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Knowledge Generality, Competition and Growth



EUROPEAN CENTRAL BANK

EUROSYSTEM

KNOWLEDGE GENERALITY, COMPETITION AND GROWTH

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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?

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)).

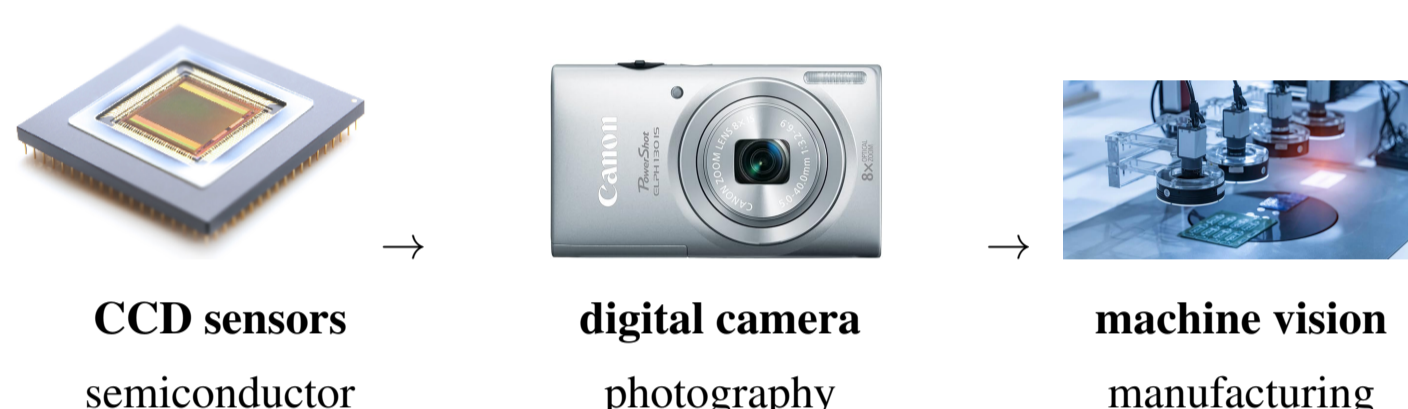
- **Households:** allocate consumption between two varieties per market.
- **Firms:** linear production + Bertrand competition.

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

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

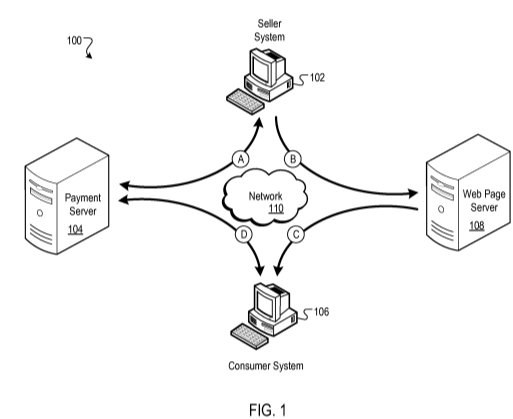
Innovation Types - Examples

General: Digital camera



Firm-specific: Google's multiple party online transactions

- trained on own data; closed ecosystem.



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_s^k : firm-specific R&D efforts.

λ_s^k : general R&D efforts.

h : follower's fixed catch-up rate.

k : industry types, heterogeneous in general R&D cost.

Optimization Problems - Leaders

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

- 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:

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

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

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**.

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:**

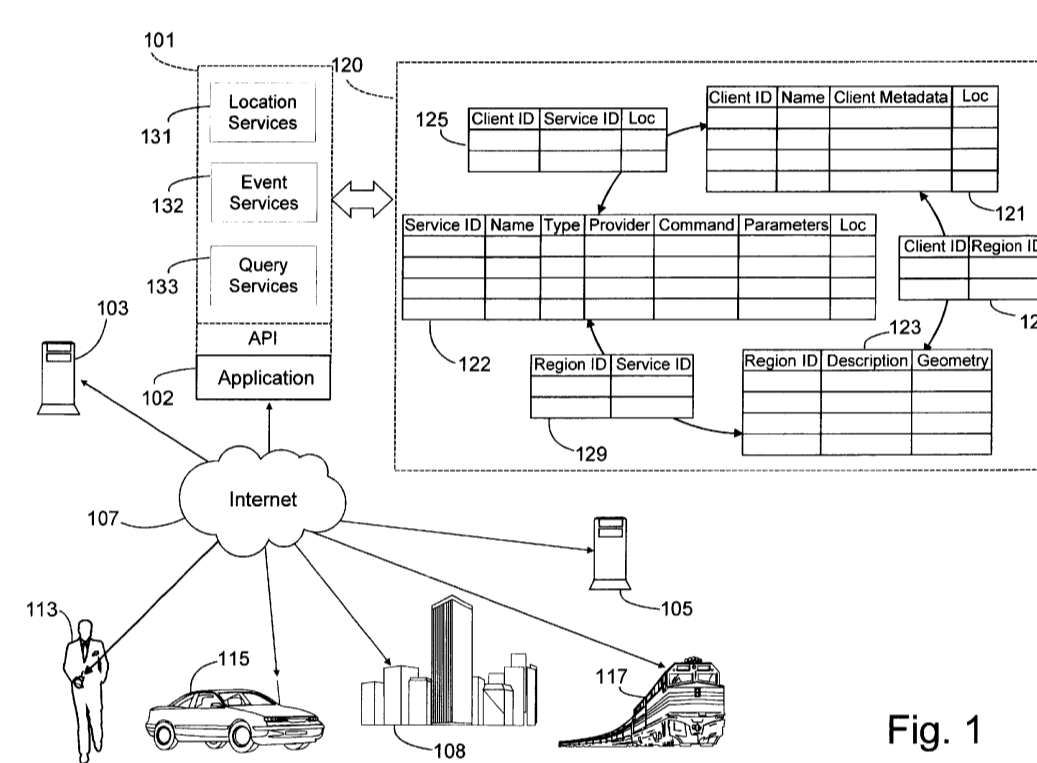
$$\psi_{f,t} = \frac{1}{n} \sum_{i=1}^n \psi_{i,t}$$

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.



Generality Score: 0.829

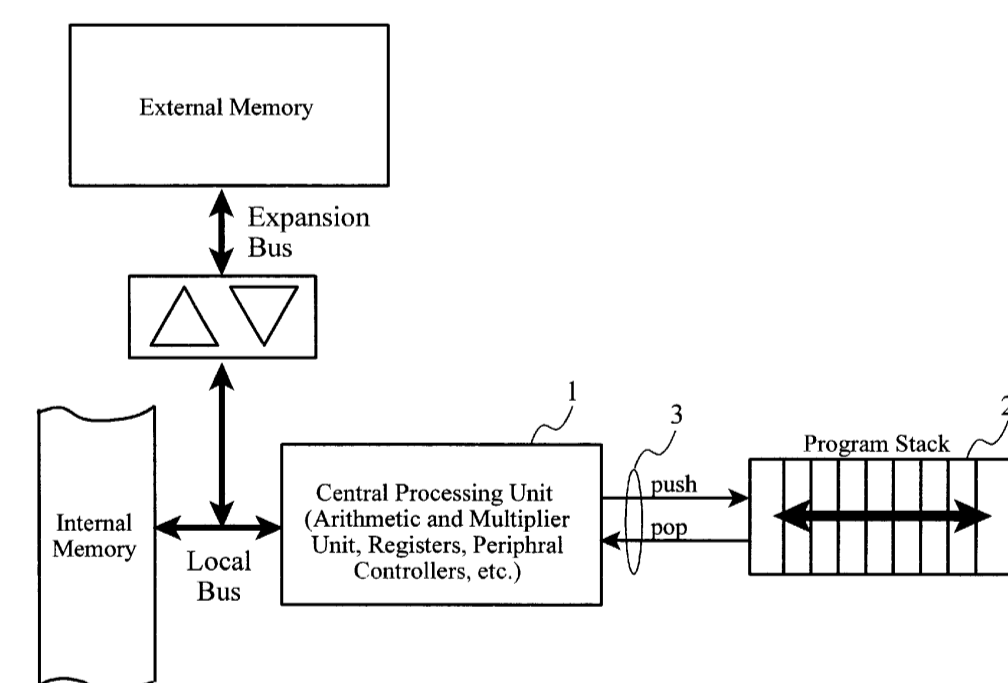
based on forward citations within 5 years since the patent grant

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 covered by former XRACs and digests	6

Example: A Firm-Specific Patent from IBM

Patent US6550058: stack-clearing device 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

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.

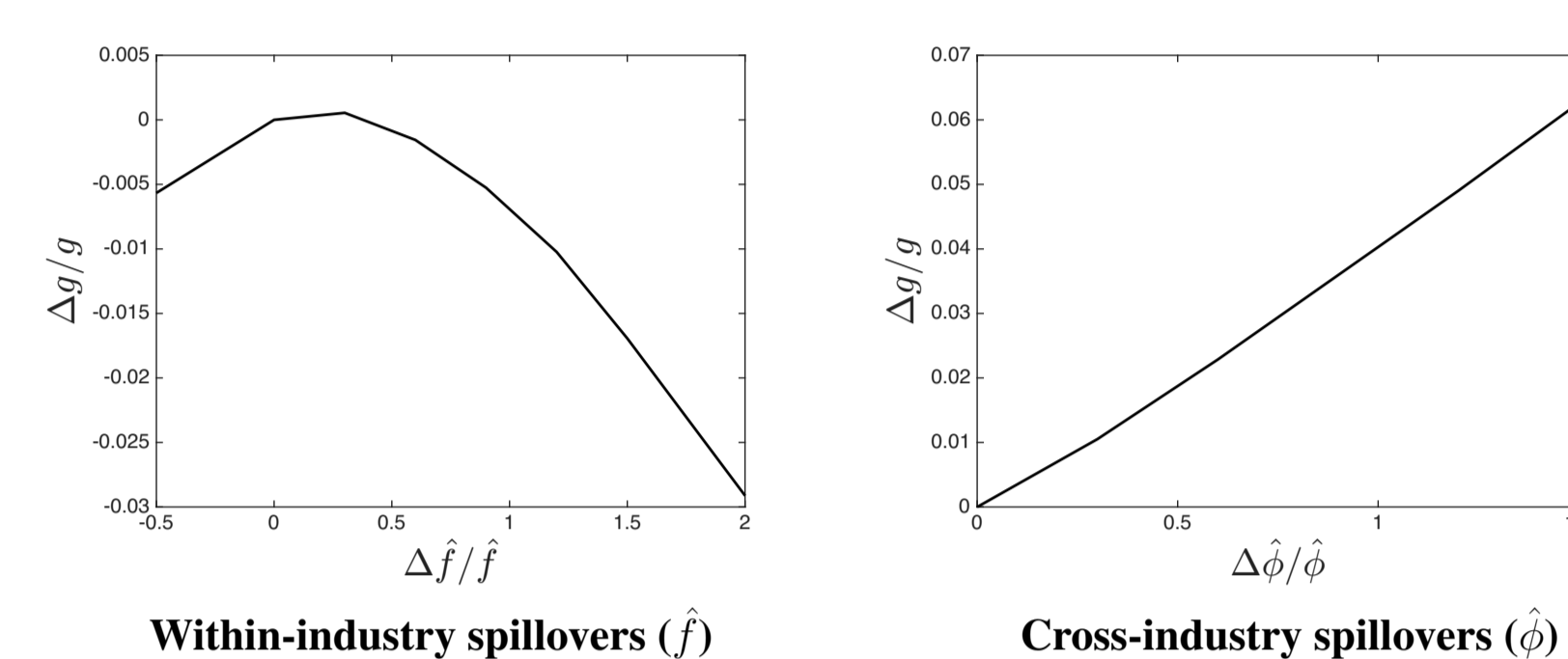
Empirics:

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

Policy Implications

Comparative Statics of Aggregate Growth

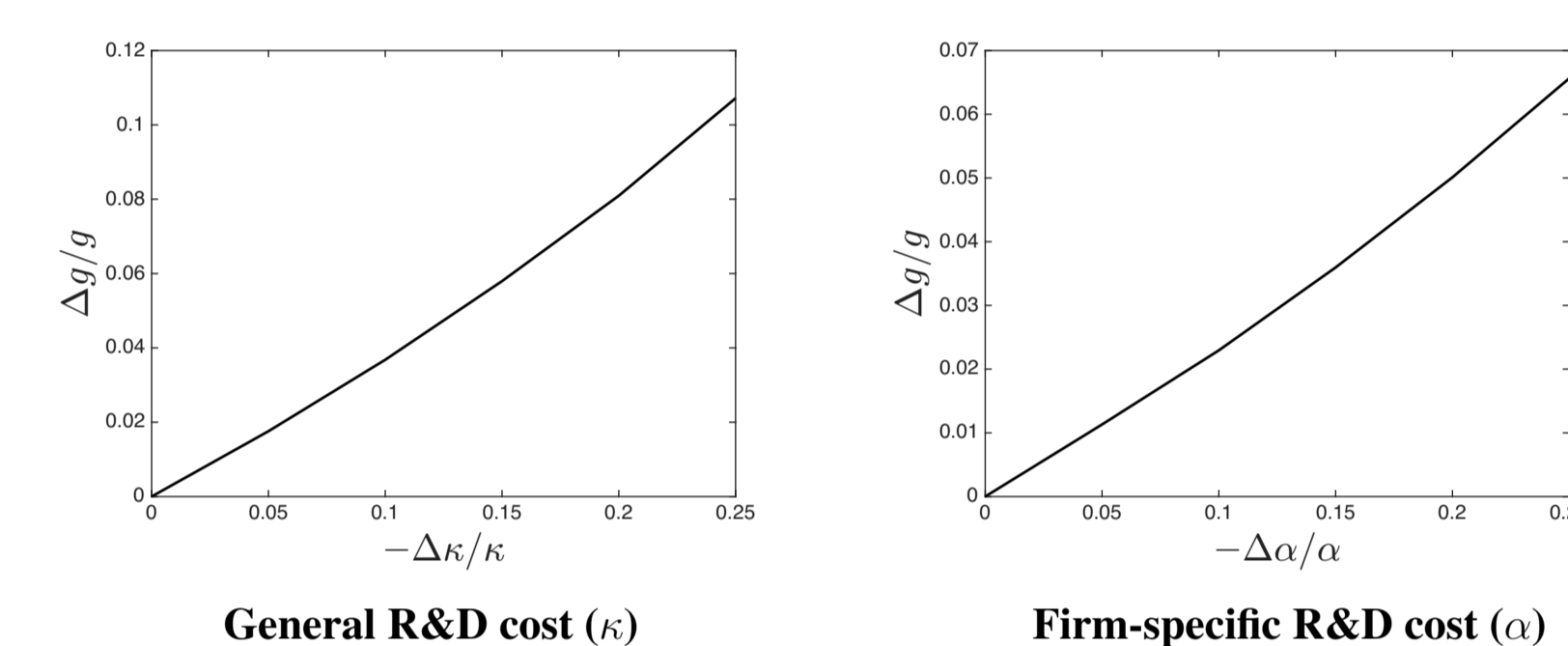
Growth elasticity w.r.t. efficiency of spillovers.



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.



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

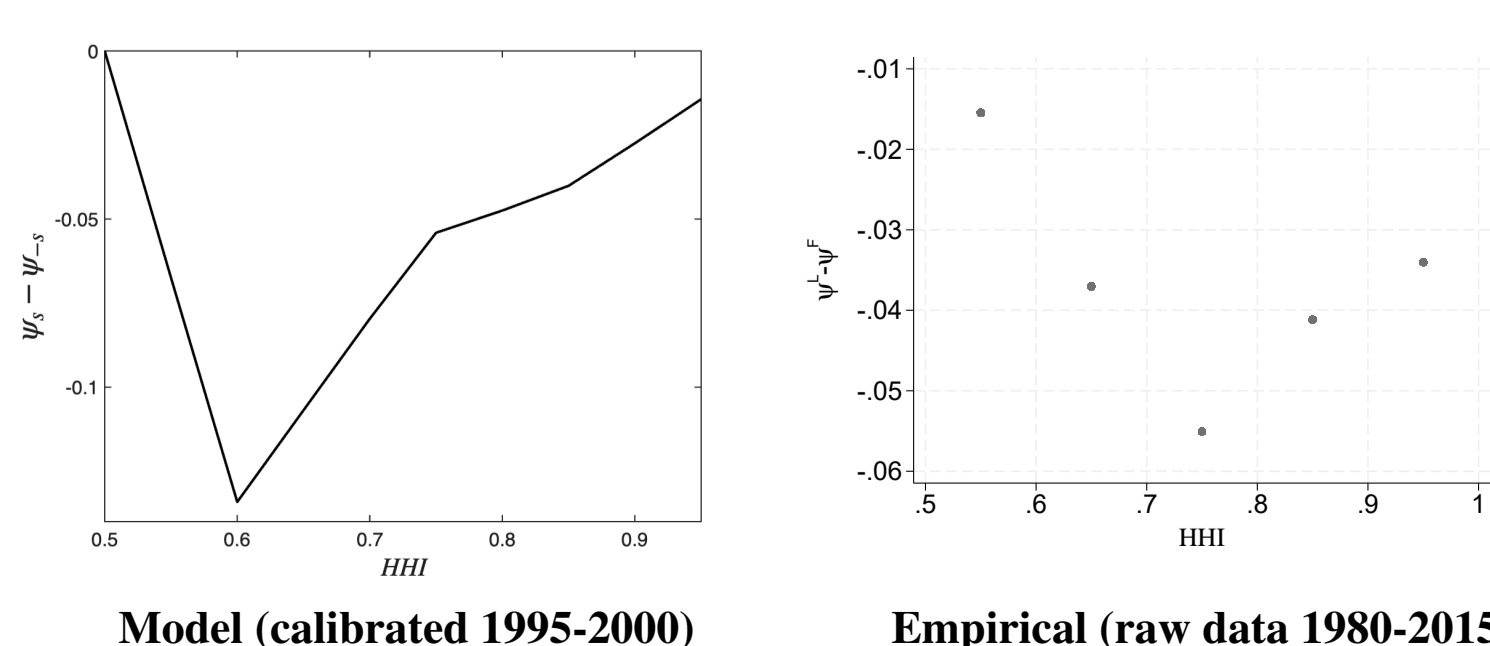
P1: Market leaders have lower innovation generality.

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

- $\psi_{f,t}$: average patent generality of firm f in year t .
- $\mathbf{1}(\text{Leader})_{f,t}$: = 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.

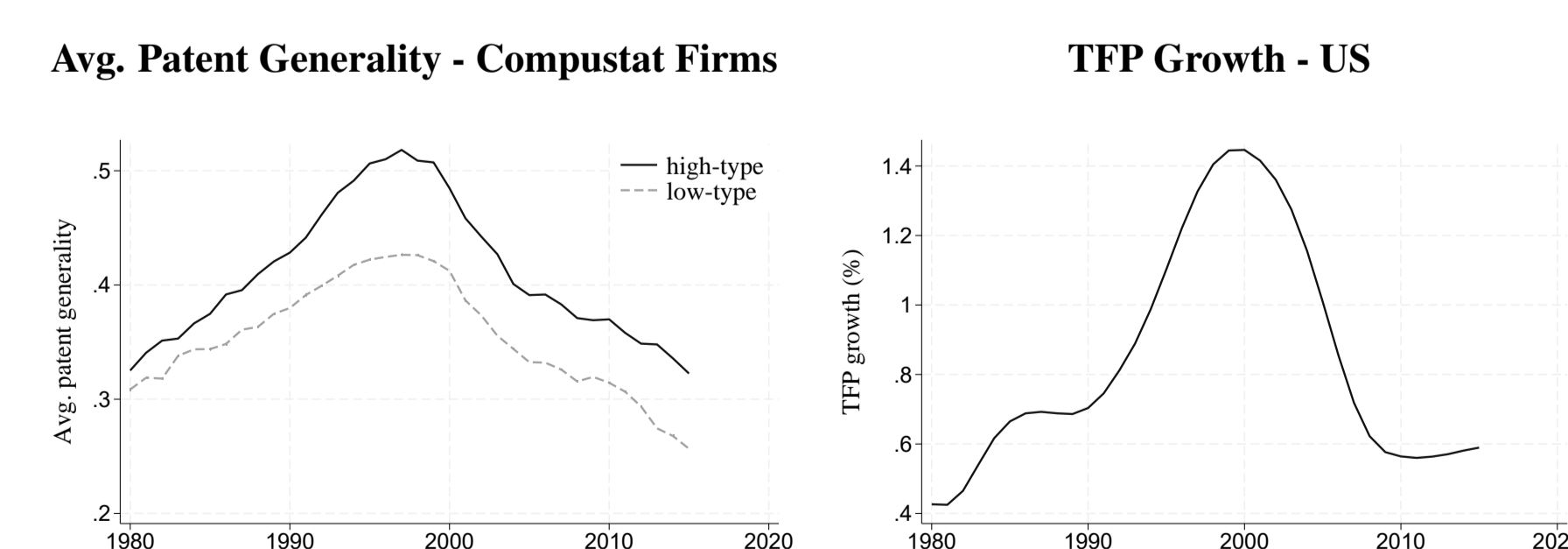
P2: The innovation generality gap between the two firms varies **non-monotonically** with market concentration.

$$\psi_{j,t}^L - \psi_{j,t}^F = -0.357 \cdot HHI_{j,t} + 0.229 \cdot HHI_{j,t}^2 + \delta_j + \delta_t + \epsilon_{j,t} \quad (\text{s.e. } 0.008) \quad (\text{s.e. } 0.080)$$



- $\psi_{j,t}^L, \psi_{j,t}^F$: 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



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.