\varepsilon_D}$$

Linear Demand Example:

$$P(Q) = a - bQ, \quad MR(Q) = a - 2bQ$$

Consumer/Producer Surplus:
Area of triangles between demand/supply and price.
Deadweight Loss (DWL):
Triangle area from restricted quantity **Long-Run Competitive Equilibrium:**

$$P = \min(AC), \quad \pi_{\text{economic}} = 0$$

Goods & Elasticities

- Substitutes: $\varepsilon_{XY} > 0$
- Complements: $\varepsilon_{XY} < 0$
- Normal good: income $\uparrow \Rightarrow$ demand $\uparrow$
- Inferior good: income $\uparrow \Rightarrow$ demand $\downarrow$

Time Horizons

- Short run: at least one input is fixed
- Long run: all inputs are variable; entry/exit possible

Cost Concepts

- Fixed vs variable costs: FC does not change with q, VC does
- Shutdown: compare P to AVC (not ATC)
- Exit (long run): compare P to AC

Market Structures

- Perfect competition: many firms, price-taking, $P = MC$
- Monopoly: single firm, $MR = MC$, $P > MC$, DWL
- Price discrimination (3rd degree): different prices in segments where $|\varepsilon|$ differs

Game Theory

- Nash equilibrium: no player can gain by unilateral deviation
- Dominant strategy: best action regardless of others' actions
- SPNE: Nash equilibrium of the entire game tree, respecting credibility in sequential moves

Tax Incidence

- Side of the market that is more inelastic bears more of the tax burden
- Legal incidence (who pays tax) can differ from economic incidence (who bears burden)

Oligopoly

- In Stackelberg, **the leader** earns higher profit than the follower.
- In Cournot and Stackelberg models, firms choose **quantity (output)**, not price.
- Cournot equilibrium is a **Nash equilibrium**.
- Stackelberg equilibrium is a **subgame-perfect equilibrium**.

C Key Concept Summary

Basic Economic Concepts

- Microeconomics studies how individuals and firms maximize well-being under **scarcity**.
- Core concept: **constrained optimization** and assessing **trade-offs**.
- **Opportunity cost**: value of the best alternative given up.
- A model describes relationships between economic variables.
- **Capitalist economy**: decentralized decisions by individuals/firms.
- **Command economy**: centralized decisions by the government.
- Adam Smith's **invisible hand**: markets can self-regulate.

Demand and Supply

- **Demand curve**: downward-sloping; shows quantity demanded at each price.
- **Supply curve**: upward-sloping; shows quantity supplied at each price.
- Market equilibrium: intersection of demand and supply.
- Demand shifters: income, preferences, prices of substitutes/complements.
- Supply shifters: input prices, technology, number of firms.
- Movement *along* vs. shift *of* curves.
- Surplus (price too high), shortage (price too low).

Elasticities

- **Price Elasticity**: $E_P = \frac{dQ}{dP} \cdot \frac{P}{Q}$.
- Inelastic ($|E_P| < 1$): price $\uparrow \implies$ revenue $\uparrow$.
- Elastic ($|E_P| > 1$): price $\uparrow \implies$ revenue $\downarrow$.
- **Income elasticity**: normal vs inferior goods.
- **Cross-price elasticity**: substitutes (positive), complements (negative).

Preferences, Utility, and Choice

- Preference assumptions: completeness, transitivity, non-satiation.
- Indifference curves: downward-sloping, convex, non-intersecting.
- **MRS**: $MRS = -\frac{MU_X}{MU_Y}$.
- Budget constraint: $p_X X + p_Y Y = I$; slope $-\frac{p_X}{p_Y}$.
- Optimal choice: $MRS = \frac{p_X}{p_Y}$ (tangency).
- Special cases: perfect substitutes, perfect complements.

Production

- Production function $q = f(K, L)$.
- Marginal product of labor: $MP_L = \frac{\partial q}{\partial L}$.
- Diminishing marginal returns.
- Short run: at least one input fixed.
- Long run: all inputs variable.
- Isoquants; MRTS $= -\frac{MP_L}{MP_K}$.

Cost

- $TC = FC + VC$; $MC = \frac{dC}{dq}$; $ATC = \frac{TC}{q}$.
- MC intersects ATC and AVC at their minimum points.
- LRAC is the envelope of SRATC curves.
- Economies and diseconomies of scale.
- Cost minimization: $\frac{MP_L}{w} = \frac{MP_K}{r}$.

Perfect Competition

- Firms are **price takers**.
- $MR = P$; profit maximization: $P = MC$.
- Shutdown rule: $P < \min AVC$.
- Long-run equilibrium: $P = \min LRAC$ and zero economic profit.

Monopoly

- Single seller; downward-sloping demand.
- $MR < P$; profit maximization: $MR = MC$.
- Lerner Index: $\frac{P-MC}{P} = -\frac{1}{\varepsilon_D}$.
- DWL from monopoly due to reduced output.

Game Theory

- Dominant strategy; Nash equilibrium.
- Best response reasoning.
- Sequential games: backward induction, SPE.

Oligopoly

- In the Stackelberg model, the **leader (Firm 1)** earns a higher profit.
- The choice variable in the Cournot/Stackelberg models is **quantity (output)**.
- The Cournot equilibrium is a **Nash equilibrium**.
- The Stackelberg equilibrium is a **subgame-perfect equilibrium**.