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

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Outline

Introduction

Model

Equilibrium Behavior

Predatory incentives

Economic significance
Predatory pricing

- Predation is (informally) defined as \textit{decreasing price in order to eliminate competitors}.
- Accusations of predation are frequent:
  - Semiconductor wars in 1970s and 1980s.
  - 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
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- 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 an incumbent 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

\[ e \xrightarrow{\text{Price-setting phase}} e' \xrightarrow{\text{Exit-Entry phase}} e'' \]

**DUOPOLY: both firms are Incumbents**

- Neither Inc. wins the sale: \( (e_1, e_2) \)
  - Both incumbents stay in: \( (e_1, e_2) \)
  - Inc. #1 exits, #2 stays in: \( (0, e_2) \)
  - Inc. #1 stays in, #2 exits: \( (e_1, 0) \)
  - Both incumbents exit: \( (0, 0) \)

- Inc. #1 wins the sale: \( (e_1 + 1, e_2) \)
  - Both incumbents stay in: \( (e_1 + 1, e_2) \)
  - Inc. #1 exits, #2 stays in: \( (0, e_2) \)
  - Inc. #1 stays in, #2 exits: \( (e_1 + 1, 0) \)
  - Both incumbents exit: \( (0, 0) \)

- Inc. #2 wins the sale: \( (e_1, e_2 + 1) \)
  - Both incumbents stay in: \( (e_1, e_2 + 1) \)
  - Inc. #1 exits, #2 stays in: \( (0, e_2 + 1) \)
  - Inc. #1 stays in, #2 exits: \( (e_1, 0) \)
  - Both incumbents exit: \( (0, 0) \)
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): $\phi_1(e')$

Bellman's equation for Incumbent:

$$U_1(e') = E_X \left[ \max \left\{ \hat{X}_1(e'), X_1 \right\} \right]$$

$$= (1 - \phi_1(e')) \beta \hat{X}_1(e') + \phi_1(e') E_X \left[ X_1 \mid X_1 \geq \hat{X}_1(e') \right],$$

where

$$\hat{X}_1(e') \equiv \beta \left[ V_1(e')(1 - \phi_2(e')) + V_1(e'_1, 0)\phi_2(e') \right]$$
Pricing phase

1. Incumbent(s) set price $p_n(e)$

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:
     \[ D_n(p_1(e), p_2(e)) = D_n(e) \]
   - 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 $\rho$ – the learning rate

Bellman’s equation:

\[
V_1(e) = \max_{p_1} (p_1 - c(e_1))D_1(p_1, p_2(e)) + U_1(e) \\
+ D_1(p_1, p_2(e)) [U_1(e_1 + 1, e_2) - U_1(e)] \\
- D_2(p_1, p_2(e)) [U_1(e) - U_1(e_1, e_2 + 1)].
\]
Parameterization and symmetry

<table>
<thead>
<tr>
<th>parameter</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>maximum stock of know-how $M$</td>
<td>30</td>
</tr>
<tr>
<td>progress ratio $\rho$</td>
<td>0.75</td>
</tr>
<tr>
<td>cost on top of learning curve $c(1)$</td>
<td>10</td>
</tr>
<tr>
<td>scrap value support</td>
<td>[0, 3]</td>
</tr>
<tr>
<td>setup cost support</td>
<td>[3, 6]</td>
</tr>
<tr>
<td>discount factor $\beta$</td>
<td>0.95</td>
</tr>
</tbody>
</table>

- Symmetry: $\phi_1(e_1, e_2) = \phi_2(e_2, e_1) \equiv \phi(e)$
  - 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
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Flat Equilibrium: no predation

Pricing function $p(e)$; probability of exiting (or not entering) $\phi(e)$; time path of probability distribution over industry structures.
Trenchy Equilibrium: Predation-Like Behavior

Same baseline parameterization, very different equilibrium
## Equilibrium comparison

<table>
<thead>
<tr>
<th>State $\mathbf{e} = (e_1, e_2)$</th>
<th>Flat eqbm.</th>
<th>Trenchy eqbm.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$(10, 1)$</td>
<td>$(10, 2)$</td>
</tr>
<tr>
<td>Leader’s price $p_1(\mathbf{e})$</td>
<td>5.58</td>
<td>5.44</td>
</tr>
<tr>
<td>Follower’s price $p_2(\mathbf{e})$</td>
<td>7.12</td>
<td>6.28</td>
</tr>
<tr>
<td>Follower’s exit Pr. $\phi_2(\mathbf{e})$</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Follower’s sale Pr. $D_2(\mathbf{e})$</td>
<td>17%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>$(10, 1)$</td>
<td>$(10, 2)$</td>
</tr>
<tr>
<td>Leader’s price $p_1(\mathbf{e})$</td>
<td>1.21</td>
<td>5.44</td>
</tr>
<tr>
<td>Follower’s price $p_2(\mathbf{e})$</td>
<td>4.86</td>
<td>6.28</td>
</tr>
<tr>
<td>Follower’s exit Pr. $\phi_2(\mathbf{e})$</td>
<td>22%</td>
<td>0%</td>
</tr>
<tr>
<td>Follower’s sale Pr. $D_2(\mathbf{e})$</td>
<td>3%</td>
<td>30%</td>
</tr>
</tbody>
</table>

- **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

\[ \rho = 0.65, \text{ eqbm. \#5: Trench occurs when follower has } e_n = 2 \]
Dynamic summary statistics

<table>
<thead>
<tr>
<th>metric</th>
<th>Flat equilibrium</th>
<th>Trenchy equilibrium</th>
</tr>
</thead>
<tbody>
<tr>
<td>structure:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>expected long-run Herfindahl index $HHI^\infty$</td>
<td>0.50</td>
<td>0.96</td>
</tr>
<tr>
<td>conduct:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>expected long-run average price $\bar{p}^\infty$</td>
<td>5.24</td>
<td>8.26</td>
</tr>
<tr>
<td>performance:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>expected long-run consumer surplus $CS^\infty$</td>
<td>5.46</td>
<td>1.99</td>
</tr>
<tr>
<td>expected long-run total surplus $TS^\infty$</td>
<td>7.44</td>
<td>6.09</td>
</tr>
<tr>
<td>discounted consumer surplus $CS^{NPV}$</td>
<td>109.07</td>
<td>104.17</td>
</tr>
<tr>
<td>discounted total surplus $TS^{NPV}$</td>
<td>121.14</td>
<td>110.33</td>
</tr>
</tbody>
</table>

Industry starts evolving from $(1, 1)$

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

$\cdot^{NPV} = \text{net present value of expectations over the first 50 periods}$
Equilibrium Correspondence: Learning rate

Predation-like behavior arises routinely.
Increasing scrap value (to and beyond setup cost) does not eliminate predation
Outline

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Isolating Predatory Incentives

- Equilibrium pricing condition of Firm 1:

\[
\begin{align*}
  h_1(p_1(e)) - c(e_1) & = - \left[ U_1(e_1 + 1, e_2) - U_1(e) \right] \\
  & - \frac{D_2(e)}{1 - D_1(e)} \left[ U_1(e) - U_1(e_1, e_2 + 1) \right],
\end{align*}
\]

where \( h_1(p_1(e)) = p_1 - \frac{\sigma}{1 - D_1(e)} \) 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

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

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

- **AB Exit** motive:
  winning a sale increases rival’s exit probability:
  \[ \Gamma^2(e) = (1 - \phi_1(e)) [\phi_2(e_1 + 1, e_2) - \phi_2(e)] \beta[V_1(e_1 + 1, 0) - V_1(e_1 + 1, e_2)] \]

- **AD Exit** motive:
  winning a sale prevents a decrease in rival’s exit probability:
  \[ \Theta^2(e) = (1 - \phi_1(e)) [\phi_2(e) - \phi_2(e_1, e_2 + 1)] \beta[V_1(e_1, 0) - V_1(e)] \]
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
  - 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 $\phi_2(\hat{e}) - \phi_2(\bar{e}) = 0$ whenever it appears
  - This would cause $\Gamma^2(e) = \Theta^2(e) = 0$
- Effect on competition $= \Gamma^2(e) + \frac{D_2(e)}{1-D_1(e)} \Theta^2(e)$
- Price $p(e)$ is predatory if
  $$\Gamma^2(e) + \frac{D_2(e)}{1-D_1(e)} \Theta^2(e) > 0$$

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

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

**Def.3 Modified C-R.** Effect on competition = *AD Exit* motive:
- Price \( p(e) \) is predatory if
  \[
  \Theta^2(e) > 0
  \]

**Def.4 Snider 2009?** Effect on competition = *AB Exit* motive only:
- Price \( p(e) \) is predatory if
  \[
  \Gamma^2(e) > 0
  \]
Broader definitions

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

- Price $p(e)$ is predatory if:

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

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

- Price $p(e)$ is predatory if:

$$\sum_{k=1}^{5} \Gamma_k(e) + \frac{D_2(e)}{1-D_1(e)} \sum_{k=1}^{4} \Theta_k(e) > 0$$
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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 $\phi_2 = 0$ 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
Loops get narrower or are eliminated
All loops are eliminated
Ignoring Pred. Incentives: Summary

<table>
<thead>
<tr>
<th>Metric</th>
<th>Equilibrium level</th>
<th>1 C-R</th>
<th>3 AD-exit</th>
<th>5 C.Vacuum</th>
<th>6 Static</th>
</tr>
</thead>
<tbody>
<tr>
<td>$HHI^\infty$</td>
<td>0.73</td>
<td>-0.05</td>
<td>-0.04</td>
<td>-0.23</td>
<td>-0.23</td>
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<tr>
<td>$CS^\infty$</td>
<td>3.88</td>
<td>+0.47</td>
<td>+0.43</td>
<td>+2.66</td>
<td>+2.66</td>
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<tr>
<td>$CS^{NPV}$</td>
<td>132.46</td>
<td>-2.93</td>
<td>+0.57</td>
<td>-3.12</td>
<td>-63.02</td>
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<tr>
<td>$TS^{NPV}$</td>
<td>142.33</td>
<td>+1.18</td>
<td>+1.10</td>
<td>+5.64</td>
<td>-9.97</td>
</tr>
</tbody>
</table>

- 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

<table>
<thead>
<tr>
<th>metric</th>
<th>Definition</th>
<th>1</th>
<th>3</th>
<th>5</th>
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<tbody>
<tr>
<td># eqba. surv</td>
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<tr>
<td># eqba. elim</td>
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<td>155.65</td>
<td>155.65</td>
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<tr>
<td>$TS^{NPV}$</td>
<td>surv.</td>
<td>159.96</td>
<td>159.75</td>
<td>148.25</td>
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<td>154.83</td>
<td>154.83</td>
<td>162.18</td>
<td>162.18</td>
</tr>
</tbody>
</table>
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.