Entry Deterrence

Entry Barriers, Deterrence, and Accommodation

Example: DuPont

- In 1972, it was the largest producer of titanium dioxide used to whiten paper and paint with 35% of market capacity.
- Its chloride process was proprietary and competed against a sulfate process.
- In early 1970s, stricter pollution controls and tripling of input price threatened the viability of the sulfate process and gave DuPont a big cost advantage.

Growth Strategies

DuPont discussed two strategies for responding to their advantageous position:

- "Maintain status quo" by increasing capacity as sulfate capacity exited the market with no real change in prices $\rightarrow$ \$192 million over ten years.

- "Growth strategy" involved investing \$394 million in new capacity and expanding capacity to 65% to discourage entry and accelerate exit.

DuPont pursued the latter strategy and in 1979 had 60% of the market.

FTC Files a Complaint

- FTC filed complaint charging DuPont with monopolizing the market.
- Court dismissed the charge primarily because FTC failed to demonstrate the DuPont had invested in excess capacity.

This case raises two questions:

1. Does it make sense for an incumbent to invest in excess capacity to keep entrants at bay or rivals from expanding their capacity?

2. Will the incumbent over-invest in capacity to deter entry but nevertheless use the capacity even if entry does not occur?

A Simple Example

Theory

We consider the following model which is a modified version of the classic Spence-Dixit model[1].

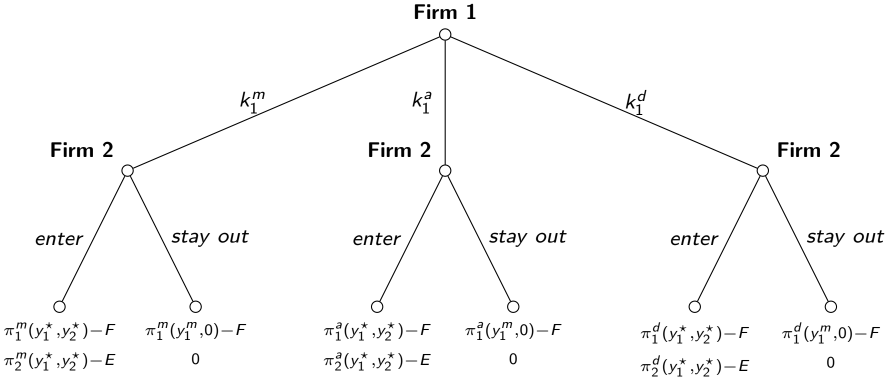
- Homogeneous good market
- Demand: P(Y) = 1 - Y.
- Firm 1 is the incumbent.
  (e.g., it has a patent that is about to expire).
- Firm 2 is poised to enter the market.
- Capital costs = $2/5$ per unit.
- Once invested, capital expense is sunk.
- Production of one unit requires one unit of capital.
- Entry costs $E > 0$.
  - Only applicable to Firm 2.

[1] See Spence (1977, 1979) and Dixit (1979, 1980).

Timing

1. Firm 1 chooses capacity k_1, paying $2/5$ per unit of capital.
   - Define $F(k_1) = \frac{2}{5} \times k_1$ as total Firm 1 capital expenditure.
   - After Firm 1 has chosen k_1, capital expenditure is a sunk fixed cost F.
2. Firm 2 observes k_1. It then chooses whether to enter. If it enters, it produces with marginal cost $2/5$.
3. Firms simultaneously choose quantity subject to the restriction $y_1 \leq k_1$.

Extensive Form Representation

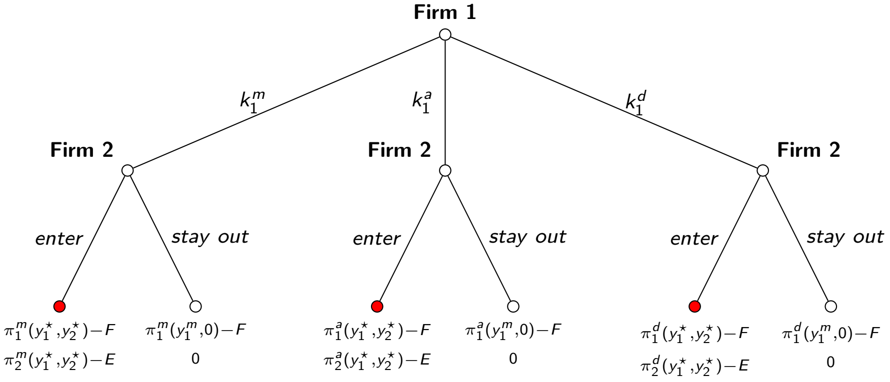


- y_1^m corresponds to the output choice when Firm 2 does not enter (*i.e.*, Firm 1 is a monopolist, hence the "m" superscript).
  - Firm 1's capital choice is a function of its capital investment so $y_1^m \equiv y_1^m(k_1)$.
- Define output $(y_1^\star, y_2^\star)$ as the Nash equilibrium quantities in homogeneous good Cournot competition.
  - We'll see Firm 1's capital choice affects the Nash eqm: $(y_1^\star, y_2^\star) \equiv (y_1^\star(k_1), y_2^\star(k_1))$.

Solving the Game

To solve this game, we proceed by solving for the Nash equilibrium at each potential node in the game.

Suppose Firm 1 has invested k_1 (paid F) and Firm 2 has entered (paid E).



Firm 2's Output Choice

To solve this game, we proceed by solving for the Nash equilibrium at each potential node in the game.

Suppose Firm 1 has invested k_1 (paid F) and Firm 2 has entered (paid E).

Firm 2 chooses y_2 to solve

$$\max_{y_2} \pi_2(y_1, y_2) \equiv \max_{y_2} (1 - y_1 - y_2 - 2/5) \times y_2$$

Solving for Firm 2's best reply yields

$$\begin{aligned} y_2 &= \mathrm{BR}_2(y_1) \\ \Rightarrow y_2 &= (3/5 - y_1)/2 \end{aligned}$$

Firm 1's Output Choice

Firm 1 chooses its output to solve

$$\max_{y_1} \pi_1(y_1, y_2) \equiv \max_{y_1} (1 - y_1 - y_2) \times y_1 \text{ s.t. } y_1 \leq k_1$$

Solving yields Firm 1's best reply:

$$\mathrm{BR}_1(y_2) = \begin{cases} (1 - y_2)/2, & \text{if } (1 - y_2)/2 < k_1 \\ k_1, & \text{if } (1 - y_2)/2 \geq k_1 \end{cases}$$

Nash Equilibrium Output Conditional on Firm 2 Entry

If $y_1 = 7/15 < k_1$, the constraint does not bind:

$$y_1 = \frac{1 - \overbrace{\left[\frac{3/5 - y_1}{2}\right]}^{\text{BR}_2(y_1)}}{2}$$

$$\Rightarrow y_1^\star(k_1) = 7/15$$

$$y_2^\star(k_1) = 1/15$$

If $k_1 < 7/15$, the constraint binds:

$$y_1^\star(k_1) = k_1$$

$$y_2^\star(k_1) = (3/5 - k_1)/2$$

Remarks

- Firm 1's best reply in the post-entry game does not depend upon capacity costs because its investment (F) is sunk.
- The entrant, however, has marginal cost of $c = 2/5$ per unit of output.
  $\approx$ it still has to invest in capacity in order to produce output.

Idle Threats

Suppose $k_1 = 1/2$ (ie, Firm 1 has idle capacity – Why?). Then equilibrium in the post- entry game conditional on entry is:

$$y_1 = 7/15, y_2 = 1/15, p = 7/15, \pi_2 = 1/225$$

Therefore, if $E < 1/225$, then Firm 2 enters and earns positive profits.

But, given entry, Firm 1 produces **less than capacity**. The **idle capacity is costly and has no benefit** since it does not affect Firm 2's entry or investment decisions.

By reducing k_1 to 7/15, Firm 1 lowers investment costs without changing revenues so investing in $k_1 = 7/15$ is profit-maximizing conditional on Firm 2 entry.

Answering One of Our Research Questions

This example illustrates the following result:

In the absence of any commitment to producing to capacity, it is never optimal for Firm 1 to invest in idle capacity. Therefore, in equilibrium, $y_1 = k_1$.

Q1: Does it make sense for an incumbent to invest in excess capacity to keep entrants at bay or rivals from expanding their capacity?

A1: No.

Commitment

Remark: If it could, Firm 1 may want to commit to produce to capacity.

- If $y_1 = 1/2$, then Firm 2's best reply is $1/20$, which yields $p = 9/20$ and $\pi_2 = 1/400$.
- If $1/400 < E$, then Firm 2 would not enter, firm 1 would produce $1/2$ and earn monopoly profits of $1/4$.

But, in this game, there is no way for Firm 1 to make such commitments and hence make its threat to produce to capacity credible.

Firm 1's Investment Choice

We are now in a position to solve equilibrium capacity choice of Firm 1 and entry decision.

Case 1: "High" Entry Costs.

Definition: Entry is blockaded if the monopoly choice of capacity by Firm 1 is sufficient to deter entry.[2]

$\Rightarrow$ The monopoly equilibrium is self-fulfilling.

[2] The term "blockaded" is consistent with the terminology of Bain (1956).

The monopoly choice of capacity is

$$\max_y (3/5 - y) \times y$$
$$\Rightarrow y^M = 3/10 = k^M$$

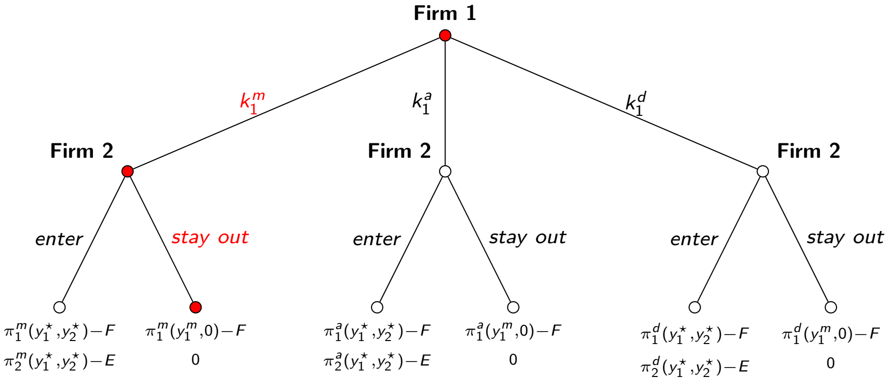
The equilibrium in the post-entry game is

$$y_1 = 3/10, y_2 = 3/20, p = 11/20, \pi_2 = 9/400$$

Therefore, entry is blockaded if $E > 9/400$.

So would Firm 2 choose to enter? Not if $E > 9/400$. Then the equilibrium outcome is:

- $k_1 = k^M = 3/10$
- Firm 2 does not enter,
- Firm 1 produces to capacity.



Case 2: "Low" Entry Costs.

Firm 1 cannot deter entry by choosing its preferred capacity of k^M.

Suppose Firm 1 accommodates entry by Firm 2. What capacity should it choose?

Firm 1 anticipates how Firm 2 will respond in the post-entry game and chooses its capacity to solve

$$\max_{y_1} \pi_1(y_1) \equiv \max_{y_1} \left[3/5 - y_1 - \underbrace{(1/2)(3/5 - y_1)}_{BR_2(y_1)}\right] \times y_1$$

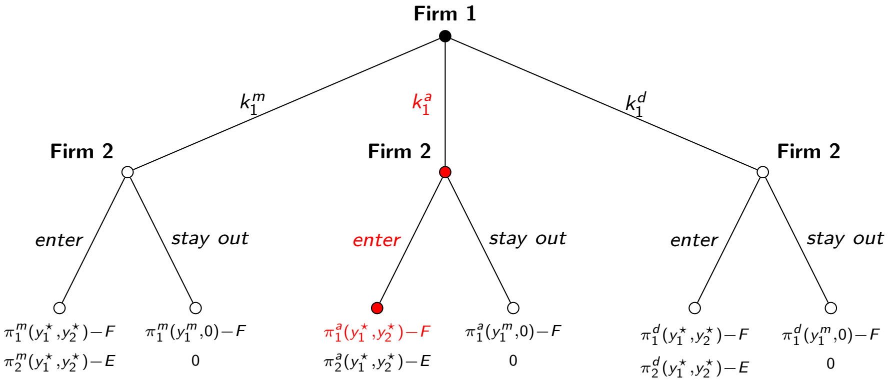
Differentiating and solving yields,

$$y_1^a = 3/10$$

Here, the Stackelberg solution is the monopoly solution!

Thus, if Firm 1 chooses to accommodate entry,

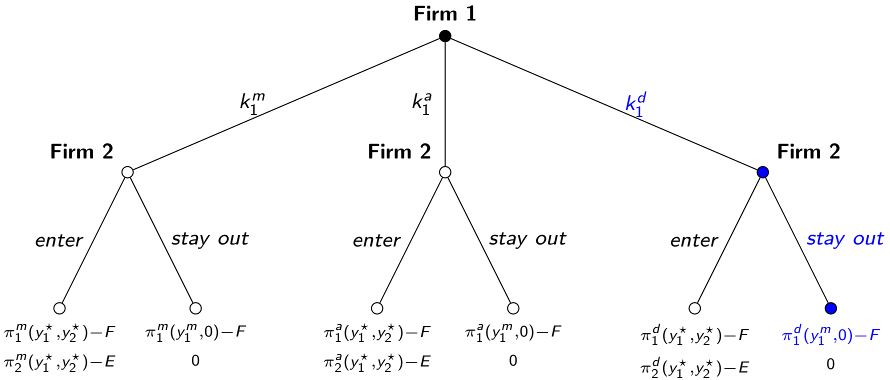
- $k_1^a = 3/10$
- Firm 2 enters.
- The Cournot Nash equilibrium is:
  $p^a = 11/20$, $\pi_1^a = 18/400$, $\pi_2^a = 9/400 - E > 0$.



Deterrence

Firm 1 has another choice. It can deter entry k^d by increasing capacity beyond k^a.

- But it needs to be able to credibly threaten to use it, which restricts k_1 to be less than the Nash equilibrium when Firm 1 accommodates ($k_1^a = 7/15$).



Deterrence

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- But it needs to be able to credibly threaten to use it, which restricts k_1 to be less than the Nash equilibrium when Firm 1 accommodates ($k_1^a = 7/15$).
- k_1^d solves $\pi_2\Big(y_1^\star(k_1^d), y_2^\star(k_1^d)\Big) \leq E$ where $\Big(y_1^\star(k_1^d), y_2^\star(k_1^d)\Big)$ are the quantities chosen by the firms in the Nash equilibrium (conditional on k_1^d).
- Plugging in specifics for this problem, we get that k_1^d solves

$$\Big[3/5 - \underbrace{k_1^d}_{y_1^\star(k_1^d)} - \underbrace{(3/5 - k_1^d)/2}_{y_2^\star(k_1^d)}\Big] \times \underbrace{(3/5 - k_1^d)/2}_{y_2^\star(k_1^d)} \leq E$$

- The solution is

$$k_1^d \geq 3/5 - 2E^{1/2}$$

- Profit-maximization implies this holds with equality.

Deterrence, cont'd

- Notice there was no calculus used here to derive k_1^d; just simple algebra. Also, notice that it may be better for Firm 1 to choose k_1^a (*i.e.*, it could be the case that $\pi_1(k_1^a) > \pi_1(k_1^d)$).
- Okay, so if Firm 2 enters we know that Firm 1 will produce k_1^d so long as $k_1^d \leq 7/15$.
- We also need to know Firm 1 output if Firm 2 does not enter conditional on k_1^d.
- In this case, Firm 1 has already incurred the cost of creating capital (F) and chooses output to solve

$$\max_{y_1} (1-y) \times y - F \text{ s.t. } y_1^M \leq k_1^d$$
$$\Rightarrow y_1^M = 1/2, \text{ if } y_1^M \leq k_1^d.$$

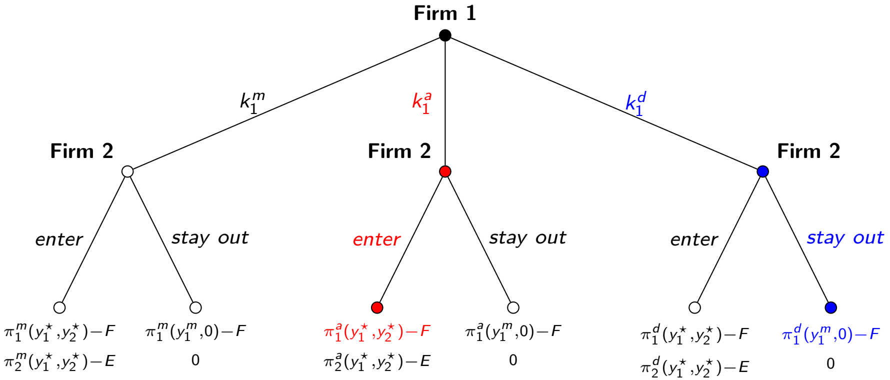
- But we also know that is only credible if $k_1^d \leq 7/15$ so it must also be the case that $y_1^M = k_1^d$.
- Therefore, if Firm 1 chooses capacity $k_1^d \leq 7/15$, Firm 2 will not enter and Firm 1 will want to produce output of $1/2$ but will be constrained to produce k_1^d (*i.e.*, $y_1^M = k_1^d$).

Is Deterrence the Optimal Strategy?

- Need to compare Firm 1's profits from choosing k_1^a to those from choosing k_1^d to determine the first move of the SPNE.; i.e.,

$$\pi_1^d\left(y_1^m(k_1^d), 0\right) \overset{?}{>} \pi_1^a\left(y_1^\star(k_1^a), y_2^\star(k_1^a)\right)$$

- Graphically, Firm 1 compares its profits generated by the sequence of events generated by accommodating (in red) to its profits generated by the sequence of events generated by deterring entry (in blue):



Is Deterrence the Optimal Strategy?

Need to compare Firm 1's profits at k_1^a and at k_1^d to determine which choice yields higher profits.

1. Accommodate:

$$k_1^a = 3/10,\ \mathrm{BR}_2(k^a) = 3/20,\ p^a = 11/20,\ \pi_2^a = 9/400,\ \pi_1^a = 9/200$$

2. Deter: Suppose $E = 4/400$. Then $k_1^d = 2/5 < 7/15$. At $k_1 = k_1^d$, Firm 2 does not enter and we get: $y_1^d = 2/5, p^d = 3/5, \pi_1^d = 2/25$.

Thus,

$$\pi_1^d = 2/25 > 9/200 = \pi_1^a$$

so it is optimal for Firm 1 to deter entry. In the SPNE, Firm 1 chooses to deter entry by choosing capacity $k_1^d = 2/5$. By definition of k_1^d, Firm 2 does not enter. Equilibrium output, price, and profit follow directly.

This example illustrates the following result:

Q2: Will the incumbent over-invest in capacity to deter entry but nevertheless use the capacity even if entry does not occur?

A2: Maybe. The answer depends upon the entry cost. We've just shown that such a strategy is reasonable.

Conclusions

1. Incumbent firm will not invest in idle capacity.

2. If entry costs are not too large, then incumbent firm will over-invest in capacity in order to deter entry.

    - This is interesting b/c we may only observe one firm in the data but this firm may not be acting like a monopolist. It may be acting more like a duopolist which is competing against the threat of entry (so it increases output).

$$\text{(Monopoly with No Threat of Entry) } y_1^m = 3/10$$
$$\text{(Monopoly with Threat of Entry) } y_1^d = 2/5$$

Insights from the Model

- Note that this game is very similar to the Stackelberg game.
- Stackelberg wrote his two-stage game in terms of quantities.
- Difficulties:
  1. How do firms acquire a first mover advantage?
  2. Why does quantity have a commitment value?
- Spence and Dixit made the Stackelberg story empirically-relevant:
  1. First mover advantage may come from one firm acquiring the technology earlier (e.g., had a patent).
  2. Capacities have a commitment value if they are sunk. They discipline future behavior.

Other Models of Entry Deterrence

Model 1: Limit Pricing & Asymmetric Information

- Bain (1949) conjectured that an established firm could discourage entry by charging a low price. We call this practice "Limit Pricing."
- Although this idea persisted for 30 years, economists were uncomfortable about applying the idea to antitrust policy since:
  - To condemn a firm for charging a low price seems weird.
  - How a low price could actually deter entry is also not clear. Bain conjectured that low prices must somehow portend bad news for would-be entrants.
- In the previous model capacity provided a commitment value in that it disciplined future behavior in the event of entry.
- But it's not clear how price could act as a commitment device since prices are easily changed.
- We need to add something else to make prices have commitment value. That something is asymmetric information.

Signaling via Low Prices with Asymmetric Information

Consider the following simplification of Milgrom & Roberts (1982).

- Two periods, two firms.
- Firm 1 is the incumbent firm and is a monopolist in period one where it chooses price p_1.
- Firm 2 can choose to enter or stay-out in period two.
- If Firm 2 enters, firms compete in prices.
- We're interested in finding equilibria where prices of the incumbent are lower than in the full-information case:
  - How and why does this happen?
  - Does such behavior decrease welfare?

Uncertainty

- Firm 1's cost is low with probability x and high with probability $1 - x$.
- Define $M_1^j(p_1)$ as monopoly profit where $j = \{L, H\} \Rightarrow p_1^L < p_1^H$.
- Firm 1 knows its cost but Firm 2 does not know Firm 1's cost before entry.
- If Firm 2 enters it has cost c_2 which is known to all. It discovers Firm 1's cost.
- Define D_1^j and D_2^j as the duopoly profits when Firm 1 is of type j. D_2^j includes entry costs.
- Assume $D_2^H > 0 > D_2^L$ so Firm 2's entry decision depends on Firm 1's cost.
- Firms discount future at rate $\beta \in (0, 1)$.

Timing

1. Firm chooses p_1 and earns $M_1^L(p_1)$ or $M_1^H(p_1)$.
   - Note that the superscript indicates Firm 1's actual cost so $M_1^L(p_1) > M_1^H(p_1)$ for any price p_1.
2. Firm 2 decides whether to enter.
   - If Firm 2 does not enter, Firm 1 is a monopolist and earns $\pi^M(c_1) = M_1^L(c_1)$ or $\pi^M(c_1) = M_1^H(c_1)$.
   - If Firm 2 does enter, duopoly competition results and profits are $\{D_1^L, D_2^L\}$ or $\{D_1^H, D_2^H\}$ where

     $$D_2^H > 0 > D_2^L$$

     and the superscripts correspond to Firm 1's marginal cost.

Signaling

- **Idea:** The incumbent may want to signal it has low cost (c_1^L) by setting a low price in period 1 ($\text{e.g.}, p_1^M(c_L)$).
- **Complication:** A firm with high cost may also choose a low period 1 low price to fool Firm 2, the prospective entrant.
- Thus, $p_1^M(c_L)$ may not say actually anything about Firm 1's cost in the equilibrium.
- We will look at two types of equilibria:
  1. Separating: A high cost firm chooses a different price than a low cost firm.
  2. Pooling: There is only one period 1 price chosen regardless of Firm 1's type.
- Either equilibrium could be consistent with what we observe in the data.

Full Information Benchmark

- It will be useful to start with the case where everyone knows Firm 1's cost.
- In period 1, p_1 is $p_1^M(c^L)$ if Firm 1 is low-cost and $p_1^M(c^H)$ if Firm 1 is high-cost.
  - Strictly-downward sloping demand implies that p_1^M reveals whether Firm 1's cost is c_1^H or c_1^L.
- In period 2: Firm 2 enters if $c_1 = c^H$ and stays out if $c_1 = c^L$.
- Period two prices are therefore either $p_1^M(c^L)$ or duopoly prices if $c_1 = c^H$.
- We'll use this equilibrium as the benchmark to evaluate whether asymmetric information can lead to lower prices when an incumbent firm faces potential entry, therefore rationalizing the hypothesis of Bain (1949).
- If we're successful, we have shown that asymmetric information may enable incumbents to deter entry by competitors.

Separating Equilibria

- In a separating equilibria, there will be a price p_1^L and p_1^H that each type will use (e.g., Firm 1's price therefore reveals its cost).
- Clearly $p_1^H = p_1^M(c^H)$ since Firm 1 might as well charge monopoly price since it does no good to fool Firm 2 into thinking it's high cost.
- What about p_1^L? How do we get $p_1^L \neq p_1^H$ (since we're looking for a separating equilibrium)?
- There are two "incentive compatibility" conditions:
  1. IC^H: High-cost type will choose $p_1^H = p_1^M(c^H)$ provided

$$\overbrace{M_1^H + \beta D_1^H}^{\text{Cost of Mimicking}} \geq \overbrace{M_1^H(p_1^L) + \beta M_1^H}^{\substack{\text{Benefit of}\\ \text{Mimicking}}}$$

$$M_1^H + \beta M_1^H(p_1^L) \geq \beta\left(M_1^H - D_1^H\right)$$

  2. IC^L: Low-cost type will choose p_1^L provided

$$\overbrace{M_1^L + \beta D_1^L}^{\substack{\text{Worst Case of } p_m^L\\ \text{is Entry}}} \leq \overbrace{M_1^L(p_1^L) + \beta M_1^L}^{\text{Profits cond. on } p_1^L}$$

$$M_1^L - M_1^L(p_1^L) \leq \beta\left(M_1^L - D_1^L\right)$$

Most Profitable Separating Equilibrium

- The most profitable separating equilibrium occurs when we just satisfy IC^H (*i.e.*, when high-cost firm is just willing to choose p_1^H).

$$M_1^H + \beta D_1^H = M_1^H(p_1^L) + \beta M_1^H \tag{1}$$

- Will $p_1^L = p_m^L$ work? Suppose at p_m^L the following is true for the high-cost firm:

$$M_1^H + \beta D_1^H < M_1^H(p_m^L) + \beta M_1^H \tag{2}$$

  then the high-cost firm will choose p_m^L.

  Note: We want looking for equilibrium where $p_1^L < p_m^L$ since we're checking whether it can be rational for an incumbent to charge a "low" price to deter entry where "low" is defined by charging a price lower than in the full information case.

- Equations (1) and (2) hold simultaneously when

$$M_1^H(p_1^L) + \beta M_1^H < M_1^H(p_m^L) + \beta M_1^H$$
$$\Rightarrow M_1^H(p_1^L) < M_1^H(p_m^L)$$

- Therefore, to separate (*i.e.*, to ensure high-cost firm does not choose p_1^L), a low-cost firm must charge $p_1^L < p_m^L$ and we get that prices are lower than the full-information case.

Most Profitable Separating Equilibrium, cont'd

- Conclusions:
  1. Firm 2 is not fooled by any manipulations of Firm 1's price and infers Firm 1's cost perfectly.
  2. The low-cost Firm 1 nonetheless modifies its pricing since it would be mistaken for the high-cost type if it did not sacrifice short-run profits to signal its type (and therefore prevent entry). Firm 1 is therefore worse off than if there was perfect information.
  3. Social welfare increases since period two entry is unaffected (pt 1) and first period prices fall (pt 2).

Pooling Equilibria

- Can we find equilibria where a high cost Firm 1 charges the low price in order to fool Firm 2?
- If p_1^L could be profitably chosen by Firm 1 with either c^L or c^H we need:

$$xD_2^L + (1-x)D_2^H < 0$$

  where the strict inequality implies that if Firm 2 is indifferent, it won't enter.
- Define $p_1^\star$ as the price chosen by Firm 1 regardless of its type.
- New IC conditions:
  1. IC^L:

$$M_1^L(p_1^\star) + \beta M_1^L \geq M_1^L + \beta D_1^L$$

  2. IC^H:

$$M_1^H(p_1^\star) + \beta M_1^H \geq M_1^H + \beta D_1^H$$

$$\underbrace{M_1^H(p_1^\star) - M_1^H}_{\substack{\text{Benefit of}\\ \text{Mimicking}}} \geq \beta \underbrace{\left(D_1^H - M_1^H\right)}_{\substack{\text{Cost of}\\ \text{Telling Truth}}}$$

Best Pooling Equilibrium

- The best Pooling Equilibrium has the highest possible price which Firm 1 can choose regardless of whether its high or low cost and also deter entry: p_m^L.
  - When Firm 1 is low-cost, choosing $p_1^\star = p_m^L$ is optimal and it's efficient for Firm 2 to not enter.
- We need to check whether a high-cost Firm 1 would do be willing to charge p_m^L. It will whenever IC^H holds:

$$M_1^H(p_m^L) + \beta M_1^H \geq M_1^H + \beta D_1^H \tag{3}$$

- If (3) holds at p_m^L, we have a pooling equilibrium where $p_1^\star = p_m^L$.
- We conclude that in the pooling equilibrium:
  1. Firm 1 charges the low-cost monopoly price regardless of its actual cost. Entry is deterred since Firm 2 cannot infer Firm 1's cost from observing p_m^L.
  2. There is less entry than under perfect information.
  3. The welfare implications are ambiguous:
     - Prices fall in period one b/c high cost firms charge a low price (period one welfare ↑).
     - There is less entry in period two (period two welfare ↓).

Discussion

- The Milgrom-Roberts model demonstrates that limit pricing may be a viable and rational business strategy provided there exists asymmetric information between the incumbent and the entrant.
- The implications of limit pricing are unclear, however, since the conclusions are sensitive to the idiosyncrasies of the industry in question (*i.e.*, the data).
- The researcher must therefore have detailed knowledge of the industry in order to diagnose whether an incumbent firm (or firms) are limit pricing to deter entry and whether such practice is welfare decreasing (*i.e.*, whether industry data imply the firms are playing the separating versus pooling equilibrium).

Model 2: "Learning by Doing"

In 1970s, several consulting firms including BCG recommended to clients that they should sacrifice short-run profits early in the product life cycle in order to gain a strategic advantage over rivals later in the cycle.

- By cutting price and producing a lot of output early, a firm slides down the learning curve more rapidly.
- The firm's lower costs in later periods give it a larger cost advantage against its rivals and may deter entry.

Key Assumption: learning is not transferable and can only be achieved by production.

Examples: airplanes, shipbuilding, semiconductors.

Q: Does this strategy work?

Model

- Two periods
- Two firms: A and B.
- A is a monopolist in period 1, B is a potential entrant in period 2.
- Demand in each period: P(Y) = 1 - Y.
- Payoffs: We ignore any discounting so A chooses output to maximize the sum of profits over the two periods.
- A's unit cost in period 1 is c; its unit cost in period 2 is

$$c_2 = c - \theta y_1, \;\; \theta > 0$$

- The Learning by Doing (LBD) effect is captured by θ since producing today decreases tomorrow's marginal cost for the firm.
  - For a monopolist there is incentive to reduce tomorrow's marginal cost in order to increase discounted profits. Call this the "Direct Effect."
  - For a monopolist facing entry, there is an incentive to reduce tomorrow's marginal cost in order improve the firm's competitive position as well as deter entry. Call this the "Strategic Effect."

Monopoly Solution

Suppose A does not have to worry about entry by B. Then it chooses output in each period (i.e., $\{y_t\}_{t=1,2}$) to solve total profits across the periods:

$$\max_{y_1, y_2} \underbrace{(1 - y_1 - c) \times y_1}_{\pi_1(y_1)} + \underbrace{(1 - y_2 - c + \theta y_1) \times y_2}_{\pi_2(y_1, y_2)}$$

We first solve for y_2. The first order condition yields

$$y_2 = (1 - c + \theta y_1)/2$$
$$\Rightarrow \pi_2(y_1) = \frac{(1 - c + \theta y_1)^2}{4}$$

Substituting this solution into the maximization problem yields

$$\max_{y_1} (1 - y_1 - c) y_1 + \underbrace{(1 - c + \theta y_1)^2 / 4}_{\pi_2(y_1)}$$

Optimal first period output solves the first order condition

$$1 - c - 2y_1 + \theta(1 - c + \theta y_1)/2 = 0$$

Monopoly Solution, cont'd

Thus, the monopoly solution is:

$$y_1^M = \frac{1-c}{2-\theta}, \;\; y_2^M = \frac{1-c}{2-\theta}$$

Interpretation: If there was no LBD (i.e., $\theta = 0$), the monopolist cares only about first period profits when it chooses y_1 and it produces $(1-c)/2$. But when it takes into account the impact of y_1 on second period profits via $c_2(y_1;\theta)$, it produces more.

Entry

Q: How does the threat of entry affect A's choice?

- Assume that y_1 is observed by B so it knows that A's costs in period 2 are c_2.
- If B enters, it pays fixed entry cost $F \geq 0$ and produces x units at cost c per unit (i.e., it has a cost disadvantage).
- For now, assume $F = 0$ (or is just really small) so that Firm A always accommodates entry.

If B enters in period 2, the best replies for A and B in the Cournot game are as follows:

$$R_A(x) = (1 - c_2 - x)/2$$

$$R_B(y_2) = (1 - c - y_2)/2$$

Solving for the Cournot equilibrium yields

$$y_2 = (1 + c - 2c_2)/3, \;\; x = (1 + c_2 - 2c)/3$$

Equilibrium profits in period 2 are therefore

$$\pi_2^A = (1 + c - 2c_2)^2/9, \;\; \pi_2^B = (1 + c_2 - 2c)^2/9$$

Optimal First Period Output

Define y_1^{a} as the optimal Duopoly solution ("a" for "accommodate"). Firm A's problem in period 1 is to solve:

$$\max_{y_1^{\mathsf{a}}} \underbrace{(1 - y_1 - c)y_1}_{\pi_1\left(y_1^{\mathsf{a}}\right)} + \underbrace{(1 - c + 2\theta y_1)^2/9}_{\pi_2\left(y_2^{\star}(y_1^{\mathsf{a}}),\, x^{\star}(y_1^{\mathsf{a}})\right)}$$

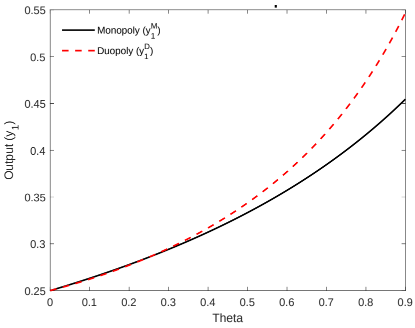
Differentiating and solving the first order condition yields

$$y_1^{\mathsf{a}} = \frac{1-c}{2} \times \left(\frac{9+4\theta}{9-4\theta^2}\right)$$

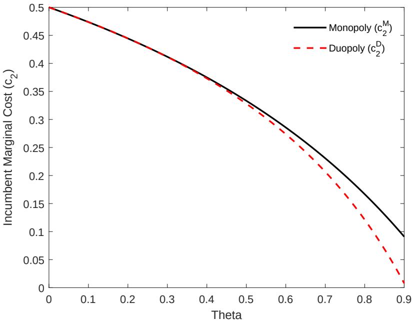
Q: Does entry of Firm B in period 2 lead Firm A to produce more in period 1 in order to increase its competitive position in period 2?

A: Yes, but the magnitude depends on the value of θ.

LBD and the Equilibrium Effect of Future Entry



(a) Period 1 Output



(b) Period 2 MC

- When θ is "low", the LBD effect is small so little difference in Firm A behavior.
- When θ is "high", Firm A produces more in period 1 to lower its period 2 marginal cost. This commits the firm to produce more in period 2 and B responds by producing less (not shown but follows given $c_2\downarrow$).

LBD as a Deterrence Strategy

If the entry cost incurred by B is sufficiently large, Firm A may be able to deter Firm B's entry.

How? It would have to increase period 1 output such that it gets such a cost advantage that Firm B cannot profitably enter.

Once again, there may be two solutions:

- Output level that accommodates entry such as the y_1^a we found.
- Larger output level that deters entry.

In the SPNE, Firm A chooses the period one output ($y_1^{\text{accommodate}}$ vs. y_1^{deter}) such that it maximizes lifetime profits.

Empirical Example

- "Predatory pricing" is the deliberate strategy of pricing aggressively (e.g., below marginal cost) in order to eliminate current or deter future competitors.
- This is a contentious issue in antitrust policy:
  1. Predatory Pricing has often been argued in court (e.g., John D. Rockefeller's Standard Oil was accused on predatory pricing) so people seem to think it exists as a rational (and often used) business strategy.
  2. But there exists little evidence that it amounts to sound strategy since prices have little commitment value. Thus, economists have regarded it as something like a great white buffalo, a unicorn, or even a leprechaun.
- When there is learning-by-doing, a firm may price aggressively in the short-term to drive up demand so as to increase long-term profits (and competitive position).
- In "*The Economics of Predation: What Drives Pricing When There Is Learning-by-Doing?*" by Besanko, Doraszelski, & Kryukov (2014); the authors develop a dynamic oligopoly model with learning-by-doing. They show there exist many equilibria:
  1. In some equilibria, incumbent firms do not price aggressively and there is future entry.
  2. In other equilibria, incumbent firms price aggressively in the short-run in order to deter future entry. Thus, pricing has a commitment value via LBD.
- Welfare effects of (1) vs (2) are unclear since short-term aggressive pricing increases short-term CS and less long-term entry reduces long-term CS.
- The welfare effects of "predatory pricing" must therefore be evaluated by industry.

Model 3: Complementarities as a Barrier to Entry

Suppose there are three cities, $g, h = 1{,}2$, and 3, and individuals living in each city who wish to travel to each of the other cities and back.

- Individuals care only about price, not number of stops or distance or airline.

Demand in each city-pair market $g - h$ is

$$D(p_{gh}) = 1 - p_{gh}$$

where p_{gh} is the price of the cheapest return ticket from city g to city h.

Remark: the $g - h$ market is distinct from the $h - g$ market.

Transport costs per passenger per flight are zero. Fixed costs of offering a direct flight between any pair of cities g and h is F. The flight services both the $g - h$ and $h - g$ markets.

Monopoly Hub Operator

Airline H is a monopolist, operates a hub and spoke network centered in city 1.

Total number of markets is 6: 4 are serviced by direct flights, 2 are serviced by a one-stop flight.

Since length does not matter either to airline or travelers, H charges the same monopoly price in each market. The price and profits in each market are

$$p^M = 1/2, \pi^M = 1/4$$

Network profits to H are

$$\Pi^M = 3/2 - 2F$$

Note: $F < 3/4$.

Threat of Spoke Entry

- A low-cost airline E is considering operating a flight between cities 1 and 2.
- Its marginal costs and fixed costs are zero (i.e., $F = 0 \Rightarrow$ "low-cost").
- If "E" enters, E and H flights are homogeneous.
- Firms compete in price.

Will H concede the 1-2 and 2-1 markets to E?

Case 1 - H does not concede and E enters.

- Pricing in the 1-2 and 2-1 markets is Bertrand so competition drives variable profits to zero.
- Each airline earns zero variable profits in these markets. E is willing to enter.
- Pricing in the other city-pair markets is not affected: H continues to charge $p = 1/2$ in 2-3, 3-2, 1-3, and 3-1 markets.

Therefore, H network profits = 1 - 2F; ($F < 1/2$).

Case 2 - H withdraws its flight between cities 1 and 2.

- H gains F in the 1-2 and 2-1 markets (i.e., its cost falls).
- Shares the 2-3 and 3-2 markets with E; pools travelers in these markets and the 1-3, 3-1 markets on the same flight.
- It cannot price discriminate based on origin or destination (result) so it has to charge everyone the same price.

Let s denote the price that E sets in the 1-2 and 2-1 markets. H's optimization problem is

$$\max_p \underbrace{2p(1-p)}_{\pi_{13}+\pi_{31}} + \underbrace{2p(1-s-p)}_{\pi_{23}+\pi_{32}}$$

Its best reply to s is

$$p = (2-s)/4$$

E's optimization problem is the same:

$$\max_s \underbrace{2s(1-s)}_{\pi_{12}+\pi_{21}} + \underbrace{2s(1-p-s)}_{\pi_{23}+\pi_{32}}$$

Therefore

$$s = (2-p)/4$$

Remark: Best responses are downward-sloping so prices are strategic substitutes and goods (flights) are therefore complements.

Equilibrium

The Nash equilibrium prices are

$$p = s = 2/5$$

Network profits for H (and E) = 16/25 - F.

Remark: Prices in H's markets fall because it can no longer distinguish between 1-3 (3-1) travelers and 2-3 (3-2) connecting travelers.

Working backwards, in the SPNE H chooses to operate a flight between cities 1 and 2 (even though it's losing money in that market) if

$$\begin{aligned} 1 - 2F = \pi^{keep} \quad &> \quad \pi^{concede} = \frac{16}{25} - F \\ \Rightarrow F \quad &< \quad 9/25 \end{aligned}$$

otherwise it concedes.

Big Idea

Q: Why do H's aggregate profits go up by staying in the unprofitable 1-2 market?

A: By staying in 1-2 market, it can discipline price in that market, thereby influencing demand (profits) in the 1-3 market so it earns higher profits in the 1-3 and 3-1 markets by flying between cities 1 and 2.

Remark 1: The complementarity of these markets implies that H may decide to stay (i.e., enter) market 1-2.

Remark 2: The loss to H from dropping the flight between cities 1 and 2 is proportional to the number of cities in the network.

Model 4: Tying as Barrier to Entry

Q: Can a firm with monopoly power in market A monopolize market B by tying the sale of product B to product A?

A simple model:

- Suppose Firm 1 is the monopolist in A and Firm 2 supplies market B.
- Potential consumers for A and B goods **are the same and equal to M**.
- In market A, consumers have unit demands and WTP equal to v.
  - $D(q) = M$ if $q \leq v$; 0 otherwise where $q \equiv$ price in market A.
- In Market B, consumers are each willing to purchase one unit but have different valuations.
  - Demand for firm i is $D_i(p_i, p_j)$.
  - Firms compete in prices.
- Marginal costs are zero.

Timing

1. Firm 1 decides whether to offer goods A and B as a bundle.
2. Firm 2 decides whether to enter market B.
3. Firms simultaneously choose prices.

Separate Sales

Suppose Firm 2 chose to enter. If Firm 1 offers to sell the goods individually, it offers good A at $q = v$ and good B at price $s^\star$ where $s^\star$ solves:

$$\pi_1^s = \max_{p_1} \left[\underbrace{p_1 D_1(p_1, p_2)}_{\pi_B} + \underbrace{vM}_{\pi_A} \right]$$

- Thus, it sells M units of good A and $D_1(s^\star, p_2)$ units of good B.
- Define π_1^s as the profits when Firm 1 sells goods A and B separately.

Tied Sales

Suppose Firm 1 sells goods A and B in a bundle. Define P as the price of the bundle.

Q: How many consumers buy from firm 1?

A: Consider one consumer k of the M consumers. Consumer k buys the bundle if his/her consumer surplus from the bundle is greater than zero; i.e.,

$$\begin{aligned} CS^k &\geq 0 \\ \Rightarrow \quad \underbrace{v + T_B^k}_{\text{Benefit / WTP}} - P &\geq 0 \\ \Rightarrow T_B^k &\geq P - v \end{aligned}$$

where T_B^k is the benefit / WTP consumer k receives from product B.

Recall that $D_1(p_1, p_2)$ tells us the number of consumers who have a WTP for product B greater than p_1 (conditional on p_2). Thus, the number of people willing to buy the bundle is $D_1(P - v, p_2)$.

Profit-Maximization

Given Firm 2's price p_2, Firm 1 chooses bundle price P to solve

$$\pi_1^t = \max_P \; P D_1(P - v, p_2) \tag{4}$$

- Define $\tilde{P}$ as the profit-maximizing bundle price.
- Define π_1^t as the profits when Firm 1 ties goods A and B.

Q: If Firm 2 is in the market, will Firm 1 offer products A and B in a bundle?

Answer this by writing down what we know:

$$\begin{aligned}
\pi_1^s &= vM + s^\star D_1(s^\star, p_2) \\
&\geq vM + \underbrace{\overbrace{(\tilde{P} - v)}^{p_1} D_1(\overbrace{\tilde{P} - v}^{p_1}, p_2)}_{\pi \text{ from market B}} \\
&= \underbrace{v[M - D_1(\tilde{P} - v, p_2])}_{>0} + \tilde{P} D_1(\tilde{P} - v, p_2) \\
&\geq \tilde{P} D_1(\tilde{P} - v, p_2) = \pi_1^t
\end{aligned}$$

NB, the first inequality follows from the fact that $s^\star$ maximizes profit when A,B sold separately and $s^\star$ may not equal $\tilde{P} - v$. The second inequality is due to the fact that $M \geq D_1(p_1, p_2)\ \forall p_1$.

Results:

1. If Firm 2 is in the market, tying is not optimal.
2. This would likely occur when the entry cost F is small (e.g., $F = 0$).

Bundling to Foreclose Entry

Q: Can Firm 1 bundle products A and B to preempt/ prevent Firm 2's entry into market B?

We need to check if bundling the products at the beginning of the game leads to lower profits for Firm 2.

Recall that the consumers who buy from Firm 1 are those who are willing to pay v for good A and $P - v$ for good B.

Define the implied price for good B as $p = P - v$. Then we can rewrite (4) in terms of p where $\tilde{p}$ is the solution to the following problem for Firm 1:

$$\max_{p_1} (p_1 + v) D_1(p_1, p_2) \tag{5}$$

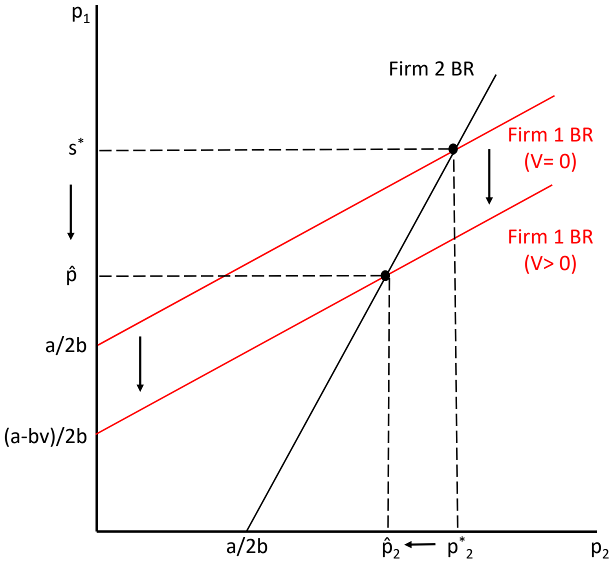
An Aside

- Suppose demand is $D_1(p_1, p_2) = a - bp_1 + cp_2$ where $b > 0$ and $c \in (0, b)$.
- Best response for Firm 1 when it solves (5) is then

$$p_1 = \frac{a - bv + cp_2}{2b}$$

- When $v = 0$ there is no market A and we have the Bertand-Nash best responses we've seen before with differentiated goods.
- As v increases the best responses for Firm 1 shifts down leading to lower equilibrium prices.
- Thus, the **implied price for the market B good is decreasng in** v.
- Intuition: as the WTP for good A increases, consumers want to buy the bundle to gain access to good A. Firm 2 has to respond by decreasing its price in market B.
- Note that solving (5) actually doesn't require much knowledge of $D_1(p_1, p_2)$ so this is a general result.

An Aside (cont'd)



Back to the Case of General $D_1(p_1, p_2)$

Given bundle price $P = p_1 + v$ and a specific bundle price $\tilde{P} = \tilde{p} + v$ which maximizes profit for Firm 1:

$$\max_{p_1} \,(p_1 + v) \times D_1(p_1, p_2)$$

And $s^\star$ solves

$$\max_{p_1} \; p_1 \times D_1(p_1, p_2)$$

- When $v = 0$ the two problems are the same so $\tilde{p} = s^\star$.
- Since Firm 1's best reply in market B is decreasing in v, we know $\tilde{p} < s^\star$ for $v > 0$.
- Bundling therefore leads Firm 1 to choose a lower implied price for good B.
- Firm 2 responds by decreasing its price leading to lower (variable) profits.
- Firm 1 may be able to foreclose entry of Firm 2 if entry cost is high enough.

Conclusions

- Bundling / Tying allows Firm 1 to influence its pricing behavior in market B, enabling it to be “tougher” competition for Firm 2.
- Is tying to preempt entry part of the SPNE? Not sure. This again would depend on the relative size of the entry cost (F).
- All we can say that tying could be a useful tactic to foreclose competitors from the market.

A More General Approach

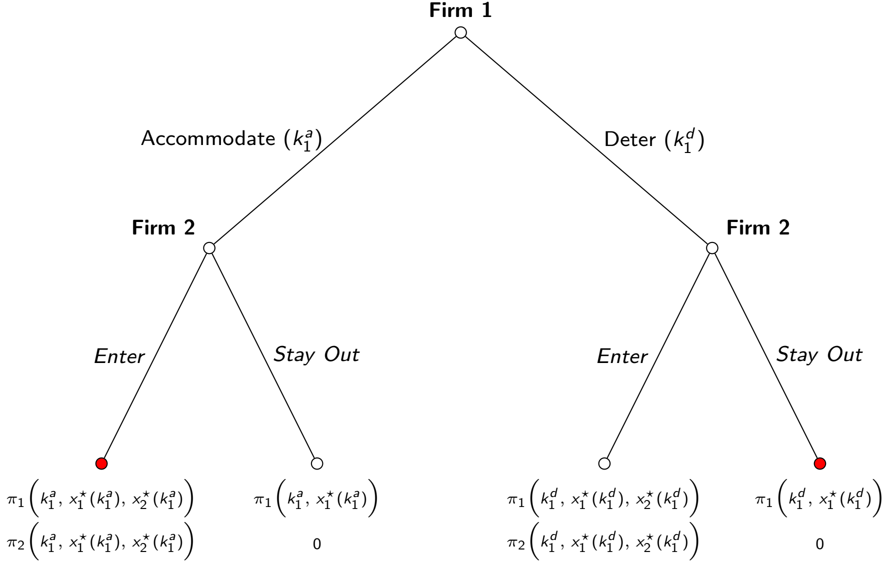
A General Taxonomy of Entry Models

- Consider the following two firm, two period model. In period 1, Firm 1 (the incumbent) chooses an "investment" (broad interpretation) k_1. Firm 2 observes k_1 and decides whether to enter.

  1. In the post-entry game, firms compete and simultaneously choose actions x_1, x_2. For example, they could choose quantities (as in our first example) or prices.
  2. If Firm 2 does not enter, incumbent enjoys a monopoly position in the second period:
  $$\pi_1\Big(k_1, x_1(k_1)\Big)$$
  3. If Firm 2 enters, the firms make simultaneous second-period choices x_1 and x_2, determined by a (assumed unique and stable) Nash equilibrium where $x_1^\star(k_1)$ and $x_2^\star(k_1)$. Profits are
  $$\pi_1\Big(k_1, x_1^\star(k_1), x_2^\star(k_1)\Big) \text{ and } \pi_2\Big(k_1, x_1^\star(k_1), x_2^\star(k_1)\Big)$$
  where for brevity I put the entry cost $F > 0$ in Firm 2's profit function.

- In our first example, $x_1^\star(k_1)$ and $x_2^\star(k_1)$ were output choices of the firms from the simultaneous move Cournot game.

Extensive Form Representation



- Terminal nodes in red emphasize that Firm 1's decision to "Accommodate" or "Deter" implies Firm 2's decision to "Enter" or "Stay Out", respectively, by construction.

Nomenclature

- Entry is **deterred** if k_1 is chosen so that

$$\pi_2\Big(k_1, x_1^\star(k_1), x_2^\star(k_1)\Big) \leq 0$$

- Entry is **accommodated** if k_1 is chosen so that

$$\pi_2\Big(k_1, x_1^\star(k_1), x_2^\star(k_1)\Big) > 0$$

- Key Insight: Firm 1's first-mover advantage is whether it chooses to deter or accommodate entry via its choice of k_1.

Entry Deterrence

- To deter entry, firm 1 chooses k_1 such that

$$\pi_2\Big(k_1, x_1^\star(k_1), x_2^\star(k_1)\Big) = 0$$

- How is this done? Look at the total derivative of π_2:

$$\frac{d\pi_2}{dk_1} = \frac{\partial \pi_2}{\partial k_1} + \frac{\partial \pi_2}{\partial x_1}\frac{dx_1^\star}{dk_1} + \underbrace{\frac{\partial \pi_2}{\partial x_2}\frac{dx_2^\star}{dk_1}}_{=0}$$

- The third term is equal to zero since Firm 2 is profit-maximizing (i.e., $\frac{\partial \pi_2}{\partial x_2} = 0$).

- Two remaining effects:
  1. **Direct Effect**: $\frac{\partial \pi_2}{\partial k_1}$. This is often zero (as in our first example).
  2. **Strategic Effect**: $\frac{\partial \pi_2}{\partial x_1}\frac{dx_1^\star}{dk_1}$ reflects the fact that k_1 impacts Firm 1's ex post behavior which ultimately impacts Firm 2's profit.

Over-Investment versus Under-Investment

- We say that investment k_1 makes Firm 1 "tough" if $\frac{d\pi_2}{dk_1} < 0$ and "soft" if $\frac{d\pi_2}{dk_1} > 0$.
- To deter entry, Firm 1 wants to invest s.t. $\pi_2 \downarrow$. If investment makes Firm 1 tough (soft), Firm 1 should **overinvest** (**underinvest**) relative to the game when k_1 is not observable by Firm 2.
- Conclusions:
  - Tough ($\frac{d\pi_2}{dk_1} < 0$): Over-invest to deter entry.
  - Soft ($\frac{d\pi_2}{dk_1} > 0$): Under-invest to deter entry.
- In our first example (Dixit-Spence):
  1. Higher capacity k_1 enabled Firm 1 to produce more in period 2.
  2. More y_1 reduced profits for Firm 2 so k_1 made Firm 1 "tough."
  3. Firm 1 therefore over-invested in capacity to deter entry.

Ways to Look "Tough"

- Investment in production capacity.
- Product positioning.
  - Moving towards center of Hotelling line.
- Product proliferation.
  - Having many products in the market.
- Tying.
  - Firm 1 is in markets A and B. Firm 2 enters market A.
  - If products are tied then entry will be more costly for firm 1.
  - Hence tying enables the incumbent to commit to reacting aggressively to entry.

Another Example: Loyalty Programs

- Firm 1 can invest in a "loyalty" program to make it costly for customers to switch to Firm 2 (e.g., frequent flier programs).
- The strategic effect has the opposite effect:
  1. Firm 1 chooses higher prices to its captive consumers.
  2. As k_1 increases (more captive consumers), $p_1 \uparrow$.
  3. A high price p_1 makes entry of Firm 2 easier.
- Therefore a large clientèle reduces how aggressive Firm 1 is in price competition, entry deterrence may require under-investment (i.e., less k_1).

Accommodation of Entry

- Deterrence may be too costly but Firm 1 can still improve its post-entry position.
- Instead of focusing on Firm 2's profit as a function of k_1, look at Firm 1's profits conditional on Firm 2 entry:

$$\frac{d\pi_1}{dk_1} = \frac{\partial \pi_1}{\partial k_1} + \underbrace{\frac{\partial \pi_1}{\partial x_1}\frac{dx_1^\star}{dk_1}}_{=0} + \frac{\partial \pi_1}{\partial x_2}\frac{dx_2^\star}{dk_1}$$

  where the second term is zero b/c of Firm 1 profit-maximization (i.e., $\frac{\partial \pi_1}{\partial x_1} = 0$).
- We're interested in how Firm 1 investment can improve its profits down the road. Put differently, whether Firm 1 (incumbent) over or under invests depends upon $\frac{d\pi_1}{dk_1} \lesseqgtr 0$.
- As before, there are two effects:
  - **Direct Effect**: $\frac{\partial \pi_1}{\partial k_1}$ investing today may impact profits directly tomorrow. The direct effect will not affect whether firm over or under-invests. This is like the LBD model under monopoly.
  - **Strategic Effect**: $\frac{\partial \pi_1}{\partial x_2}\frac{dx_2^\star}{dk_1}$ investment impacts Firm 2's behavior.

Accommodation of Entry, cont'd

- Suppose $\frac{d\pi_i}{dx_j}$ terms are all the same sign.
  1. If second period competition is in quantities: $\frac{d\pi_i}{dx_j} < 0$.
  2. If second period competition is in prices: $\frac{d\pi_i}{dx_j} > 0$.
- Note that Firm 2's response to Firm 1's investment choice can be decomposed as follows:

$$\frac{dx_2^\star}{dk_1} = \underbrace{\left(\frac{dx_2^\star}{dx_1}\right)}_{\mathrm{BR}_2(x_1^\star)} \times \left(\frac{dx_1^\star}{dk_1}\right)$$

- We then get:

$$sign\left(\frac{\partial \pi_1}{\partial x_2}\frac{dx_2^\star}{dk_1}\right) = \underbrace{sign\left(\frac{\partial \pi_2}{\partial x_1}\frac{dx_1^\star}{dk_1}\right)}_{\text{Tough vs Soft}} \times \underbrace{sign\Big(\mathrm{BR}_2\Big)}_{\text{SS vs SC}}$$

where we used the assumption $sign\left(\frac{\partial \pi_1}{\partial x_2}\right) = sign\left(\frac{\partial \pi_2}{\partial x_1}\right)$.

Accommodation of Entry, cont'd

$$\text{sign}\left(\frac{\partial \pi_1}{\partial x_2}\frac{dx_2^\star}{dk_1}\right) = \underbrace{\text{sign}\left(\frac{\partial \pi_1}{\partial x_1}\frac{dx_1^\star}{dk_1}\right)}_{\text{Tough vs Soft}} \times \underbrace{\text{sign}\Big(\text{BR}_2\Big)}_{\text{SS vs SC}}$$

- This means the sign of the strategic effect and therefore whether or not the firm over or under-invests depends upon:
  1. Whether or not investment makes you tough or soft.
  2. The slope Firm 2's Best Response curve:
     - $\text{BR}_2 > 0$: "strategic complements" (e.g., Goods subst, Bertrand price competition).
     - $\text{BR}_2 < 0$: "strategic substitutes" (e.g., Goods subst, Cournot quantity competition).

- Conclusions:
  - Tough / SC or Soft / SS: Under-invest when accommodating entry.
  - Tough / SS or Soft / SC: Over-invest when accommodating entry.

Four Cases

1. **Tough + SS**: Firm 1 investment triggers a muted response by Firm 2.
   ⇒ Over-invest for both deterrence and accommodation ("Top Dog").
   e.g., Capacity investment with quantity competition.

2. **Soft + SC**: Firm 1 investment triggers a muted response by Firm 2.
   ⇒ Under-invest to deter entry ("Lean and Hungry Look").
   ⇒ Over-invest to accommodate entry ("Fat Cat").
   e.g., Loyalty model.

3. **Tough + SC**: Firm 1 investment triggers a muted response by Firm 2.
   ⇒ Over-invest to deter entry ("Top Dog").
   ⇒ Under-invest to accommodate entry ("Puppy Dog").
   e.g., Capacity investment with price competition.

4. **Soft + SS**: Firm 1 investment triggers an aggressive response by Firm 2.
   ⇒ Under-invest for both deterring and accommodating entry.
   ("Lean and Hungry Look")