

Strategic Pre-Commitment

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Week 8-9

Strategic Commitment

- Limiting our own future options does not seem like a good idea.
- However, it might be beneficial if, by doing so, we can alter other players' behavior (once they know that we will not be able to use some of our available actions).

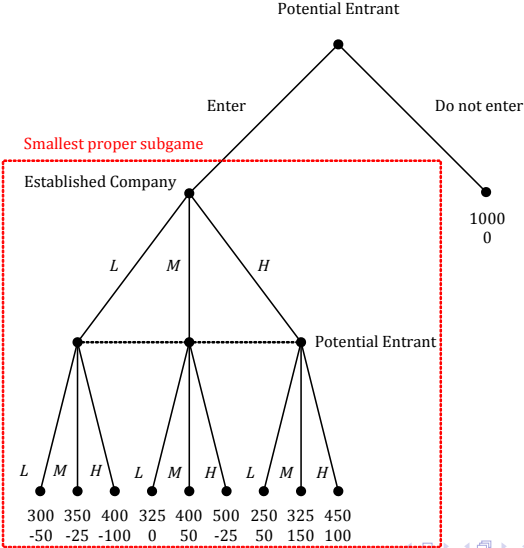
Strategic Commitment

- Let's see the benefits of commitment in an entry game, where the incumbent firm commits a huge investment in capacity in order to modify post-entry competition.
 - As we will see, entry does not even occur!
 - Indeed, the entrant finds entry unprofitable once the incumbent has invested in capacity.

Entry deterrence game

- Consider an incumbent firm.
 - It monopolized a particular market for a few years (e.g., it was the first firm initiating a new technology).
 - But... now the incumbent is facing the threat of entry by a potential entrant.
- In the first stage, the entrant must decide whether to enter the industry.
 - If it were to enter, then the established company and the entrant simultaneously set prices. For simplicity: Low, Medium or High prices.
 - Otherwise, the incumbent maintains its monopoly power.

Entry deterrence game



Entry deterrence game

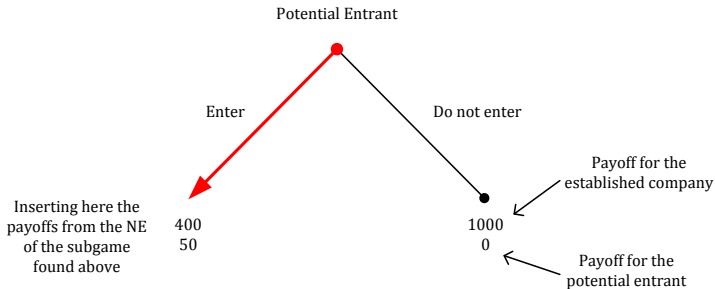
- Representing the post-entry subgame in its matrix form:

		<i>Entrant</i>		
		Low	Medium	High
<i>Established Company</i>	Low	300, -50	350, <u>-25</u>	400, -100
	Medium	<u>325</u> , 0	<u>400</u> , <u>50</u>	<u>500</u> , -25
	High	250, 50	325, <u>150</u>	450, 100

- Unique NE of this subgame: (*Moderate, Moderate*) with corresponding payoffs (400, 50).

Entry deterrence game

- Therefore, plugging the payoffs that arise in the equilibrium of the post entry game, we obtain:



- Hence, the unique SPNE is: $(\underbrace{Enter / Moderate}_{Entrant}, \underbrace{Moderate}_{Incumbent})$

Entry deterrence game

- What about the set of NE?
- Note that the potential entrant has $2 \times 3 = 6$ available strategies.
- The established company only has three available strategies.

		<i>Established Company</i>		
		Low	Moderate	High
<i>Potential Entrant</i>	Do not enter/Low	<u>0, 1000</u>	<u>0, 1000</u>	<u>0, 1000</u>
	Do not enter / Moderate	<u>0, 1000</u>	<u>0, 1000</u>	<u>0, 1000</u>
	Do not enter / High	<u>0, 1000</u>	<u>0, 1000</u>	<u>0, 1000</u>
	Enter / Low	-50, 300	<u>0, 325</u>	50, 250
	Enter/ Moderate	-25, 350	<u>50, 400</u>	<u>150, 325</u>
	Enter / High	-100, 400	-25, <u>500</u>	100, 450

Entry deterrence game

- Hence, there are *four* NEs:
 - ① Do not enter/Low, Low
 - ② Do not enter/Moderate, Low
 - ③ Do not enter/High,Low, and
 - ④ Enter/Moderate, Moderate [This NE coincides with the SPNE of this game]
- In the first three NEs, the potential entrant stays out because he believes the incredible threat of low prices from the incumbent. Upon entry, we know that only moderate prices are sequentially rational for the incumbent.

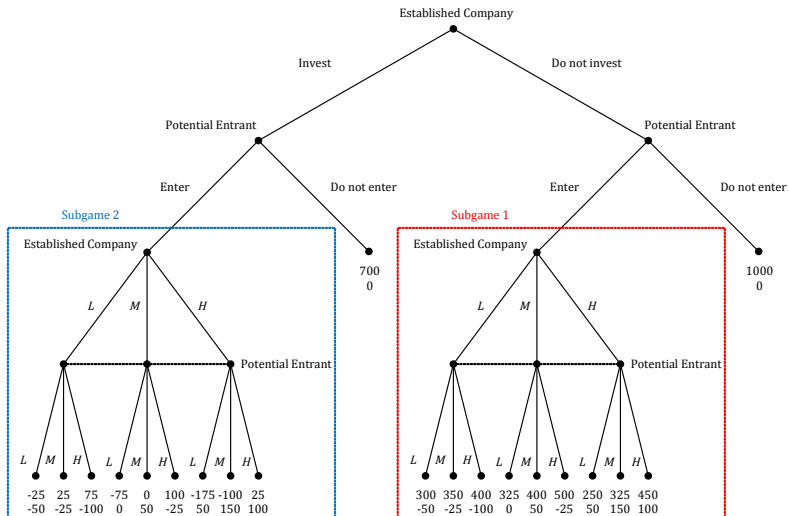
Entry deterrence game

- What actions can the incumbent take in order to avoid this unfortunate result?
- Resort to organized crime?
 - *Example:* New York garbage-hauling business.
 - As reported in The Economist, soon after a company began to enter the market, an employee found a dog's severed head in his mailbox with the note:

"Welcome to New York"

- Seriously... what **legal** actions can the incumbent take?
 - Invest in cost-reducing technologies (e.g., at a cost of \$500).
 - This increases his own incentives to set low prices.
 - (See the following figure)

Entry deterrence game



Entry deterrence game

- **Subgame 1** (after no investment) exactly coincides with the smallest subgame we analyzed in the previous version of the game where the incumbent didn't have the possibility of investing.
 - We know that the NE of that subgame is (Moderate, Moderate) with payoffs (400, 50) for the incumbent and entrant, respectively.
- **Subgame 2** (after investment) was not analyzed before.
 - Let's represent it in its matrix form in order to find the NE of this subgame.
 - (See next slide).

Entry deterrence game

- **Subgame 1:** (After no investment. Same pricing game as when cost-reducing investments were not available).

		<i>Entrant</i>		
		Low	Medium	High
<i>Established Company</i>	Low	300, -50	350, <u>-25</u>	400, -100
	Medium	<u>325</u> , 0	<u>400</u> , <u>50</u>	<u>500</u> , -25
	High	250, 50	325, <u>150</u>	450, 100

- NE of this subgame: (*Moderate, Moderate*) with corresponding payoffs (400, 50).

Entry deterrence game

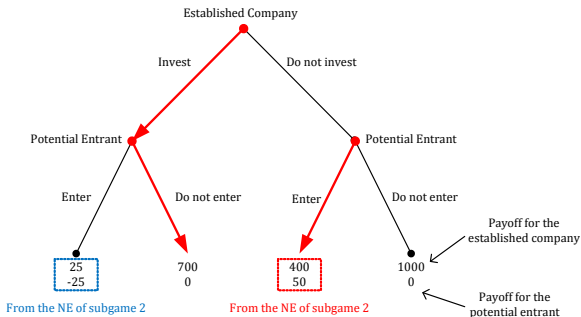
- **Subgame 2** (After investment) in its matrix form:

		<i>Entrant</i>		
		Low	Medium	High
<i>Established Company</i>	Low	<u>-25</u> , -50	<u>25</u> , <u>-25</u>	75, -100
	Medium	-75, 0	0, <u>50</u>	<u>100</u> , -25
	High	-175, 50	-100, <u>150</u>	25, 100

- Hence, the psNE of this subgame is (*Low*, *Moderate*) with associated payoffs (25, -25).
- *Remark*: The incumbent now finds low prices to be a best response to the entrant setting low or moderate prices.
 - In contrast, when the incumbent does not invest in cost-reducing technologies, the incumbent's dominant pricing strategy is moderate regardless of the entrant's price.

Entry deterrence game

- We can now plug the payoffs associated with the NE of both subgame 1 (after no investment) and subgame 2 (after investment) into our extensive form game.



- Hence, the SPNE is: (*Invest / Low / Moderate, Do not enter / Moderate / / Enter / Moderate*)

Describing the SPNE in the Entry deterrence game

- Interpretation of the SPNE

$$\underbrace{(Invest / Low / Moderate)}_{\text{Incumbent}},$$
$$\underbrace{(Do \text{ not enter} / Moderate / / Enter / Moderate)}_{\text{Potential Entrant}}$$

- This SPNE strategy profile describes that:

- **Incumbent:**

- The incumbent invests in cost-reducing technologies.
- If the incumbent makes such investment, it subsequently sets a low price. If, in contrast, such investment does not occur, the incumbent sets a moderate price.
- [Notice that we specify the incumbent's behavior both in equilibrium and off-the-equilibrium path.]

Describing the SPNE in the Entry deterrence game

- **Entrant:**

- After observing that the incumbent invests, the entrant responds by not entering.
 - If the entrant enters, however, it sets a moderate price. [Note, that this is again an off-the-equilibrium behavior]
- After observing that the incumbent does not invest, the entrant responds entering.
 - If the entrant enters, it sets a moderate price. [Note, that this is in-equilibrium behavior]

- **Equilibrium path** (shaded branches): *invest, do not enter.*

Entry deterrence game

- As a result, investing in cost-reducing technologies serves as an entry-deterrence tool for the incumbent.
- Note that essentially the incumbent conveys to the potential entrant that it will price low in response to entry.
 - Thus, the entrant can anticipate entry to be unprofitable.

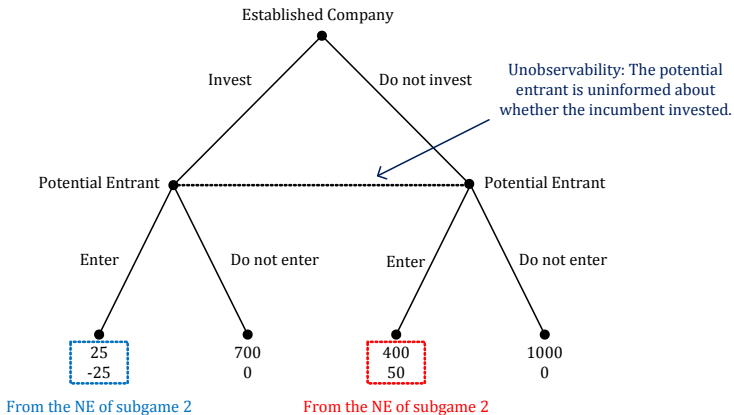
- If the incumbent states that he will set low prices, the entrant wouldn't believe such a threat.
- Instead, the incumbent can convey a more credible threat by altering his own preferences for low prices:
 - By investing in cost-reducing technologies, he makes low prices more attractive, and hence low prices become credible.

Entry deterrence game

- **Observability:**

- for an investment to work as a credible threat, it must be observable by the potential entrant.
- What would happen if, instead, the potential entrant didn't observe the incumbent's investment before deciding whether to enter?
 - See figure in next slide. →

Entry deterrence game



Entry deterrence game

- Since the game is now simultaneous, we can represent it in its matrix form as follows

		<i>Entrant</i>	
		Enter	Do not Enter
<i>Established Company</i>	Invest	25, -25	700, <u>0</u>
	Do not Invest	<u>400, 50</u>	<u>1000, 0</u>

- Hence, the SPNE is:
 - *Do not invest / Low / Moderate*
 - *Enter / Moderate / Moderate*
- No entry deterrence without observability!

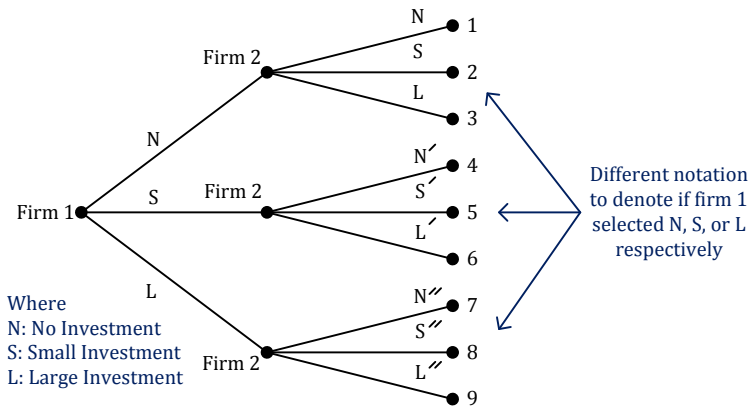
A model of limit capacity

- Watson, pp. 183-186 (Posted on Angel as Ch. 16)
- Can it be rational for a firm to overinvest in capacity in order to deter entry? Yes!
 - Alcoa was found guilty of anticompetitive practices because of doing this.
- Consider a game where two firms are analyzing whether to sequentially enter a new industry
 - The inverse demand function is $p(q_1, q_2) = 900 - q_1 - q_2$.

A model of limit capacity

- Time structure of the game:
 - ① First, firm 1 decides to invest in a small plant (S), large plant (L), or to not invest (N).
 - ② Second, firm 2, observing firm 1's decision to invest in S, L, or N, decides similarly.
- The cost of building these facilities is:
 - \$50,000 for the small facility, which allows the firm to produce up to 100 units.
 - \$175,000 for the large facility, which allows the firm to produce any number of units.
- See figure. →

A model of limit capacity



Computing Profits (Payoffs in terminal nodes 1-9)

- 1) (No Investment, No Investment). Recall that no investment is equivalent to no entry. Profits = 0 for both firms: (0, 0)

Computing Profits (Payoffs in terminal nodes 1-9)

2) (No Investment, Small) (Implies $q_1 = 0$)

$$\max_{q_2} (900 - q_2)q_2 - \underbrace{50,000}_{\text{Cost of building the small plant}}$$

Taking FOCs with respect to q_2 ,

$$900 - 2q_2 = 0 \implies q_2 = 450 > \underbrace{100}_{\text{Capacity constraint if I build a small plant}}$$

Hence, profits for firm 2 are:

$$(900 - \underbrace{100}_{\text{Max capacity}}) \cdot 100 - 50,000 = 80,000 - 50,000 = 30,000$$

Payoff of (N, S) is then $(\underbrace{0}_{\text{Firm 1 (Did not enter)}}, \underbrace{30}_{\text{Firm 2 (In Thousands)}})$

Computing Profits (Payoffs in terminal nodes 1-9)

3) (No Investment, Large). Similarly to above,

$$\max_{q_2} (900 - q_2)q_2 - \underbrace{175,000}_{\text{Cost of building the large facility}}$$

Taking FOCs,

$$900 - 2q_2 = 0 \implies q_2 = \underbrace{450}_{\text{Now output is unconstrained since my capacity is large.}}$$

Profits for firm 2 are:

$$(900 - 450) \cdot 450 - 175,000 = 202,500 - 175,000 = 27,500$$

Payoff of (N, L) is $(0, 27.5)$.

Computing Profits (Payoffs in terminal nodes 1-9)

- 4) (Small, No Investment). This case is symmetric to case 2 of (N, S) . Hence, profits are $(30, 0)$.

Computing Profits (Payoffs in terminal nodes 1-9)

5) (Small, Small). Both firms are in the market. Hence:

$$\max_{q_1} (900 - q_1 - q_2)q_1 - \underbrace{50,000}_{\text{Cost of building a small plant}}$$

FOCs with respect to q_1 ,

$$900 - 2q_1 - q_2 = 0 \implies q_1 = 450 - \frac{1}{2}q_2 \quad ((BRF))$$

Plugging BRF_2 into BRF_1 ,

$$\begin{aligned} q_1 &= 450 - \frac{1}{2} \left(\underbrace{450 - \frac{1}{2}q_1}_{q_2(q_1)} \right) \\ \implies q_1 &= q_2 = 300 > \underbrace{100}_{\text{Max. Capacity}} \end{aligned}$$

Computing Profits (Payoffs in terminal nodes 1-9)

Therefore each firm produces only up to capacity (100 units) which yields,

$$\begin{aligned}\text{Profits}_1 &= (900 - \underbrace{100 - 100}_{\text{Max. Capacity}}) \cdot 100 - 50,000 \\ &= 70,000 - 50,000 = 20,000 \text{ (Similarly for firm 2)}\end{aligned}$$

Payoff under (S, S) is $(20, 20)$

Computing Profits (Payoffs in terminal nodes 1-9)

- 6) (Small, Large). Firm 1 suffers a capacity constraint, and $q_1 = 100$. Firm 2 plays a best response to $q_1 = 100 \implies q_2(100) = 450 - \frac{1}{2} \cdot 100 = 400$.

Profits of Firm 1:

$$\begin{aligned} & (900 - \underbrace{100}_{q_1 \text{ (Max capacity)}} - \underbrace{400}_{q_2 \text{ (Unconstrained)}}) \cdot 100 - \underbrace{50,000}_{\text{Cost of small plant}} \\ &= 40,000 - 50,000 = -10,000 \end{aligned}$$

Profits of Firm 2:

$$\begin{aligned} & (900 - 100 - 400) \cdot 400 - \underbrace{175,000}_{\text{Cost of large plant}} \\ &= 160,000 - 175,000 = -15,000 \end{aligned}$$

Profits under (S, L) are $(-10, -15)$.

Computing Profits (Payoffs in terminal nodes 1-9)

- 7) (Large, No Investment). This case is symmetric to (N, L) in case 3. Hence, profits of (L, N) are $(27.5, 0)$.
- 8) (Large, Small). This case is symmetric to (S, L) in case 6. Hence, profits of (L, S) are $(-15, -10)$.

Computing Profits (Payoffs in terminal nodes 1-9)

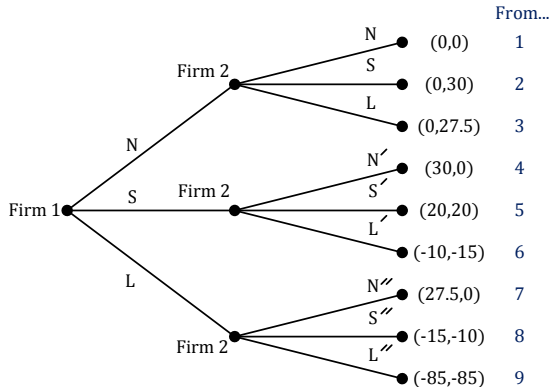
- 9) (Large, Large). Since no firm is constrained, we have $q_1 = q_2 = 300$. (From *BRF*, see explanation in case 5). Profits are then,

$$\begin{aligned} & (900 - 300 - 300) \cdot 300 - 175,000 \\ = & 90,000 - 175,000 = -85,000 \end{aligned}$$

(And similarly for the other firm, since both firms produce the same output, and incur the same large installation costs). Profits of (L, L) are $(-85, -85)$.

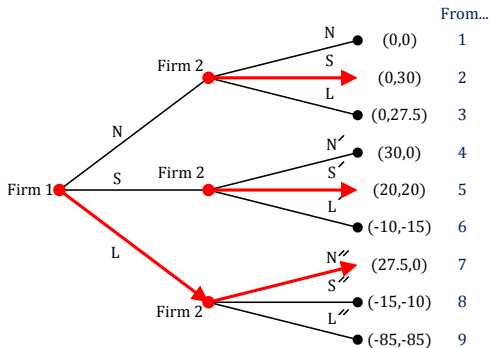
A model of limit capacity

- We can now plug the payoffs we obtained into the terminal nodes 1 through 9 as follows:



A model of limit capacity

- We are now ready to apply backward induction!



- SPNE: $(L, SS'N'')$.

A model of limit capacity

- Summarizing...
- As a consequence, firm 1 invests in a large production facility...
 - and firm 2 decides not to enter the industry.
- Hence, investment in large capacity serves as an "entry deterrence" tool.
 - **Without the threat of entry:** firm 1 would have invested in a small plant, making profits of \$30,000. [We know that by fixing no plant for firm 2, and thus comparing firm 1 profits from no plant, 0, small facility, 30, and large facility, 27.5.]
 - **With the threat of entry:** firm 1 overinvests (in order to deter entry), but obtains profits of only \$27,500.

- Is overinvestment irrational? No! The previous two statements are comparing two states of the world (with and without entry threats): under threats of entry, the best firm 1 can do is to overinvest in capacity.

Advertising and Competition

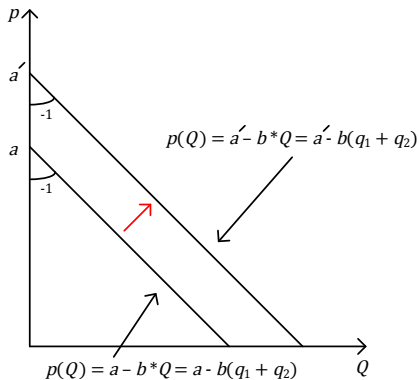
- Watson, pp. 180-182 (Posted on Angel as Ch. 16).
- Advertising is frequently used by firms to make customers aware of their product.
- In a monopoly setting, the analysis of advertising is relatively simple: my advertising affects my sales.(see Perloff, or Besanko and Braeutigam's textbooks)
 - But, what about the effect of advertising in a **duopoly**?
- The theory of sequential-move games (and SPNE) can help us examine advertising decisions in this context.

Advertising and Competition

- Let's consider the following sequential-move game:
 - ① In the first period, Firm 1 decides how much to invest in advertising, a dollars. [The cost of advertising a is $\frac{2a^3}{81}$]
 - ② In the second period, given Firm 1's advertising expenditure, both firms choose their output level competing in quantities (Cournot competition).
- Inverse demand function is $p(q_1, q_2) = a - b(q_1 + q_2)$.
- For simplicity, we assume no marginal costs, i.e., $c = 0$.

Advertising and Competition

- Hence, an increase in advertising, from a to a' , shifts market demand upwards:



Advertising and Competition

- **Second Period**
- We apply backward induction, by starting from the second stage of the game:
- We maximize the firm's profits, for a given level of advertising (which was chosen in the first stage).

$$\max_{q_1} \underbrace{(a - q_1 - q_2)q_1}_{\substack{\text{Gross profits} \\ \text{(We assume } c=0)}} - \underbrace{\frac{2a^3}{81}}_{\substack{\text{Cost of} \\ \text{advertising}}}$$

- Taking FOCs, with respect to q_1 ,

$$a - 2q_1 - q_2 = 0 \implies q_1(q_2) = \frac{a}{2} - \frac{1}{2}q_2 \quad (BRF_1)$$

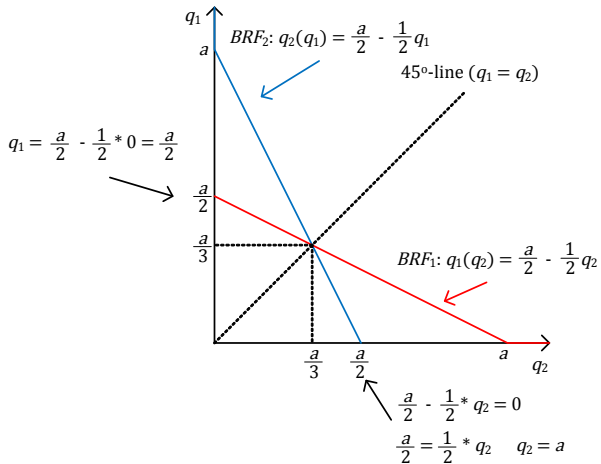
Advertising and Competition

- Likewise for firm 2,

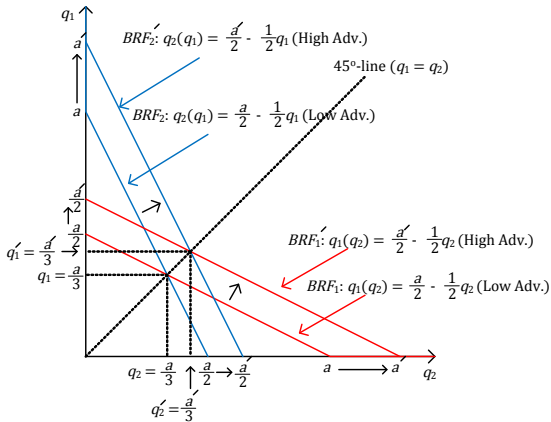
$$q_2(q_1) = \frac{a}{2} - \frac{1}{2}q_1 \quad (BRF_2)$$

- Let us graphically analyze the effect of advertising on firms' *BRFs*.
- Figures:
 - *BRFs* and Equilibrium output,
 - The effect of advertising on the *BRFs*, and as a consequence on equilibrium output. (Point where both *BRFs* cross each other).

Increasing Advertising Shifts BRFs Upwards



Increasing Advertising Shifts Both BRFs Upwards



- Hence, advertising attracts more customers to the market (e.g., making the market more well-known), shifting both firms BRFs upwards.
- As a consequence, both firms' equilibrium output increases from $q_i = \frac{a}{3}$ to $q'_i = \frac{a'}{3}$, where $i = \{1, 2\}$.
- Advertising in this context can thus be interpreted as a public good: while only Firm 1 is allowed to advertise in our model, both firms benefit from its advertising.

Advertising and Competition

- Plugging BRF_1 into BRF_2 , we obtain the equilibrium output level

$$q_1 = \frac{a}{2} - \frac{1}{2} \underbrace{\left(\frac{a}{2} - \frac{1}{2} q_1 \right)}_{q_2} \implies q_1 = \frac{a}{3}$$

And similarly for firm 2, $q_2 = \frac{a}{3}$.

Advertising and Competition

- Hence, profits for firm 1 are

$$\begin{aligned}\pi_1(a) &= (a - q_1 - q_2)q_1 - \frac{2a^3}{81} \\ &= \left(a - \frac{a}{3} - \frac{a}{3}\right)\frac{a}{3} - \frac{2a^3}{81} = \frac{a^2}{9} - \frac{2a^3}{81}\end{aligned}$$

(Note that profits are only a function of the expenditure on advertising, a , since we have already plugged in the equilibrium output levels of q_1 and q_2 .)

Advertising and Competition

- **First Period**

- Anticipating the profits firm 1 will obtain in the second stage, $\frac{a^2}{9} - \frac{2a^3}{81}$, firm 1 seeks to choose the value of advertising, a , that maximizes its profits, $\pi_1(a)$.

$$\max_a \frac{a^2}{9} - \frac{2a^3}{81}$$

- Taking FOCs with respect to a ,

$$\frac{2a}{9} - \frac{6a^2}{81} = 0$$

Solving for a on the above expression, $\frac{2a}{9} - \frac{6a^2}{81} = 0$, we have

$$\frac{2a}{9} = \frac{6a^2}{81} \implies 18a = 6a^2 \implies 18 = 6a \implies a^* = \frac{18}{6} = 3$$

- We are done!!

Advertising and Competition

- But wait...
- How should we report the SPNE of this game?
 - Firm 1 chooses advertising $a^* = 3$, and output level $q_1(a) = \frac{a}{3}$ and $q_2(a) = \frac{a}{3}$.
- Note that we don't write $q_1(a^*) = \frac{3}{3} = 1$ evaluating output at the optimal level of advertising $a^* = 3$.
 - Why? Because we need to specify equilibrium actions at every subgame of the second period.
 - That is, we need to specify equilibrium output after every advertising decision. (Even off-the-equilibrium path).

A classification of dogs...

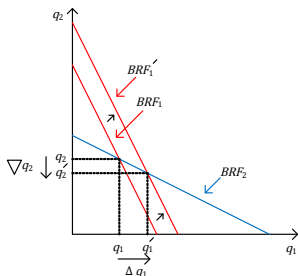
- Consider the following game:
 1. In the first period, Firm 1 chooses a pre-commitment strategy that is visible and understandable by other players. In addition, Firm 1 cannot renege from such commitment in future periods.
 - **Examples:**
 - investment in new technology that reduces marginal costs,
 - expenditure on advertising,
 - investment in additional capacity in an already mature industry that actually *raises* marginal costs.

A classification of dogs...

- Continues:
 2. In the second period, given such pre-commitment strategy from firm 1, firm 1 and 2 compete by simultaneously selecting quantities (Cournot competition), or prices (Bertrand competition for differentiated products). [We will analyze both cases].

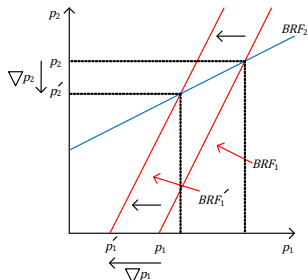
Depending on the type of competition during the second period (competition in quantities or prices), it is easy to show that firm 1 will choose to make a certain investment, or to refrain from it.

First Case: "Top Dog"



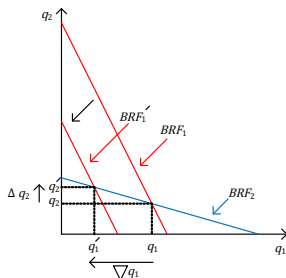
- *Example:* Firm 1 invests in reducing marginal costs in the first stage of the game.
 - 1 BRF_2 is decreasing in q_1 .
 - 2 BRF_1 increases (shifts upward) in the pre-commitment strategy that firm 1 takes (Lowering marginal costs shifts BRF_1 upwards).
- Great! *Another example:* Advertising.

Second Case: "Puppy Dog Ploy"



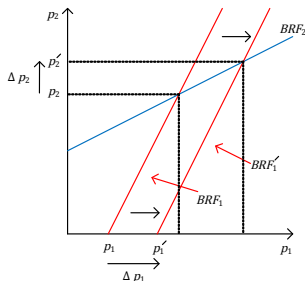
- *Example:* Firm 1 invests in reducing marginal costs in the first stage of the game.
 - 1 BRF_2 is increasing (In this case in p_1).
 - 2 BRF_1 decreases in the pre-commitment strategy of firm 1 (Lowering marginal costs shifts BRF_1 inwards).
- Avoid!

Third Case: "Lean and Hungry Look"



- 1 BRF_2 is decreasing (In this case in q_1).
- 2 BRF_1 decreases (shifts downward) in the pre-commitment strategy chosen by firm 1 in the first period of the game (e.g., additional capacity in a mature industry, which actually raises marginal costs).
- Avoid!

Fourth Case: "Fat Cat"



- 1 BRF_2 is increasing (In this case in p_1).
- 2 BRF_1 increases (shifts outward) in the pre-commitment strategy of firm 1 in the first period of the game (e.g., additional capacity in a mature industry, which actually raises marginal costs).
 - great !

All Four Cases Together

		Slope of BRF_2	
		Strategic Substitutes (- slope)	Strategic Complements (+ slope)
Shifts Outwards	BRF_1 increases in the pre-commitment strategy of firm 1.	Case 1: TOP DOG Make	Case 4: FAT CAT Make
Shifts Inwards	BRF_1 decreases in the pre-commitment strategy of firm 1.	Case 3: LEAN AND HUNGRY LOOK AVOID	Case 1: PUPPY DOG PLOY AVOID

Examples:

- One example we already saw in class: Firm 1 choosing how much money to spend on advertising during the first period, and then competing in quantities during the second period.
 - Firm 1 is playing “top dog” strategy (check it).
- More examples:
 - Consider the following game with two firms. In the first stage, each firm i independently decides how much capital k_i to invest in R&D. As a result of this investment, total costs of firm i become

$$TC(q_i) = F + (c_0 - \alpha k_i) q_i$$

where α represents the effectiveness of the expenditure in R&D.

- In the second stage of the game, given the marginal costs of every firm, firms compete in quantities. (Top Dog again!)

Examples:

- Another example (of "Top Dog" behavior):
 - In the first stage of the game, every country independently provides an export subsidy to domestic firms.
 - Larger export subsidies firms' marginal costs (resembling the effect of R&D on firms' marginal costs).
 - In the second stage of the game, firms compete in quantities.
 - As a consequence, countries tend to provide too generous export subsidies to their exporting firms.

Examples:

- Another example:
 - In the first stage of the game, every country independently sets the environmental standards that firms installed within its jurisdiction must obey.
 - Laxer environmental standards reduce firms' marginal costs (resembling the effect of R&D on firms' marginal costs).
 - In the second stage of the game, firms compete in quantities.
 - Hence, countries tend to set lax environmental standards in order to facilitate the competitiveness of their national firms...
 - leading to too much global pollution!!!

Examples:

- What if... firms compete during the second stage of the game using prices instead of quantities.
 - Do you think a strategic government would set lax environmental standards as well? No!
- For more examples and references, read:
 - "The Fat Cat effect, the Puppy-Dog Ploy and the Lean and Angry look", by Drew Fudenberg and Jean Tirole, *The American Economic Review*, 1984, 74(2), pp.361-66. (super short!!)