Competing for Inventors: Market Concentration and the Misallocation of Innovative Talent

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October 5, 2021

Research Questions and Main Idea

I ask three main questions:

1. What are the boundaries of labor markets for *inventors?*
2. Does *competition for scarce inventors* between *different* product markets affect R&D allocation and productivity?
3. If so, which policies can restore efficiency?

Across product markets, more market power gives:

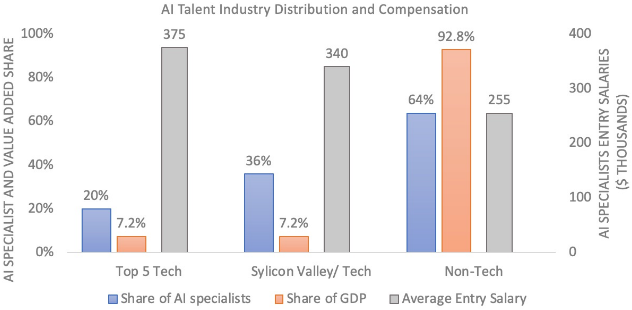
- Higher *private* returns to R&D, demand for inventors
- Lower *social* returns to R&D, less growth per inventor
- Uneven growth in concentration leads to *misallocation across sectors*

Complementary explanation for observed decline in R&D

Paper in a Slide

1. Build data on inventors' flows (USPTO) across product markets (NAICS 3-4 digits)
   - Competition for inventors extends beyond product markets
2. Long regressions (EC and regulations data, 1997-2012)
   - *Across product markets:* ↑ market concentration ↑ inventors
   - *Within product markets* that gained inventors*:* ↑ top 10% share, ↑ incremental/defensive innovation, ↓ growth/inventor
   - Misallocation explains up to .45pp lower annual growth
3. Schumpeterian model with defensive patenting:
   - Uneven markup increases lead to misallocation
   - Policy: entrant subsidies in *less competitive sectors*
   - Cost-neutral gives .28pp higher annual growth

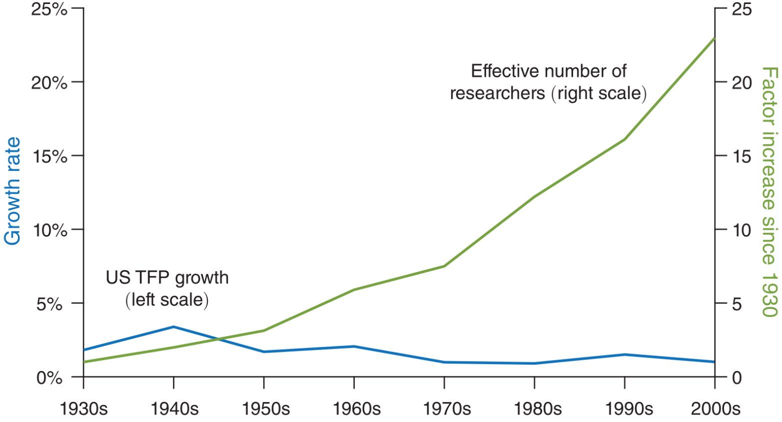
Motivating Example: The Allocation of AI Talent



Source: Global AI Talent Report (TalentSeer, 2020), BEA

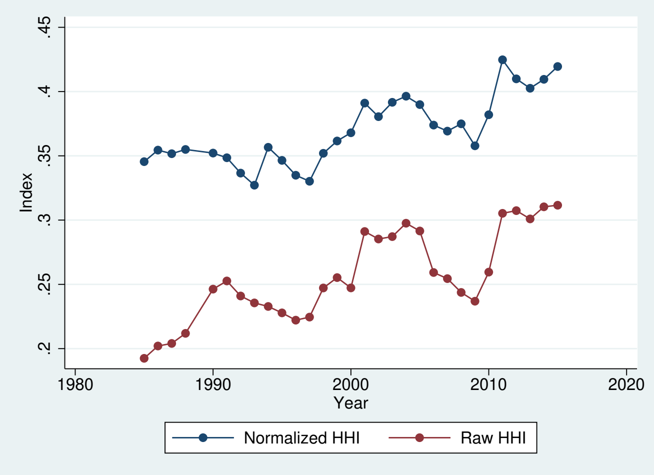
- AI is a GPT, but top Tech attracts a disproportionate share of specialists (and offer higher wages)
  - Anecdotal widespread shortage in other sectors and smaller companies "outcompeted" by big tech ▸ Headlines

Are Ideas Harder to Find?



Source: Bloom et al. (2021)

Increased Concentration



Source: Annual Compustat Data (3d NAICS)

Related Literature

- *Trends in innovation and R&D.*

  Akcigit and Kerr (2018), Akcigit and Ates (2020), **Bloom et al.** (2020, 2021), Goldschlag et al. (2016)

- *Increasing Concentration Facts and Measurement*

  Barkai (2020), De Loecker et al. (2020), **Gutiérrez and Philippon** (2017, 2018), Grullon et al. (2019), Keil (2017)

- *Competition and Innovation*

  Aghion et al. (2005, 2009, 2019), **Argente et al. (2020)**, Gutiérrez and Philippon (2017), Autor et al. (2021)

- *Models of innovation and growth*

  Aghion and Howitt (1992), Aghion et al. (2001), Acemoglu and Akcigit (2012), **Abrams et al. (2018)**, **Jo (2019)**

How is This Paper Different?

Empirical Literature:

- Focus on R&D *output* (patents and citations)
- Allocation of R&D expenditure *within* markets

This paper:

- Focus on R&D *input* (inventors)
- Allocation of *relevant* inventors *across* markets

Theory Literature:

- R&D activity is (usually) non-rival
- Competition and innovation *within* product markets

This paper:

- R&D is *rival* (scarce inventors and defensive innovation)
- Competition and innovation *across* different product markets

Plan of the Talk

1. Data construction
2. Regression analysis
3. Model
4. Calibration and Policy

Empirics Objectives

- Understand boundaries of markets for inventors
  - Identify "knowledge markets" as sets of product markets that hire the same type of inventors
  - Use patent data to build a network of flows of inventors across sectors
  - Identify connected sectors maximizing network's modularity
- Look *within knowledge markets* to see how product markets' share of inventors relate to concentration

Data Sources

- USPTO (patent-year) and Goldschlag et al. (2016):
  - patent citation and disambiguated inventor id's, 1975-present;
  - patent classification by NAICS of application (1978-2016)
- Economic Census and Keil (2017) (5-year-NAICS)
  - Concentration measure: HHI and HHI lower bound
  - Output per worker growth
- NBER-CES:
  - Constructed Lerner Index
- Mercatus RegData 4.0 (2021):
  - Sector-specific regulation counts
  - Extended using text similarity across NAICS for missing sectors

Dataset Structure

Patent ID	Inventor ID	Goldschlag et al. (2016) NAICS	Year
US00001	00001-1	1111	1980
US00001	00001-1	1112	1980
US00001	00001-2	1111	1980
US00001	00001-2	1112	1980
US00002	00001-1	3111	1981

Dataset Structure

Patent ID	Inventor ID	Goldschlag et al. (2016) NAICS	Year
US00001	00001-1	1111	1980
US00001	00001-1	1112	1980
US00001	00001-2	1111	1980
US00001	00001-2	1112	1980
US00002	00001-1	3111	1981

$\Downarrow \quad \Downarrow \quad \Downarrow$

Inventor ID	NAICS 1	NAICS 2	Year	Total Flow
00001-1	1111	1112	1980	2
00001-2	1111	1112	1980	2
00001-1	1112	3111	1981	1

"Knowledge Markets"

- *Knowledge Market:* set of NAICS (product markets) that employ the same type of inventors
  - To capture similar *required knowledge* to innovate
- From data, undirected network:
  - NAICS (4-digit) as nodes
  - *Minimal share of inventor flows* as edge weights, W

"Effective inventors"

- *Effective inventors:*
  - "Productivity-adjusted" inventor. Fixed effect α_i in regression:

$$\#\text{Patents}_{cfit} = \alpha_i + \alpha_{cft} + \varepsilon_{cfit}$$

  - α_{cft}: CPC class 1-digit, c, by firm (assignee), f, by year, t
  - Raw number of inventors for robustness

Effective Inventor Flows

- Strength of connection between two sectors
- Build directed flows for each inventor i (avoid double counting):

$$\tilde{\text{flow}}_{1\to 2,i,t} \equiv \frac{\sum \mathbb{1}\{i \text{ moves } 1 \to 2 \text{ in } t\}}{\sum_{j,k} \mathbb{1}\{i \text{ moves } j \to k \text{ in } t\}} \times \alpha_i$$

- Compute total outflows and inflows for each NAICS 4-digit sector:

$$\tilde{\text{inflow}}_{\text{NAICS}} = \sum_n \sum_t \sum_i \tilde{\text{flow}}_{n\to \text{NAICS},i,t},$$

Network Weights

- Compute share of inflows and outflows, e.g.:

$$\text{share in}_{1\leftarrow 2} = \frac{\sum_t \sum_i \tilde{\text{flow}}_{\,2\rightarrow 1,i,t}}{\tilde{\text{inflow}}_1}$$

- Define weight:

$$W_{12} = W_{21} = \min\left\{\frac{\text{share in}_{1\leftarrow 2} + \text{share out}_{1\rightarrow 2}}{2}, \frac{\text{share in}_{2\leftarrow 1} + \text{share out}_{2\rightarrow 1}}{2}\right\}$$

- Average tends to overstate flows from small sectors to large

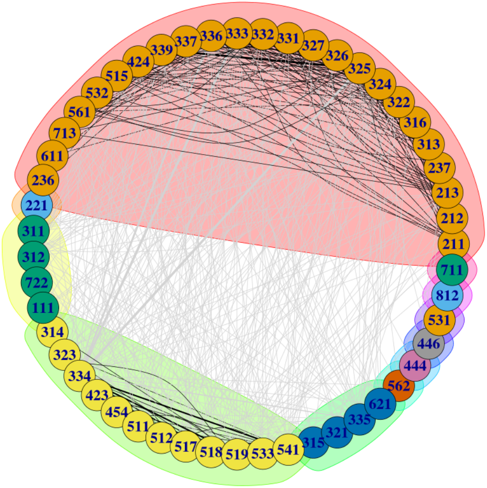
Detecting Knowledge Markets

- Run a weighted community detection algorithm:
  - Maximizes modularity of the network
  - Finds N *non-overlapping* communities to maximize:

$$Q = \sum_{c=1}^{N} \left[W_{cc} - \left(\sum_{j} W_{cj} \right)^2 \right],$$

    where W_{cj} is the weight edges that have one end in community c and the other in community j.
  - "How much more the community is connected internally than externally".
  - Result: 10 non-singleton sets of NAICS 4-digit that share inventors

Visualization at 3-digit NAICS



Features of Flows and Knowledge Markets

- Many connections across product markets even at 3 digits!
- Same inventors are employed by firms in *highly different* product markets
- Broad communities
- Reasonable?
  - Green Cluster collects "Food and Agriculture": Crop Production, Food Manufacturing and Services, Beverage and Tobacco;
  - Orange Cluster is mostly "Mining" and "Heavy Industry": e.g. Petroleum and Coal Products, Chemical, Machinery Manufacturing;
  - Yellow Cluster collects "Communications", "Electronics" and "Publishing":e.g. Computer and Electronic Products, Telecommunications, Data Processing;

Variables

- Sector p's share of effective inventors in market, k:

$$\text{Share}^k_{p,t} \equiv \frac{\sum_{p_i(t)=p} \alpha_i}{\sum_{k_i(t)=k} \alpha_i}.$$

- Baseline concentration measure is HHI lower bound (Keil, 2017):

$$\underline{\text{HHI}}_{p,t} = 4\left[\frac{\text{Top-4 Share}_{p,t}}{4}\right]^2 + 4\left[\frac{\text{Top-8 Share}_{p,t} - \text{Top-4 Share}_{p,t}}{4}\right]^2, + 12\left[\frac{\text{Top-20 Share}_{p,t} - \text{Top-8 Share}_{p,t}}{12}\right]^2 + 30\left[\frac{\text{Top-50 Share}_{p,t} - \text{Top-20 Share}_{p,t}}{30}\right]^2$$

top shares come from Economic Census (corr. with HHI .93)

- Regulation measure from Mercatus RegData 4.0:
    - counts of regulation affecting NAICS 4d using text analysis
    - Extended to all sectors with $\underline{\text{HHI}}$ using cos-similarity ▸ Details

Specification

- At the NAICS 4-digit sector, p:

$$\Delta \text{Outcome}_p = f_k 1\{p \in k\} + \beta \Delta \text{Indep.Var.}_p + \gamma' \Delta \text{Controls}_p + \varepsilon_p,$$

- Δ denotes the long-difference operator:

$$\Delta \text{Outcome}_p = \text{Outcome}_{p,2012} - \text{Outcome}_{p,1997}$$

- $f_k 1\{p \in k\}$, indicator that sector p belongs to knowledge market k

Main Specification:

- $\Delta \text{Outcome}_p$: ΔShare_p^k
- $\Delta \text{Indep.Var.}_p$: $\Delta \underline{\text{HHI}}_p, \Delta \text{HHI}_p$
- $\Delta \text{Controls}_p$: Change in log-real sales; controls for sector size

$\beta > 0$: Sectors where concentration increased attracted more

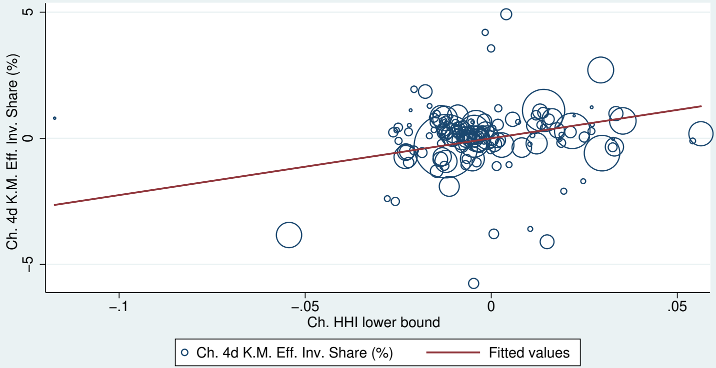
Main Specification Results

Actual HHI | Robustness to Outliers | Raw Inventors

	Ch. 4d K.M. Eff. Inv. Share (%)	
	(1)	(2)
Ch. HHI lower bound	26.093*	22.509*
	(10.696)	(10.848)
Ch. Log Real Sales	0.914**	0.548*
	(0.278)	(0.243)
4D Knowledge Market FE		✓
Sample	Full Sample	Full Sample
Weight	Sales	Sales
Observations	157	153

$+\ p < 0.1, ^{*}\ p < 0.05, ^{**}\ p < .01, ^{***}\ p < .001$

Graphically



Full Sample. Absorbed FE: 4d Knowledge Market. Partialled out: Ch. Log Real Sales. Observations weighted by Sales.

Robustness to Individual Firm Size

▸ Robustness to Outliers

	Ch. 4d K.M. Eff. Inv. Share (%)	
	(1)	(2)
Ch. HHI lower bound	35.230**	20.783+
	(12.759)	(10.615)
Ch. Log Real Sales per company	0.175	-0.040
	(0.382)	(0.253)
4D Knowledge Market FE		✓
Sample	Full Sample	Full Sample
Weight	Sales	Sales
Observations	81	79

$+\ p < 0.1,^{*}\ p < 0.05,^{**}\ p < .01,^{***}\ p < .001$

IV Regression: Reduced Form and First Stage

	Ch. 4d K.M. Eff. Inv. Share (%)	Ch. HHI lower bound
	(1)	(2)
Ch. Log Restricitions (NAICS 4d)	0.478*	0.016*
	(0.220)	(0.007)
Ch. Log Real Sales	0.539+	-0.000
	(0.274)	(0.005)
4D Knowledge Market FE	✓	✓
Sample	Full Sample	Full Sample
Weight	Sales	Sales
Observations	153	153

$+\ p < 0.1,^{*}\ p < 0.05,^{**}\ p < .01,^{***}\ p < .001$

IV Regression: 2SLS Results

	Ch. 4d K.M. Eff. Inv. Share (%)	
	(1)	(2)
Ch. HHI lower bound	30.560+	30.096+
	(15.904)	(15.819)
Ch. Log Real Sales	0.544*	0.525*
	(0.244)	(0.247)
4D Knowledge Market FE	✓	✓
Sample	Full Sample	Mahalanobis 5%
Weight	Sales	Sales
Observations	157	150
First-Stage F	4.587229	4.753009
Anderson-Rubin p-value	.0281448	.0321185

$+ \ p < 0.1, ^{*} \ p < 0.05, ^{**} \ p < .01, ^{***} \ p < .001$

What Happens within Knowledge Markets?

An increase in inventor shares:

- Significantly increases
  - Top 10% firms' inventor shares, Top 10%/Bottom 50% ratio
    ▸ Table
  - Self-citations ▸ Table
- Significantly decreases
  - Inventors' productivity (next slide)
  - Patents' forward citations ▸ Table

Fall in Inventors' Productivity

▸ Robustness to Outliers

	Ch. Avg. Output/Worker Growth/Inventor (%)	
	(1)	(2)
Ch. 4d K.M. Eff. Inv. Share (%)	-0.007**	-0.005*
	(0.002)	(0.002)
Ch. Log Real Sales		-0.051*
		(0.021)
4D Knowledge Market FE	✓	✓
Sample	Full Sample	Full Sample
Weight	Sales	Sales
Observations	101	101

$+\ p < 0.1,^{*}\ p < 0.05,^{**}\ p < .01,^{***}\ p < .001$

Back-of-the-envelope Loss from Misallocation

Using medians in the data

- $-.005pp$ of growth per 1pp increase in inventors' share
- Median increase effective inventors' share .014pp
- Median effective inventors FE: 2018
- .15pp lower growth from misallocation
  $(-.005 \times .014pp \times 2018)$

Using HHI and predicted increase:

- Increase of .045pp in the share of inventors
- $\approx$.45pp lower growth from misallocation
  $(-.005 \times .045pp \times 2018)$

Model Objectives

- Explain intuition on decrease in competition driving lower growth through misallocation
- Build a model that generates a positive relation between concentration and inventor demand
  - Schumpeterian model
    - Entrants give creative-destruction growth
    - Incumbents can engage in defensive innovation
    - Two sectors, one knowledge market
- Calibration matching R&D statistics to evaluate policy:
  - Optimal to subsidize entrants in concentrated sectors
  - Cost-neutral policy gives up to .155pp higher annual growth

Single-Sector: Market Structure

Concentration v. Markup

Consumption good is C-D of intermediates:

$$Y_t = \int_0^1 y_t(i) \mathrm{d}i$$

Intermediate, i, produced with linear technology by either:

- Incumbent: unit cost $\frac{c_t(i)}{\phi}$, $\phi > 1$; or
- Entrants: unit cost $c_t(i)$

Bertrand competition, incumbent sets $p_t(i) = c_t(i)$, realizes monopoly profits:

$$\Pi_t = \left(\frac{\phi - 1}{\phi}\right) c_t(i) y_t(i) = \left(\frac{\phi - 1}{\phi}\right) Y_t.$$

Innovation

Entrants and incumbents can invest in R&D to obtain an innovation reducing costs to:

$$c_{t+\Delta t} = \frac{c_t}{(1+\eta)\,\phi},$$

If innovation is *implemented*, cost of all other firms drops to:

$$c_{t+\Delta t} = \frac{c_t}{(1+\eta)}$$

Normalized incumbents' profits are constant:

$$\pi_t \equiv \frac{\Pi_t}{Y_t} = \left(\frac{\phi - 1}{\phi}\right)$$

Incumbents' R&D results in:

- an innovation w.p. $\lambda \in [0, 1]$,
- a patent wall of size $\omega > 1$ w.p. 1, which raises entrants' costs.

Incumbents' Values

- State of each market is the size of patent wall $\Omega \in \{1, \omega\}$
- With constant economy-wide output growth, g, obtain normalized values $v = \frac{V(\Omega)}{Y}$:

$$\rho v(1) = \max_{x_I} \left(\frac{\phi - 1}{\phi}\right) - \alpha_I \frac{x_I^{\gamma}}{\gamma} + x_I \left(v(\omega) - v(1)\right) - x_{e,1}\left(v(1)\right)$$

$$\rho v(\omega) = \left(\frac{\phi - 1}{\phi}\right) + \delta \left(v(1) - v(\omega)\right) - x_{e,\omega}\left(v(\omega)\right)$$

- x_I research intensity for incumbent,
- $\alpha_I \frac{x_I^{\gamma}}{\gamma}$, incumbents' inventors ($w^{RD} = 1$)
- $x_{e,1}, x_{e,\omega}$: total research intensity of entrants
- δ: depreciation of patent wall (patent protection)

Entrants

- Successful entrants destroy any existing patent wall and get "unprotected value" $v(1)$
- Entrants are atomistic, mass determined in equilibrium
- Crowding externalities in entrants' research (Abrams et al., 2018)
- Linear cost $\zeta \times \Omega$:

$$\max_{x_{e,\Omega,i}} x_{e,\Omega,i} v(1) - \zeta \Omega x_{e,\Omega,i} x_{e,\Omega}.$$

- Finite demand IFF:

$$x_{e,\Omega} = \frac{v(1)}{\zeta \Omega}$$

- Total entrants' inventors sector with wall Ω given by $v(1) = \zeta \Omega x_{e,\Omega}$

Growth and Inventors' Productivity

Equilibrium Definition

Stationary distribution with constant growth: Derivation

$$\boldsymbol{\mu} = \begin{bmatrix} \mu_1 & \mu_\omega & \mu_{e,1} & \mu_{e,\omega} \end{bmatrix}$$

Growth is given by:

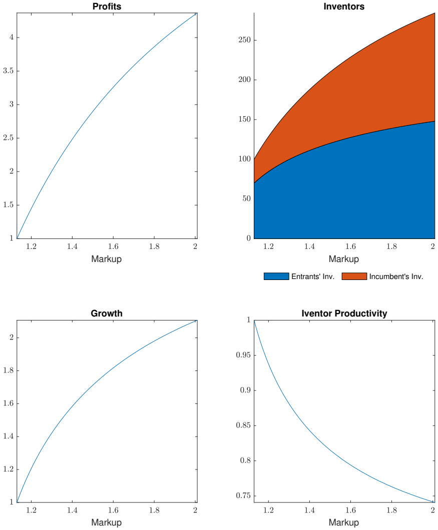
$$g = \eta \left(x_{e,\omega}\mu_{e,\omega} + x_{e,1}\mu_{e,1} + \lambda x_I \mu_1 \right)$$

Inventors' productivity (growth per inventor):

$$\frac{g}{L^{RD}} = \eta \frac{x_{e,\omega}\mu_{e,\omega} + x_{e,1}\mu_{e,1} + \lambda x_I \mu_1}{\zeta \left(\omega x_{e,\omega}\mu_{e,\omega} + x_{e,1}\mu_{e,1} \right) + \alpha_I \frac{x_I^2}{2} \mu_1}.$$

Single Sector Comparative Statics: Markup Increase

Proposition



Two-Sectors, Inventor Market Equilibrium

- Two Cobb-Douglas sectors as above:

$$Y = \left[\int_0^1 y_{1,t}(i)\mathrm{d}i\right]^{\beta_1} \left[\int_0^1 y_{2,t}(i)\mathrm{d}i\right]^{1-\beta_1}$$

- Researchers now earn w^{RD}, separate market from production
- Inventors' market clearing:

$$L^{RD,s}\left(w^{RD}\right) = \sum_{i=1,2} \left\{ \mu_{1,i}\left(w^{RD}\right)\alpha_I \frac{x_{I,i}^2\left(w^{RD}\right)}{2} + \right.$$
$$\left. +\mu_{\omega,i}\left(w^{RD}\right)\zeta_i\omega_i x_{e,\omega,i}\left(w^{RD}\right) + \mu_{1,e,i}\left(w^{RD}\right)\zeta_i x_{e,1,i}\right.$$

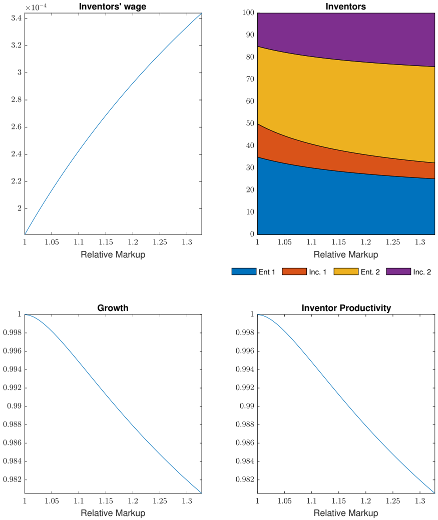
- Normalize $L^{RD,s} = 100$.

Calibration

- Objective: study policy, provide *lower bound of growth effects*
- Match only R&D statistics and Lerner Index gaps, not the estimated drop in growth
- Produces about 20% of lower bound growth loss from empirics
- Internal calibration for α_I, ζ, η, target incumbents' R&D share, Business R&D Share, avg. GDP growth 1997-2012 Values
- External calibration for the rest All Parameters
  - $\beta = .5$: sectors that saw an increase in Lerner Index ($\approx$ 50%)
  - $\phi = 1.13$ (Aghion et al., 2019)
  - $\omega = 1.469$ (el. of entry to patents Hall and Helmers (2015))
  - $\lambda = .785$ (21% internal patents, Akcigit and Kerr (2018))
  - τ, s: corp. tax 23% and R&D subsidy 19% (Akcigit et al.)

CS: Unbalanced Increase in Markup

Sector Aggregates



≈ 1.5% lower growth for 20% increase in gap, 1/5 of empirics

Growth-Maximizing Policy

- Planner wishes to maximize constant growth rate
- Instruments:
  - corporate tax, fixed and flat $\tau = 23\%$
  - sector- and position-specific R&D subsidies, $s_{I,i}, s_{e,1,i}, s_{e,\omega,i}$
  - balanced budget
- Four scenarios versus "current" system (everything flat):
  - Unconstrained specific subsidies
  - Cost-Neutral sector- and position-specific subsidies
  - Cost-Neutral sector-specific subsidies
  - Cost-Neutral position-specific subsidies

Policy Results

	Baseline, Sector 1 (1)	Baseline, Sector 2 (2)	Optimal Subsidies, Sector 1 (3)	Optimal Subsidies, Sector 2 (4)	Optimal C.-N. Subsidies, Sector 1 (5)	Optimal C.-N. Subsidies, Sector 2 (6)	Flat C.-N. Sector Subsidies, Sector 1 (7)	Flat C.-N. Sector Subsidies, Sector 2 (8)	Flat C.-N. Entry Subsidies, Sector 1 (9)	Flat C.-N. Entry Subsidies, Sector 2 (10)
Tax system:										
τ	23.00%	23.00%	23.00%	23.00%	23.00%	23.00%	23.00%	23.00%	23.00%	23.00%
s_I	19.00%	19.00%	0.03%	0.01%	0.00%	0.00%	41.90%	0.02%	0.02%	0.00%
s_e	19.00%	19.00%	0.99%	75.39%	0.06%	42.42%	41.90%	0.02%	28.25%	28.25%
Aggregates:										
L_I^{RD}	8.66	22.20	5.83	4.47	8.01	13.89	12.65	17.45	6.26	16.41
L_e^{RD}	27.36	41.78	23.12	66.57	26.44	51.66	32.42	37.47	30.61	46.72
L_{TOT}^{RD}	36.02	63.98	28.96	71.04	34.45	65.55	45.07	54.93	36.87	63.13
Sector Growth	1.91%	2.93%	1.62%	4.67%	1.85%	3.61%	2.27%	2.62%	2.14%	3.26%
Subsidy/GDP	0.20%	0.36%	0.01%	1.66%	0.00%	0.56%	0.55%	0.00%	0.22%	0.34%
Revenue/GDP	1.02%	2.32%	1.02%	2.32%	1.02%	2.32%	1.02%	2.32%	1.02%	2.32%

- Growth without policy: 2.42%
- Optimal: 3.145%
- Best Cost-neutral: 2.73%
- Flat entry subsidies: 2.7%
- Flat sector subsidies: 2.445%

Conclusion

- Competition for inventors extends far beyond product markets
- Concentrating sectors attract inventors away from competitive
- Misallocation explains up to .45pp lower annual growth
- Policy: entrant subsidies in *less competitive sectors*
- Cost-neutral entry subsidies give .28pp higher annual growth

Headlines ▸ Back

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Deals

Big Tech Swallows Most of the Hot AI Startups

An acquisition spree by Apple, Amazon, Facebook, Google and Microsoft eliminated potential rivals and concentrated brain power in this critical field.

The New York Times https://www.nytimes.com/2017/10/22/technology/artificial-intelligence-experts-salaries.html

Tech Giants Are Paying Huge Salaries for Scarce A.I. Talent

Filling in Missing Regulations ▸ Back

- For all pairs NAICS 4-d sectors:
  - Build cosine similarity between descriptions
- For each NAICS 4-d without missing data:
  - Rank 5 most similar sectors with regulation data
  - Attribute regulations of top 5 most similar sectors, weighted by cos. similarity
  - If highest cos-similarity is smaller than .2, use only most similar sector.

Main Specification: Actual HHI ▸ Back

	Ch. 4d K.M. Eff. Inv. Share (%)					
	(1)	(2)	(3)	(4)	(5)	(6)
Ch. HHI lower bound	27.293*		27.183*		27.326*	
	(11.569)		(11.941)		(11.620)	
Ch. HHI		22.399***		22.399***		22.350***
		(6.345)		(6.345)		(6.343)
4D Knowledge Market						
Sample	Full Sample	Full Sample	Trim Outliers	Trim Outliers	Mahalanobis 5%	Mahalanobis 5%
Weight	Sales	Sales	Sales	Sales	Sales	Sales
Observations	157	80	155	80	150	71

$+\ p < 0.1,^{*}\ p < 0.05,^{**}\ p < .01,^{***}\ p < .001$

Main Specification: Robustness to Outliers

Back

	Ch. 4d K.M. Eff. Inv. Share (%)					
	(1)	(2)	(3)	(4)	(5)	(6)
Ch. HHI lower bound	26.093*	22.509*	25.904*	22.716*	26.111*	22.554*
	(10.696)	(10.848)	(11.124)	(10.948)	(10.725)	(11.019)
Ch. Log Real Sales	0.914**	0.548*	0.881**	0.539*	0.918**	0.562*
	(0.278)	(0.243)	(0.275)	(0.242)	(0.283)	(0.261)
4D Knowledge Market FE		✓		✓		✓
Sample	Full Sample	Full Sample	Trim Outliers	Trim Outliers	Mahalanobis 5%	Mahalanobis 5%
Weight	Sales	Sales	Sales	Sales	Sales	Sales
Observations	157	153	155	152	150	139

$+\ p < 0.1, ^{*}\ p < 0.05, ^{**}\ p < .01, ^{***}\ p < .001$

Robustness to Individual Firm Size Back

	Ch. 4d K.M. Eff. Inv. Share (%)					
	(1)	(2)	(3)	(4)	(5)	(6)
Ch. HHI lower bound	35.230**	20.783+	35.230**	20.783+	35.154**	22.854*
	(12.759)	(10.615)	(12.759)	(10.615)	(12.647)	(11.197)
Ch. Log Real Sales per company	0.175	-0.040	0.175	-0.040	0.300	-0.055
	(0.382)	(0.253)	(0.382)	(0.253)	(0.460)	(0.346)
4D Knowledge Market FE		✓		✓		✓
Sample	Full Sample	Full Sample	Trim Outliers	Trim Outliers	Mahalanobis 5%	Mahalanobis 5%
Weight	Sales	Sales	Sales	Sales	Sales	Sales
Observations	81	79	81	79	75	67

$+\ p < 0.1, ^{*}\ p < 0.05, ^{**}\ p < .01, ^{***}\ p < .001$

Robustness to Raw Inventors

Back

	Ch. 4d K.M. Eff. Inv. Share (%)					
	(1)	(2)	(3)	(4)	(5)	(6)
Ch. HHI lower bound	71.724+	67.160+	72.123+	67.736+	71.772+	68.398+
	(39.265)	(37.176)	(39.530)	(37.504)	(39.316)	(37.717)
Ch. Log Real Sales	1.864*	1.422*	1.852*	1.402+	1.878*	1.443+
	(0.766)	(0.717)	(0.764)	(0.712)	(0.774)	(0.745)
4D Knowledge Market FE		✓		✓		✓
Sample	Full Sample	Full Sample	Trim Outliers	Trim Outliers	Mahalanobis 5%	Mahalanobis 5%
Weight	Sales	Sales	Sales	Sales	Sales	Sales
Observations	157	156	156	155	150	142

$+\ p < 0.1, ^{*}\ p < 0.05, ^{**}\ p < .01, ^{***}\ p < .001$

Within-Sector Distribution ▸ Back

	Ch. Inv. 90/50 Quantile Ratio	Ch. Inv. Top-10/Bottom-50 Share Ratio	Ch. Inv. Top-50/Bottom-50 Share Ratio	Ch. Inv. Top 10% Share	Ch. Inv. Bottom 50% Share
	(1)	(2)	(3)	(4)	(5)
Ch. 4d K.M. Eff. Inv. Share (%)	0.211+	0.243*	0.314+	0.018**	-0.008*
	(0.107)	(0.097)	(0.184)	(0.006)	(0.004)
Ch. Log Real Sales	-0.100	0.328	0.147	0.026	0.005
	(0.122)	(0.294)	(0.316)	(0.020)	(0.007)
4D Knowledge Market FE	✓	✓	✓	✓	✓
Sample	Full Sample	Full Sample	Full Sample	Full Sample	Full Sample
Weight	Sales	Sales	Sales	Sales	Sales
Observations	118	118	118	118	118

$+\ p < 0.1, ^{*}\ p < 0.05, ^{**}\ p < .01, ^{***}\ p < .001$

Self-Citations (Midrange of Sample) Back

	Ch. excess self-c. over CPC group		Ch. excess self-c. over CPC subgroup	
	(1)	(2)	(3)	(4)
Ch. 4d K.M. Eff. Inv. Share (%)	5.540**	5.244*	4.561***	4.110*
	(1.783)	(2.469)	(1.211)	(1.600)
Ch. Log Real Sales	-2.217	-2.099	-1.780	-1.780
	(1.879)	(1.976)	(1.287)	(1.265)
4D Knowledge Market FE		✓		✓
Sample	Full Sample	Full Sample	Full Sample	Full Sample
Weight				
Observations	145	144	145	144

$+\ p < 0.1, ^{*}\ p < 0.05, ^{**}\ p < .01, ^{***}\ p < .001$

Forward Citations (Midrange of Sample)

Back

	Ch. in log citations per patent (CPC2 based)	Ch. in log citations per patent (Total)	Ch. in patent generality
	(1)	(2)	(3)
Ch. 4d K.M. Eff. Inv. Share (%)	-0.545***	-0.618***	-0.025*
	(0.113)	(0.137)	(0.012)
Ch. Log Real Sales	-0.232*	-0.255+	0.008
	(0.109)	(0.146)	(0.012)
4D Knowledge Market FE	✓	✓	✓
Sample	Full Sample	Full Sample	Full Sample
Weight			
Observations	144	144	144

$+\ p < 0.1,^{*}\ \ p < 0.05,^{**}\ \ p < .01,^{***}\ \ p < .001$

Robustness for Inventor Productivity ▸ Back

	Ch. Avg. Output/Worker Growth/Inventor (%)			
	(1)	(2)	(3)	(4)
Ch. 4d K.M. Eff. Inv. Share (%)	-0.007**	-0.005*	-0.007**	-0.005*
	(0.002)	(0.002)	(0.002)	(0.002)
Ch. Log Real Sales		-0.051*		-0.054*
		(0.021)		(0.021)
4D Knowledge Market FE	✓	✓	✓	✓
Sample	Full Sample	Full Sample	Mahalanobis 5%	Mahalanobis 5%
Weight	Sales	Sales	Sales	Sales
Observations	101	101	96	93

$+\ p < 0.1,^{*}\ p < 0.05,^{**}\ p < .01,^{***}\ p < .001$

Lerner Index v. Concentration in Sample

Back

	Markup Change 1997-2012, 6d Lerner Index	Markup Change 1997-2012, 4d Lerner Index
	(1)	(2)
HHI Change 1997-2012	1.490***	1.652***
	(0.229)	(0.257)
Observations	258	258
R-squared	.1424476	.139197

$+\ p < 0.1, ^{*}\ p < 0.05, ^{**}\ p < .01, ^{***}\ p < .001$

Constant-Growth Equilibrium

Back

Definition

A constant-growth equilibrium is a set of prices $p(i)$, investment intensities $x_I, x_{e,\omega}, x_{e,1}$, and normalized values $v(\omega), v(1)$, such that, given a wage for production and R&D workers, incumbent and entrants optimally choose research intensities, the stationary distribution satisfies:

$$0 = -\left(x_I + x_{e,1}\right)\mu_1 + \delta\mu_\omega + x_{e,\omega}\mu_{e,\omega} + x_{e,1}\mu_{e,1},$$

$$0 = -\left(x_{e,\omega} + \delta\right)\mu_\omega + x_I\mu_1,$$

$$0 = -\left(x_{e,1} + x_I\right)\mu_{e,1} + x_{e,1}\mu_1 + \delta\mu_{e,\omega},$$

$$0 = -\left(x_{e,\omega} + \delta\right)\mu_{e,\omega} + x_{e,\omega}\mu_\omega + x_I\mu_{e,1}.$$

Stationary Distribution

Back

LOM:

$$
\begin{aligned}
\dot{\mu}_1 &= -\left(x_I + x_{e,1}\right)\mu_1 + \delta\mu_\omega + x_{e,\omega}\mu_{e,\omega} + x_{e,1}\mu_{e,1},\\
\dot{\mu}_\omega &= -\left(x_{e,\omega} + \delta\right)\mu_\omega + x_I\mu_1,\\
\dot{\mu}_{e,1} &= -\left(x_{e,1} + x_I\right)\mu_{e,1} + x_{e,1}\mu_1 + \delta\mu_{e,\omega},\\
\dot{\mu}_{e,\omega} &= -\left(x_{e,\omega} + \delta\right)\mu_{e,\omega} + x_{e,\omega}\mu_\omega + x_I\mu_{e,1}.
\end{aligned}
$$

$$
\mu_\omega = \frac{x_I}{x_I + x_{e,\omega} + \delta}, \qquad \mu_1 = \frac{x_{e,\omega} + \delta}{x_I + x_{e,\omega} + \delta},
$$

$$
\mu_{e,\omega} = \frac{\omega x_I\mu_1 + \left(\omega x_{e,\omega} + x_I\right)\mu_\omega}{\omega\left(x_{e,\omega} + \delta\right) + x_I}, \qquad \mu_{e,1} = \frac{\omega\left(x_{e,\omega} + \delta\right)\mu_1 + \delta\mu_\omega}{\omega\left(x_{e,\omega} + \delta\right) + x_I}.
$$

One-Sector Equilibrium Proposition

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Proposition

Consider the above model with a perfectly elastic production and R&D labor supply. Assume $\delta, \lambda = 0$, *and*

$$\sqrt{\frac{\phi - 1}{\phi}} \left(\frac{\alpha_I - \zeta\omega(\omega - 1)}{\alpha_I \zeta \omega} \right) > \rho.$$

An increase in the markup factor $m \equiv \frac{\phi-1}{\phi}$, *increases incumbents' and entrants' R&D, growth, and the incumbents' share of total R&D labor, and decreases inventor productivity,* g/L^{RD}.

- Parametric sufficient condition, prop. holds for much wider range of parameters
- $\delta, \lambda = 0$ solely for analytical convenience

Internal Calibration Parameters and Sources

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Parameter Name	Symbol	Value	Target
Incumbent Costs	α_I	6.67	Share of Inventors of top 10% firm distribution, 1997: 30.3%
Entrants' Costs	ζ	3.38	Business R&D Share over GDP, 1997: 1.81%
Innovation Step	η	0.0024	Average Annual GDP Growth, 1997-2012: 2.45%

External Calibration Parameters and Sources

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Parameter Name	Symbol	Value	Source/Target
Discount rate	ρ	.04	Annual real interest rate of 4%
Shares of Sectors' Value Added	β	.5	Share of sales of sectors that saw an increase in HHI over total $\approx$ .5
Average Sectors' Markup, Technology Gap	ϕ	1.13	Incumbent efficiency from Aghion et al. (2019)
Curvature of Innovation Function	γ	$1/.6$	Lower bound of estimates in Kortum (1993)
Intensity of Patent Expiration	δ	.05	Uruguay Round Agreements Act (1994)
Share of Implemented Innovations	λ	.785	Internal patent share of 21.5% (Akcigit and Kerr, 2018)
Blocking Value of Patents	ω	1.469	El. of Entry to patents from Hall and Helmers (2015)

Two-Sector CS: Sector Aggregates

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