The Economics of Predation: What Drives Pricing When There Is Learning-by-Doing?

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Outline

Predatory pricing

- Predation is (informally) defined as
  decreasing price in order to eliminate competitors
- Accusations of predation are frequent:
  - Semiconductor wars in 1970s and 1980s.
  - American Airlines vs. Vanguard in 1990's
  - Intel vs. AMD in mid/late 2000s.
- But there are problems with concept of predation:
  - Very hard to prove in court
  - Low prices do benefit consumers
  - Chicago school criticizes predation as unprofitable

Predation and Learning-by-doing

- Learning-by-doing = "practice makes perfect":
  - Production today reduces costs in the future
  - E.g. programming, chip-making, ship-building
- Moving down the learning curve can justify low prices
  - Sale today buys lower cost in the future
- Moving down *before the rival does* can lead to even lower prices:
  - Cabral & Riordan 1994,
  - Besanko, Doraszelski, Kryukov & Satterthwaite 2010
- Predation-like behavior is hard to distinguish from competition for efficiency on a learning curve

Contribution: Does Predation happen?

- Yes, predation-like behavior arises for many plausible parameterizations, confirming Cabral & Riordan 1994.
- Predation can coexist with non-predatory equilibria for the same parameterization
  - Edlin 2010: predation possible "*if business folks think so*"
- Why is predation rational in our model?
  - Market share translates into cost advantage
  - Incumbent can adjust its price after entry
  - Sunk entry cost, although it is not necessary
- We do not have typical predation drivers:
  - Firms have full information on costs and demand
  - There are no financial constraints

Contribution II: Separating predation from competition

How do we separate predatory pricing from competition for efficiency?

- Decompose equilibrium pricing condition into various terms
- Represent existing definitions of predation as combinations of these terms:
  - Ordover & Willig 1981
  - Cabral & Riordan 1997
  - Snider 2009
- Develop narrower/broader definitions of predatory incentives

Contribution III: Effect of predation

What is the impact of **removing** predatory incentives?

- Long-term industry structure becomes less concentrated, improving welfare
  - Less severe conduct restrictions have smaller impact
- Considering short-term transition makes it less clear:
  - Consumers benefit from low predatory prices despite the subsequent monopolization
  - Total surplus can be improved by faster learning
- A lot of improvement in the average is generated by eliminating the worst of multiple equilibria
  - Changing the equilibria is less important

Outline

Introduction

Model

Equilibrium Behavior

Predatory incentives

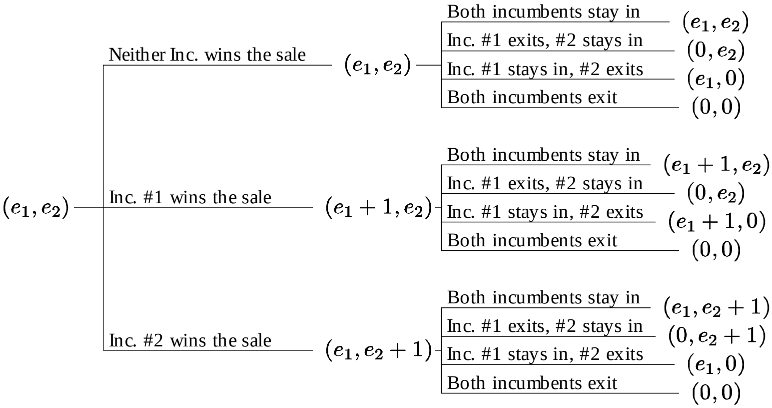
Economic significance

- Discrete-time, infinite-horizon dynamic stochastic game
- Two firms $n \in \{1, 2\}$, each characterized by state e_n
  - State $e_n \in \{1, \ldots, M\}$ = cumulative experience of anincumbent firm
  - State $e_n = 0$ denotes firm as a potential entrant.
- State of the industry: $\mathbf{e} = (e_1, e_2)$
- Markov-perfect equilibrium:
  - Optimal strategy (policy) is a function of state
  - $V_n(\mathbf{e})$ is net present value of a firm n in state $\mathbf{e}$
- Timing:
  1. Price-setting phase (transitions from state $\mathbf{e}$ to $\mathbf{e}'$)
  2. Exit-entry phase (transitions from $\mathbf{e}'$ to $\mathbf{e}''$)

Transitions

e —— ***Price-setting phase*** ——▶ **e′** —— ***Exit-Entry phase*** ——▶ **e″**

DUOPOLY: both firms are Incumbents



Entry-exit phase

1. Each Incumbent privately draws a scrap value X_n
   - Each entrant privately draws setup cost S_n
   - Distributions of are X_n and S_n are triangular
     $\Rightarrow$ bounded support & tractability
2. Incumbent(s) decide whether to exit
   - Entrant(s) decide whether to exit.
   - Probability of exiting (or staying out): $\phi_1(\mathbf{e}')$

Bellman's equation for Incumbent:

$$
\begin{aligned}
U_1(\mathbf{e}') &= E_X\left[\max\left\{\widehat{X}_1(\mathbf{e}'), X_1\right\}\right] \\
&= (1-\phi_1(\mathbf{e}'))\beta\widehat{X}_1(\mathbf{e}') + \phi_1(\mathbf{e}')E_X\left[X_1 | X_1 \geq \widehat{X}_1(\mathbf{e}')\right], \\
\text{where } \widehat{X}_1(\mathbf{e}') &\equiv \beta\left[V_1(\mathbf{e}')(1-\phi_2(\mathbf{e}')) + V_1(e_1', 0)\phi_2(\mathbf{e}')\right]
\end{aligned}
$$

Pricing phase

1. Incumbent(s) set price $p_n(\mathbf{e})$
2. Buyer comes in, observes price and preference shocks (E.V.), buys 1 unit from an incumbent or the outside good
   - Probability of firm n winning a sale: $D_n(p_1(\mathbf{e}), p_2(\mathbf{e})) \equiv D_n(\mathbf{e})$
   - Preference shocks are E.V. $\Rightarrow$ Logit demand formula
3. Firm that wins the sale gains a unit of experience $e'_n = e_n + 1$
   - Unit cost $c(e_n)$ decreases with experience
   - Doubling e_n multiplies cost by ρ – the learning rate

Bellman's equation:

$$\begin{aligned} V_1(\mathbf{e}) \quad = \quad & \max_{p_1} (p_1 - c(e_1)) D_1(p_1, p_2(\mathbf{e})) + U_1(\mathbf{e}) \\ & + D_1(p_1, p_2(\mathbf{e})) \left[U_1(e_1 + 1, e_2) - U_1(\mathbf{e}) \right] \\ & - D_2(p_1, p_2(\mathbf{e})) \left[U_1(\mathbf{e}) - U_1(e_1, e_2 + 1) \right]. \end{aligned}$$

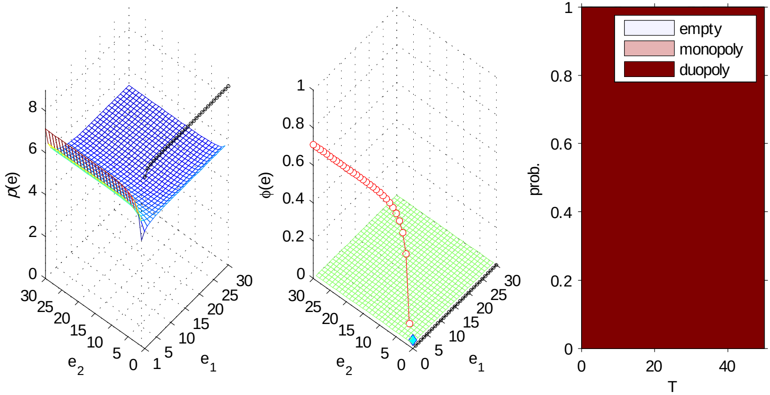
Parameterization and symmetry

parameter	value
maximum stock of know-how M	30
progress ratio ρ	0.75
cost on top of learning curve $c(1)$	10
scrap value support	$[0, 3]$
setup cost support	$[3, 6]$
discount factor β	0.95

- Symmetry: $\phi_1(e_1, e_2) = \phi_2(e_2, e_1) \equiv \phi(\mathbf{e})$
  - Same applies to $p_n(\cdot)$, $V_n(\cdot)$, $U_n(\cdot)$
  - Only need to solve for strategies and value of Firm 1.
- Equilibrium in pure strategies always exists (Doraszelski & Satterthwaite 2010)
  - But it will not always be unique

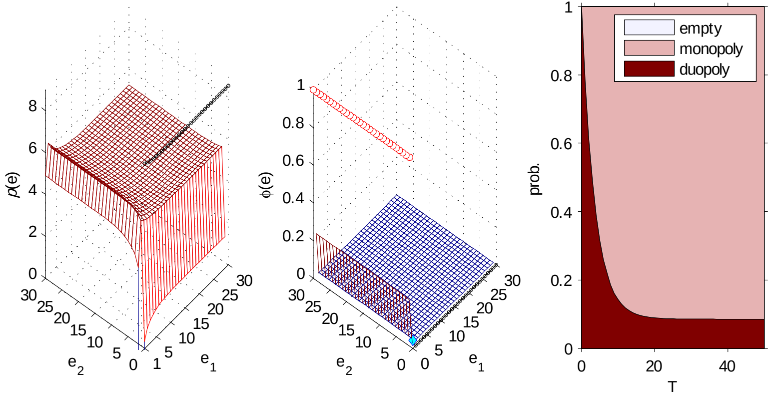
Outline

Flat Equilibrium: no predation



Pricing function $p(\mathbf{e})$; probability of exiting (or not entering) $\phi(\mathbf{e})$; time path of probability distribution over industry structures.

Trenchy Equilibrium: Predation-Like Behavior



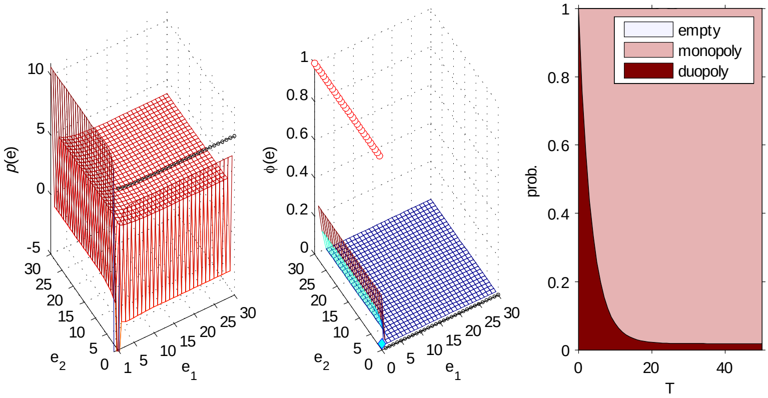
Same baseline parameterization, very different equilibrium

Equilibrium comparison

		Flat eqbm.		Trenchy eqbm.	
State $\mathbf{e} =$	(e_1, e_2)	$(10, 1)$	$(10, 2)$	$(10, 1)$	$(10, 2)$
Leader's price	$p_1(\mathbf{e})$	5.58	5.44	1.21	5.44
Follower's price	$p_2(\mathbf{e})$	7.12	6.28	4.86	6.28
Follower's exit Pr.	$\phi_2(\mathbf{e})$	0%	0%	**22%**	0%
Follower's sale Pr.	$D_2(\mathbf{e})$	17%	30%	3%	30%

- Flat equilibrium:
  - Leader's price is barely affected by follower's state
- Trenchy equilibrium:
  - When follower has a chance of exit, ...
  - ... leader's price is substantially below cost, $c(10) = 3.8$
  - Exit of follower leads to permanent monopoly;
  - ... sale by follower leads to permanent duopoly

An equilibrium with more intense learning



$\rho = 0.65$, eqbm. #5: Trench occurs when follower has $e_n = 2$

Dynamic summary statistics

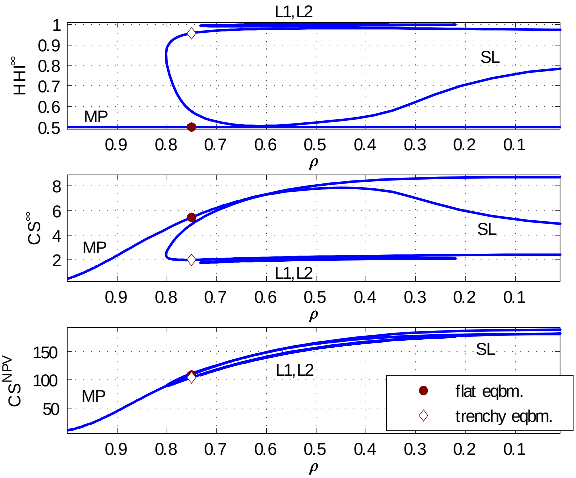
metric	Flat equilibrium	Trenchy equilibrium
structure:		
expected long-run Herfindahl index HHI^{∞}	0.50	0.96
conduct:		
expected long-run average price $\overline{p}^{\infty}$	5.24	8.26
performance:		
expected long-run consumer surplus CS^{∞}	5.46	1.99
expected long-run total surplus TS^{∞}	7.44	6.09
discounted consumer surplus CS^{NPV}	109.07	104.17
discounted total surplus TS^{NPV}	121.14	110.33

Industry starts evolving from $(1,1)$

$(\cdot)^{\infty}$ = expectation over states at stable (ergodic) distribution

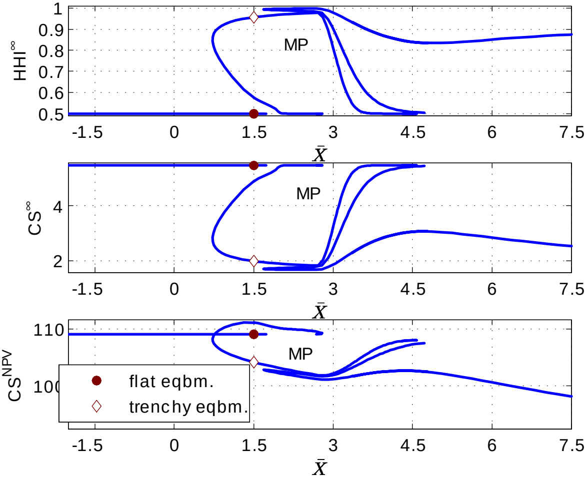
$(\cdot)^{NPV}$ = net present value of expectations over the first 50 periods

Equilibrium Correspondence: Learning rate



Predation-like behavior arises routinely.

Equilibrium Correspondence: Mean Scrap Value



Increasing scrap value (to and beyond setup cost) does not eliminate predation

Outline

Isolating Predatory Incentives

- Equilibrium pricing condition of Firm 1:

$$\overbrace{h_1(p_1(\mathbf{e})) - c(e_1)}^{\text{static FOC}} = -\overbrace{[U_1(e_1+1, e_2) - U_1(\mathbf{e})]}^{\text{Advantage-Building motive}} - \frac{D_2(\mathbf{e})}{1-D_1(\mathbf{e})} \underbrace{[U_1(\mathbf{e}) - U_1(e_1, e_2+1)]}_{\text{Advantage-Denying motive}},$$

where $h_1(p_1(\mathbf{e})) = p_1 - \frac{\sigma}{1-D_1(\mathbf{e})}$ is marginal revenue.

- *Advantage-Building (AB)* motive: By winning a sale, firm **moves itself** down the learning curve.
- *Advantage-Denying (AD)* motive: By winning a sale, firm **prevents the rival** from moving down learning curve.

Decomposing Pricing Motives

$$U(e_1+1, e_2) - U(\mathbf{e}) = \sum_{k=1}^{5} \Gamma^k(e)$$
$$U(\mathbf{e}) - U(e_1, e_2+1) = \sum_{k=1}^{4} \Theta^k(e)$$

Due to lack of time, here are the two most important terms:

- *AB Exit* motive*:*
  winning a sale increases rival's exit probability:

  $$\Gamma^2(\mathbf{e}) = (1-\phi_1(\mathbf{e}))\left[\phi_2(e_1+1, e_2) - \phi_2(\mathbf{e})\right]\beta[V_1(e_1+1, 0) - V_1(e_1+1, e_2)]$$

- *AD Exit* motive:
  winning a sale prevents a decrease in rival's exit probability:

  $$\Theta^2(\mathbf{e}) = (1-\phi_1(\mathbf{e}))\left[\phi_2(\mathbf{e}) - \phi_2(e_1, e_2+1)\right]\beta[V_1(e_1, 0) - V_1(\mathbf{e})]$$

Defining predation: approach

- Areeda-Turner standard (price below cost) is not applicable
  - Follower has price below cost in Flat equilibrium
- Edlin & Farrel 2004 sacrifice approach:
  - Consider the counterfactual payoff that incorporates *"everything except effect on competition"*
  - Predation = price that maximizes CF payoff exceeds actual one
  - $\Rightarrow$ CF payoff will have positive derivative at actual price
- What does "*effect on competition*" mean?
  - We interpret it as a subset of $\{\Gamma_k, \Theta_k\}$ terms, ...
  - ... and develop several definitions below
  - Predation = sum of these terms is positive at actual price

Definitions from literature

Def.1 Cabral & Riordan 1997: *"An action is predatory if ... [a] different action would be more profitable [if] the* ***rival's viability were unaffected****."*

- Interpret as $\phi_2(\hat{\mathbf{e}}) - \phi_2(\tilde{\mathbf{e}}) = 0$ whenever it appears
  - This would cause $\Gamma^2(\mathbf{e}) = \Theta^2(\mathbf{e}) = 0$
- Effect on competition $= \Gamma^2(\mathbf{e}) + \frac{D_2(\mathbf{e})}{1-D_1(\mathbf{e})}\Theta^2(\mathbf{e})$
- Price $p(\mathbf{e})$ is predatory if

$$\Gamma^2(\mathbf{e}) + \frac{D_2(\mathbf{e})}{1-D_1(\mathbf{e})}\Theta^2(\mathbf{e}) > 0$$

Def.2 Ordover & Willig 1981: *"Predatory behavior ... sacrifices ... profit that could be earned ... were the* ***rival to remain viable****"*

- Interpret as $\phi_2(\mathbf{e}) = 0$ in all terms where it appears.
- Price is predatory if sum of affected terms exceeds similar sum with $\phi_2(\mathbf{e}) \equiv 0$

Narrower definitions

Def.3 Modified C-R. Effect on competition $=$ *AD Exit* motive:

- Price $p(\mathbf{e})$ is predatory if

$$\Theta^2(\mathbf{e}) > 0$$

Def.4 Snider 2009? Effect on competition $=$ *AB Exit* motive only:

- Price $p(\mathbf{e})$ is predatory if

$$\Gamma^2(\mathbf{e}) > 0$$

Broader definitions

Def.5 Competitive vacuum. Effect on competition $=$ all A-D motives

- Price $p(\mathbf{e})$ is predatory if:

$$U(\mathbf{e}) - U(e_1, e_2 + 1) = \sum_{k=1}^{4} \Theta^k(\mathbf{e}) > 0$$

Def.6 Static pricing. all A-B and A-D motives

- Price $p(\mathbf{e})$ is predatory if:

$$\sum_{k=1}^{5} \Gamma^k(\mathbf{e}) + \frac{D_2(\mathbf{e})}{1-D_1(\mathbf{e})} \sum_{k=1}^{4} \Theta^k(\mathbf{e}) > 0$$

Outline

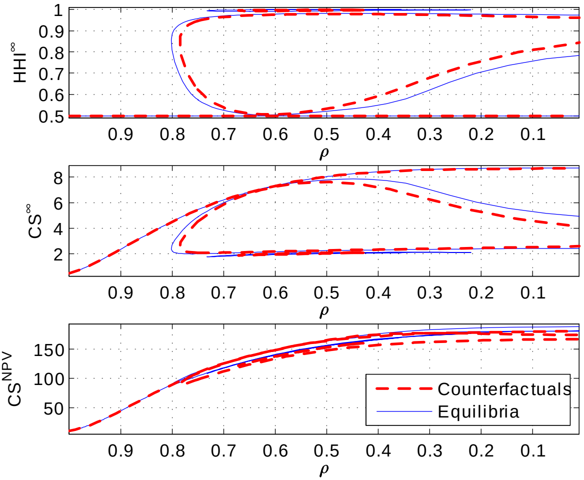
Ignoring Predatory Incentives: Setup

For each Definition above:

- "Switch off" predatory incentives:
  - Set terms appearing in the Definition to zero
  - In Def. 3 (O-W), use $\cdot|_{\phi_2=0}$ terms instead of originals ones
- Trace out the counterfactual correspondence

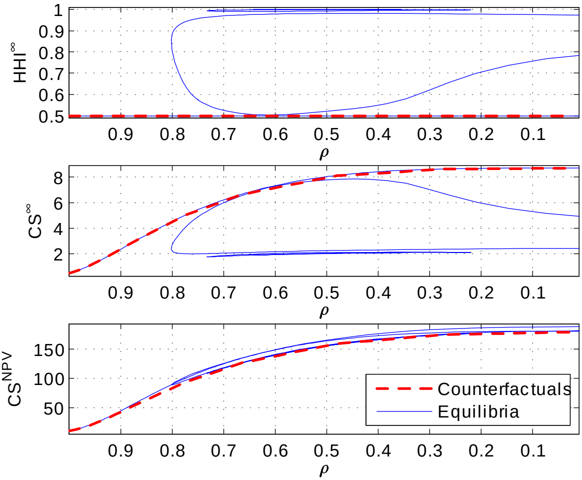
- This amounts to a conduct restriction on firm's behavior
  - Essentially, government forces firms to ignore various pricing motives
- Not very feasible, but provides a best-case benchmark

Ignoring Pred. Incentives: Def. 1 (Cabral-Riordan)



Loops get narrower or are eliminated

Ignoring Pred. Incentives: Def. 5 (Comp. vacuum)



All loops are eliminated

Ignoring Pred. Incentives: Summary

		Counterfactual Definition			
Metric	Equilibrium level	1 C-R	3 *AD*-exit	5 C.Vacuum	6 Static
HHI^{∞}	0.73	-0.05	-0.04	-0.23	-0.23
CS^{∞}	3.88	+0.47	+0.43	+2.66	+2.66
CS^{NPV}	132.46	-2.93	+0.57	-3.12	-63.02
TS^{NPV}	142.33	+1.18	+1.10	+5.64	-9.97

- Definitions 2 and 4 are similar to Def.1
- All Definitions reduce concentration
- All increase long-term consumer (& total) surplus
- All but Def.6 increase NPV of total surplus
- All but Def.3 decrease NPV of consumer surplus

Equilibria elimination

		Definition			
		1	3	5	6
metric		C-R	AD-exit	C.Vacuum	Static
# eqba.	surv.	76%	77%	26%	26%
	elim.	23%	23%	74%	74%
HHI^{∞}	surv.	0.72	0.73	0.50	0.50
	elim.	0.98	0.98	0.88	0.88
CS^{∞}	surv.	4.77	4.73	6.55	6.55
	elim.	2.07	2.07	3.28	3.28
CS^{NPV}	surv.	150.65	150.50	133.92	133.92
	elim.	148.69	148.69	155.65	155.65
TS^{NPV}	surv.	159.96	159.75	148.25	148.25
	elim.	154.83	154.83	162.18	162.18

Conclusions and Implications

- Predation-like behavior arises routinely and under plausible parameterizations.
- Equilibria with predation-like behavior typically coexist with flat equilibria: Predatory pricing becomes feasible "*if business folks think so*" (Edlin 2010).
- Defining predatory pricing is hard, but we can usefully isolate and measure predatory incentives by decomposing equilibrium pricing condition.
  - Definitions 1 and 5 appear to do this well.
  - They may be intuitively appealing from an antitrust perspective because they emphasize preventing rival from improving its competitive position.
- Conduct restrictions may eliminate equilibria with predation-like behavior: Guiding firms' expectations may be key role for competition policy.