Strategic Investment

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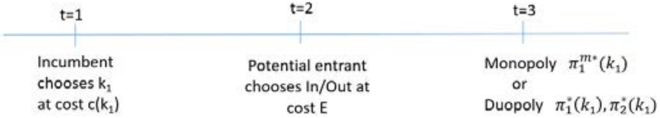
Introduction

Last week we discussed the effect of entry on markets. This week we move back another step, thinking about actions that firms can take to affect both entry and post-entry competition.

Many classic models are versions of a three stage game:

- Stage 1: Firm 1 chooses some "investment" k_1.
- Stage 2: Firm 2 observes k_1 and then chooses In/Out. Entry cost E.
- Stage 3: If firm 2 stays out, firm 1 is a monopoly: $\max_{a_1} \pi_1^m(k_1, a_1)$.
  If firm 2 enters, firms 1 and 2 choose a_1, a_2 and earn profits $\pi_i(k_1, a_1, a_2)$.
  Assume that π_i is concave with unique NE $(a_1^*(k_1), a_2^*(k_1))$



We interpret "investment" broadly include any action with sunk costs and durable effects: product design, cost reduction, advertising, differentiating products, building capacity, etc.

Possible Outcomes

Bain (1956) distinguished three possible outcomes.

- Blockaded entry: Entry does not occur even if the incumbent ignores the entry treat.
- Deterred entry: Entry would occur if the incumbent ignored it, but the monopolist chooses its investment to deter entry.
- Accommodated entry: Deterring entry is impossible or prohibitively expensive so the monopolist chooses its investment to prepare for post-entry competiton.

We think of these as three possible equililibria and focus on two questions:

1. Will firms choose to deter or accommodate entry?
2. How will the investment k_1 be distorted to accomplish this?

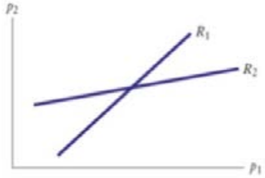
The answers will depend on the nature of the investment and the post-entry game. Fudenberg and Tirole (1984) noted that a simple classification of games and investments helps to think about this.

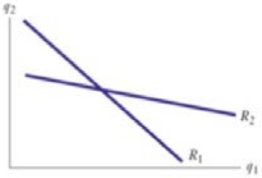
Games: Strategic Complements and Substitutes

Consider a two-player simultaneous move game with payoffs $\pi_i(a_i, a_j)$. Let $BR_i(a_j)$ be player i's best response correspondence.

Definition

The game has strategic complements if $BR_i'(a_j) > 0$ for all i, a_j.
The game has strategic substitutes if $BR_i'(a_j) < 0$ for all i, a_j.





Recall that Hotelling competition had strategic complements and Cournot competition had strategic substitutes.

Games: Strategic Complements and Substitutes

A classic result on complements/substitutes, which can be stated more generally using the increasing differences machinery from 14.121, is:

Proposition

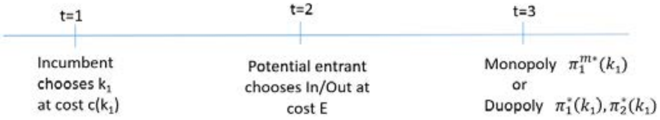
Suppose the π_i are twice continuously differentiable and the best responses are well defined. Then, the game has strategic complements if $\frac{\partial^2 \pi_i}{\partial a_i \partial a_j}(a_i, a_j) > 0$ *for all* i, a_i, a_j *and strategic substitutes if* $\frac{\partial^2 \pi_i}{\partial a_i \partial a_j}(a_i, a_j) < 0$ *for all* i, a_i, a_j.

Price competition models usually have strategic complements and quantity competition models usually have strategic substitutes although this need not be true for all demand functions.

$$\begin{aligned}
\frac{\partial^2}{\partial p_i \partial p_j}(p_i - c)D_i(p_i, p_j) &= \frac{\partial}{\partial p_j}\left[(p_i - c)\frac{\partial D_i}{\partial p_i} + D_i(p_i, p_j)\right] \\
&= (p_i - c)\frac{\partial^2 D_i}{\partial p_i \partial p_j} + \frac{\partial D_i}{\partial p_j}
\end{aligned}$$

Types of Investments

We classify investments based on their effect on the potential entrant. In the strategic investment model define $\pi_i^*(k_1) \equiv \pi_i(k_1, a_1^*(k_1), a_2^*(k_2))$.



Definition

Investment makes firm 1 tough if $\frac{d\pi_2^*}{dk_1} < 0$.

Investment makes firm 1 soft if $\frac{d\pi_2^*}{dk_1} > 0$.

Often the effect that an investment will have is obvious, e.g. cost reduction vs. lobbying to lower tax rates.

When it is not obvious it may be helpful to think about the direct and strategic effects:

$$\frac{d\pi_2^*}{dk_1} = \underbrace{\frac{\partial \pi_2}{\partial k_1}}_{\text{Direct}} + \underbrace{\frac{\partial \pi_2}{\partial a_1}\frac{da_1^*}{dk_1}}_{\text{Strategic}} + \frac{\partial \pi_2}{\partial a_2}\frac{da_2^*}{dk_1}$$

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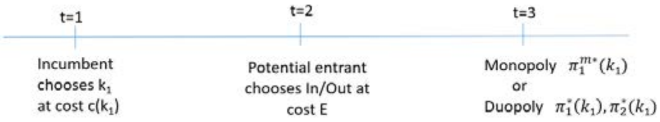
Investment	Competition	Direct	Strategic	Total
Cost reduction	Quantities	0	$- \quad + \Rightarrow -$	Tough
Locating away from entrant	Prices	$+$	$+ \quad + \Rightarrow +$	Soft
Advertising to capture consumers	Prices	$-$	$+ \quad + \Rightarrow +$	????

Blockaded Entry

There's not much to say about blockaded entry. It's just a benchmark that occurs when E is large.



Let $k_1^m, a_1^m = argmax_{k_1,a_1} \pi_1^m(a_1, k_1)$.

If $\pi_2(k_1^m, a_1^*(k_1^m), a_2^*(k_1^m)) < E$, then entry is blockaded.

The incumbent ignores the potential entry and chooses k_1^m.

Deterred Entry

The deterred entry case of the model occurs when E is somewhat smaller. The incumbent's problem determining k_1^{ED} is:

$$\max_{k_1, a_1} \pi_1^m(k_1, a_1)$$

s.t.

$$\pi_2(k_1, a_1^*(k_1), a_2^*(k_1)) \leq E$$

Given that entry is not blockaded the constraint is binding and the incumbent must distort k_1^{ED} away from k_1^m.

Proposition

If investment makes firm 1 tough then $k_1^{ED} > k_1^m$. If investment makes firm 1 soft, then $k_1^{ED} < k_1^m$.

Proof:
We know that $\pi_2^*(k_1^m) > E$ and $\pi_2^*(k_1^{ED}) \leq E$. If investment makes firm 1 tough then π_2^* is decreasing so these imply that $k_1^m < k_1^{ED}$. The opposite occurs in the soft case.

Deterred Entry

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s.t.

$$\pi_2(k_1, a_1^*(k_1), a_2^*(k_1)) \leq E$$

Proposition

If investment makes firm 1 tough then $k_1^{ED} > k_1^m$. If investment makes firm 1 soft, then $k_1^{ED} < k_1^m$.

Some examples are:

- Cost reduction. Firm 1 overinvests in reducing costs to deter entry.
- Advertising to increase market size. Firm 1 will limit such advertising to avoid attracting entry.
- Differentiation. Firm 1 avoids differentiating from the potential entrant to deter entry.

Accommodated Entry

When entry costs are lower deterring entry requires a larger distortion in k_1. Firms will choose between the deterrence and accommodation solutions.

The entry accommodation solution is $k_1^{AC} = argmax_{k_1} \pi_1^*(k_1)$.

As a point of comparison we define k_1^{OL} to be the nonstrategic investment firm 1 would choose if entry was going to occur and firm 2 could not observe k_1 (or equivalently if k_1, a_1 and a_2 were all chosen simultaneously). It solves $\frac{\partial \pi_1}{\partial k_1}(k_1^{OL}, a_1^*(k_1^{OL}), a_2^*(k_1^{OL})) = 0$.

One characterization highlights the relevant strategic effect.

Proposition

Firms "overinvest" to accommodate entry, $k_1^{AC} > k_1^{OL}$ if and only if $\frac{\partial \pi_1}{\partial a_2} \frac{da_2^*}{dk_1} > 0$

Proof

$$\frac{d\pi_1^*}{dk_1}(k_1^{OL}) = \underbrace{\frac{\partial \pi_1}{\partial k_1}(k_1^{OL})}_{\text{Zero}} + \underbrace{\frac{\partial \pi_1}{\partial a_1}\frac{da_1^*}{dk_1}}_{\text{Zero}} + \underbrace{\frac{\partial \pi_1}{\partial a_2}\frac{da_2^*}{dk_1}}_{\textit{Strategic}}$$

Accommodated Entry

An alternate characterization connects to the type of game and investment.

Proposition

Suppose that $\frac{\partial \pi_2}{\partial k_1} = 0$ *and* $Sign(\frac{\partial \pi_i}{\partial a_j}) = Sign(\frac{\partial \pi_j}{\partial a_i})$. *Then, firms "overinvest" to accommodate entry,* $k_1^{AC} > k_1^{OL}$ *if*
(a) the game has strategic complements and investment makes 1 soft; or
(b) the game has strategic substitutes and investment makes 1 tough.
We get underinvestment in the other two cases.

To deter entry firms always wanted to be tough. With accommodation, things reverse in games with strategic complements.

	Tough	Soft
Strategic Complements	Under *Puppy dog*	Over *Fat cat*
Strategic Substitutes	Over *Top dog*	Under *Lean & hungry*

Proof

$$\frac{\partial \pi_2}{\partial a_2}(k_1, a_1^*(k_1), a_2^*(k_1)) = 0 \quad \text{for all } k_1.$$

Differentiating w.r.t. k_1 gives

$$\frac{\partial^2 \pi_2}{\partial k_1 \partial a_2} + \frac{\partial^2 \pi_2}{\partial a_1 \partial a_2}\frac{da_1^*}{dk_1} + \frac{\partial^2 \pi_2}{\partial a_2^2}\frac{da_2^*}{dk_1} = 0$$

$$\implies \text{Sign}\left(\frac{da_2^*}{dk_1}\right) = \text{Sign}\left(BR_2' \frac{da_1^*}{dk_1}\right)$$

Using this to sign the strategic effect from the previous proposition we find

$$\text{Sign}\left(\frac{\partial \pi_1}{\partial a_2}\frac{da_2^*}{dk_1}\right) = \underbrace{\text{Sign}(BR_2')}_{\textit{Complements}} \cdot \underbrace{\text{Sign}\left(\frac{\partial \pi_2}{\partial a_1}\frac{da_1^*}{dk_1}\right)}_{\textit{Softness}}.$$

Learning By Doing

Consider a three stage model:

- Firm 1 is a monoplist with marginal cost c_0 and sells q_1^1.
- Firm 2 chooses In/Out at cost E.
- Monopoly or duopoly. Firm 1's marginal cost is $c(q_1^1)$ with $c' < 0$.

"Overproducing" is a strategic investment that makes firm 1 tough. (It reduces costs in the competition stage.)

Let q_1^B be the first period production with blockaded entry. In the entry deterrence case, the incumbent will set $q_1^1 > q_1^B$.

In the entry accommodation case firm 1 will underproduce ($q_1^1 < q_1^{OL}$) in the first period if the second-period game has strategic complements. Firm 1 will overproduceproduce ($q_1^1 > q_1^{OL}$) in the first period if the second-period game has strategic substitutes.

The benchmark q_1^{OL} would itself be less than q_1^B if the incentive to reduce costs is lower due to the lower second-period quantity.

Leverage Theory

Whinston (*AER* 1990) discusses the ability of firm to extend market power. Suppose firm 1 is a monopolist in good A and competes wtih firm 2 in good B. All consumers get value v from good A. Demand $D_i^B(p_1, p_2)$ for good B.

- Firm 1 can design its products so they cannot be used separately.
- Firm 2 chooses In/Out at cost E.
- Monopoly or duopoly. Prices p_2^B and $(p_1^A,\ p_1^B)$ or p_1^{AB}.

Absent any strategic effects, i.e. if the tying decision can't prevent entry or alter p_2^B, firm 1 would never tie the products. Selling a bundle at p_1^{AB} is dominated by selling A at v and B at $p_1^{AB} - v$. You sell more units of good A, with good B sales unchanged.

Tying the goods is a strategic investment that makes firm 1 tough. It is as if firm 1 earns $v - c_A$ on good A only if it sells good B, so the opportunity cost of selling B is reduced from c_B to $c_B - (v - c_A)$. Strategically, this is like a cost reduction

Firm 1 may tie the goods to deter entry.

In the entry accommodation case with strategic complements, firm 1 would not want to tie its products.

Limit Pricing

Can firms use low prices to deter entry? In a standard separable model with firm 1 as a monopolist at $t = 1$ and a potental entrant for period 2 the answer would be no: p_{11} has no effect on entry or future behavior.

Milgrom and Roberts (*Ema* 1982) noted prices can affect future competition is firm 2 is uncertain about firm 1's cost and prices signal costs.

- Firm 1's cost $c_1 \in \{\underline{c}, \overline{c}\}$ known only to 1. 2's prior is $\text{Prob}\{c_1 = \overline{c}\} = \mu$.
- Firm 1 chooses p_{11} at $t = 1$.
- Firm 2 observes p_{11}. Chooses In/Out at cost E.
- Monopoly with profits $\pi_1^{m*}(c_1)$ or Duopoly with profits $\pi_i^{D*}(c_1, c_2)$.

In this model we can have a limit pricing equilibrium where firm 1 sets $p_{11}(c_1) < p_1^m(c_1)$ to deter entry.

Sometimes (if firm 2 won't enter if it gets no new information) this can be a pooling equilibrium where firm 1 sets a low price at $t = 1$ regardless of c_1. Firm 2 stays out if it sees this price and enters otherwise.

For other parameters, there can be a separating equilibrium where firm 1 sets $p_{11} \equiv \underline{p}_1^* < p_1^m(\underline{c})$ if its cost is low and sets $p_{11} = p_1^m(\overline{c})$ if cost is high. Firm 2 enters unless it sees $p_{11} = \underline{p}_1^*$.

Signal Jamming

Firms can also set prices below the static optimum in "signal jamming" models in which firms 1 and 2 are symmetrically uninformed about some state. Signal jamming can be motivated by a desire to deter entry or induce exit. Here's a predation example:

- Firms 1 and 2 choose q_{11} and q_{21}. Market demand determines price $P(q_1, q_2) = \theta - (q_1 + q_2)$. θ is unknown with common prior $\theta \sim N(\mu, \sigma^2)$.
- Firms 1 and 2 observe market price, but not rival's quantity. Firm 2 can exit and earn scrap value K.
- Monopoly or Duopoly

The equilibirum will have q_{11} greater than the static BR to q_{21}. Firm 2 correctly anticipates q_{11} and is not fooled by the overproduction. Exit occurs exactly when it would with θ known.

But the equilibrium must have overproduction at $t = 1$. Otherwise, firm 1 would want to deviate from the equilibrium and overproduce: there is no first order loss from doing so. And every extra unit produced drives down the price, lowering firm 2's posterior and increasing the probability of exit.

Entry Deterrence via Long-Term Contracts

Aghion Bolton (*AER* 1987) discusses deterring entry by signing consumers to long-term contracts. Would rational forward-looking consumers ever sign?

- Incumbent firm 1 has cost $c_1 = \frac{1}{2}$. Can sign consumer to long term contract, e.g. "Buyer agrees to buy from firm 1 at $p = \frac{3}{4}$ or pay penalty of $\frac{1}{2}$."
- Firm 2 learns $c_2 \sim U[0, 1]$. Chooses In/Out at cost $E \approx 0$.
- Monopoly or Bertrand duopoly. Buyer has value $v = 1$ for either product.

Again, signing the buyer to the long-term contract can be seen as a strategic investment that makes firm 1 tough (and hence might be used to deter entry).

With <u>no contract</u> firm 2 enters iff $c_2 < \frac{1}{2}$. $p^* = \frac{1}{2}$ or 1. $CS = \frac{1}{2} \cdot \frac{1}{2} = \frac{1}{4}$.
With the <u>contract</u> firm 2 enters iff $c_2 < \frac{1}{4}$. $p^* = \frac{1}{4}$ or $\frac{3}{4}$. $CS = \frac{1}{4}$.

Firm 1 is better off: it earns $\frac{3}{4} \cdot (\frac{3}{4} - \frac{1}{2}) + \frac{1}{4} \cdot \frac{1}{2} = \frac{5}{16}$ with vs. $\frac{1}{2} \cdot (1 - \frac{1}{2}) = \frac{1}{4}$ without.

Firm 1 and the consumer jointly benefit from reducing 2's rents.

Exclusionary contracts can also be rationalized via free riding among small consumers.

Most Favored Customer Clauses

Most-favored customer clauses can have strategic accommodation effects.

- Firm 1 can commit to a most-favored customer policy: "if it sells to another customer at a lower price it will rebate the difference to past customers."
- Firms 1 and 2 choose prices p_1^1, p_2^1. Differentiated product demand $D_i(p_1^1, p_2^1)$.
- Firms 1 and 2 choose prices p_1^2, p_2^2. Demand $D_i(p_1^2, p_2^2)$.

With no MFC clause we simply repeat the static NE, p_1^*, p_2^*, in both periods.

Adopting the MFC clause is a strategic investment that makes firm 1 soft. It creates a disincentive to reduce p_1^2 below p_1^1, and an increase in p_1^2 helps firm 2.

In equililibrium, firm 1 will commit to the MFC and set $p_1^1 > p_1^*$. There is no first-order loss from raising the first period price, and it has the strategic effect of getting firm 2 to increase p_2^2.

Firm 2 benefits even more than firm 1 does from the MFC.

On Wednesday I'll discuss some empirical papers on strategic investment including

- *Chevalier*
- *Ellison and Ellison*
- *Sweeting, Roberts, and Gedge*

See you then!