Chapter 13

Imperfect Competition and Game Theory

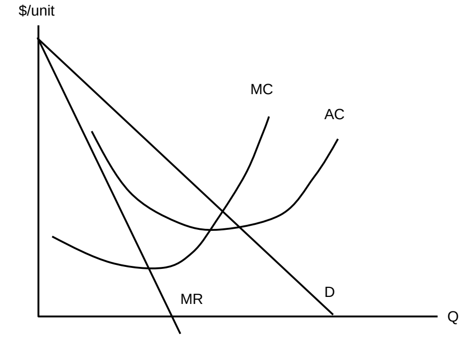
Monopolistic Competition

- Market power exists when a firm faces a downward sloping demand
  - Such firms are NOT price takers
- When firms in a market produce differentiated products, they can all have downward sloping demand curves

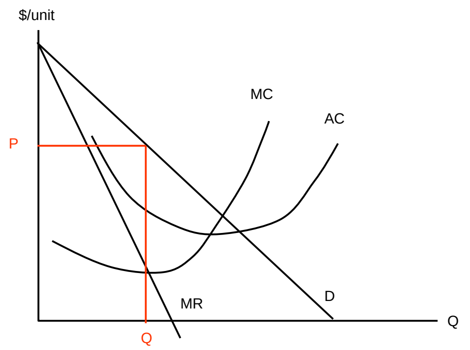
Monopolistic Competition: Assumptions

- Many firms
- Differentiated products
  - Downward sloping demand
- Free entry in the long run
  - Zero profits in the long run

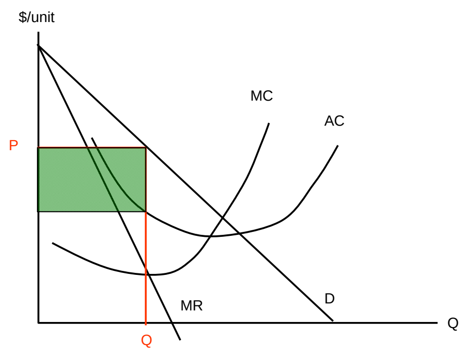
Monopolistic Competition



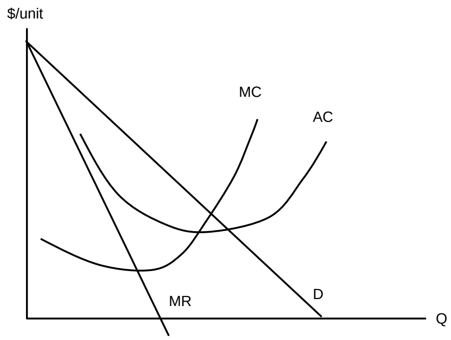
Price and Quantity



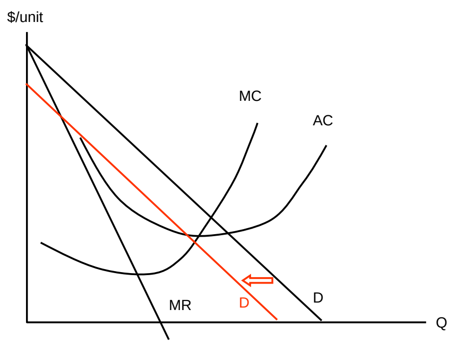
Profit



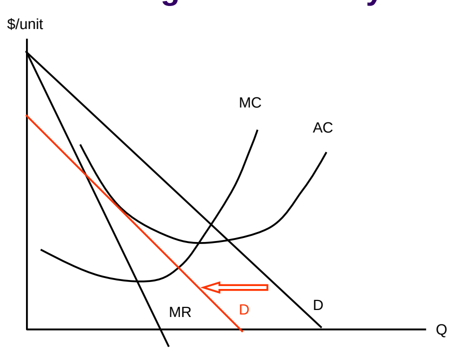
In the Long Run …



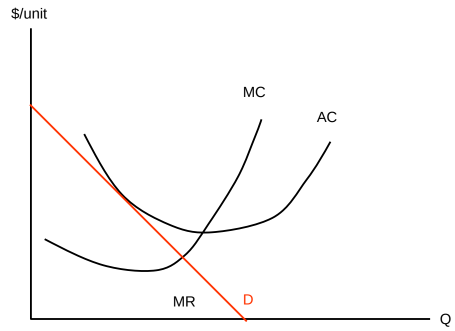
In the Long Run … Entry



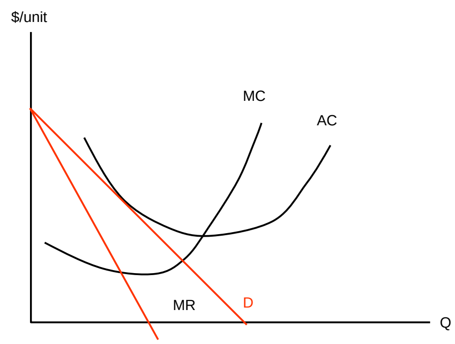
In the Long Run … Entry



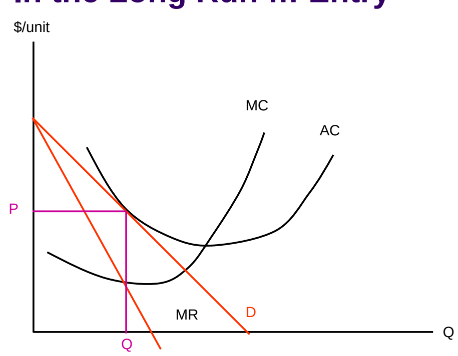
In the Long Run … Entry



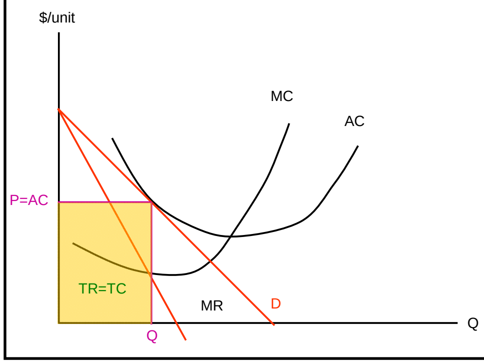
In the Long Run … Entry



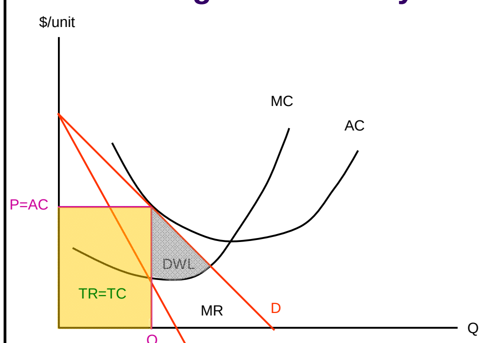
In the Long Run … Entry



In the Long Run … Entry



In the Long Run … Entry



Monopolistic Competition: Summary

- Profit maximization: *MR* = *MC*
- Long Run: Entry leads to zero profit: *P* = *AC*
- At the chosen output, the firm does NOT operate at the minimum of the AC curve
  - However, the firm does produce its chosen output at the minimum cost for that output
- There is a deadweight loss, as under monopoly
- Optimal variety for society? Ambiguous.
- Because monopolistic competition is common, monopoly theory is broadly relevant.

Game Theory: Why?

- Game theory is the discipline that analyzes equilibrium in situations where "players" must anticipate rival's incentives, choices, and reactions

Game Theory: Why?

- Neither perfect competition nor monopoly markets involved strategic interaction between firms
  - Under monopoly, there was just one firm
  - Under competition, each firm was so small that its actions had no perceptible effects on others
- Oligopoly markets have few firms
  - Firms are large enough that their actions affect others, and strategic interactions are inherent

Noncooperative Games

- Game theory is divided into 2 branches
  - Noncooperative
  - Cooperative
- In noncooperative games, players must make choices independently, without cooperation or negotiation
  - In oligopoly settings, cooperative behavior might often be judged illegal under the antitrust laws, so our emphasis will be on noncooperative games

Basic Assumptions

- Firms are rational
  - They pursue goals; e.g., profit
- Firms apply their rationality to the process of reasoning strategically

Oligopoly Theory: A Warning

- Oligopoly markets are varied
  - Number of competitors
  - Variety of strategic choices: prices, quantities, investment, advertising, etc.
  - Information environment
  - Timing of actions
- There is no single theory of oligopoly

What is a Game?

- A game consists of
  - Players
  - Rules
  - Possible strategies for the players
  - Payoffs to be earned by the players under all possible strategy combinations (a strategy combination is a list of strategies, one for each player)

Equilibrium

- Equilibrium
  - An equilibrium is a strategy combination (i.e., a group of strategies, one for each player), such that no player wants to unilaterally change her strategy choice
  - This is the Nash equilibrium concept

Game Theory and Oligopoly

- We will assume that players are firms
- Strategies will often be choices for price or quantity
- Payoffs will normally be profits
- Example:
  - If firms must each select a quantity in a single market period, then an equilibrium consists of a quantity for each firm, such that no individual firm wishes to unilaterally change its quantity

Strategic Thinking

- When one firm selects a strategy, it must anticipate what all other firms will do
- To anticipate what others will do, it must analyze the problem others face
  - What would I do if I were in her shoes?
- The Nash equilibrium concept is compatible with such thinking
  - When I forecast my opponent's behavior, if I fail to forecast a Nash equilibrium strategy, then I must be assuming that someone is playing irrationally!

A Pricing Game

		Firm 2	
		Low	High
Firm 1	Low	Firm 1: $30 Firm 2: $30	Firm 1: $80 Firm 2: $10
	High	Firm 1: $10 Firm 2: $80	Firm 1: $60 Firm 2: $60

Equilibrium?

		Firm 2	
		Low	High
Firm 1	Low	Firm 1: $30 Firm 2: $30	Firm 1: $80 Firm 2: $10
	High	Firm 1: $10 Firm 2: $80	Firm 1: $60 Firm 2: $60

Firm 1 Prefers Low

		Firm 2	
		Low	High
Firm 1	Low	Firm 1: $30 Firm 2: $30	Firm 1: $80 Firm 2: $10
	High	Firm 1: $10 Firm 2: $80	Firm 1: $60 Firm 2: $60

Firm 2 Also Prefers Low

		Firm 2	
		Low	High
Firm 1	Low	Firm 1: $30 Firm 2: $30	Firm 1: $80 Firm 2: $10
	High	Firm 1: $10 Firm 2: $80	Firm 1: $60 Firm 2: $60

Not an Equilibrium

- Since both players would want to depart from the conjectured “high-high” equilibrium, in fact that is NOT an equilibrium

Equilibrium?

		Firm 2	
		Low	High
Firm 1	Low	Firm 1: $30 Firm 2: $30	Firm 1: $80 Firm 2: $10
	High	Firm 1: $10 Firm 2: $80	Firm 1: $60 Firm 2: $60

Not an Equilibrium
Firm 2 Prefers Low

		Firm 2	
		Low	High
Firm 1	Low	Firm 1: $30 Firm 2: $30	Firm 1: $80 Firm 2: $10
	High	Firm 1: $10 Firm 2: $80	Firm 1: $60 Firm 2: $60

Equilibrium?

		Firm 2	
		Low	High
Firm 1	Low	Firm 1: $30 Firm 2: $30	Firm 1: $80 Firm 2: $10
	High	Firm 1: $10 Firm 2: $80	Firm 1: $60 Firm 2: $60

Not an Equilibrium
Firm 1 Prefers Low

		Firm 2	
		Low	High
Firm 1	Low	Firm 1: $30 Firm 2: $30	Firm 1: $80 Firm 2: $10
	High	Firm 1: $10 Firm 2: $80	Firm 1: $60 Firm 2: $60

Equilibrium?

		Firm 2	
		Low	High
Firm 1	Low	Firm 1: $30 Firm 2: $30	Firm 1: $80 Firm 2: $10
	High	Firm 1: $10 Firm 2: $80	Firm 1: $60 Firm 2: $60

Firm 1 is Satisfied

		Firm 2	
		Low	High
Firm 1	Low	Firm 1: $30 Firm 2: $30	Firm 1: $80 Firm 2: $10
	High	Firm 1: $10 Firm 2: $80	Firm 1: $60 Firm 2: $60

Firm 2 is Satisfied

		Firm 2	
		Low	High
Firm 1	Low	Firm 1: $30 Firm 2: $30	Firm 1: $80 Firm 2: $10
	High	Firm 1: $10 Firm 2: $80	Firm 1: $60 Firm 2: $60

Low-Low is a Nash Equilibrium

		Firm 2	
		Low	High
Firm 1	Low	Firm 1: $30 Firm 2: $30	Firm 1: $80 Firm 2: $10
	High	Firm 1: $10 Firm 2: $80	Firm 1: $60 Firm 2: $60

Interpretation of the Game

- One can see the gains that might be had from cooperation/collusion
- However, the noncooperative Nash equilibrium results in lower profit than might be achieved with cooperation
- Under oligopoly, firms are always attracted by the gains from cooperating, but they always have an incentive to unilaterally deviate from cooperative outcomes

The Prisoners' Dilemma

- The Prisoners' Dilemma game has almost exactly the same structure (despite the different story)
  - Two suspects, A and B, are arrested by the police.
  - The police do not have enough evidence to convict for the serious charge
  - The prisoners are separated and each is offered this deal: if you confess and your accomplice does not, you will get off free and your accomplice will get 10 years
  - If neither confesses, each gets 1 year for a lesser charge.
  - If both confess, each receives a 3-year sentence.
  - Each prisoner must make the choice of whether to "fink" or "stonewall"
- How should the prisoners act?

Prisoners' Dilemma

		Bonnie	
		Fink	Stonewall
Clyde	Fink	B: 3 C: 3	B: 10 C: 0
	Stonewall	B: 0 C: 10	B: 1 C: 1

Bigger numbers (sentences) are lower payoffs

Prisoners' Dilemma: Equilibrium

		Bonnie	
		Fink	Stonewall
Clyde	Fink	B: 3 C: 3	B: 10 C: 0
	Stonewall	B: 0 C: 10	B: 1 C: 1

Bigger numbers (sentences) are lower payoffs

Dominant Strategies

- The primary "equilibrium" or "solution" concept for games is the Nash equilibrium
- Solutions for the preceding examples illustrate a stronger equilibrium concept that can sometimes be invoked
- In the prisoners' dilemma, each player had a dominant strategy, and the equilibrium is termed a dominant strategy equilibrium

Dominant and Dominated Strategies

- In the prisoners' dilemma, each player will prefer to fink, regardless of the choice of the opponent
  - "Fink" is a dominant strategy for both Bonnie and Clyde
- Fink is always a better choice than stonewalling, regardless of an opponent's play
  - "Stonewall" is a dominated strategy
- In other games, strategies might be neither dominant nor dominated.

Dominant Strategy for Bonnie

		Bonnie	
		Fink	Stonewall
Clyde	Fink	B: 3 C: 3	B: 10 C: 0
	Stonewall	B: 0 C: 10	B: 1 C: 1

Bigger numbers (sentences) are lower payoffs

Dominant Strategy for Bonnie

		Bonnie	
		Fink	Stonewall
Clyde	Fink	B: 3 C: 3	B: 10 C: 0
	Stonewall	B: 0 C: 10	B: 1 C: 1

Bigger numbers (sentences) are lower payoffs

Dominant Strategy for Clyde?

- Clyde also has a dominant strategy, which is to “fink”

Nash Equilibrium and Dominant Strategy Equilibrium

- A dominant strategy equilibrium is always a Nash equilibrium
- However, a Nash equilibrium need not be a dominant strategy equilibrium
  - Nash only requires that an equilibrium strategy be best against the opponent’s equilibrium choice; dominance requires that the equilibrium strategy be best against any possible opponent strategy
- Nash equilibria generally exist; dominant strategy equilibria often do not

Another Game: Rock, Paper , Scissors

- There are 2 players
- Play is simultaneous
- Strategy options for each player are “rock,” “paper,” or “scissors”
- The winner is determined by:
  - Rock breaks scissors
  - Scissors cut paper
  - Paper covers rock

Rock, Paper, Scissors

		Nicole		
		Rock	Paper	Scissors
Anna	Rock	A: 0 N: 0	A: -1 N: 1	A: 1 N: -1
	Paper	A: 1 N: -1	A: 0 N: 0	A: -1 N: 1
	Scissors	A: -1 N: 1	A: 1 N: -1	A: 0 N: 0

Nash Equilibrium for Rock, Paper, Scissors?

- There is no "pure strategy" equilibrium
  - There is no pair of strategies in the table, one for each player, such that both players are happy with their choice, given their opponent's choice
- There will be a Nash equilibrium in mixed strategies
  - A mixed strategy consists of a set of strategy choices and associated probabilities, such the strategy choice in a play of the game is determined randomly (according to the prescribed probabilities)
- What is the mixed strategy equilibrium for this game?

Real-World Mixed Strategies

- Do football teams pass with probability 1.0 on third and eight?
- If you play tennis against an opponent with a weak backhand, do you serve to his backhand with probability 1.0?
- Suppose workers like to goof off when the boss is not watching—could the equilibrium may involve random monitoring?

A Sequential Move Game: A Market Entry Game

- Assumptions
  - There are two firms, "Incumbent" and "Entrant"
  - Entrant moves first, deciding to "Enter" or Stay Out"
  - After Entrant moves, Incumbent must choose to "Prey" or "Accommodate"

The Entry Game

- Payoffs
  - If Entrant stays out, the entrant gets 0 and the incumbent gets monopoly profit of $50
  - If Entrant enters and the incumbent preys, then Entrant makes -$20 (a loss) and the incumbent earns $10
  - If Entrant enters and the incumbent accommodates, then Entrant earns $20 and Incumbent earns $30

Entry Game Payoff Matrix

		Incumbent	
		Prey	Accommodate
Entrant	Enter	E: -$20 I: $10	E: $20 I: $30
	Stay Out	E: $0 I: $50	E: $0 I: $50

Two Nash Equilibria

		Incumbent	
		Prey	Accommodate
Entrant	Enter	E: -$20 I: $10	E: $20 I: $30
	Stay Out	E: $0 I: $50	E: $0 I: $50

Incumbent is Satisfied

		Incumbent	
		Prey	Accommodate
Entrant	Enter	E: -$20 I: $10	E: $20 I: $30
	Stay Out	E: $0 I: $50	E: $0 I: $50

Entrant is Satisfied

		Incumbent	
		Prey	Accommodate
Entrant	Enter	E: -$20 I: $10	E: $20 I: $30
	Stay Out	E: $0 I: $50	E: $0 I: $50

Incumbent is Satisfied

		Incumbent	
		Prey	Accommodate
Entrant	Enter	E: -$20 I: $10	E: $20 I: $30
	Stay Out	E: $0 I: $50	E: $0 I: $50

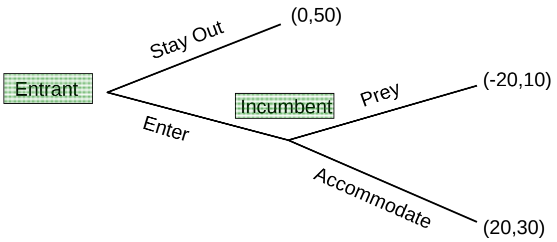
Entrant is Satisfied

		Incumbent	
		Prey	Accommodate
Entrant	Enter	E: -$20 I: $10	E: $20 I: $30
	Stay Out	E: $0 I: $50	E: $0 I: $50

Which Equilibrium is "Better"?

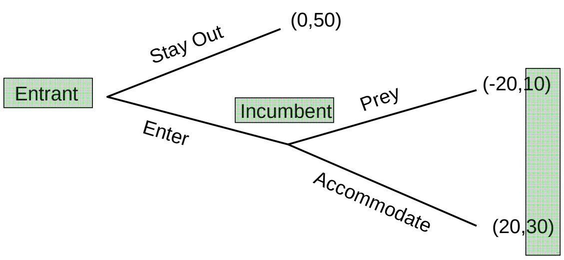
- It is not unusual for games to have multiple Nash equilibria, and often it is difficult to say that one is any more likely to occur than another
- However, for this game, there is a good way to choose

The Game Tree



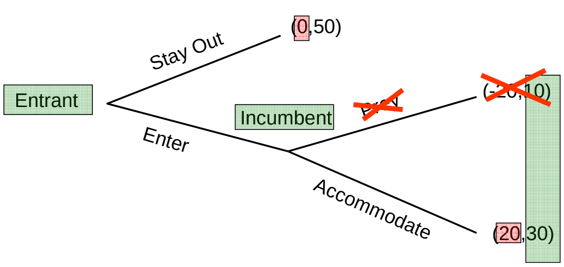
Backward Induct

If Entrant enters, then Incumbent will accommodate



Backward Induct

Entrant, anticipating accommodation upon entry, will enter.



Two Nash Equilibria

		Incumbent	
		Prey	Accommodate
Entrant	Enter	E: -$20 I: $10	E: $20 I: $30
	Stay Out	E: $0 I: $50	E: $0 I: $50

Incumbent Threat to "Prey" is NOT Credible

		Incumbent	
		Prey	Accommodate
Entrant	Enter	E: -$20 I: $10	E: $20 I: $30
	Stay Out	~~E: $0 I: $50~~	E: $0 I: $50

Subgame Perfect Nash Equilibrium

		Incumbent	
		Prey	Accommodate
Entrant	Enter	E: -$20 I: $10	E: $20 I: $30
	Stay Out	~~E: $0 I: $50~~	E: $0 I: $50

Subgame Perfect Nash Equilibrium

- Subgame perfection
  - Requires that in sequential games, an equlibrium must satisfy the logic implied by backward induction
  - Eliminates Nash equilibria based upon threats that are not credible

Cournot and Bertrand Models

- This presentation describes two oligopoly models, the Cournot and Bertrand models
- Both models assume:
  - 2 firms (no entry)
  - Homogeneous good
  - Single market period
  - Simultaneous moves
  - Payoffs are profits
- Cournot assumes firms set quantities; Bertrand assumes firms set prices
- The equilibrium concept is the “Nash” equilibrium

Nash Equilibrium

- A Nash equilibrium is a strategy combination (i.e., a listing of strategies, one for each player), such that no player wants to unilaterally change her strategy choice

A Cournot Problem

- As noted, The Cournot Model assumes that strategies are quantities
  - Price is determined by demand, once quantities have been selected by each firm
- The strategy space is continuous
  - Unlike the games presented in the out-of-class handout
- We look at a specific numerical example

Demand and Cost

- Demand is given by:

$$P = 100 - Q$$

$$P = 100 - q_1 - q_2$$

- There is a constant marginal cost:

$$c = 20$$

The Problem

- Each firm must choose its quantity
- Once quantities are chosen, price is determined by the demand function
- Once price is determined, we find the profit payoffs for firms
- We seek quantities, q_1 and q_2, such that each firm is satisfied with its choice, given the choice of its rival

Firm 1's Problem

- Suppose firm 1 knows (or forecasts) that firm 2 will produce a given quantity, q_2
- Given q_2, its problem is to maximize its own profit by choosing q_1,

$$\text{Max } \pi = (100 - q_1 - q_2)q_1 - 20q_1$$

Firm 1's Problem

$$\pi = (100 - q_1 - q_2)q_1 - 20q_1$$

Firm 1's Problem

$$\pi = (100 - q_1 - q_2)q_1 - 20q_1$$

$$\pi = 100q_1 - q_1^2 - q_2 q_1 - 20q_1$$

$$\frac{d\pi}{dq_1} = 100 - 2q_1 - q_2 - 20 = 0$$

$$-2q_1 = -80 + q_2$$

$$q_1 = 40 - \frac{1}{2}q_2$$

Best Response Functions

- We just found the "best-response function" or "reaction function" for firm 1
- Our problem is completely symmetric, so we can find the best-response function for firm 2 in the same way
- The best response functions for the two firms are (note the symmetry):

$$q_1 = 40 - \frac{1}{2}q_2 \qquad q_2 = 40 - \frac{1}{2}q_1$$

Best Response Functions

- Find quantities for the two firms so that each is the best response to the other
- Jus solve the two equations for the two unknowns, q_1 and q_2:

$$q_1 = 40 - \frac{1}{2}q_2 \qquad q_2 = 40 - \frac{1}{2}q_1$$

Solving

$$q_1 = 40 - \frac{1}{2}q_2 \text{ and } q_2 = 40 - \frac{1}{2}q_1$$

$$q_1 = 40 - \frac{1}{2}\left(40 - \frac{1}{2}q_1\right)$$

$$q_1 = 40 - 20 + \frac{1}{4}q_1$$

$$\frac{3}{4}q_1 = 20$$

$$q_1 = \frac{80}{3}$$

… and by Symmetry

$$q_1 = 40 - \frac{1}{2}q_2 \text{ and } q_2 = 40 - \frac{1}{2}q_1$$

$$q_1 = 40 - \frac{1}{2}\left(40 - \frac{1}{2}q_1\right)$$

$$q_1 = 40 - 20 + \frac{1}{4}q_1$$

$$\frac{3}{4}q_1 = 20$$

$$q_1 = \frac{80}{3} \qquad q_2 = \frac{80}{3}$$

Solve for *P*

$$P = 100 - q_1 - q_2$$

$$P = \frac{140}{3} = 46.67$$

Solve for Profit

$$\pi_1 = \pi_2 = \frac{140}{3}\cdot\frac{80}{3} - 20\cdot\frac{80}{3}$$

$$\pi_1 = \pi_2 = \frac{140}{3}\cdot\frac{80}{3} - 20\cdot\frac{80}{3}$$

$$\pi_1 = \pi_2 = 711.11$$

Cournot Model Implications

- Price is less than would have been charged by a monopoly with the same demand and costs
- The sum of the firms' profits are less than would have been earned by a monopoly with the same demand and costs
- Price exceeds marginal cost
- Both firms earn positive profits

The Bertrand Model

- Recall that the Bertrand model is like that of Cournot except that firms select prices rather than quantities

The Bertrand Model: Demand Facing a Firm

- As in the Cournot example, we let market demand be given by:

$$P = 100 - Q$$

Or, equivalently:

$$Q = 100 - P$$

Also, marginal cost is again constant, and equal to 20.

What Prices?

- Prices are now strategies, so we look to find a Nash equilibrium: a pair of prices such that each firm is satisfied with its choice, given the choice of its rival.

The Bertrand Model: Demand Facing a Firm

- Demands for each firm are determined as follows:
  - When the firms charge different prices, only the low-price firm can sell any output; its quantity demanded is given by the market demand at that low price
  - When both firms charge the same price, the two firms split the market demand

Demand Examples

- If firm 1 chooses p_1 = 50 and firm 2 chooses p_2 = 40, then
  - Firm 1 sells $q_1 = 0$
  - Firm 2 sells $q_2 = 100 – 40 = 60$
- If both firms charge $p_1 = p_2 = 50$
  - Market demand is $Q = 100 - 50 = 50$
  - Each firm sells $q_1 = q_2 = 25$

The Nash Equilibrium is …

- The unique Nash Equilibrium has each firm charging a price equal to marginal cost ($MC = 20$)
  - Suppose that in equilibrium a firm sets price is lower than marginal cost. At least one firm must be making negative profits, and could do better by raising price
  - Suppose $p_i > p_j > 20$. Then the high price firm *i*, would prefer to set its price lower than p_j but above 20
  - Similarly, suppose that $p_i = p_j > 20$. Either firm would prefer to set its price lower than its rival, but above 20
  - Suppose $p_i > p_j = 20$. Then the low price firm *j*, would prefer to set its price above 20 but lower than p_i
  - The only possible case left is $p_i = p_j = 20$. Neither would wish to deviate from this point.

Bertrand Model Intuition

- In this model firms always want to undercut a rival's price when that price is above marginal cost
- This leads to the inevitable result that both firms charge a price equal to marginal cost

Escaping the Bertrand Result

- The result that price equals marginal cost under duopoly seems implausible
  - After all, duopoly seems more like monopoly than like perfect competition
- Can the model be altered to give a more appealing result?
  - More periods? (Infinite, or at least indefinite horizon)
  - Capacity constraints
  - Product differentiation
  - Cooperation

Escaping the Bertrand Result

- When individuals play a game with an undesirable equilibrium, they are likely to try to change the rules of the game!
  - For example, if playing the Bertrand game leads to low prices and zero profit, firms may instead try to cooperate (which is contrary to the rules of the game, as we have described them).

Cooperation?

- Oligopoly firms may often see themselves in situations like the prisoners' dilemma
  - They see gains possible from cooperative outcomes
  - However, in the absence of binding agreements, they have incentives to act independently
- As a practical matter firms sometimes do cooperate, or they act "as if" they are cooperating

What Facilitates Collusion?

- Conditions that facilitate collusion (explicit or tacit collusion):
  - High profit potential
  - Impediments to entry
  - Symmetry of costs
  - Homogeneous products
  - Few firms (each with a large market share)
  - Easy detection of price-cutting
  - Market stability

Strategies Aiding Collusion

- Provision of Information by Trade Associations
- Most-favored customer guarantees
- Meeting the competition guarantees
- "Tit-for-Tat" play in repeated interactions
  - This is a limited response retaliation for an aggressive action from a rival

The End