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

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Predatory Pricing or Competition for Efficiency?

- Dynamic pricing models (e.g., Cabral & Riordan 1994, Besanko, Doraszelski, Kryukov & Satterthwaite 2010) can generate extremely aggressive pricing.
- Allegations of predation often surface in industries with learning-by-doing:
  - Semiconductor wars in 1970s and 1980s.
  - Japanese color televisions in 1960s and 1970s.
  - Intel vs. AMD in mid/late 2000s.
  - Chinese solar panels in 2012.
- Is this really predatory pricing or merely competition for efficiency on a learning curve?

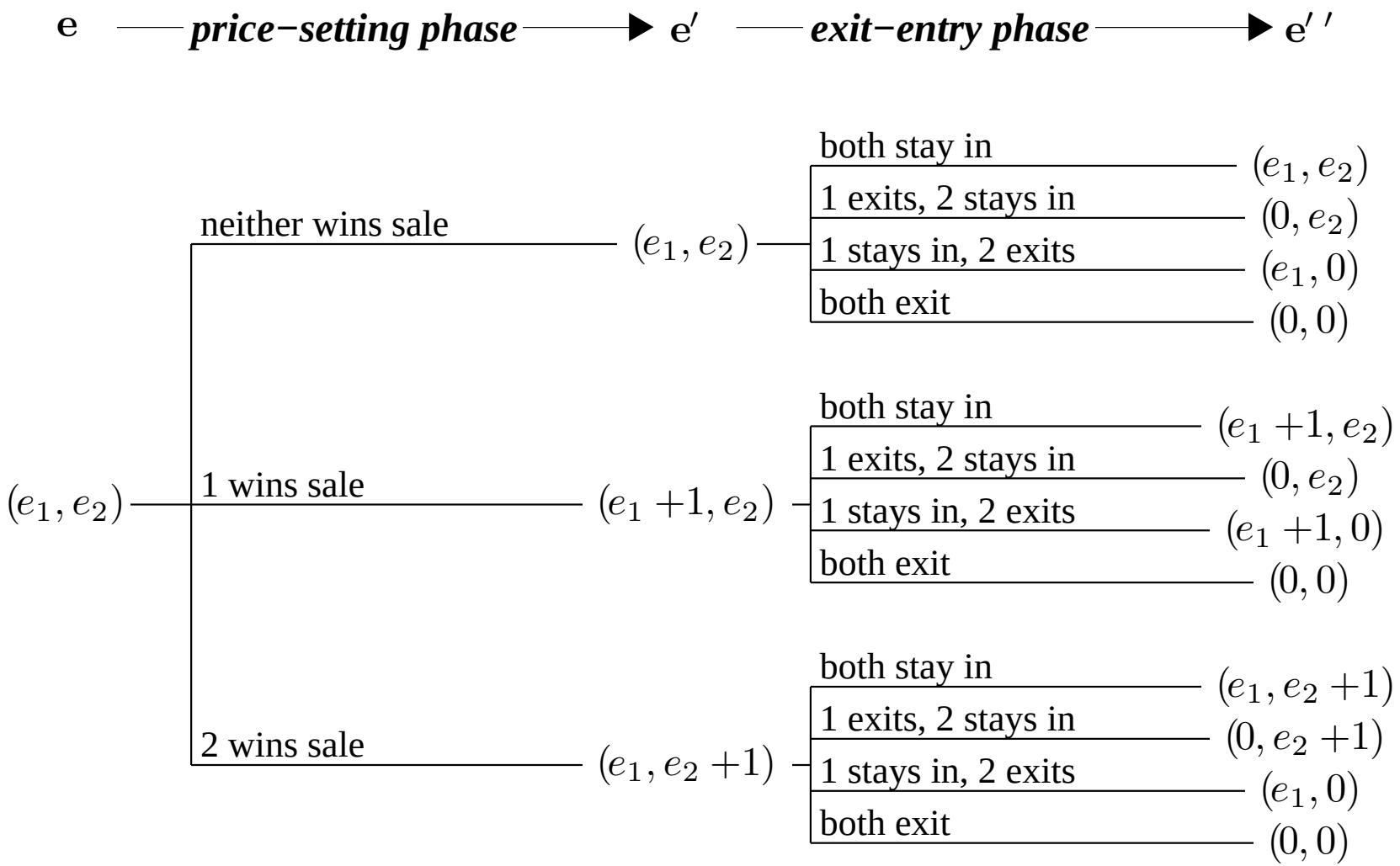
Research Questions and Contributions

- When does predation-like behavior arise?
  - Routinely and under plausible conditions (generalize Cabral & Riordan 1994).
  - Coexists with non-predatory equilibria for same parameterization (formalize Edlin 2010).
- What drives pricing?
  - Isolate predatory incentives by decomposing equilibrium pricing condition.
  - Decomposition provides coherent and flexible way to define predatory incentives.
- What is the impact of predatory incentives (however defined) on industry structure, conduct, and performance?
  - Less severe conduct restrictions have small impact "on average."
  - More severe conduct restrictions have large impact by eliminating equilibria with predation-like behavior.
  - But they reduce competition for the market.

Dynamic Pricing Model with Learning-by-Doing

- Discrete-time, infinite-horizon stochastic game with two firms similar to Cabral & Riordan (1994) and Besanko, Doraszelski, Kryukov & Satterthwaite (2010).
- State $e_n = 0$ denotes firm $n \in \{1, 2\}$ as potential entrant.
- State $e_n \in \{1, \ldots, M\}$ indicates cumulative experience of incumbent firm. By winning sale, incumbent firm adds to cumulative experience and lowers production cost through learning-by-doing.
- Within-period timing:
  - Price-setting phase (transitions from state $\mathbf{e}$ to state $\mathbf{e}'$);
  - Exit-entry phase (transitions from state $\mathbf{e}'$ to state $\mathbf{e}''$).

Decisions and State-to-State Transitions



Exit Decision of Incumbent Firm

- Value functions: Expected net present value of future cash flows to firm 1...
  - ... in state $\mathbf{e}$ at beginning of period $\rightarrow V_1(\mathbf{e})$;
  - ... in state $\mathbf{e}'$ after pricing decisions but before exit and entry decisions are made $\rightarrow U_1(\mathbf{e}')$.
- Value of remaining a going concern in the subsequent period:

$$\widehat{X}_1(\mathbf{e}') = \beta \left[V_1(\mathbf{e}')(1 - \phi_2(\mathbf{e}')) + V_1(e_1', 0)\phi_2(\mathbf{e}') \right],$$

  where β is discount factor.
- Firm 1's decision to exit:

$$\phi_1(\mathbf{e}', X_1) = 1\left[X_1 \geq \widehat{X}_1(\mathbf{e}') \right].$$

- Probability of exiting:

$$\phi_1(\mathbf{e}') = E_X\left[\phi_1(\mathbf{e}', X_1) \right] = 1 - F_X(\widehat{X}_1(\mathbf{e}')).$$

- Bellman equation:

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

Pricing Decision of Incumbent Firm

- Bellman equation:

$$\begin{aligned} V_1(\mathbf{e}) &= \max_{p_1}(p_1 - c(e_1))D_1(p_1, p_2(\mathbf{e})) + D_0(p_1, p_2(\mathbf{e}))U_1(\mathbf{e}) \\ &\quad + D_1(p_1, p_2(\mathbf{e}))U_1(e_1 + 1, e_2) \\ &\quad + D_2(p_1, p_2(\mathbf{e}))U_1(e_1, e_2 + 1). \end{aligned}$$

- Pricing decision:

$$\overbrace{mr_1(p_1, p_2(\mathbf{e})) - c(e_1)}^{\text{static profit}} + \overbrace{[U_1(e_1 + 1, e_2) - U_1(\mathbf{e})]}^{\text{advantage-building motive}} + \Upsilon(p_2(\mathbf{e}))\underbrace{[U_1(\mathbf{e}) - U_1(e_1, e_2 + 1)]}_{\text{advantage-denying motive}} = 0,$$

where

- $\Upsilon(p_2(\mathbf{e})) = \frac{D_2(p_1, p_2(\mathbf{e}))}{1 - D_1(p_1, p_2(\mathbf{e}))}$ is conditional probability of firm 2 making sale;
- $mr_1(p_1, p_2(\mathbf{e})) = p_1 - \frac{\sigma}{1 - D_1(p_1, p_2(\mathbf{e}))}$ is marginal revenue.

Advantage-Building and Advantage-Denying Motives

- *Advantage-building motive*: By winning sale, firm may move further down learning curve and improve its competitive position in the future.
- *Advantage-denying motive*: By winning sale, firm may prevent rival from moving further down learning curve and becoming a more formidable competitor.
- Antitrust authorities question intent behind business strategy.
- Many ways to draw line between predatory pricing and competition for efficiency:
  - Short-run profit: AB and AD motives are predatory.
  - Dynamic competitive vacuum (Farrell & Katz 2005): AD motive is predatory.
  - Rival exit (Ordover & Willig 1981, Cabral & Riordan 1997): Specific terms in AB and AD motives are predatory.

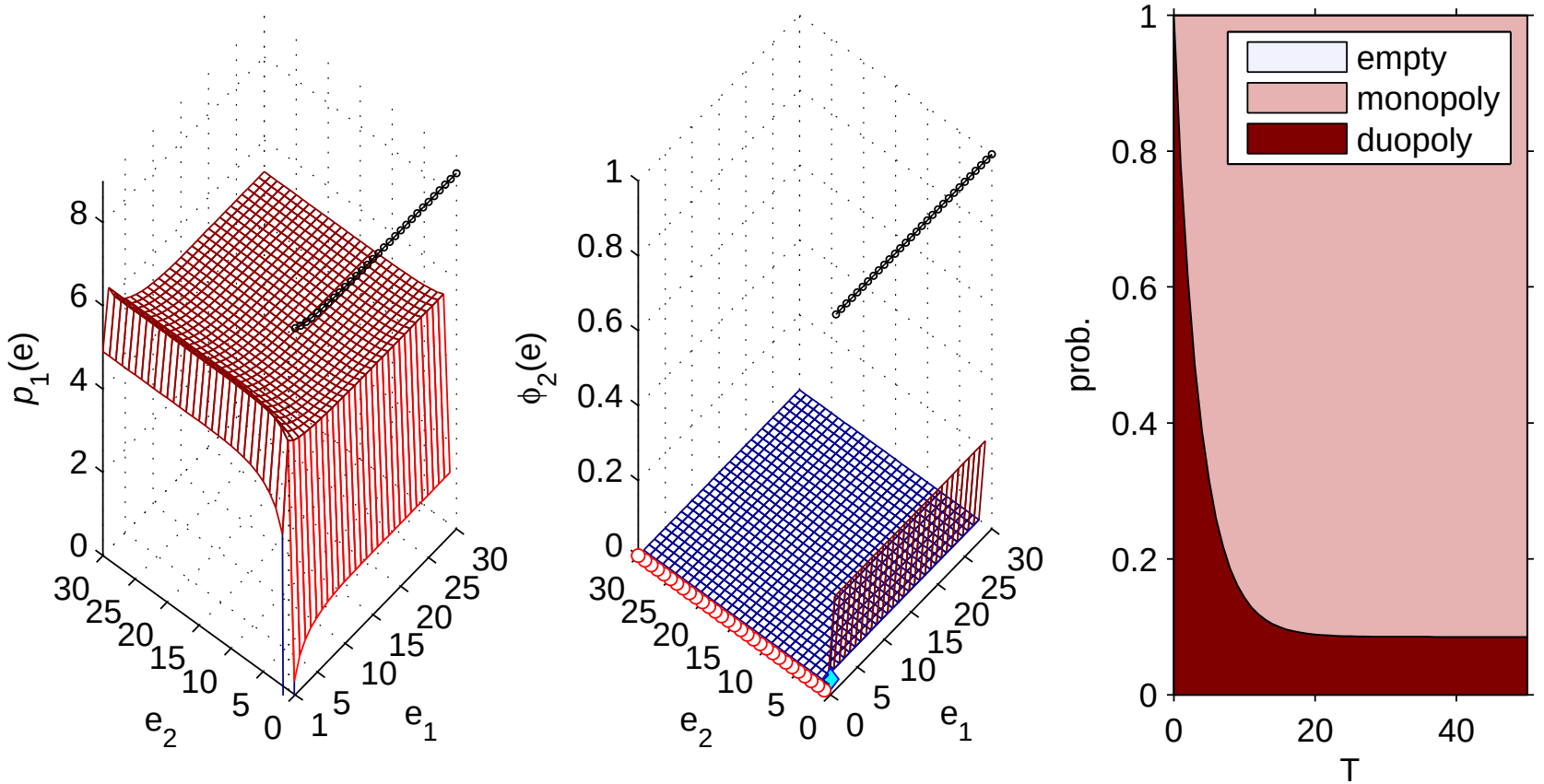
Equilibrium and Computation

- Symmetric Markov perfect equilibrium in pure strategies:

$$V_2(e_1, e_2) = V_1(e_2, e_1), \quad U_2(e_1, e_2) = U_1(e_2, e_1),$$
$$p_2(e_1, e_2) = p_1(e_2, e_1), \quad \phi_2(e_1, e_2) = \phi_1(e_2, e_1).$$

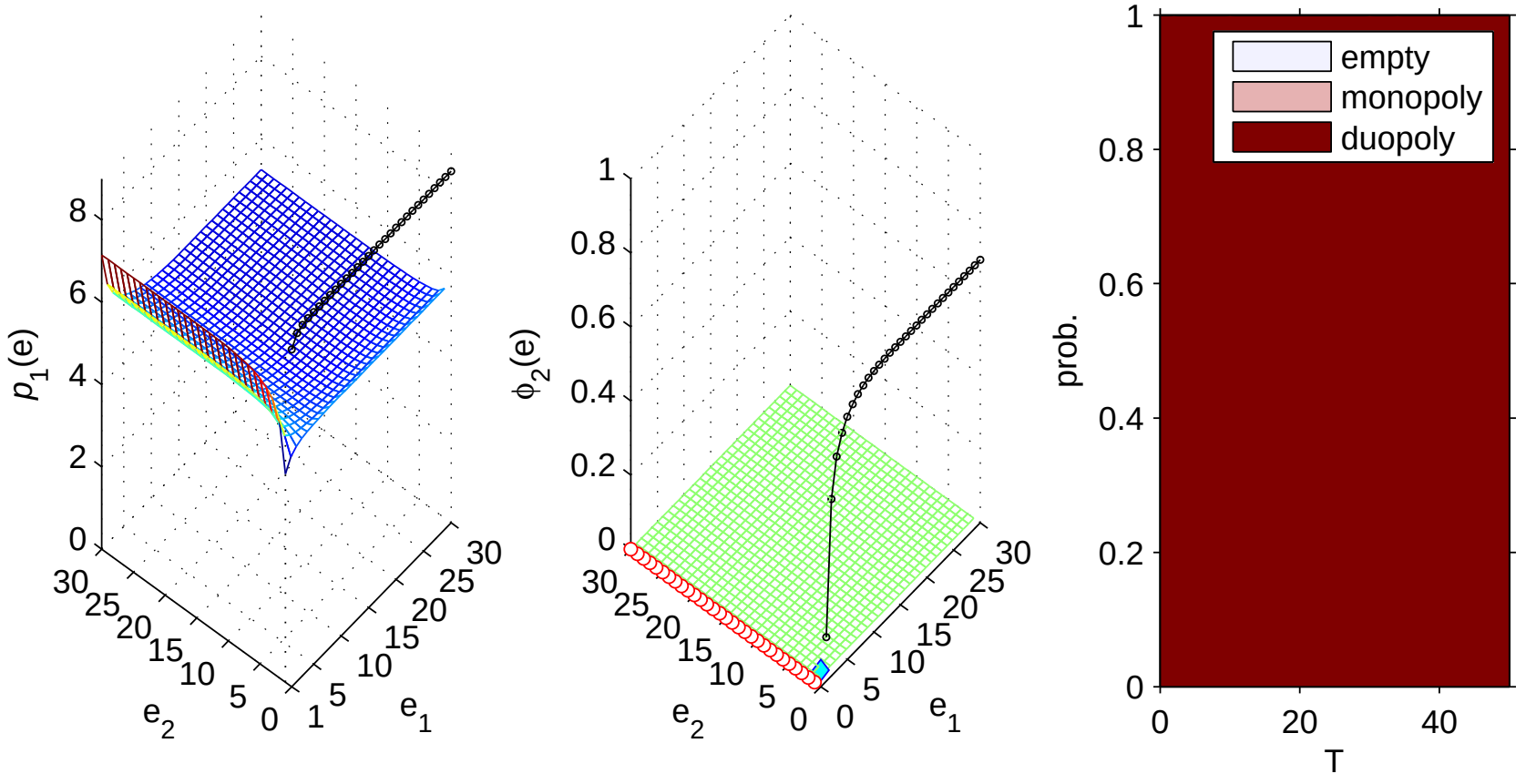
- Value and policy functions are the solution to a system of nonlinear equations (Bellman equations and optimality conditions).
- Existence is guaranteed (Doraszelski & Satterthwaite 2010), uniqueness is not.
- Natural-parameter homotopy to trace out slices of the equilibrium correspondence.

Aggressive Equilibrium: Predation-Like Behavior



Pricing decision of firm 1, non-operating probability of firm 2, and time path of probability distribution over industry structures.

Accommodative Equilibrium

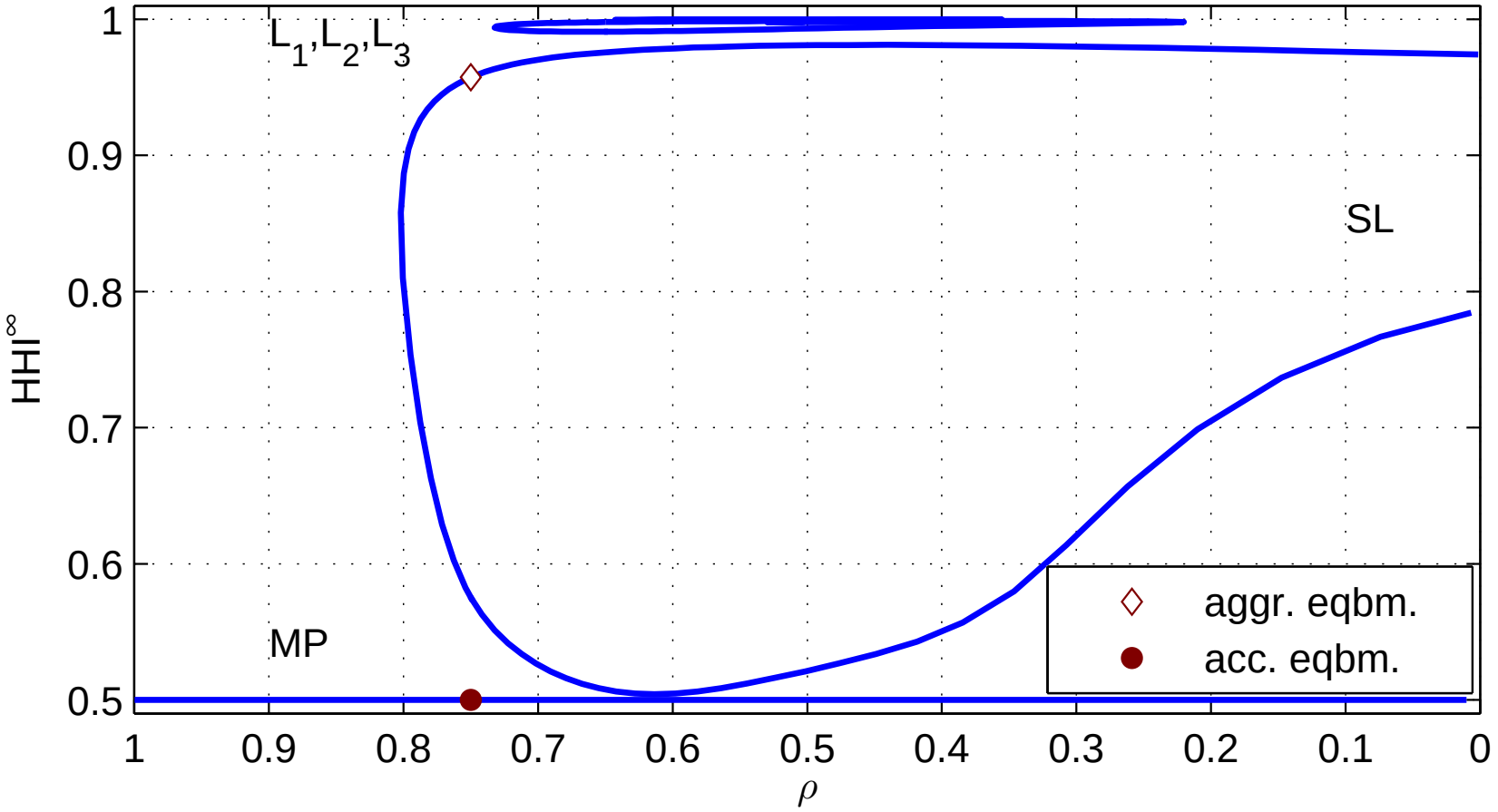


Pricing decision of firm 1, non-operating probability of firm 2, and time path of probability distribution over industry structures.

Competition for and in the Market

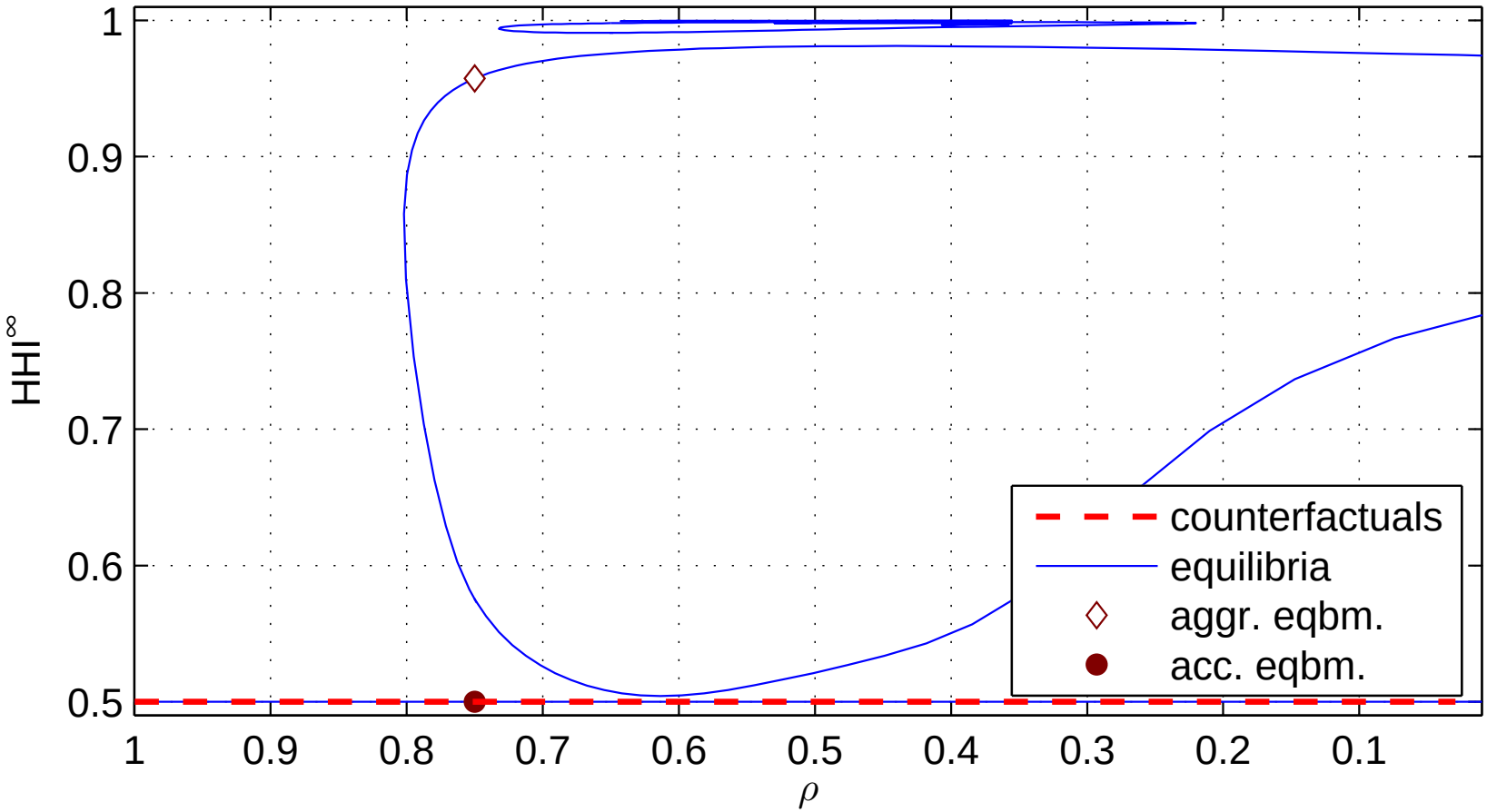
	aggressive equilibrium	accommod. equilibrium
structure:		
expected long-run Herfindahl index HHI^{∞}	0.96	0.50
conduct:		
expected long-run average price $\overline{p}^{\infty}$	8.26	5.24
performance:		
expected long-run consumer surplus CS^{∞}	1.99	5.46
expected long-run total surplus TS^{∞}	6.09	7.44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

Predation-Like Behavior Arises Routinely



Equilibrium correspondence: Progress ratio ρ.

Conduct Restrictions Eliminate Equilibria

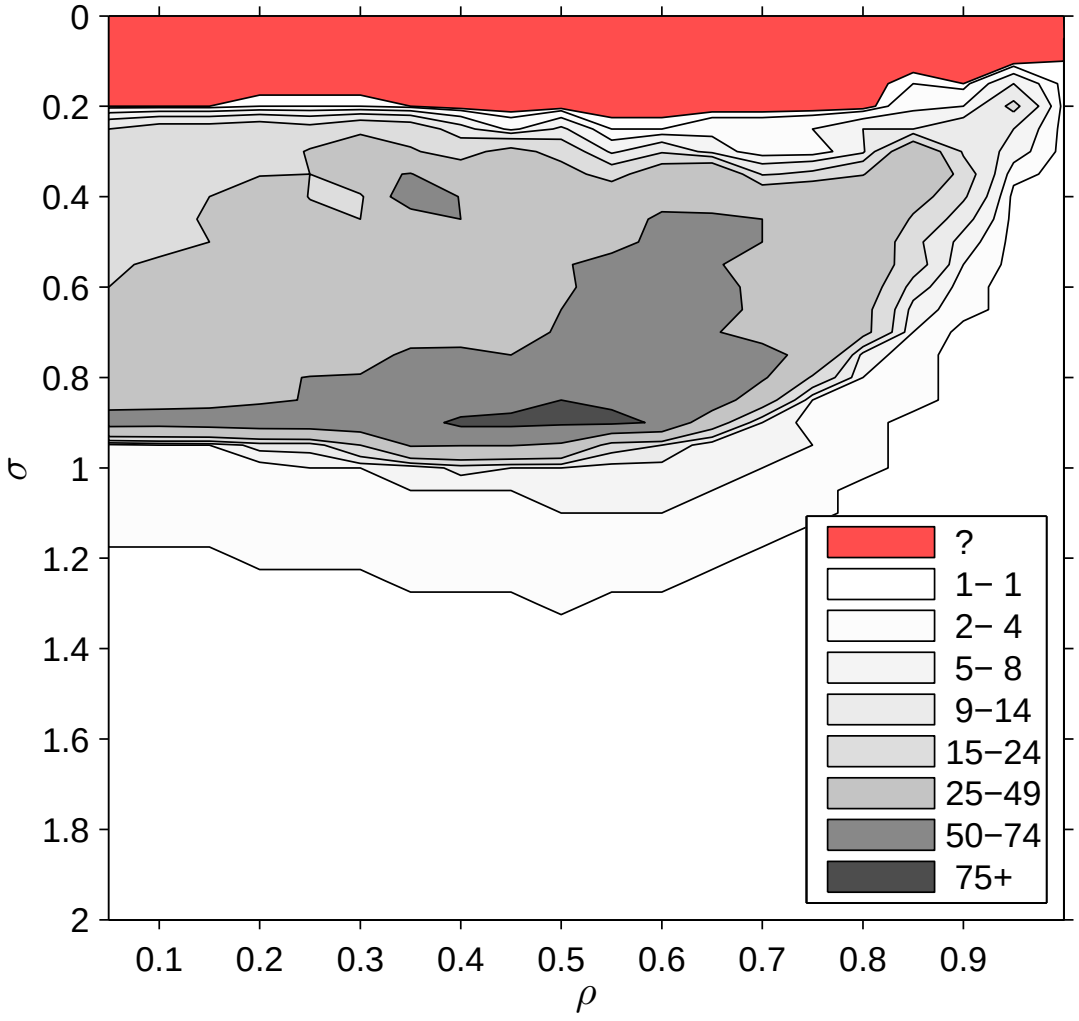


Counterfactual correspondence for dynamic competitive vacuum: Progress ratio ρ.

Multiple Equilibria

- In 2000 Ariel Pakes wrote: "...we have experimented quite a bit with the core version of the algorithm, and we never found two sets of equilibrium policies for a given set of primitives..."
- In 2013 an anonymous referee wrote: "I should note that virtually all Markov Perfect Models have multiple equilibria..."

Multiple Equilibria



Number of equilibria. Progress ratio ρ and degree of horizontal product differentiation σ.

Multiple Equilibria

- Some equilibria are similar to each other, others are different.
- How to estimate primitives? How to conduct counterfactual exercises?
- Are 181 equilibria very different from a continuum?
- Are we better off computing subgame perfect equilibria (Judd, Yeltekin & Conklin 2003)?
- State summarizes history of play $\rightarrow$ bootstrapping and sunspots (Besanko, Doraszelski, Kryukov & Satterthwaite 2010).

Concluding Remarks

- Predation-like behavior arises routinely and under plausible conditions in dynamic pricing models.
- Aggressive equilibria with predation-like behavior typically coexist with accommodative equilibria.
  - Guiding firms' expectations can be powerful tool for antitrust authorities.
- Conduct restrictions may eliminate equilibria with predation-like behavior, but they reduce competition for the market.
  - Judge Breyer's "bird-in-hand:" Price of making future consumers better off is making current consumers worse off.
- Viewing a dynamic world from a static perspective can be costly.
  - Current *Brooke Group* standard takes a static perspective.
- Embarrassment of riches: Multiple equilibria.