ECN 453: Stackelberg Competition

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Static Models of Oligopoly: Stackelberg Competition

- Today we will study a third static model of oligopoly: **Stackelberg Competition**.
- What is this model and how does this model of competition compare to the ones we have studied so far?
- Bertrand competition:
  - Homogeneous product, simultaneous move, firms choose prices
- Cournot competition:
  - Homogeneous product, simultaneous move, competition on quantities
- Stackelberg competition:
  - Homogeneous product, **sequential move**, competition on **quantities**

Stackelberg Competition: Typical Applications

- Industries with a 'leader' firm and a 'follower' firm
- Incumbent (chooses first) and entrant (chooses second)
  - We will use this application of the model to study *entry deterrence by capacity expansion*

Plan

1. Stackelberg Competition: Setup
2. Stackelberg Competition: Solution
3. Stackelberg Competition: Entry Deterrence

Plan

1. **Stackelberg Competition: Setup**
2. Stackelberg Competition: Solution
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Stackelberg Competition: Setup

- **Players**: Two firms (denote each by i where i = 1 or 2)
- **Strategies**: Each firm chooses output level q_1, q_2
  - Sell homogeneous (identical) products
  - **Sequential moves:**
    - Firm 1 (the 'leader') moves first
    - Firm 2 (the 'follower') moves second
- **Payoffs:** Each firm i's payoff is profit: $\pi_i = q_i P(Q) - C_i(q_i)$
  - Prices are determined by a demand curve $P(Q)$ where $Q = q_1 + q_2$.
  - Total cost is $C_i(q_i)$
- Observe that the setup is the same as Cournot <u>except</u> the timing.

Plan

1. Stackelberg Competition: Setup
2. **Stackelberg Competition: Solution**
3. Stackelberg Competition: Entry Deterrence

Stackelberg Competition: Solution outline

- Solve with the 'usual steps' (same steps as for Cournot except for computing the best responses)
- 1. Write down the payoffs for both firms
- 2. Get the best responses
  - Key difference in the steps vs Cournot: solve the game backwards:
  - Start with Firm 2's best response
  - Then, given Firm 2's best response, solve Firm 1's best response.
- 3. Using the best responses, find the (subgame-perfect) Nash equilibrium

Stackelberg Competition: Solution

- **Setup:**
- Consider a Stackelberg game of quantity competition between two firms. Firm 1 moves first and Firm 2 moves second.
- Market demand is $p = 50 - 2Q$ where $Q = q_1 + q_2$
- Each firm has a marginal cost of production equal to 10.
- **Questions:**
- 1. Solve for the equilibrium quantities.
- 2. What are the firms' profits?

Stackelberg Competition: Solution

- **Solution (Part 1):**
- Get the payoffs:

$$\pi_1 = q_1(50 - 2Q - 10) = q_1(40 - 2q_1 - 2q_2)$$
$$\pi_2 = q_2(50 - 2Q - 10) = q_2(40 - 2q_1 - 2q_2)$$

Stackelberg Competition: Solution

- Get the best responses (solving the game backwards):

- Firm 2:

$$\frac{d\pi_2}{dq_2} = 40 - 2q_1 - 2q_2 - 2q_2$$

- Set derivative $= 0$ (profit maximization):

$$q_2 = \frac{40 - 2q_1}{4} = 10 - \frac{1}{2}q_1$$

Stackelberg Competition: Solution

- Get the best responses (solving the game backwards):
- Firm 1: (**Trick**: unlike Cournot, plug firm 2's choice into firm 1's payoff before solving for the best response)

$$\pi_1 = q_1(40 - 2q_1 - 2q_2) = q_1(40 - 2q_1 - 2(10 - \frac{1}{2}q_1)) = q_1(20 - q_1) = 20q_1 - q_1^2$$

- Now, get derivative and set it $= 0$:

$$\frac{d\pi_1}{dq_1} = 20 - 2q_1 = 0$$

- So: $q_1 = 10$ (and plugging back into Firm 2's best response, $q_2 = 5$)

Stackelberg Competition: Solution

- **Solution (Part 2):**
- Profits:

$$\pi_1 = q_1(40 - 2q_1 - 2q_2) = 10(40 - 20 - 10) = 100$$
$$\pi_2 = q_2(40 - 2q_1 - 2q_2) = 5(40 - 20 - 10) = 50$$

- Firm 1 has a **first mover advantage**

Stackelberg Competition: Solution

- Given the more general setup of Stackelberg Competition (where Firm 1 moves first):
- Demand: $p = a - bQ$
- Marginal costs: c_1, c_2
- General solution for optimal quantities (following exactly the same steps as before) is:

$$q_1 = \frac{a + c_2 - 2c_1}{2b}$$
$$q_2 = \frac{a - 3c_2 + 2c_1}{4b}$$

- (Same caution as in the 'general solutions' in previous weeks: make sure the assumptions are satisfied before applying the formula)

Plan

1. Stackelberg Competition: Setup
2. Stackelberg Competition: Solution
3. **Stackelberg Competition: Entry Deterrence**

Stackelberg Competition: Entry Deterrence

- The standard Stackelberg model (detailed in the previous slides) is a model of **entry accommodation**.
  - Essentially, if Firm 1 is the incumbent and Firm 2 the entrant, what should Firm 1 do knowing that Firm 2 will enter?
- But what if Firm 2 *chooses* whether to enter?
- Can Firm 1 choose a capacity level so large that it deters entry? (And is this profitable?)

Stackelberg Competition: Entry Deterrence - Dupont Example p305

- Titanium dioxide: pigment used in paint, paper, etc to make them white
- In 1970: 7 firms. Dupont (main one) and 6 smaller firms
- In 1972, by chance, Dupont found itself with three unforseen competitive advantages:
    - 1. Production process was using a cheaper input than its rivals (and rivals' input suffered a cost shock)
    - 2. Dupont complied better with newly imposed environmental standards
    - 3. Firm was in better financial shape (due to 1.)

DuPont®

Stackelberg Competition: Entry Deterrence - Dupont Example p305

- Dupont task force: how to leverage these advantages?
- Strategy: *expand capacity and discourage expansion or entry by rivals*
- Task force: deterrence to establish a dominant position

Stackelberg Competition: Entry Deterrence - Dupont Example p305

	1972	1973	1974	1975	1976	1977	1982
Dupont	265	354	367	421	425	425	520
Rival firms	504	545	549	560	562	489	409

Figure: Titanium dioxide US capacity

- **Outcome**: 5 of the firms competing with Dupont had exited by 1985

Stackelberg Competition: Entry Deterrence

- **Example:** Let's use the same numbers as in the previous example (demand is $p = 50 - 2Q$ and both firms have a constant marginal cost of 10)
- Except for this example change the timing to add an entry choice:
  - 1. Firm 1 chooses capacity/output q_1
  - 2. Firm 2 chooses whether to enter; entering costs $E > 0$
  - 3. Firm 2 chooses capacity/output q_2

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Stackelberg Competition: Entry Deterrence

- Solving the game backwards:
  - 3. Firm 2 has the same best response as before:

$$q_2 = 10 - \frac{1}{2}q_1$$

  - After some rearranging, profits are:

$$\pi_2 = \frac{1}{8}(40 - 2q_1)^2$$

  - 2. Firm 2 does not enter if:

$$E \geq \frac{1}{8}(40 - 2q_1)^2$$

Stackelberg Competition: Entry Deterrence

- Continuing to solve the game backwards:
  - 1. The minimum capacity level of Firm 1 that deters entry q_1^D is where the previous 'Firm 2 does not enter' equation holds with equality:

$$q_1^D = \frac{1}{2}(40 - 2\sqrt{2E})$$

  - Firm 1's profit is:

$$\pi_1^D = (40 - 2\sqrt{2E})(\sqrt{2E}) = 40\sqrt{2E} - 4E$$

  - Note that profits π_1^D are increasing in E (unless E is really large - in which case we will be in the 'blockaded entry' case on the next slide anyway)

Stackelberg Competition: Entry Deterrence - Summary p308

- An incumbent's optimal capacity choice depends on the level of entry costs:
  - If entry costs are very low: **accommodate entry**
    - choose moderate q - the Stackelberg quantity
  - If entry costs are intermediate: **entry deterrence** (i.e. with capacity preemption)
    - choose high q
  - If entry costs are high: set monopoly capacity and ignore entry threat - **blockaded entry**
    - choose low q - monopoly quantity
- Note: quantity is **non-monotonic** (it goes up then goes down) as the entry cost increases.

Stackelberg Competition: Entry Deterrence - 'Games Hospitals Play'

- Previous non-monotonicity of quantity choice (i.e. capacity investment) in entry costs suggests an empirical test:

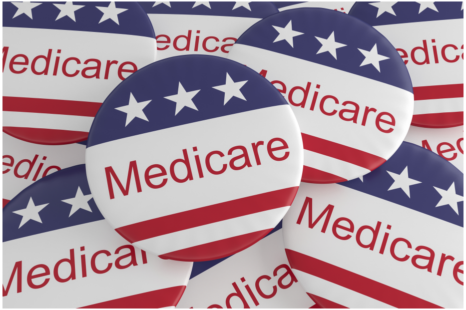
- **'Monotonicity Test':** Capacity investment should vary non-monotonically in the probability of entry.

- **Application:** Medicare

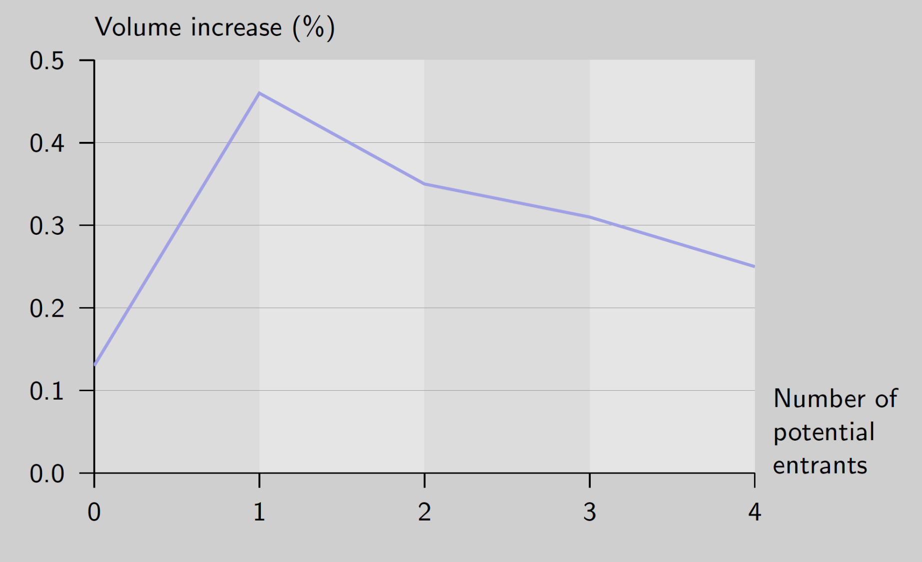
- Increased reimbursement for a procedure

- Announcement made 1 year prior, so firms had a chance to prepare for possible entry

- How did investment change with number of 'potential entrants'? (i.e. nearby firms)



Stackelberg Competition: Entry Deterrence - 'Games Hospitals Play'



Stackelberg Competition: Entry Deterrence - Implicit Assumptions

- Running assumption in the previous analysis: firms choose capacity and then set output at the capacity levels.
  - How reasonable is this assumption? (Ok if marginal cost is low)
- Another assumption: incumbent commits to capacity and does not change it even if potential entrant stays out
  - What if capacity investment is reversible? (We are implicitly assuming that capacity investment is irreversible)

Related entry deterrence strategies

- In differentiated product markets:

- **Proliferation strategies**
  - Produce lots of different varieties so there are no 'market holes' to position their product

- Example: breakfast cereals (Kellogg, General Mills, General Foods, Quaker Oats)
  - High profits, (probably) easy to enter since making cereal doesn't involve much technology

  - But: no firm entry in 1950s-1970s!

  - However: huge entry of *brands* (**product proliferation**)$\rightarrow$ can deter entry without lowering prices

- Another example (geographical proliferation): Staples
  - Staples CEO: *Staples was trying to build a critical mass of stores in the Northeast to shut out competitors*

Summary of key points*

- Know how to solve Stackelberg models of competition (i.e. use backwards induction etc)
- Apply the Stackelberg model to an entry deterrence application
- Know the 'monotonicity test' to check for entry deterrence motives in real-world data

*To clarify, all the material in the slides, problem sets, etc is assessable unless stated otherwise, but I hope this summary might be a useful place to start when studying the material.

Question

- Suppose that two firms compete under Stackelberg competition with $p = 90 - 3Q$. Firm 1 moves first and the marginal costs are given by $c_1 = 10$ and $c_2 = 20$.

- **Question:** What are the Stackelberg equilibrium quantities?