Strategic Location Choice under Dynamic Oligopolistic Competition and Spillovers

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Motivation

- Anecdotal and empirical evidence suggest that technologically advanced firms tend to avoid locations with industrial activity to distance themselves from competitors (e.g. Alcacer & Chung (2007)).

- On the other hand, technological spillovers in clusters are well documented, implying positive externalities in clusters leading to fast dynamics of knowledge generation (e.g. Jaffe et al. (1993)).

- How should location decisions of advanced firms look like taking into account the future dynamics in the cluster?
Research Questions

- Under which circumstances is it optimal for technological leaders to locate outside an area with rich R&D activity?

- How do the incentives to locate in a cluster depend on the discount rate, the intensity of spillovers in the core, the intensity of competition?

- What is the short and long run effect of the leaders’ location decision on competitors and consumers?

- Does it make a difference whether technological leads have temporary or structural knowledge advantages?


The Model

- **Dynamic Cournot oligopoly**: $n$ firms producing a homogeneous good
- **Linear inverse demand**:
  \[
  p(t) = a - b \sum_{j=1}^{n} q_j(t), \ a, b > 0
  \]
- **Constant marginal costs of production**:
  \[
  c_i(t) = \bar{c} - \gamma k_i(t), \ \bar{c}, \gamma > 0.
  \]
- **Location**: There is a single firm cluster in the industry and each firm is located in the cluster ($l_i = C$) or in isolation ($l_i = I$).
The Model

- **Dynamics of the knowledge stock:**

  \[
  \dot{k}_i(t) = \begin{cases} 
  x_i + \beta \sum_{j \in N_C \setminus i} k_j - \delta k_i & \text{if } l_i = C \\
  x_i - \delta k_i & \text{if } l_i = I 
  \end{cases}
  \]  

- **Costs of R&D effort:**

  \[g(x_i) = \frac{\eta_i}{2} x_i^2\]

- **Technological Leadership of Firm 1: 2 Scenarios**

  1.) **Initial knowledge advantage:**
  \[
  \eta_i = \eta > 0, \ i = 1, \ldots, n, \quad k_{i1}^{\text{ini}} > 0, \ k_{i2}^{\text{ini}} = \ldots = k_{in}^{\text{ini}} = 0
  \]

  2.) **Structural knowledge advantage:**
  \[
  \eta_i = \eta > 0, \ i = 2, \ldots, n, \ \eta_1 < \eta,
  \]
  \[
  k_{i1}^{\text{ini}}: \text{steady state knowledge stock of version of the game where all firms are in isolation}
  \]
Differential Game for Given Location Choice

- **Objective Function:**
  \[
  J_i = \int_0^\infty e^{-rt} \left[ \left( a - b \sum_{j=1}^n q_j(t) - (\bar{c} - \gamma k_i(t)) \right) q_i(t) - \frac{n_i}{2} x_i^2 \right] \, dt
  \]

- **Controls:** \( q_i(t), x_i(t) \geq 0 \)

- **State Dynamics:** \( n \)-dimensional state with dynamics (1) and initial conditions \( k_j(0) = k_j^{ini}, \ j = 1, \ldots, n \)

- **State constraints:** \( k_j(t) \leq \bar{c}/\gamma, \ j = 1, \ldots, n \)

Only the choice of \( x_i(t) \) has intertemporal implications, quantities are at each \( t \) determined according to the Cournot equilibrium given the current marginal costs.
Markov Perfect Equilibria

- Markovian Strategies: $\Phi_j : [0, \bar{c}]^n \rightarrow \mathcal{R}^2, \ j=1,...,n$

- **Proposition.** Under appropriate conditions there exists a MPE with the following properties:
  - all firms in the cluster (apart from F1) use identical strategies of the form $\Phi^C(k, K^C, K^P, k_1)$,
  - all firms in isolation (apart from F1) use identical strategies of the form $\Phi^I(k, K^C, K^P, k_1)$,
  - firm 1 uses a strategy of the form $\Phi_1(k_1, K^C, K^P)$,

where $k$ is the firms’ own knowledge stock for $i = 2, \ldots, n$, $k_1$ is the knowledge stock of F1, and $K^C = \sum_{j \in \mathcal{N}_C} k_j$, $K^P = \sum_{j \notin \mathcal{N}_C} k_j$.

Under this MPE there exists a globally stable steady state.
Setup of the Analysis

- For each of the two choices of the technological leader (Firm 1), $l_1 = C$ and $l_1 = I$ the MPE of the resulting differential game is calculated and the value functions for Firm 1 are compared.

- The linear-quadratic structure of the game allows for the explicit calculation of value functions and feedback rules of all firms in the MPE.

- Baseline parameter setting (chosen in accordance with some empirical evidence on mark-ups and R&D intensity):
  
  \[
  \eta = 10, \quad \gamma = 0.22, \quad \bar{c} = 40, \quad r = .05, \quad \delta = 0.1, \quad a = 100, \quad b = 1, \\
  n = 7, \quad l_i = C, \quad i = 2, \ldots, 4, \quad l_i = I, \quad i = 5, \ldots, 7, \quad \beta = 0.005.
  \]

- Measure of initial knowledge advantage (induced relative cost advantage):
  \[
  \tilde{k} = \frac{\gamma k_{i_{1}}}{\bar{c}}
  \]

- Measure of structural advantage:
  \[
  \Delta \eta = \frac{\eta - \eta_1}{\eta}
  \]
Scenario 1: Initial Knowledge Advantage

Incentives for F1 to locate in the cluster

Difference in value functions (cluster - isolation)
Dynamic Effects of Location Choice for Techn. Leader

Instantaneous profits
(cluster - isolation)

knowledge stock
(cluster - isolation)
Effects of Location Choice of F1 for Techn. Laggards

Instantaneous profits (cluster - isolation)

Value functions (cluster - isolation)

red: cluster firm, green: firm in isolation
Sensitivity of Firm 1 Threshold: Discount Rate

\[ \hat{k}^* \]

Cluster

Isolation

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COST 2013 13 / 25
Scenario 2: Structural R&D Advantage

Incentives for F1 to locate in the cluster

Difference in value functions (cluster - isolation)
Dynamic Effects of Location Choice for Techn. Leader

Instantaneous profits (cluster - isolation)

knolwedge stock (cluster - isolation)
Effects of Location Choice of F1 for Techn. Laggards

Dynamics of instantaneous profits (cluster - isolation)

Value functions (cluster - isolation)

red: cluster firm, green: firm in isolation
Sensitivity of Firm 1 Threshold: Discount Rate
Effect of Discount Rate on F1 R&D Effort

Difference in Feedback Functions of F1 (cluster - isolation)

black: $r = 0.05$, blue: $r = 0.1$, red: $r = 0.15$
Sensitivity of Firm 1 Threshold: Number of Competitors

**Initial Advantage**
- red: number of firms in isolation increases
- black: number of firms in cluster increases

**Structural Advantage**

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Sensitivity of Firm 1 Threshold: Spillover Intensity

Initial Advantage

Structural Advantage

\[ \tilde{k}^* \]

\[ r = 0.05 \]

\[ r = 0.1 \]

\[ r = 0.15 \]

\[ \Delta \eta^* \]

\[ r = 0.05 \]

\[ r = 0.1 \]

\[ r = 0.15 \]
Sensitivity of Firm 1 Threshold: Forgetting Rate

Initial Advantage

Structural Advantage
Conclusions

- Dynamic analysis of the strategic location choice of a technological leader under consideration of spillovers in a cluster
- Leader prefers to locate in the cluster only if technological advantage is not too large (threshold strategy)
- Properties of threshold strategy and implications of cluster location of techn. leader differ qualitatively between the cases of initial and structural advantage
Conclusions

1. Initial Advantage for F1:
   - Location of F1 in cluster implies
     ▶ lower profits for F1 in the short run but higher profits in the long run
     ▶ higher profits for cluster firms and lower profits for firms in isolation
     ▶ higher consumer surplus.
   - Incentives for techn. leader to locate in the cluster increase if
     ▶ firms become less myopic,
     ▶ intensity of spillovers in the core increases,
     ▶ forgetting rate decreases,
     ▶ market concentration decreases.
Conclusions

2. Structural Advantage for F1:
   - Location of F1 in cluster implies
     - *higher* profits for F1 in the short run but *lower* profits in the long run
     - higher profits for cluster firms and lower profits for firms in isolation
     - higher consumer surplus.
   - Incentives for techn. leader to locate in the cluster increase if
     - firms become *more* myopic,
     - intensity of spillovers in the core increases,
     - forgetting rate *increases*,
     - market concentration decreases.
Extensions

- Asymmetric absorptive capacities
- Option to relocate after $t = 0$