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Knowledge Generality, Competition and Growth

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EUROSYSTEM

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Motivation

Innovations drive long-run growth but differ widely in **spillovers**.

Generality: the breadth of an idea's impact (Trajtenberg et al., 1997).

- **General Innovation** (e.g., semiconductors, machine learning)
  - Spillovers **within** and **across** industries.
  - ↑ Firms' ability of absorbing outside **general** knowledge.
- **Firm-specific Innovation** (e.g., target a specific technical problem)
  - Private returns, limited external impact.

⇒ Firms choose R&D **strategically**:
protect market position **vs.** exploit others' general knowledge.

This paper:

- How do these choices shape competition and growth? Roles for policy?

Approach

Theory:

- A growth model: leader–follower framework + quality ladders.
- **New:** **within-** and **cross-industry** spillovers arising from **general** R&D.
  - within-industry: leader → follower.
- **Core predictions:** link **generality** with **leadership** & **market concentration**.

Empirics:

- Construct **firm-level** innovation generality measure.
- Test model's predictions.
- Validate spillovers mechanisms using **quasi-experimental variation**.

Findings

Model Predictions:

- **Leaders prefer firm-specific R&D:** limit spillovers to followers.
  Followers prefer general R&D: absorb leaders' general knowledge.
- The gap in innovation generality between them has a **U-shaped** pattern with market concentration.

Empirics:

- Empirical patterns consistent with model predictions.
- Validate spillovers mechanisms (within-industry):
  - **State-level enforceability of non-compete agreements**.
  - ↑ enforceability ⇒ ↑ leaders' generality, ↓ followers' generality.

A Growth Model with Knowledge Generality

Model Setup

A continuum of heterogeneous duopoly markets.
In each market, two firms compete along a quality ladder (Aghion et al. (2001); Liu et al. (2022); Akcigit and Ates (2023)).

- **Households:** allocate consumption between two varieties per market.
- **Firms:** linear production + Bertrand competition.

$$(\pi_s, \pi_{-s}) \quad \text{s.t. } \pi_s \geq \pi_{-s}$$

$s \in \mathbb{N}_0$: productivity distance between the two firms.
$s = 0$: neck-and-neck competition;
$s \geq 1$: *temporary* leader and follower.

Innovation Types - Examples

General: Digital camera

CCD sensors → **digital camera** → **machine vision**
semiconductor — photography — manufacturing

Firm-specific: Google's multiple party online transactions

- trained on own data; closed ecosystem.

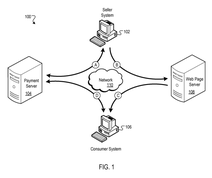


FIG. 1

Spillover Mechanisms

Spillovers arising from **general** knowledge:

- **Cross-industry** spillovers: $\Phi \equiv \Phi(\Lambda)$, Λ = aggregate general R&D.
- **Within-industry** spillovers: $f(\lambda_s^k)$, flow from leader → follower.

Leader productivity growth: $(\eta_s^k + \Phi\lambda_s^k)$.

Follower productivity growth: $(\eta_{-s}^k + \Phi f(\lambda_s^k)\lambda_{-s}^k + h)$

η^k: firm-specific R&D efforts.
λ^k: general R&D efforts.
h: follower's fixed catch-up rate.
k: industry types, heterogeneous in general R&D cost.

Optimization Problems - Leaders

$$rv_s^k = \max_{\eta_s^k, \lambda_s^k \geq 0} \{\underbrace{\pi_s - c_\eta(\eta_s^k) - c_\lambda^k(\lambda_s^k)}_{\text{net profits}} + \underbrace{[\eta_{-s}^k + \Phi f(\lambda_s^k)\lambda_{-s}^k + h]}_{\text{Prob. follower upgrades}}(v_{s-1}^k - v_s^k) + \underbrace{(\eta_s^k + \Phi\lambda_s^k)}_{\text{Prob. leader upgrades}}(v_{s+1}^k - v_s^k) - \tau^k v_s^k\}$$

v_s^k: leader's value function with productivity distance s.
$c_\eta(\cdot)$: firm-specific R&D cost. $c_\lambda^k(\cdot)$: general R&D cost.
τ^k: endogenous creative destruction rate.

Model Predictions

Assumptions and Definitions.

- Convex R&D cost functions.
- Within-industry spillovers: $f(x) \geq 1$, $f'(x) > 0$.
- Firm-level innovation generality: $\psi^k = \frac{\lambda^k}{\lambda^k + \eta^k}$.

Predictions.

P1: Leaders have lower innovation generality, i.e.,

$$\psi_{-s}^k > \psi_s^k \quad \forall\, s \geq 1$$

P2: As the productivity distance diverges:

$$\psi_s^k,\ \psi_{-s}^k \ \to\ \psi_0^k \quad \text{as } s \to \infty$$

ψ_0^k: innovation generality when neck-and-neck ($s = 0$).

Knowledge Generality in the Data

Data Sources

- **United States Patent and Trademark Office (USPTO) & PatentsView:** Patent-level data (e.g., application/grant years, citations, technology classes).
- **Compustat:** Firm-level information.
- **Patent-firm mapping:** Kogan et al. (2017).

Measurement

- **Patent generality** (Trajtenberg et al., 1997)**:**

$$\psi_i = 1 - \sum_j s_{ij}^2$$

s_{ij}: the share of citations to patent i coming from class j.

- **Firm-level innovation generality:**

$$\psi_{f,t} = \frac{1}{n}\sum_{i=1}^{n} \psi_{i,t}$$

Average over all patents by firm f in year t.

Example: A General Patent from ORACLE

Patent US6594666: location aware application development framework.
Application: app-based taxi services, logistics, tourism, marketing, healthcare.

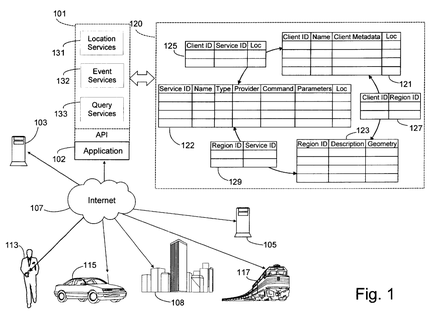


Fig. 1

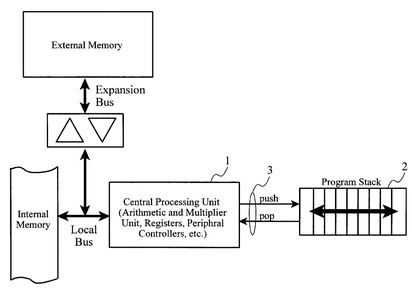
Generality Score: 0.829

based on forward citations within 5 years since the patent grant

CPC subclasses	Definitions	Citations
$G01C$	measuring, surveying, navigation, gyroscopic instruments	8
$G06F$	electric digital data processing	19
$G06Q$	ICT for admin., comm., fin., manag. or superv. purposes	3
$G08G$	traffic control system	3
$G09B$	signaling or calling systems	1
$H04B$	transmission	1
$H04L$	transmission of digital information	6
$H04M$	telephonic communication	4
$H04W$	wireless communication networks	12
$Y10S$	technical subjects coverd by former XRACs and digests	6

Example: A Firm-Specific Patent from IBM

Patent US6550058: stack-clearing decive and method.
Application: security, debugging.



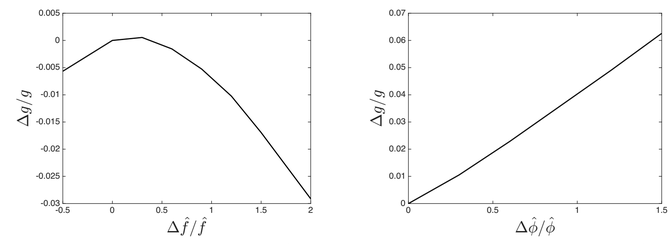
Generality Score: 0.180

CPC subclasses	Definitions	Citations
$G06F$	electric digital data processing	9
$G06Q$	ICT for admin., comm., fin., manag. or superv. purposes	1

Policy Implications

Comparative Statics of Aggregate Growth

Growth elasticity w.r.t. efficiency of spillovers.

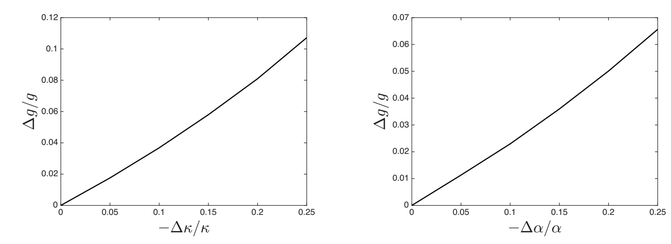


Within-industry spillovers ($\hat{f}$) **Cross-industry spillovers ($\hat{\phi}$)**

Takeaways:

- Weak non-compete agreements do **not** necessarily promote growth.
- Should encourage **cross-sector** knowledge sharing.

Growth elasticity w.r.t. R&D cost scale.



General R&D cost (κ) **Firm-specific R&D cost (α)**

Takeaways:

- Growth is more elastic w.r.t. general R&D costs.
- Should support **general** innovations.

General R&D Subsidies: Who to Subsidize?

Budget-balanced scheme:

- Fixed corporate tax rate δ.
- Revenues fund R&D subsidies.

Tax rate	δ	0.1	0.15	0.2	0.25
Scheme 1: Subsidizing Leaders					
Growth rate	g	1.76%	1.82%	1.88%	1.95%
Average Generality - Leaders	ψ^L	0.65	0.71	0.77	0.83
Average Generality - Followers	ψ^F	0.60	0.61	0.62	0.63
Scheme 2: Subsidizing Followers					
Growth rate	g	1.73%	1.77%	1.80%	1.80%
Average Generality - Leaders	ψ^L	0.48	0.47	0.47	0.47
Average Generality - Followers	ψ^F	0.67	0.71	0.74	0.79

Takeaways:

- Subsidizing **leaders'** general R&D promotes growth more efficiently.
- Differs from conventional wisdom (see, e.g., Liu et al., 2022; Akcigit and Ates, 2023), which suggests subsidizing followers.
- **Prizes vs. Subsidies.** (Che et al., 2021; Graff Zivin and Lyons, 2021)
  A prize system: rewards leading firms for general innovations.

  Example: King's Award for Innovation in UK.

2024 Recipient: Ultramed - a digital health company

Testing Model Predictions

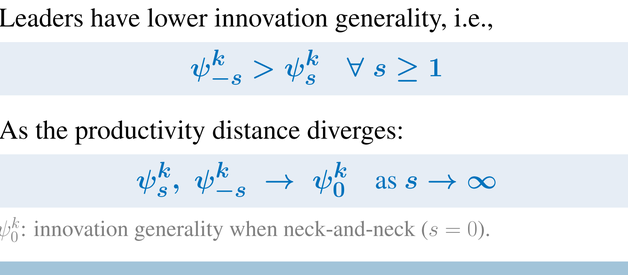
P1: Market leaders have lower innovation generality.

$$\psi_{f,t} = \underset{(s.e.\ 0.003)}{-0.028} \cdot \mathbb{1}(Leader)_{f,t} + \delta_{j,t} + \epsilon_{f,t}$$

- $\psi_{f,t}$: average patent generality of firm f in year t.
- $\mathbb{1}(Leader)_{f,t}$: = 1 if firm f has the largest sale in industry j in year t.
- Industry classification: 4-digit SIC. $\delta_{j,t}$: industry–year fixed effects.

P2: The innovation generality gap between the two firms varies **non-monotonically** with market concentration.

$$\psi_{j,t}^L - \psi_{j,t}^F = \underset{(s.e.\ 0.098)}{-0.357} \cdot HHI_{j,t} + \underset{(s.e.\ 0.080)}{0.229} \cdot HHI_{j,t}^2 + \delta_j + \delta_t + \epsilon_{j,t}$$

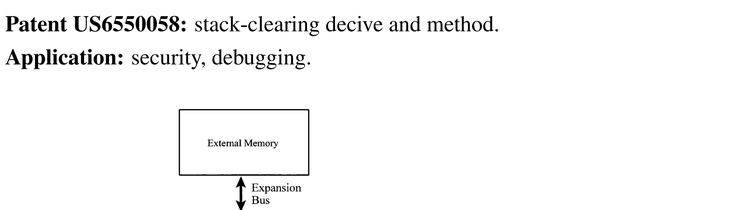


Model (calibrated 1995-2000) **Empirical (raw data 1980-2015)**

- $\psi_{j,t}^L$, $\psi_{j,t}^F$: average patent generality of leaders, followers in industry j, year t.
- $HHI_{j,t}$: Herfindahl–Hirschman Index, sum of squared market shares.

General Ideas Become Harder to Find

Avg. Patent Generality - Compustat Firms **TFP Growth - US**



Post-2010 US economy:

- Ideas get harder to find (Bloom et al., 2020):
  ↑ general and firm-specific R&D costs.
- Changes in the efficiency of within- and cross-industry spillovers.

Decomposition of Aggregate Growth Decline (Post-2010 vs. Pre-2000)

	Implied g	Contribution
Less eff general R&D - high-type only	1.46%	30%
Less eff general R&D - all industries	1.32%	**51%**
Less eff general + firm-specific R&D	0.98%	100%

Conclusion

- Innovation generality plays a crucial role in shaping market concentration, knowledge diffusion, and growth.
- The model yields two key results:
  - **Leaders prefer firm-specific R&D.**
    Followers prefer general R&D.
  - Innovation generality gaps between them have a **U-shaped** pattern with market concentration.
- **Policy implications:**
  - Incentivize **general** R&D in **leading** firms.
  - Promote **cross-sector** knowledge sharing.