Part II. Market power

Chapter 3. Static imperfect competition

Slides

Industrial Organization: Markets and Strategies

Paul Belleflamme and Martin Peitz, 2d Edition

Oligopolies

- Industries in which a few firms compete
- Market power is collectively shared.
- Firms can't ignore their competitors' behaviour.
- **Strategic interaction** → Game theory

Oligopoly *theories*

- *Cournot* (1838) → quantity competition
- *Bertrand* (1883) → price competition
- Not competing but complementary theories
  - Relevant for different industries or circumstances

Organization of Part II

- Chapter 3
  - Simple settings: unique decision at single point in time
  - How does the nature of strategic variable (price or quantity) affect
    - strategic interaction?
    - extent of market power?
- Chapter 4
  - Incorporates time dimension: sequential decisions
  - Effects on strategic interaction?
  - What happens before and after strategic interaction takes place?

Case. **DVD-by-mail industry**

- Facts
  - < 2004: *Netflix* almost only active firm
  - 2004: entry by *Wal-Mart* and *Blockbuster* (and later *Amazon*), not correctly foreseen by Netflix
- Sequential decisions
  - Leader: *Netflix*
  - Followers: *Wal-Mart*, *Blockbuster, Amazon*
- Price competition
  - *Wal-Mart* and *Blockbuster* undercut *Netflix*
  - *Netflix* reacts by reducing its prices too.
- Quantity competition?
  - Need to store more copies of latest movies

Chapter 3. Learning objectives

- Get (re)acquainted with basic models of oligopoly theory
  - Price competition: Bertrand model
  - Quantity competition: Cournot model
- Be able to compare the two models
  - Quantity competition may be mimicked by a two-stage model (capacity-then-price competition)
  - Unified model to analyze price & quantity competition
- Understand the notions of strategic complements and strategic substitutes
- See how to measure market power empirically

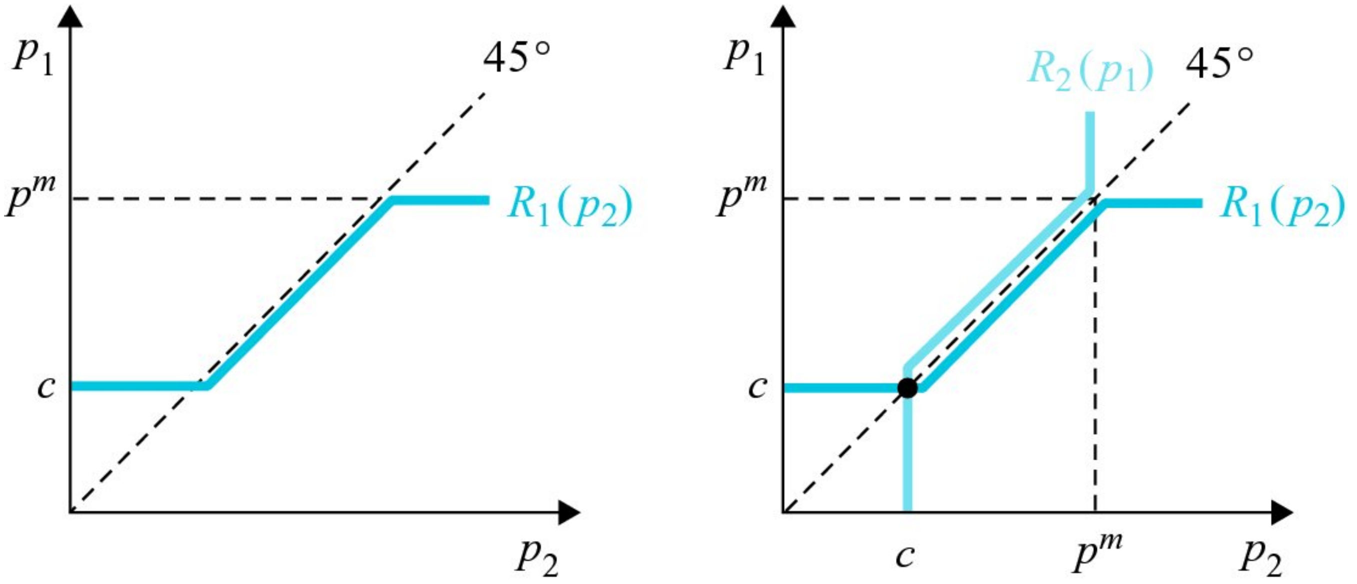
The standard Bertrand model

- 2 firms
  - Homogeneous products
  - Identical constant marginal cost: c
  - Set price simultaneously to maximize profits
- Consumers
  - Firm with lower price attracts all demand, $Q(p)$
  - At equal prices, market splits at α_1 and $\alpha_2 = 1 - \alpha_1$
- $\rightarrow$ Firm *i* faces demand

$$Q_i(p_i) = \begin{cases} Q(p_i) & \text{if} \quad p_i < p_j \\ \alpha_i Q(p_i) & \text{if} \quad p_i = p_j \\ 0 & \text{if} \quad p_i > p_j \end{cases}$$

The standard Bertrand model (cont'd)

- Unique Nash equilibrium
  - Both firms set price = marginal cost: $p_1 = p_2 = c$
  - *Proof*
    - For any other (p_1,p_2), a profitable deviation exists.
    - Or: unique intersection of firms' *best-response functions*



The standard Bertrand model (cont'd)

- 'Bertrand Paradox'
  - Only 2 firms **but** perfectly competitive outcome
  - Message: there exist circumstances under which duopoly competitive pressure can be very strong

- **Lesson**: In a homogeneous product Bertrand duopoly with identical and constant marginal costs, the equilibrium is such that
  - firms set price equal to marginal costs;
  - firms do not enjoy any market power.

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- Cost asymmetries: n firms, $c_i < c_{i+1}$
  - Equilibrium: any price $p_i = p_j = p \in [c_1, c_2]$
  - Select $p^* = c_2$

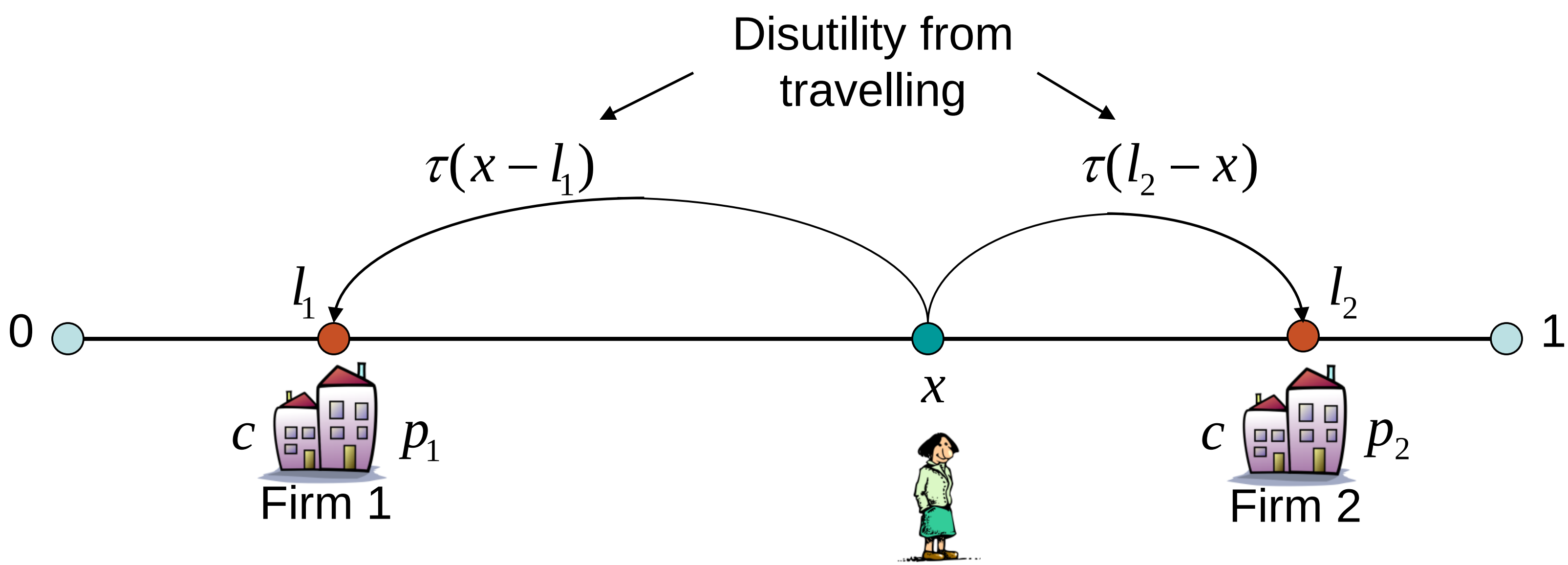
Bertrand competition with uncertain costs

- Each firm has private information about its costs
  - Trade-off between margins and likelihood of winning the competition
  - See particular model in the book.

- **Lesson**: In the price competition model with homogeneous products and private information about marginal costs, at equilibrium,
  - firms set price above marginal costs;
  - firms make strictly positive expected profits;
  - more firms $\rightarrow$ price-cost margins$\downarrow$, output$\uparrow$, profits$\downarrow$;
  - number of firms explodes $\rightarrow$ competitive limit.

Price competition with differentiated products

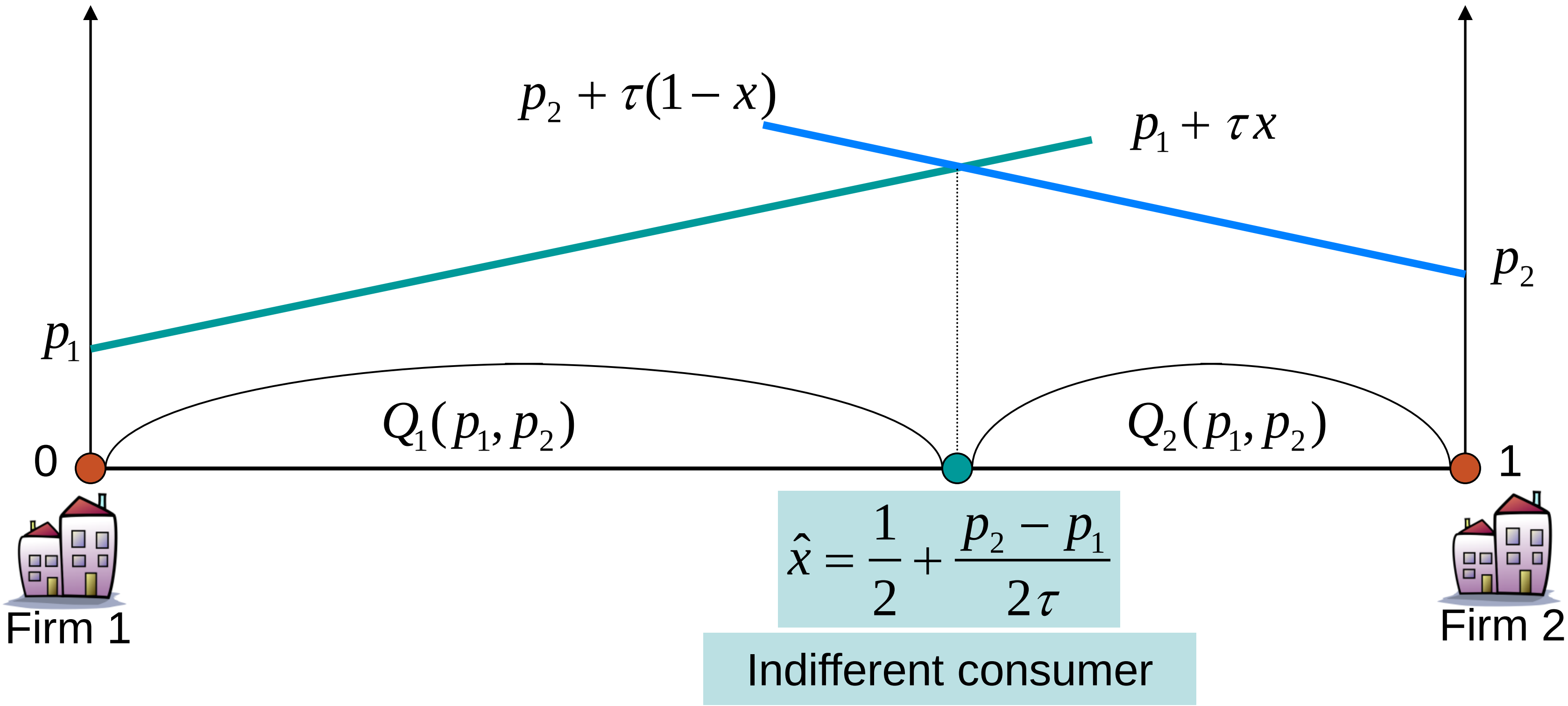
- Firms may avoid intense competition by offering products that are imperfect substitutes.
- **Hotelling model** (1929)



Mass 1 of consumers, uniformly distributed

Hotelling model (cont'd)

- Suppose location at the extreme points



Hotelling model (cont'd)

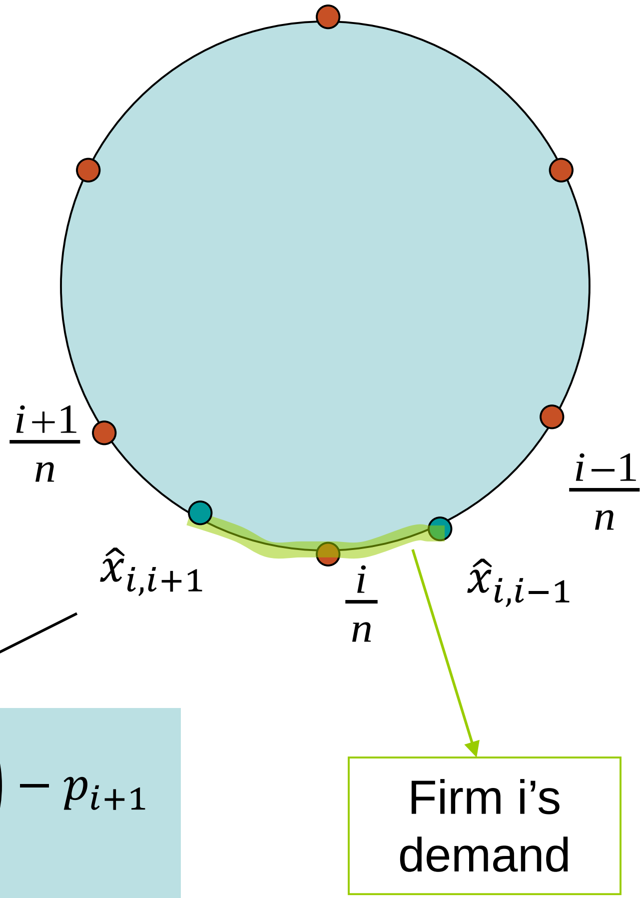
- Resolution
  - Firm's problem: $\max_{p_i} (p_i - c)\left(\frac{1}{2} + \frac{p_j - p_i}{2\tau}\right)$
  - From FOC, best-response function: $p_i = \frac{1}{2}(p_j + c + \tau)$
  - Equilibrium prices: $p_i = p_j = c + \tau$

- **Lesson**: If products are more differentiated, firms enjoy more market power.

- Extensions
  1. Localized competition with n firms: **Salop** (circle) **model**
  2. Asymmetric competition with differentiated products

Extension 1: Salop model

- Setting
  - Firms equidistantly located on circle with circumference 1
  - Consumers uniformly distributed on circle
  - They buy at most one unit, from firm with lowest 'generalized price'
  - Unit transportation cost, τ



$$r-\tau\left(\hat{x}_{i,i+1}-\frac{i}{n}\right)-p_i=r-\tau\left(\frac{i+1}{n}-\hat{x}_{i,i+1}\right)-p_{i+1}$$

$$\Leftrightarrow \hat{x}_{i,i+1}=\frac{2i+1}{2n}+\frac{p_{i+1}-p_i}{2\tau}$$

Extension 1: Salop model (cont'd)

- Focus on symmetric equilibrium
- Firm *i*'s problem:

$$\max_{p_i} (p_i - c)Q(p_i, p) = (p_i - c)\left(\frac{1}{n} + \frac{p - p_i}{\tau}\right)$$

- FOC: $1/n + (p - 2p_i + c)/\tau = 0$
- Setting $p_i = p$ yields: $p^* = c + \tau / n$
  - $n \uparrow \rightarrow$ closer substitutes on the circle $\rightarrow$ competitive pressure $\uparrow \rightarrow p^* \downarrow$
  - If $nn \rightarrow \infty$, then $p^* \rightarrow c$ (perfect competition)

Extension 2: Asymmetric competition with differentiated products

- Same setting as Hotelling model
- Only difference: product 1 is of superior quality
  - Consumer's indirect utility:

$$\begin{cases} r_1 - \tau x - p_1 & \text{if buy 1} \\ r_2 - \tau(1-x) - p_2 & \text{if buy 2} \end{cases} \quad \text{with } r_1 > r_2$$

  - Assume: $r_2 + \tau > r_1 \rightarrow$ product 2 more attractive for some consumers
- Indifferent consumer

$$\hat{x} = \frac{1}{2} + \frac{(r_1 - r_2) - (p_1 - p_2)}{2\tau} = Q_1(p_1, p_2)$$

Extension 2: Asymmetric competition with differentiated products (cont'd)

- Firm 1 chooses p_1 to maximize $(p_1 - c)Q_1(p_1, p_2)$
- Similarly for firm 2.
- Solving for the two FOCs:

$$\begin{cases} p_1^* = c + \tau + \tfrac{1}{3}(r_1 - r_2) \\ p_2^* = c + \tau - \tfrac{1}{3}(r_1 - r_2) \end{cases}$$

$$Q_1(p_1^*, p_2^*) = \frac{1}{2} + \frac{r_1 - r_2}{6\tau}$$

- High-quality firm sets a higher price and sells more.

Extension 2: Asymmetric competition with differentiated products (cont'd)

- Welfare maximization $\rightarrow$ sell at marginal cost

$$Q_1(c,c) = \frac{1}{2} + \frac{r_1 - r_2}{2\tau} > Q_1(p_1^*, p_2^*) = \frac{1}{2} + \frac{r_1 - r_2}{6\tau}$$

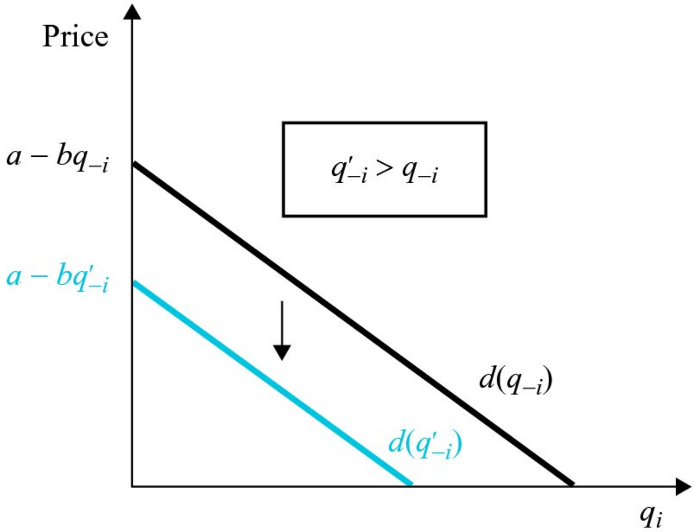
  - Firm 1's equilibrium demand is too low from a social point of view.
  - Same analysis if $r_1 = r_2 = r$, but $c_1 < c_2$

- Lesson: Under imperfect competition, the firm with higher quality or lower marginal cost sells too few units from a welfare perspective.

The linear Cournot model

- Model
  - Homogeneous product market with n firms
  - Firm *i* sets quantity q_i
  - Total output: $q = q_1 + q_2 + \dots + q_n$
  - Market price given by $P(q) = a - bq$
  - Linear cost functions: $C_i(q_i) = c_i\, q_i$
  - Notation: $q_{-i} = q - q_i$
- Residual demand

$$P(q) = (a - bq_{-i}) - bq_i$$
$$\equiv d(q_i; q_{-i})$$



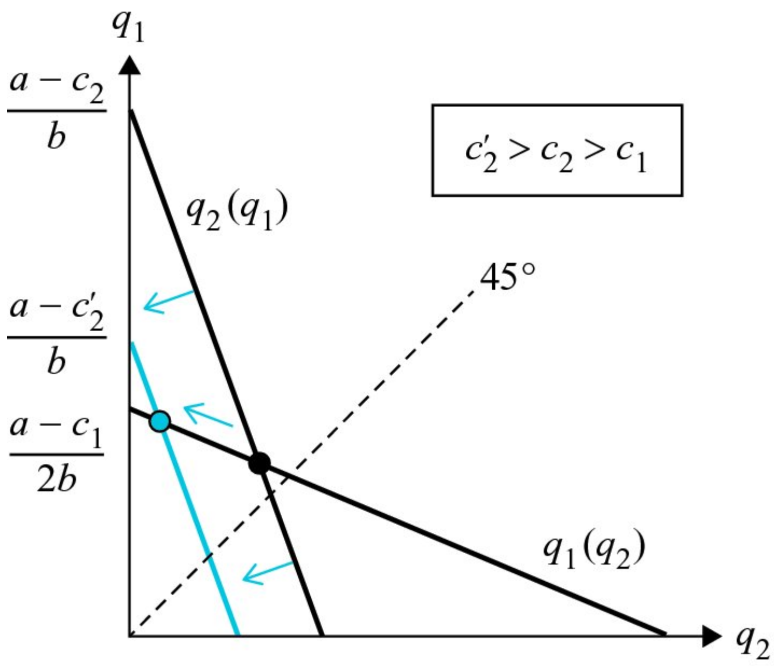
The linear Cournot model (cont'd)

- Firm's problem
  - Cournot conjecture: rivals don't modify their quantity
  - Firm *i* acts as a monopolist on its residual demand: $\max_{q_i} (P(q) - c_i) q_i$
  - FOC: $a - c_i - 2bq_i - bq_{-i} = 0$
  - Best-response function: $q_i(q_{-i}) = \frac{1}{2b}(a - c_i - bq_{-i})$
- Nash equilibrium in the duopoly case
  - Assume: $c_1 \leq c_2$ and $c_2 \leq (a + c_1)/2$
  - Then, $q_1^* = \frac{1}{3b}(a - 2c_1 + c_2)$ and $q_2^* = \frac{1}{3b}(a - 2c_2 + c_1)$

$$q_1^* \geq q_2^* \Rightarrow \pi_1^* \geq \pi_2^*$$

The linear Cournot model (cont'd)

- Duopoly



- **Lesson**: In the linear Cournot model with homogeneous products, a firm's equilibrium profit increases when the firm becomes relatively more efficient than its rivals.

Symmetric Cournot oligopoly

- Suppose that $c_i = c$ for all $i = 1 \ldots n$
- Then

$$q^*(n) = \frac{a-c}{b(n+1)} \rightarrow L(n) = \frac{p^*(n)-c}{p^*(n)} = \frac{a-c}{a+nc}$$

  - If $n\uparrow$ → individual quantity ↓, total quantity ↑, market price ↓, markup ↓
  - If $n \rightarrow \infty$, then markup → 0

- **Lesson**: The (symmetric linear) Cournot model converges to perfect competition as the number of firms increases.

Implications of Cournot competition

- General demand and cost functions
- Cournot pricing formula (details see next slide)

$$\frac{P(q)-C_i'(q_i)}{P(q)}=\frac{\alpha_i}{\eta} \text{ with } \alpha_i = q_i / q$$

- **Lesson**: In the Cournot model, the markup of firm *i* is larger the larger is the market share of firm *i* and the less elastic is market demand.

- If marginal costs are constant

$$\frac{p-\sum_{i=1}^{n}\alpha_i c_i}{p}=\frac{I_H}{\eta} \text{ with } I_H=\sum_{i=1}^{n}\alpha_i^2, \text{ Herfindahl index}$$

Average Lerner index

Details: Cournot pricing formula

- F.O.C. of profit maximization for Cournot firm

$$P'(q)q_i + P(q) - C_i'(q_i) = 0 \Leftrightarrow$$

$$P(q) - C_i'(q_i) = -P'(q)q_i \Leftrightarrow$$

$$\frac{P(q) - C_i'(q_i)}{P(q)} = \frac{-P'(q)q}{P(q)}\frac{q_i}{q} = \frac{1}{\eta}\alpha_i$$

- Suppose constant marginal costs: $C_i(q_i) = c_i q_i$

$$\frac{p - c_i}{p} = \frac{\alpha_i}{\eta} \rightarrow \sum_{i=1}^{n} \pi_i = \sum_{i=1}^{n} (p - c_i)\alpha_i q = \begin{cases} (p - \sum_{i=1}^{n} \alpha_i c_i)q \\ \frac{pq}{\eta}\sum_{i=1}^{n} \alpha_i^2 \end{cases}$$

$$\Rightarrow \frac{p - \sum_{i=1}^{n} \alpha_i c_i}{p} = \frac{\sum_{i=1}^{n} \alpha_i^2}{\eta} = \frac{I_H}{\eta}$$

→ Lerner index (weighted by market shares) is proportional to Herfindahl index

Price versus quantity competition

- Comparison of previous results
  - Let $Q(p)=a-p$, $c_1=c_2=c$
  - Bertrand: $p_1=p_2=c$, $q_1=q_2=(a-c)/2$, $\pi_1=\pi_2=0$
  - Cournot: $q_1=q_2=(a-c)/3$, $p=(a+2c)/3$, $\pi_1=\pi_2=(a-c)^2/9$

- **Lesson**: Homogeneous product case $\rightarrow$ higher price, lower quantity, higher profits under quantity than under price competition.

- To refine the comparison
  - Limited capacities of production
  - Direct comparison within a unified model
  - Identify characteristics of price or quantity competition

Limited capacity and price competition

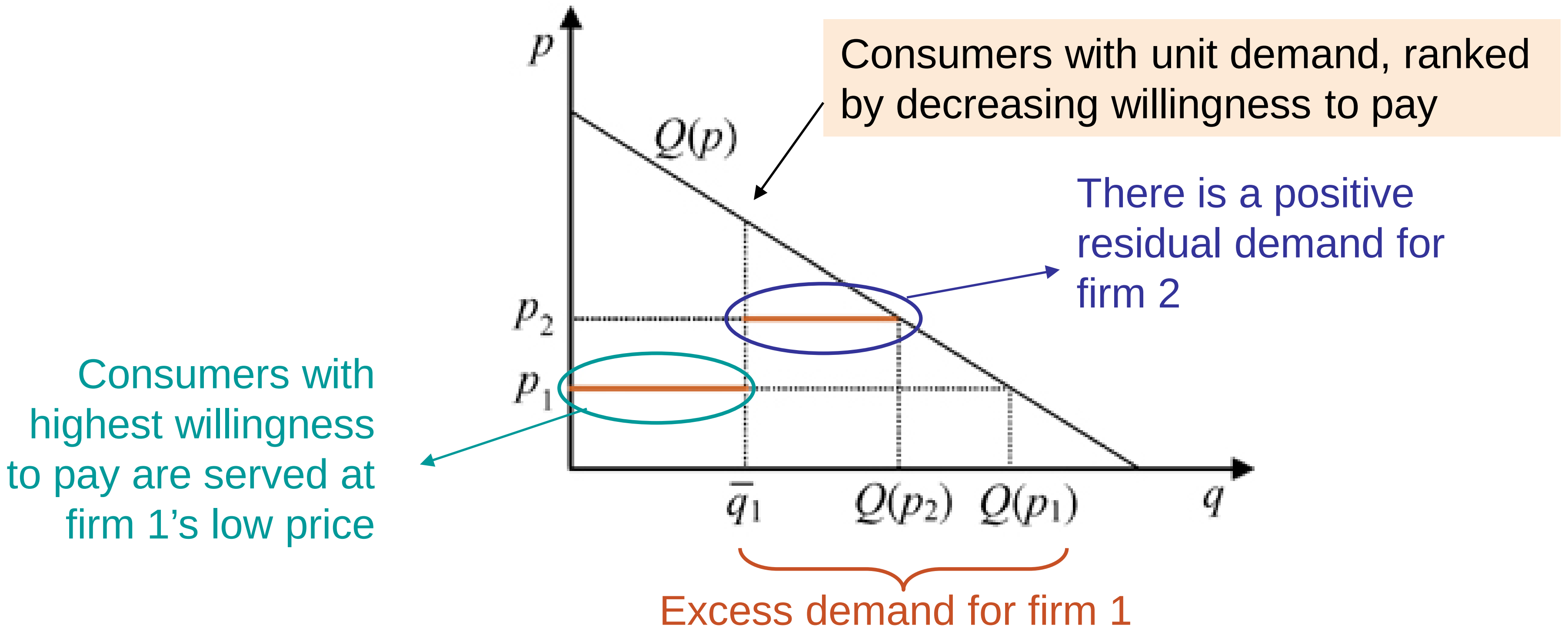
- Edgeworth's critique (1897)
  - Bertrand model: no capacity constraint
  - But capacity may be limited in the short run.
- Examples
  - Retailers order supplies well in advance
  - DVD-by-mail industry
    - Larger demand for latest movies → need to hold extra stock of copies → higher costs and stock may well be insufficient
  - Flights more expensive around Xmas
- To account for this: **two-stage model**
  1. Firms precommit to capacity of production
  2. Price competition

Capacity-then-price model (Kreps & Scheinkman)

- Setting
  - Stage 1: firms set capacities $\bar{q}_i$ and incur cost of capacity, c
  - Stage 2: firms set prices p_i; cost of production is 0 up to capacity (and infinite beyond capacity); demand is $Q(p) = a - p$.
  - Subgame-perfect equilibrium: firms know that capacity choices may affect equilibrium prices
- Rationing
  - If quantity demanded to firm i exceeds its supply...
  - ... some consumers have to be rationed...
  - ... and possibly buy from more expensive firm j.
  - Crucial question: Who will be served at the low price?

Capacity-then-price model (cont'd)

- Efficient rationing
  - First served: consumers with higher willingness to pay.
  - Justification: queuing system, secondary markets



Capacity-then-price model (cont'd)

- Equilibrium (details next slides)
  - Stage 2. If $p_1 < p_2$ and excess demand for firm 1, then demand for 2 is:

$$\tilde{Q}(p_2) = \begin{cases} Q(p_2) - \bar{q}_1 & \text{if } Q(p_2) - \bar{q}_1 \geq 0 \\ 0 & \text{else} \end{cases}$$

    Claim: if $c < a < (4/3)c$, then both firms set the market-clearing price: $p_1 = p_2 = p^* = a - \bar{q}_1 - \bar{q}_2$
  - Stage 1. Same reduced profit functions as in Cournot:

$$\bar{\pi}_1(\bar{q}_1, \bar{q}_2) = (a - \bar{q}_1 - \bar{q}_2)\bar{q}_1 - c\bar{q}_1$$

- **Lesson**: In the capacity-then-price game with efficient consumer rationing (and with linear demand and constant marginal costs), the chosen capacities are equal to those in a standard Cournot market.

Details: Capacity-then-price model

- Setting
  - Stage 1: firms set capacities $\bar{q}_i$ and incur cost of capacity, c
  - Stage 2: firms set prices p_i; cost of production is 0 up to capacity (and infinite beyond capacity); demand is $Q(p) = a - p$.
  - Subgame-perfect equilibrium: firms know that capacity choices may affect equilibrium prices
  - Efficient rationing
- Upper bound on capacity at stage 1

$$c\bar{q}_i \leq \max_q (a-q)q = a^2/4 \Leftrightarrow \bar{q}_i \leq a^2/(4c)$$

Details: Capacity-then-price model (cont'd)

- Claim: if $c < a < (4/3)c$, then both firms set the market-clearing price: $p_1 = p_2 = p^* = a - \bar{q}_1 - \bar{q}_2$
- Proof
  - Let $p_1 = p^*$ and show that 2's best-response is $p_2 = p^*$.
  - $p_2 < p^*$ doesn't pay: same quantity (because firm 2 sells all its capacity) sold at lower price
  - $p_2 > p^*$ could pay as firm 1 is capacity constrained... For this, revenues should be increasing at p^* ...
  - Firm 2's revenues:

$$p_2 Q(p_2) = \begin{cases} p_2(a - p_2 - \bar{q}_1) & \text{if } a - p_2 \geq \bar{q}_1, \\ 0 & \text{else} \end{cases}$$

Details: Capacity-then-price model (cont'd)

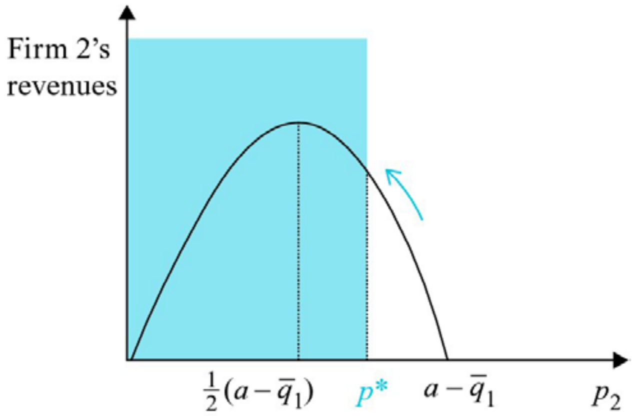
- Proof (cont'd)
  - Max reached at $\bar{p}_2 = (a - \bar{q}_1)/2$
  - Revenues are decreasing at p^* if

$$p^* > \bar{p}_2 \Leftrightarrow a - \bar{q}_1 - \bar{q}_2 > \frac{a - \bar{q}_1}{2} \Leftrightarrow a > \bar{q}_1 + 2\bar{q}_2$$

Since $\bar{q}_1, \bar{q}_2 \leq a^2/(4c)$, $\bar{q}_1 + 2\bar{q}_2 \leq (3/4)(a^2/c)$

Assumption $a < (4/3)c \Leftrightarrow (3/4)(a/c) < 1$

  - Hence, not profitable to set $p_2 > p^*$. QED



Differentiated products: Cournot vs. Bertrand

- Setting
  - Duopoly, substitutable products ($b > d > 0$)
  - Consumers maximize linear-quadratic utility function

$$U(q_0, q_1, q_2) = aq_1 + aq_2 - (bq_1^2 + 2dq_1q_2 + bq_2)/2 + q_0$$

under budget constraint $y = q_0 + p_1q_1 + p_2q_2$

  - Inverse demand functions

$$\begin{cases} P_1(q_1, q_2) = a - bq_1 - dq_2 \\ P_2(q_1, q_2) = a - bq_2 - dq_1 \end{cases}$$

  - Demand functions

$$\begin{cases} Q_1(p_1, p_2) = \bar{a} - \bar{b}p_1 + \bar{d}p_2 \\ Q_2(p_1, p_2) = \bar{a} - \bar{b}p_2 + \bar{d}p_1 \end{cases} \quad \text{with} \quad \bar{a} = a/(b+d),\ \bar{b} = b/(b^2 - d^2),\ \bar{d} = d/(b^2 - d^2)$$

Differentiated products

$$\max_{p_i} (p_i - c_i)(\bar{a} - \bar{b}p_i + \bar{d}p_j)$$

- Maximization program
  - Cournot: $\max_{q_i} \ (a - bq_i + dq_j - c_i)q_i$
  - Bertrand: $\max_{p_i} (p_i - c_i)(\bar{a} - \bar{b}p_i + \bar{d}p_j)$
- Best-response functions
  - Cournot: $q_i(q_j) = (a - dp_j - c_i)/(2\bar{b})$

    Downward-sloping $\rightarrow$ Strategic **substitutes**
  - Bertrand: $p_i(p_j) = (\bar{a} + \bar{d}p_j + \bar{b}c_i)/(2\bar{b})$

    Upward-sloping $\rightarrow$ Strategic **complements**
- Comparison of equilibria
  - **Lesson**: Price as the strategic variable gives rise to a more competitive outcome than quantity as the strategic variable.

Appropriate modelling choice: price or quantity?

- Monopoly: it doesn't matter.
- Oligopoly: price and quantity competitions lead to different residual demands
  - Price competition
    - p_j fixed $\rightarrow$ rival willing to serve any demand at p_j
    - i's residual demand: market demand at $p_i < p_j$; zero at $p_i > p_j$
    - So, residual demand is very sensitive to price changes.
  - Quantity competition
    - q_j fixed $\rightarrow$ irrespective of price obtained, rival sells q_j
    - i's residual demand: "what's left" (i.e., market demand – q_j)
    - So, residual demand is less sensitive to price changes.

Appropriate modelling choice (cont'd)

- How do firms behave in the market place?
  - Stick to a price and sell any quantity at this price?
    → **price competition**
    → appropriate choice when
    - Unlimited capacity
    - Prices more difficult to adjust in the short run than quantities
    - Example: mail-order business
  - Stick to a quantity and sell this quantity at any price?
    → **quantity competition**
    → appropriate choice when
    - Limited capacity (even if firms are price-setters)
    - Quantities more difficult to adjust in the short run than prices
    - Example: package holiday industry
  - Influence of technology (e.g. Print-on-demand vs. batch printing)

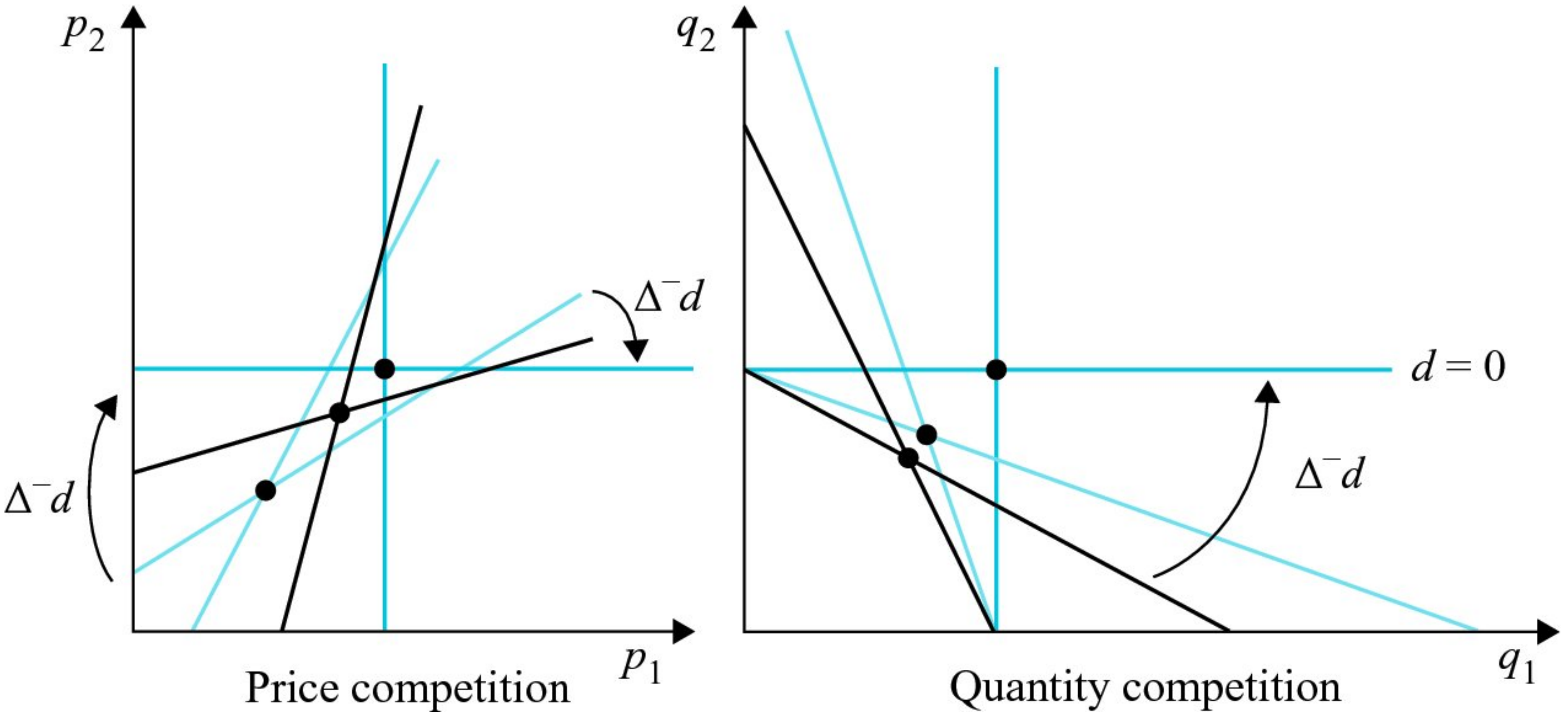
Strategic substitutes and complements

- How does a firm react to the rivals' actions?
- Look at the slope of reaction functions.
  - Upward sloping: competitor ↑ its action → marginal profitability of my own action ↑
    → variables are strategic **complements**
    - Example: price competition (with substitutable products); See Bertrand and Hotelling models
  - Downward sloping: competitor ↑ its action → marginal profitability of my own action ↓
    → variables are strategic **substitutes**
    - Example: quantity competition (with substitutable products); see Cournot model

Strategic substitutes and complements (cont'd)

- Linear demand model of product differentiation

  (with d measuring the degree of product substitutability)



Estimating market power

- Setting
  - Symmetric firms producing homogeneous product
  - Demand equation: $p = P(q,x)$ (1)
    - q: total quantity in the market
    - x: vector of exogenous variables affecting demand (not cost)
  - Marginal costs: $c(q,w)$
    - w: vector of exogenous variables affecting (variable) costs
- Interpretation 1. Nest various market structures in a single model

$$MR(\lambda) = p + \lambda \frac{\partial P(q,x)}{\partial q} q$$

$\lambda = 0$	competitive market
$\lambda = 1$	monopoly
$\lambda = 1/n$	n-firm Cournot

Firm's *conjecture* as to how strongly price reacts to its change in output

Estimating market power (cont'd)

- Interpretation 1 (cont'd)
  - Basic model to be estimated non-parametrically: demand equation (1) + equilibrium condition (2)

$$MR(\lambda) = p + \lambda \frac{\partial P(q,x)}{\partial q} q = c(q,w)$$

- Interpretation 2. Be agnostic about precise game being played
  - From equilibrium condition (2), Lerner index is

$$L = \frac{p - c(q,w)}{p} = -\lambda \frac{\partial P(q,x)}{\partial q} \frac{q}{p} = \frac{\lambda}{\eta}$$

  - (2) is identified if single $c(q,w)$ and single λ satisfy it

Review questions

- How does product differentiation relax price competition? Illustrate with examples.
- How does the number of firms in the industry affect the equilibrium of quantity competition?
- When firms choose first their capacity of production and next, the price of their product, this two-stage competition sometimes looks like (one-stage) Cournot competition. Under which conditions?
- Using a unified model of horizontal product differentiation, one comes to the conclusion that price competition is fiercer than quantity competition. Explain the intuition behind this result.

Review questions (cont'd)

- Define the concepts of strategic complements and strategic substitutes. Illustrate with examples.
- What characteristics of a specific industry will you look for to determine whether this industry is better represented by price competition or by quantity competition? Discuss.