Industrial Economics

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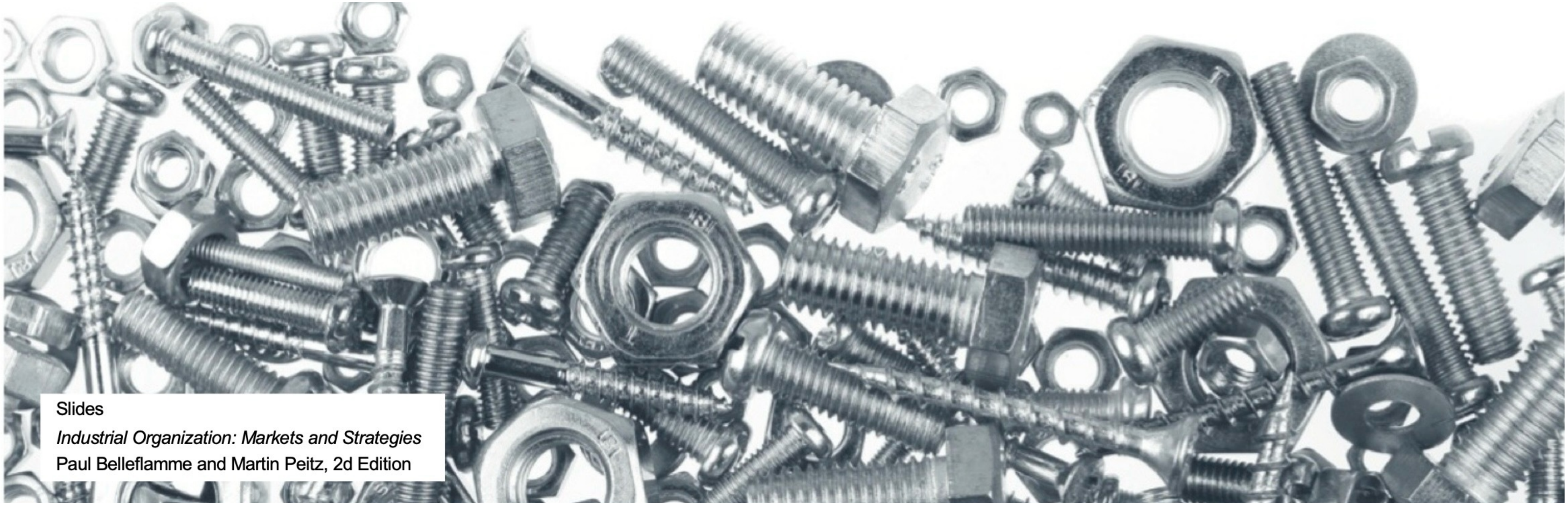
AUEB – Erasmus Program



Slides

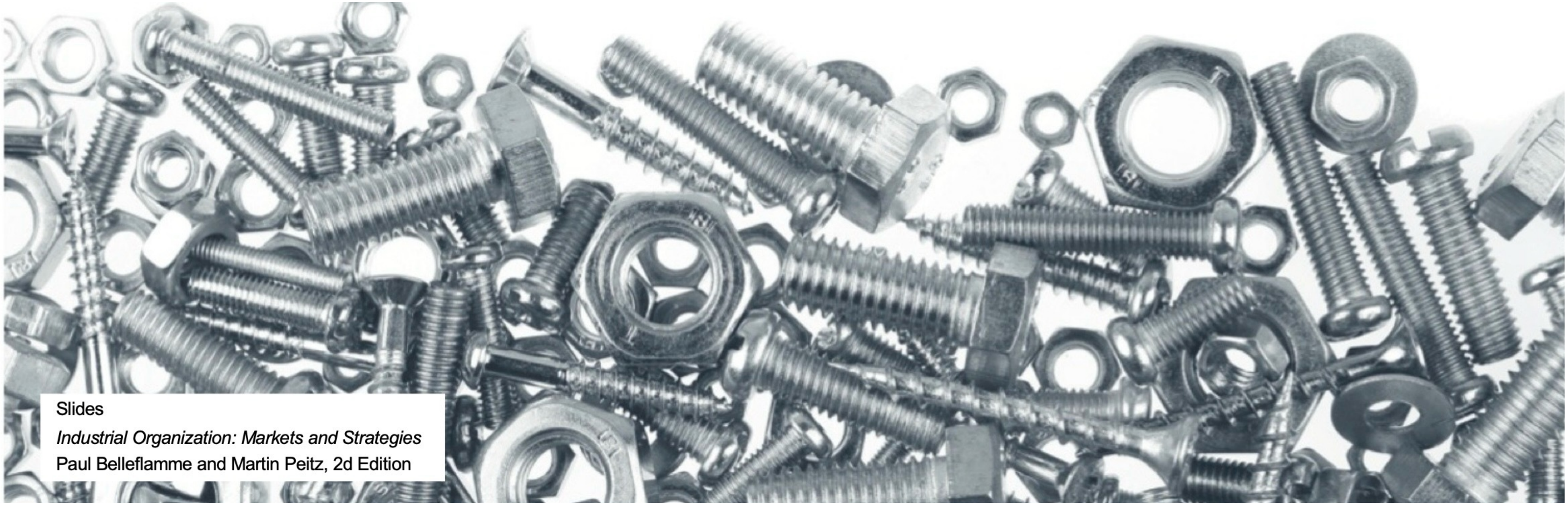
Industrial Organization: Markets and Strategies

Paul Belleflamme and Martin Peitz, 2d Edition

Couse Outline

1. Basic Concepts ✓
2. Monopoly ✓
3. Static Oligopoly
4. Dynamic Oligopoly
5. Product Differentiaton
6. Cartels & Tacit Collusion
7. Horizontal Mergers
8. Vertically Related Markets
9. R&D

3. STATIC OLIGOPOLY



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Industrial Organization: Markets and Strategies
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Contents

3.1 Introduction

Oligopoly

- Market characteristics:
  - Small number of firms in the market.
  - Firms have some market power.
  - Firms produce (imperfect) substitute products.

→

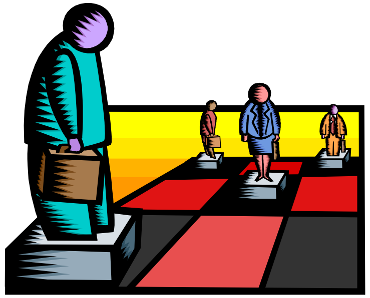
Firms *compete* among them.

Firms take into account their competitors' behaviour.

(≠ monopolist has no competitors)

Strategic interactions

Thinking through how a firm's competitors will respond to its actions, and what that means for what actions it should take –is central to firms decisions in oligopoly.



How do we analyse strategic interactions (decisions)?

→ Game theory

Short review of Game Theory

- Each game is a formal description of a situation with strategic interactions; it necessarily includes the following three elements:
  - Players
  - Actions which are available -- Strategies, i.e. available plans of what action to take at every possible decision point.
  - Payoffs for every potential combination of actions.
- Key distinction of games:

  - Static (simultaneous move) games

    Games where **all players choose their actions at the same time**, without knowledge of the other players' chosen actions. Players **make their decisions once**, and the game is resolved in a single stage.

  - Dynamic (sequential move) games

    Games where **players make decisions in (specified) sequence**, meaning one player makes a move before others do, and later players can observe the earlier moves before making their decisions. They include at least two stages.

Focus on Non-Cooperative games, i.e., games in which players act independently.

Short review of Game Theory

- Solution concepts/methods:
  - Dominant strategy

    A strategy that is better for the player (higher or equal payoff) than any other strategy regardless of what the other players do.
  - Dominated strategy

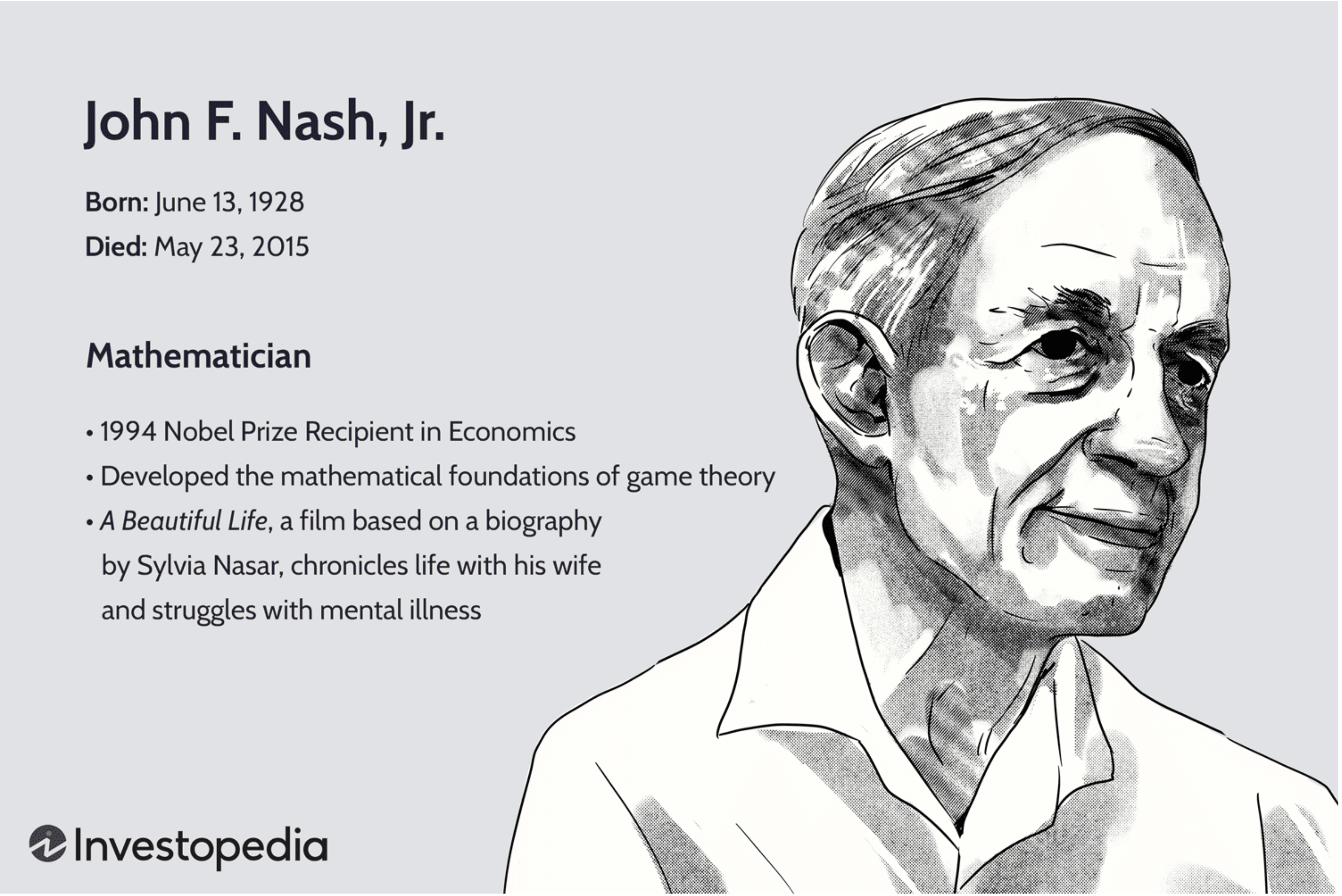
    A strategy that is worse for the player (lower payoff) than some other strategy regardless of what the other players do.

  In equilibrium, players do not choose dominated strategies; they choose dominant strategies if they exist.

  - Best response

    A strategy that maximizes the player's payoff given rivals' strategies.

Short review of Game Theory



John F. Nash, Jr.

Born: June 13, 1928

Died: May 23, 2015

Mathematician

- 1994 Nobel Prize Recipient in Economics
- Developed the mathematical foundations of game theory
- *A Beautiful Life*, a film based on a biography by Sylvia Nasar, chronicles life with his wife and struggles with mental illness

Investopedia

Short review of Game Theory

- Solution concepts/methods (cont.):
  - Nash equilibrium (NE): A strategy profile (one strategy for each player in the game) such that each player's strategy is a **best response** to the other players' strategies.

    A Nash Equilibrium is a strategy profile where **no player can improve its payoff by unilaterally changing its strategy**, given the strategies chosen by the others.

    It is used for solving static games. For dynamic games, use of a refinement of the Nash equilibrium:
  - Subgame Perfect Nash equilibrium (SPNE): Nash equilibrium in every subgame of the game as well as in the whole game.

    SPNE is often found through *backward induction*.

Famous Static game: "Prisoner's Dilemma"

Two criminals in separate prison cells face the same offer from the public prosecutor: If they both *confess* to a bloody murder, they each face 8 years in jail. If one stays *silent* while the other confesses, then the snitch will get to go free, while the other will face 20 years in jail. And if both hold their tongue, then they each face a minor charge, and only a year in jail.

Prisoner 2

Prisoner 1

	Confess	*Silent*
Confess	- 8, - 8	0, - 20
Silent	- 20, 0	- 1, - 1

Normal form
of the game

The first number in each cell corresponds to the payoff of the player in the lines and the second to the player in the columns.

Famous Static game: **“Prisoner’s Dilemma”**

Finding the Nash equilibrium of this game:

1. Define the actions and payoffs. ✓
2. Find each player’s best response strategies to every possible rival’s strategy.
3. Find strategies that are mutual best responses. These will be the Nash equilibria.

Prisoner 2

		Confess	*Silent*
Prisoner 1	*Confess*	$\underline{- 8}$, - 8	$\underline{0}$, - 20
	Silent	- 20, 0	- 1, - 1

- <u>Consider Player 1:</u>

  \- What is the best response if Player 2 plays *Silent*?

  Play *Confess*

  \- What is the best response if Player 2 plays *Confess*?

  Play *Confess*

Confess is a dominant strategy for Player 1.

Famous Static game: "Prisoner's Dilemma"

Finding the Nash equilibrium of this game:

1. Define the actions and payoffs. ✓
2. Find each player's best response strategies to every possible rival's strategy. ✓
3. Find strategies that are mutual best responses. These will be the Nash equilibria.

Prisoner 2

Prisoner 1

	Confess	*Silent*
Confess	$-\underline{8}, \ -\underline{8}$	$\underline{0}, \ -20$
Silent	$-20, \ \underline{0}$	$-1, \ -1$

- <u>Consider Player 2</u>:

  - What is the best response if Player 1 plays *Confess*?

    Play *Confess*

  - What is the best response if Player 1 plays *Silent*?

    Play *Confess*

Confess is a dominant strategy for Player 2.

Famous Static game: “Prisoner’s Dilemma”

Finding the Nash equilibrium of this game:

1. Define the actions and payoffs. ✓
2. Find each player’s best response strategies to every possible rival’s strategy. ✓
3. Find strategies that are mutual best responses. These will be the Nash equilibria. ✓

(*Confess*, *Confess*)
Nash equilibrium

Prisoner 2

		Confess	*Silent*
Prisoner 1	*Confess*	$\underline{-8}$, $\underline{-8}$	$\underline{0}$, - 20
	Silent	- 20, $\underline{0}$	- 1, - 1

Collectively, it would be best for both to keep silent.

But optimal *individual choices* leads to a worse outcome for both players.

Cooperation would be better, but *self-interest* prevents it.

(This can change if the game is repeated – cooperation could be achieved then).

Static Oligopoly

- Main oligopoly theories in static setting (unique decision at single point in time):
  - ➢ Choice of quantity - quantity competition → Cournot model (1838)
  - ➢ Choice of price - price competition → Bertrand model (1883)

Not competing but complementary theories; Relevant for different industries or circumstances.

How does the nature of strategic variable (price or quantity) affect:

- strategic interaction?
- extent of market power?

As we will see, in contrast to monopoly, setting quantities vs. prices gives *very* different predictions in oligopoly.

(In section 4 of the course, we will see oligopoly theories in a dynamic setting.)

3.2 Quantity Competition

3.2.1 The Standard Cournot Model

Standard Cournot model

- **Model Assumptions:**
  - $n = 2$ firms ($i = 1, 2$)
  - Homogeneous products with the following market demand function:

    $$P(q) = a - bq$$

    where total quantity $q = q_1 + q_2$
  - Cost function of firm i: $C_i(q_i) = cq_i$ with $a > c \geq 0$

    → constant symmetric MC: c
  - Static game:

    Both firms choose simultaneously and separately the quantity of their products, q_1 and q_2.
  - No capacity constraints.

Standard Cournot model

- **Model Solution – Equilibrium:**

  Which quantities firms choose in equilibrium?

  Each firm i solves the following problem:

$$\max_{q_i} \pi_i = q_i P(q) - C_i(q_i) = q_i (a - bq_i - bq_{-i}) - c\, q_i$$

Note: Residual demand of firm i is $P = (a - bq_{-i}) - bq_i$ over which it acts as a monopolist.

FOC:

$$\pi_i' = \frac{\partial \pi_i}{\partial q_i} = a - 2bq_i - bq_{-i} - c = 0$$

$MR_i = MC_i$

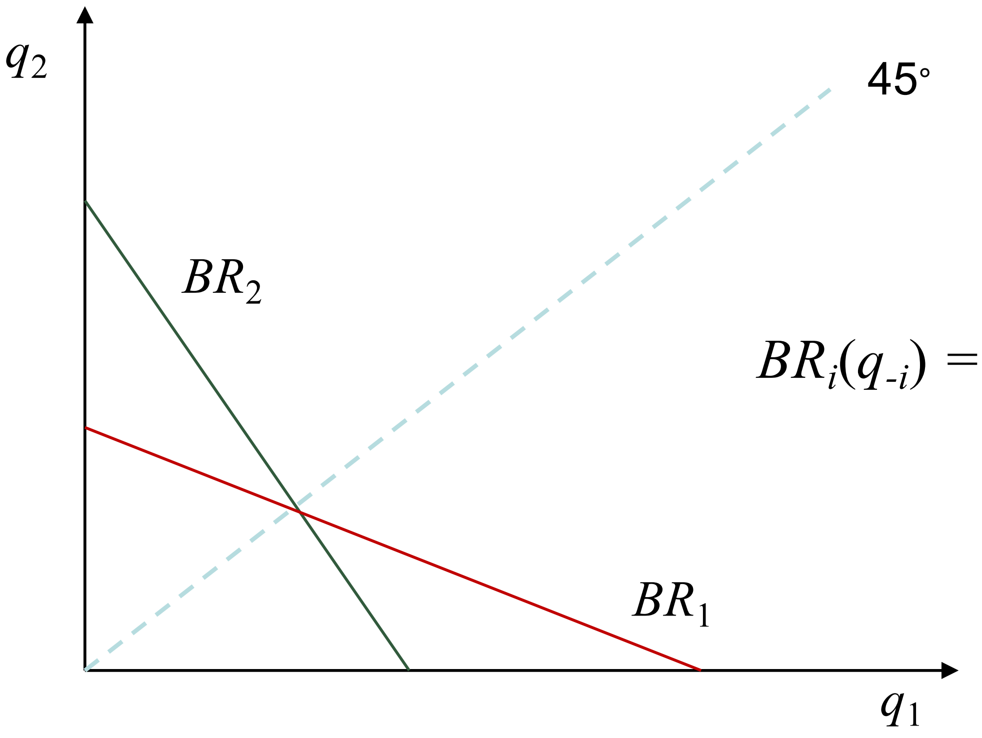
$$\rightarrow$$

$$BR_i(q_{-i}) = q_i(q_{-i}) = \frac{a - c - bq_{-i}}{2b}$$

Best-response functions

Standard Cournot model

- **Model Solution – Equilibrium** (cont.):



$$BR_i(q_{-i}) = q_i(q_{-i}) = \frac{a - c - bq_{-i}}{2b}$$

$$\partial BR_i(q_{-i})/\partial q_{-i} = -\frac{1}{2} < 0$$

Quantities are "Strategic substitutes"

Standard Cournot model

- **Model Solution – Equilibrium** (cont.):

$$BR_1(q_2) = \frac{a-c-bq_2}{2b} \quad \text{and} \quad BR_2(q_1) = \frac{a-c-bq_1}{2b}$$

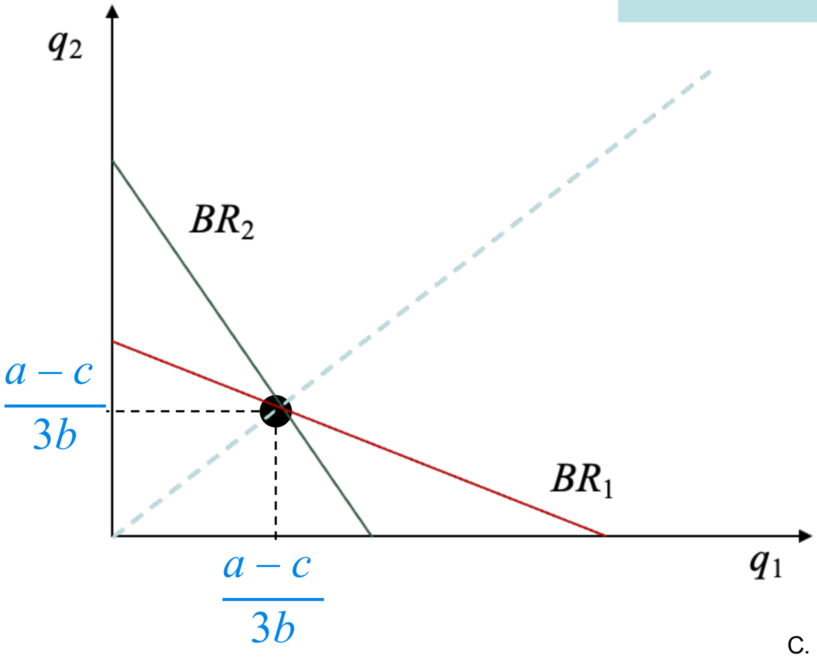
Both *BR* functions must hold in Nash equilibrium:

Two equations
& two unknowns

$$q_1 = \frac{a-c-b(\frac{a-c-bq_1}{2b})}{2b}$$

$$\rightarrow \boxed{q_1^C = \frac{a-c}{3b} = q_2^C}$$

Equilibrium quantity of each firm



Standard Cournot model

- **Model Solution – Equilibrium** (cont.):

Total quantity:

$$q^C = q_1^C + q_2^C = \frac{2(a-c)}{3b}$$

Important observation: $q^{pc} > q^C > q^m = \frac{a-c}{2b}$

Price: $P(q) = a - bq = a - b(q^C) = a - b\,\frac{2(a-c)}{3b}$

$$P^C = \frac{a+2c}{3}$$

Important observation: $P^{pc} = c < P^C < P^m = \frac{a+c}{2}$

Firm's profit:

$$\pi_i^C = \frac{(a-c)^2}{9b}$$

for each firm $i = 1, 2$

Important observation: $\pi_i^{pc} = 0 < \pi_1^C + \pi_2^C < \pi^m = \frac{(a-c)^2}{4b}$

Standard Cournot model

- Why the Cournot oligopolists do not maximize joint profits?

  Why doesn't each firm produce half of the monopoly quantity?

  - When the monopolist considers selling a higher quantity, it takes into account that the reduced price reduces profits on all inframarginal units.

  - When an oligopolist considers selling a higher quantity, it takes into account that the reduced price reduces profits on ITS OWN inframarginal units.

    But it does not take into account the fact that it is also reducing OTHER firms' profits – that it imposes a negative externality on other firms.

→

In the Cournot equilibrium, firms produce more than the quantity that maximizes total producer surplus.

Prisoners' Dilemma situation

However, this is good for consumer surplus and total surplus!

$CS^{pc} > CS^{C} > CS^{m}$ and $TS^{pc} > TS^{C} > TS^{m}$

3.2.2 Variations of the Cournot Model

Cournot model with Asymmetric Costs

- **Model Assumptions:**

  Same assumptions as in the standard Cournot model with only one difference:

  - Cost function of firm i: $C_i(q_i) = c_i q_i$ with $c_1 < c_2$ and $c_2 < (a+c_1)/2$

    i.e., firm 1 is more efficient than firm 2.

- **Model Solution – Equilibrium:**

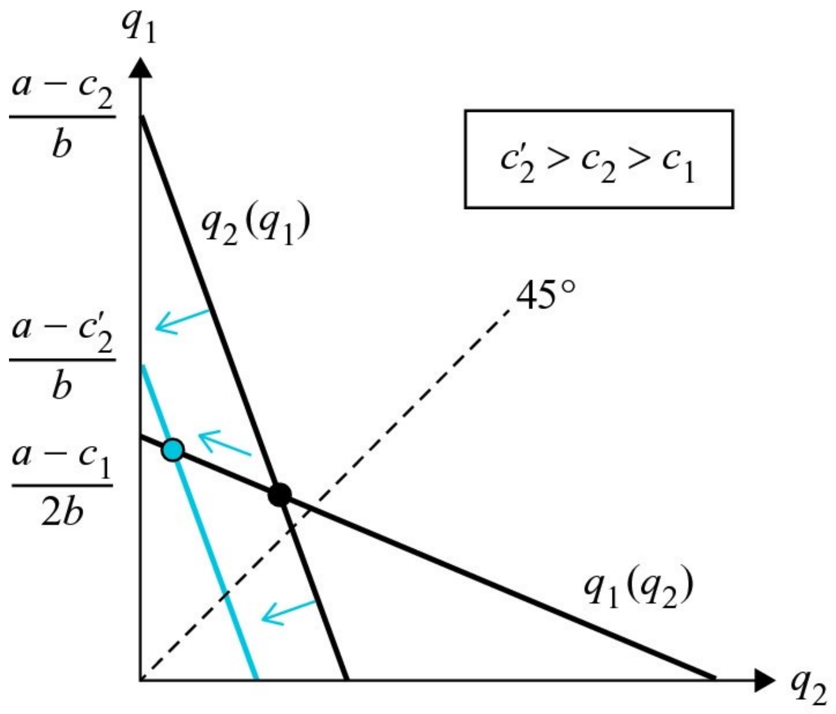
  Profit maximization of each firm (following the same steps as before) leads to the following Nash equilibrium:

$$q_1^* = \tfrac{1}{3b}(a - 2c_1 + c_2) \text{ and } q_2^* = \tfrac{1}{3b}(a - 2c_2 + c_1)$$

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

Cournot model with Asymmetric Costs

- **Model Solution – Equilibrium** (cont.):



In the Cournot model with homogeneous products, a firm's equilibrium quantity and profit increases when the firm becomes relatively more efficient than its rivals.

Cournot model with n firms

- **Model Assumptions:**

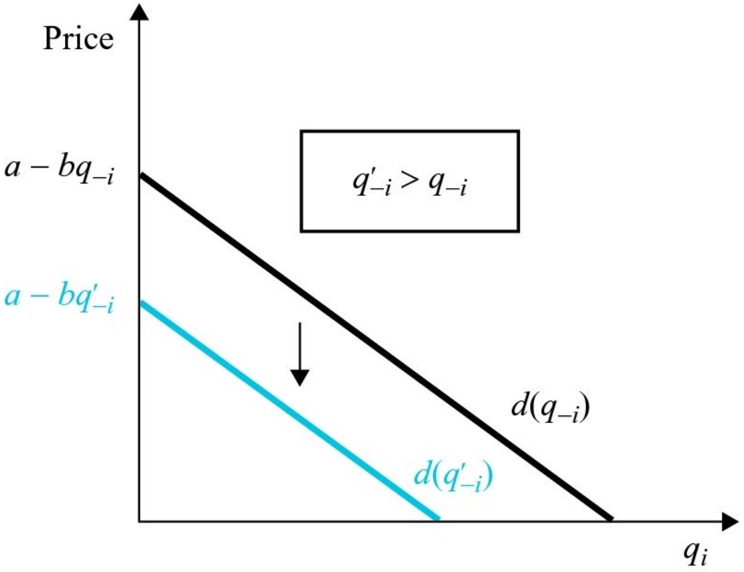
  Same assumptions as in the standard Cournot model with the following differences:

  - $n > 2$ firms, $i = 1, 2, 3, \ldots, n$
  - $P(q) = a - bq$ where total quantity $q = q_1 + q_2 + \ldots + q_n$

Residual demand for firm i:

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

where $q_{-i} = q - q_i$



Cournot model with n firms

- **Model Solution – Equilibrium:**

Each firm i solves the following problem:

$$\max_{q_i} \pi_i = q_i P(q) - C_i(q_i) = q_i (a - bq_i - bq_{-i}) - c\, q_i$$

FOC

$$\pi_i' = \frac{\partial \pi_i}{\partial q_i} = a - 2bq_i - bq_{-i} - c = 0 \rightarrow BR_i(q_{-i}) = q_i(q_{-i}) = \frac{a - c - bq_{-i}}{2b}$$

All *BR* functions must hold in Nash equilibrium and since firms are symmetric we expect that in equilibrium $q_1^* = q_2^* = \ldots = q_i = q_n^*$.

Using this, we can rewrite $q_{-i} = (n - 1)q_i$ and substitute it in $BR_i(q_{-i})$:

$$q_i = \frac{a - c - b(n-1)q_i}{2b}$$

[WATCH OUT! We cannot substitute $q_1 = q_i = \ldots. = q_n$ before deriving the best response function. This is a common mistake.

Why is it a mistake? Assuming that $q_1 = q_i = \ldots. = q_n$ before we take the FOCs implies that firm i has control over all firms' output decisions (the q_{-i} 's).]

Cournot model with n firms

- **Model Solution – Equilibrium** (cont.):

$$q_i = \frac{a - c - b(n-1)q_i}{2b}$$

$$\rightarrow$$

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

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

The (symmetric) Cournot model converges to perfect competition as the number of firms increases.

Cournot model with Differentiated Products

- **Model Assumptions:**

  Same assumptions as in the standard Cournot model with only one difference:

  - Demand function for each firm:

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

with $b > d > 0$

where d/b is inverse measure of degree of (horizontal) product differentiation.

When $d \to 0$ independent products

$d \to 1$ perfect substitutes

Cournot model with Differentiated Products

- **Model Solution – Equilibrium:**

  Profit maximization of each firm:

$$\max_{q_i} (a - bq_i - dq_j - c_i)q_i$$

  Following the same steps as before, we find the following Nash equilibrium:

$$q_1^* = \frac{a - c}{2b+d} = q_2^*$$

$$\pi_i^* = \frac{(a - c)^2}{(2b+d)^2}$$

➢ If $d \downarrow$ (higher differentiation) → individual quantity ↑, price ↑, profit↑

Observations on Quantity competition

- Cournot pricing formula:

Using general demand and cost functions, we obtain (details see next slide):

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

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.

- Relation between market power & market concentration:

If marginal costs are constant, we obtain:

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

Average Lerner index

Details: Cournot pricing formula

FOC 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