Oligopoly

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Oligopoly: Introduction

• Alternative Models of Imperfect Competition
  – Monopoly and monopolistic competition
  – Duopoly - two firms in industry
  – Oligopoly - a few (> 2) firms in industry

• Essential Features
  – Nature of interaction between firms (beyond those captured in price) is essence of theories
  – No single “grand theory”

Oligopoly: Analysis

• Simplest Model of Oligopoly: Duopoly
  – Assume only two firms (to limit interactions)
  – Assume homogeneous output
    • No product differentiation
    • Single market price
    • No competition in quality
  – Equilibrium: Solve for output, price of each firm

Oligopoly Models

• We use Game Theory to model strategic behavior
  – Strategic Behavior takes into account how others will react to one’s actions

• Non-cooperative simultaneous games
  – Simultaneously choose quantities (or prices)

• Non-cooperative sequential games
  – Quantity (or price) leader (dominant/barometric firm)
  – Quantity (or price) follower

• Cooperative games
  – Collusion -- jointly set quantities (or prices)
Quantity Competition: Introduction

• Assume firms choose output and allow prices to adjust to clear markets
• Each firm chooses output to max profits, given output level of competitor
• “Firms compete in outputs”
• Firm 1: $y_1$ units; Firm 2: $y_2$ units
  – total quantity supplied is $y_1 + y_2$
  – market price will be $p(y_1 + y_2)$
  – total cost functions are $c_1(y_1)$ and $c_2(y_2)$

Quantity Competition: Profits

• Firm 1 maximizes profit, given $y_2$
• Firm 1 profit function:
  $\pi_1(y_1; y_2) = p(y_1 + y_2) y_1 - c_1(y_1)$
• Firm 1 “Reaction Function”
  – What output $y_1$ maximizes firm 1 profit?
  – Given $y_2$ (expected or observed)
  – Solve for reaction function $y_1 = f(y_2)$

Quantity Competition: Example

• Let market inverse demand function be
  – $p(y_T) = 60 - y_T$
  – $y_T = y_1 + y_2$
• Let firms’ (different) total cost functions be
  – $c_1(y_1) = y_1^2$
  – $c_2(y_2) = 15y_2 + y_2^2$

Example: Firm 1

• Firm 1 profit function is
  – $\pi_1(y_1; y_2) = (60 - y_1 - y_2)y_1 - y_1^2$
• So, given $y_2$, solve for firm 1 profit-maximizing $y_1$
  $\frac{\partial \pi_1}{\partial y_1} = 60 - 2y_1 - y_2 - 2y_1 = 0$
  $y_1 = R_1(y_2) = 15 - \frac{1}{4} y_2$
Graph: Firm 1

Firm 1’s “Reaction Curve” $R_1(y_2)$

\[ y_1 = R_1(y_2) = 15 - \frac{1}{4} y_2 \]

(or $y_2 = 60 - 4 y_1$)

Example: Firm 2

• Similarly, given $y_1$, Firm 2’s profit function is
  \[ -\pi_2(y_2; y_1) = (60 - y_1 - y_2)y_2 - 15y_2 - y_2^2 \]

• To get Firm 2’s profit-maximizing output
  \[ \frac{\partial \pi_2}{\partial y_2} = 60 - y_1 - 2y_2 - 15 - 2y_2 = 0 \]

• Firm 1’s reaction function (best response) is
  \[ y_2 = R_2(y_1) = \frac{45 - y_1}{4} \]

Equilibrium

• Equilibrium is a Cournot-Nash equilibrium
  • Each firm’s output level is best response to other firm’s output level
  • Stable: neither firm wants to change output
  • Thus, $(y_1^*, y_2^*)$ such that
    \[ y_1^* = R_1(y_2^*) \]
    \[ y_2^* = R_2(y_1^*) \]
  • Essentially solving a pair of simultaneous equations
Equilibrium

\[ y_1^* = R_1(y_2^*) = 15 - \frac{1}{4} y_2^* \]
\[ y_2^* = R_2(y_1^*) = \frac{45 - y_1^*}{4} \]

Substitute for \( y_2^* \) to get

\[ y_1^* = 15 - \frac{1}{4} \left( \frac{45 - y_1^*}{4} \right) \Rightarrow y_1^* = 13 \]

\[ y_2^* = \frac{45 - 13}{4} = 8 \]

Cournot-Nash equilibrium is \((y_1^*, y_2^*) = (13, 8)\)

Cournot v Monopoly

- Price
  - Less than monopoly
  - Greater than perfect competition
- Quantity
  - Greater than monopoly
  - Less than perfect competition
- Total profit
  - Less than monopoly
  - Greater than perfect competition

Price Competition: Bertrand Games

- Alternative strategic behavior
- Firms compete using only price (not quantity)
- Bertrand games
  - Simultaneous game
  - Firms use price as strategic variable
- Get results dramatically different from quantity competition
Bertrand Games: Introduction

- Example of Bertrand game
  - Each firm’s MC = c, constant
  - All firms simultaneously set their prices
- Nash Equilibrium: All firms set \( p = c \)
  - All firms have same \( p \), or high \( p \) loses all sales
  - Any \( p > c \), slight price reduction yields big profit
  - Any \( p < c \), lose money

Sequential Games

- Sequential games
- One firm (larger firm) moves first
- Then “follower firms” react
- Both consider reactions of other
- Can compete in
  - Quantity—von Stackelberg Model
  - Price—Price leadership models

The von Stackelberg Model

- Outputs are strategic variables
- Firm 1—leader firm—chooses \( y_1 \) first
- Firm 2—follower—then reacts
- Leader anticipates reaction of follower (doesn’t assume \( y_2 \) constant as in C-N)
- Issues
  - What are prices, outputs, profits
  - Is there a “first mover” advantage?

The von Stackelberg Model

- Follower firm will choose \( y_2 \) to maximize profit, given leader firm \( y_1 \) (C-N assumption)
- Thus, follower reaction function: \( y_2 = R_2(y_1) \)
- Leader firm (1) anticipates follower firm’s (2) reaction function, so chooses \( y_1 \) to max profit
  - \( \pi_1(y_1) = p[y_1 + R_2(y_1)]y_1 - c_1(y_1) \)
Von Stackelberg Game: Profits

- Note: leader firm makes a profit at least as large as Cournot-Nash profit
  - Can always choose $y_1 = \text{C-N output}$
  - Follower will respond with $y_2 = \text{C-N output}$
  - So, can at least achieve C-N profit
- Return to duopoly example w/ different MC’s
  - Leader firm 1 has lower costs $c_1(y_1) = y_1^2$
  - Follower firm 2 has higher costs $c_2(y_2) = 15y_2 + y_2^2$

Von Stackelberg Game: Example

- Same characteristics as before
- Market inverse demand function is
  - $p = 60 - y_T$
- The firms’ cost functions are
  - $c_1(y_1) = y_1^2$ and $c_2(y_2) = 15y_2 + y_2^2$
- Firm 2 is follower, with reaction function
  $$y_2 = R_2(y_1) = \frac{45 - y_1}{4}$$

Von Stackelberg Game: Example

Leader’s profit function is
$$\pi_l^s(y_1) = [60 - y_1 - R_2(y_1)]y_1 - y_1^2$$
$$= \left(60 - y_1 - \frac{45 - y_1}{4}\right)y_1 - y_1^2$$
$$= \frac{195}{4}y_1 - \frac{7}{4}y_1^2$$

For a profit-maximum, first order condition is
$$\frac{195}{4} = \frac{7}{2}y_1 \Rightarrow y_l^s = 13.9$$

Von Stackelberg Game: Example

- Follower firm’s response to $y_1 = 13.9$ is
  $$y_2^s = R_2(y_1^s) = \frac{45 - 13.9}{4} = 7.8$$
- Recall C-N outputs are $(y_1^*, y_2^*) = (13, 8)$
- So leader produces more than C-N output, follower produces less than its C-N output
- First mover advantage to leader (but modest because leader also has cost advantage)
Sequential Price Games: Introduction

- **Price-leadership**
  - Sequential game
  - Price-leader firm sets its price
  - Typically large, respected firm
    - Dominant firm
    - Barometric firm
  - Follower firms – usually smaller – react to leader
- Note: Follower firms are price takers
  - Analogous to competitive firms

Price Leadership

- Market demand function is $D(p)$
- Given leader price $p$, follower firms supply $Y_f(p)$, anticipated by leader
- So leader gets residual demand
  - $L(p) = D(p) - Y_f(p)$
- Leader’s chooses $p$ to max profit
  - $\pi_L(p) = p[D(p) - Y_f(p)] - c_L[D(p) - Y_f(p)]$

Price Leadership Results

- Followers act as competitors
  - $P=MC$
  - Economic profit of each is zero
- Leader acts as monopolist w/ residual demand
  - $MR_L=MC_L$
  - Only leader earns monopoly profits

Co-operative Behavior: Collusion

- Collusion is illegal in US
- But not for international cartels
  - OPEC
  - Bauxite, copper, tin, coffee, tea, mercury, iodine
- Goal of cartel: Joint profit maximization
  - Can achieve (joint) monopoly profits
  - Must divide among cartel members
  - If cartel is part of market, like dominant firm model
Co-operative Behavior: Collusion

- Fundamental tension for cartels
- Stability: Higher profits (share of joint max)
- Instability
  - Successful cartel has $p >> MC$
  - One member alone faces nearly fixed $p$
  - Gets huge profits if lowers own price while others hold price constant (cheat on agreement)

Co-operative Behavior: Collusion

- Factors that promote cartel cohesion
  - Similar costs, expectations of demand, motives so can agree on strategy
  - Inelastic demand so potential profits large (disincentive for cheating)
  - Inelastic demand in LR so profits maintained
  - Little expansion of supply by non-members in LR