Learning and Collusion in New Markets with Uncertain Entry Costs

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Learning and cooperation in market entry games

- Entry into new geographical market
  - Market research to learn about demand and investigation of production and distribution alternatives.
  - Commonly rival firms form joint subsidiary to access foreign markets.
- R&D race
  - Often firms build small prototype, run small-scale experiments before investing in large-scale project.
  - Race often concluded with a merger before new product reaches the market.
  - Sometimes, merger mediated by outside agency.

Learning and cooperation in market entry games

- Interplay between learning and preemption in entry timing games, and interplay between learning and collusion between firms:
  - How much time to spend on learning about one's entry cost before deciding whether to invest?
  - In case of collusion/cooperation, whose project to select?
  - Can collusion with learning one's entry cost before entry be implemented? How?

Learning and cooperation in market entry games

- Model market entry game with learning between two firms;
  - initially, firms do not know their cost of entry; can experiment (wait) and learn their cost before deciding to enter or they can enter without learning their cost first;
  - firms face optimal timing problem: have to decide when to enter;
  - model private value version of that problem and distinguish private learning and public learning;
- Study two collusive schemes, compensating payments and a collusive mechanism.

Main insights

- Learning can create preemption dynamics.
- Inefficiencies in the non-cooperative solution (private and public learning):
  - Excess momentum: firms enter before learning their type even though it would be optimal to learn first; there is more excess momentum with private than with public learning;
  - Effort duplication and rent dissipation: after a first firm entered, a follower firm that learned it has low cost enters even though this is undesirable.
- In model with private learning,
  - With compensating payments, collusion only possible if a firm enters sufficiently early; sharing rule between firms matters for how much of the inefficiency a compensating mechanism eliminates.
  - With collusion mediated by outside party, no surplus sharing with inactive firm needed if collusion with learning sufficiently valuable.

Related literature

- Patent race literature (Loury 79, Reiganum 82, Harris & Vickers 85; with private information: Spatt & Sterbenz 85, Choi 91)
- Learning in continuous time (Keller & Rady 99, Keller Cripps & Rady 05; with private signals Rosenberg, Solan & Vieille 07, Murto Välimäki 10)
- Technology adoption and innovation timing with preemption or waiting (Fudenberg & Tirole 85, Katz & Shapiro 87; Weeds 02, Mason & Weeds 10)
- Cooperation among research teams with private information (Gandal & Scotchmer 93, Akcigit & Liu in progress)
- Closest: Preemption games with private information (Hopenhayn & Squintani 11) and patent races with private information (Moscarini & Squintani 10)

The model: main parameters

- Two firms in entry game;
- Fixed entry cost of firm i denoted θ_i.
  - Initially unknown by the firms
  - Takes one of two different values, $\theta_i = \underline{\theta}$ and $\theta_i = \overline{\theta}$, with equal probability; expected value: $\widetilde{\theta} = \frac{\underline{\theta} + \overline{\theta}}{2}$.
  - uncorrelated across firms (private values model).

Experimentation

- Discrete time with periods $t = 1, 2, \dots, \infty$; length of period Δ; will study situations where grid becomes infinitely fine ($\Delta \to 0$);
- In every period, each firm receives costless signal about its cost;
- With probability $\lambda\Delta$, signal says $\underline{\theta}$ or $\overline{\theta}$, with probability $1 - \lambda\Delta$, it says $\widetilde{\theta}$;
- The signals are *private* (private learning) or *public* (public learning). With private learning, signal is non-verifiable.

Market

- In any period $t = 0, 1, 2, \ldots$, a firm can choose to make an irreversible, publicly observable investment to enter the market;
- Entry involves the immediate payment of fixed cost θ_i, it allows to receive product market profits, π_m in a monopoly and π_d in a duopoly;
- r denotes the common discount rate of the two firms.

Assumptions on the main parameters

Assumption

$$\underline{\theta} \leq \pi_d \leq \widetilde{\theta} \leq \pi_m \leq \overline{\theta}.$$

- → Low cost firms have an incentive to enter, even if they compete in the market;
- → High cost firms do not have an incentive to enter, even if they were a monopoly in the market;
- → Firms that do not know their cost have an incentive to enter if they are a monopoly but not if they are a duopoly in the market.

Assumption

$$\pi_m > 2\pi_d$$

- → It is never jointly optimal for both firms to enter.

Strategies

- Given assumption, firms that have learned they have high cost never enter;
- Firms that have learned they have low cost at period t enter immediately;
- Relevant choices to be made by firms that do not know their cost;
- Strategies specify after every possible history a probability with which firm enters when it does not know its cost;

Collusive benchmark

- By assumption: Select one project. Either (1) immediately, or (2) collect one signal (only), or (3) collect signals until low cost;
- Relevant payoffs:
  - Immediate investment: $\pi_m - \widetilde{\theta}$;
  - Immediate investment after first signal: $V_{E2} = \frac{2\lambda}{2\lambda+r}\left(\pi_m - \frac{\underline{\theta}+\widetilde{\theta}}{2}\right)$;
  - If first signal is bad, wait for second signal: $V_{E1} = \frac{\lambda}{2(\lambda+r)}\left(\pi_m - \underline{\theta}\right)$;
- $\widetilde{\theta} < \pi_m - V_{E2}$: Invest immediately;
- $\pi_m - V_{E2} \leq \widetilde{\theta} < \pi_m - V_{E1}$: Invest immediately after receiving first signal that is $\underline{\theta}$ or $\overline{\theta}$;
- $\pi_m - V_{E1} \leq \widetilde{\theta}$: Invest only after receiving a low-cost signal.

Entry timing with public signals

- Only need to look at strategy of firms that did not learn their cost.
- Assume a first firm has invested. A follower firm will enter only if it has low cost, hence it receives in expectation

$$V_F = \frac{\lambda}{2(\lambda + r)}(\pi_d - \underline{\theta}).$$

- Leader extracts monopoly profits as long as follower has not entered, hence it receives in expectation (gross of θ)

$$V_L = \pi_m - \frac{\lambda}{2(\lambda + r)}(\pi_m - \pi_d).$$

Entry timing with public signals: Results

- If a firm observes the other one draws $\overline{\theta}$, either invest immediately or wait for signal on its cost. Compare $\pi_m - \widetilde{\theta}$ to V_{E1}. Further: $V_L - V_F = \pi_m - V_{E1}$.

Proposition

In the entry timing game with public information, as $\Delta \to 0$,

1. *If $\pi_m - \widetilde{\theta} > V_{E1}$, preemption occurs and (i) a firm which does not know its cost invests with positive probability p at any date $t = 0, 1, 2, \ldots$ whenever the other firm has not invested and (ii) a firm invests immediately after it learns that the other firm has a high cost.*
2. *If $\pi_m - \widetilde{\theta} < V_{E1}$, firms do not enter unless they learn that their cost is low.*

- Entry timing game is either a preemption game or a waiting game.
- If $\pi_m - V_{E2} \leq \widetilde{\theta} < \pi_m - V_{E1}$, there is excess momentum.
- Follower invests if it learns $\underline{\theta}$: Entry cost duplication and rent dissipation.

Entry timing with private signals

- Now signals are private: if a firm learns $\overline{\theta}$ drops from the race, this is not observed by the other firm.
- Need beliefs.
  - Denote by $\gamma_T(\underline{\theta})$ ($\gamma_T(\overline{\theta})$, $\gamma_T(\widetilde{\theta})$) a firm's belief that its opponent, who has not yet entered, has learned it has low cost (has learned it has high cost, has not yet learned its cost).
- $\gamma_T(\underline{\theta}) = 0$.
- $\gamma_T(\widetilde{\theta}) = 1 - \gamma_T(\overline{\theta})$ with $\gamma_0(\widetilde{\theta}) = 1$, $\gamma_T'(\widetilde{\theta}) < 0$, and $\lim_{T\to\infty} \gamma_T(\widetilde{\theta}) = 0$;

$\rightarrow$ "No news is good news".

$\rightarrow$ Endogenous generation of payoff dynamics that have been assumed in preemption literature (e.g., Fudenberg & Tirole, REStud 1985).

Entry timing with private signals

- Expected profit of leader now (gross of θ)

$$V_L(T) \quad = \quad \gamma_T(\bar{\theta})\pi_m + \gamma_T(\widetilde{\theta})V_L$$

- Note: No news is good news:

$$V_L'(T) > 0; V_L(0) = V_L < \pi_m; \lim_{T \to \infty} V_L(T) = \pi_m$$

$\rightarrow$ Firms that don't know their costs may eventually find it profitable to invest because they believe the other firm has drawn a high cost.

Entry timing with private signals: Results

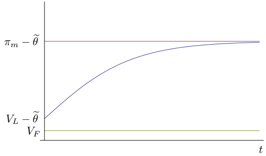

Figure 1: Case 1: $V_L - \widetilde{\theta} > V_F$

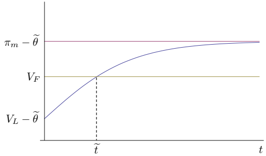

Figure 2: Case 2: $\pi_m - \widetilde{\theta} \geq V_F \geq V_L - \widetilde{\theta}$

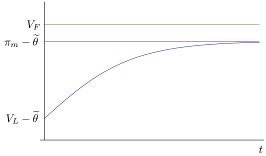

Figure 3: Case 3: $V_F > \pi_m - \widetilde{\theta}$

Entry timing with private signals: Results (Continued)

Theorem

In the entry timing game with private signals, a firm which learns its cost invests immediately.

1. *If* $\pi_m - \widetilde{\theta} > V_{E1}$*, preemption occurs at the beginning of the game and both firms invest with positive probability at date* 0*.*
2. *If* $V_{E1} \geq \pi_m - \widetilde{\theta} \geq V_F$*, in a symmetric equilibrium, rents between the leader and the follower are equalized and each firm invests with probability* $\frac{1}{2}$ *at time* $\widetilde{T}$ *such that:* $V_L(\widetilde{T}) - \widetilde{\theta} = V_F$*.*
3. *If* $V_F > \pi_m - \widetilde{\theta}$*, firms do not enter unless they learn that their cost is low.*

- Rent equalization in case 2 (as Fudenberg & Tirole, REStud 1985).
- Preemption time $\widetilde{T}$ is implicitly defined as the unique solution to the equation $V_L(\widetilde{T}) - \widetilde{\theta} - V_F = 0$.

Entry timing with private signals: Results (Continued)

- Excess momentum, entry cost duplication, and rent dissipation.
- Excess momentum is stronger than with public learning, contrary to Hopenhayn & Squintani, REStud 2011.
  - In Hopenhayn & Squintani, new information can only signal improvement in competitive situation, so competition is fiercer with public signals.
  - In our model, private information private info can only signal degradation of competitive situation, so competition is fiercer with private signals.

Collusive schemes

- Can firms attain collusive outcome?
- Assume experimentation is optimal $(\pi_m - V_{E2} \leq \widetilde{\theta} \leq \pi_m - V_F)$ and signals are private.
- Consider
  - Compensating payments where first firm to invest pays transfer after investment against the commitment of the other firm not to invest;
  - Collusive mechanism where outside party makes investment decision for the two firms and implements transfers.

Collusive schemes

Compensating payments

- Need: $U_L(T) \geq V_L(T)$ and $U_F(T) \geq V_F$ for individual rationality;
- Need $U_L(T) + U_F(T) = \pi_m$ for budget balance;
- Together they imply $\pi_m \geq V_L(T) + V_F$;
- Remember: $V_L'(T) > 0$ with $\lim_{T \to \infty} V_L(T) = \pi_m$.

Lemma

There exists a unique date T^*, such that no budget balanced individually rational compensating payment exist if the first firm enters at date $T \geq T^*$.

Collusive schemes

Compensating payments

In order to implement the collusive benchmark, two conditions have to be fulfilled:

1. The payment to the follower must be large enough to prevent early entry by firms which do not know their costs.
2. The payment to the follower should not be too large to give incentives to a firm that learns it has a low cost to enter immediately.

→ There is an upper and a lower bound on payoffs of the follower and leader firm; surplus must be shared in a balanced way.

Proposition

A differentiable compensating payment scheme $U_F(T)$ implements the cooperative benchmark when a firm learns that it has a low cost before T^* if and only if for all $T < T^*$,

$$\pi_m - \widetilde{\theta} < 2U_F(T) < \frac{2r+\lambda}{r+\lambda}\pi_m + \frac{U_F'(t)}{r+\lambda}.$$

Collusive schemes

Collusive mechanism

- At each date $T = \Delta, 2\Delta, \ldots, t\Delta$, planners asks firms to report types $(\widehat{\theta}_1, \widehat{\theta}_2)$.
- Planners investment and transfer decision
  - $\widehat{\theta}_i \neq \underline{\theta}, \widehat{\theta}_j \neq \underline{\theta}$, the planner does not select any firm to invest.
  - If $\widehat{\theta}_i = \underline{\theta}, \widehat{\theta}_j \neq \underline{\theta}$ at time T, the planner selects firm i to invest. Firm i pays a tax and firm j receives a subsidy.
  - If $\widehat{\theta}_i = \widehat{\theta}_j = \underline{\theta}$, each firm is chosen to invest with probability $\frac{1}{2}$. Transfers such that each firm's payoff is $\frac{\pi_m - \underline{\theta}}{2}$.
- Impose individual rationality, incentive compatibility, budget balance.
- If payoff in collusive benchmark exceeds $2(\pi_m - \widetilde{\theta})$, collusion is possible without sharing the surplus with inactive firm (contrary to compensating payments).

Proposition

The efficient outcome can be supported by the compensating mechanism without subsidies if and only if $\frac{\lambda(\pi_m - \underline{\theta})}{2(2\lambda + r)}[1 + \frac{\lambda}{2(\lambda + r)}] \geq \pi_m - \widetilde{\theta}$.

Main insights

- Learning can create preemption dynamics.
- Inefficiencies in the non-cooperative solution (private and public learning):
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