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

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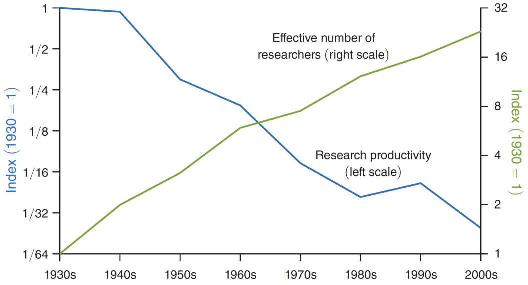
October 5, 2021

Motivation

- **R&D is key to innovation and growth**
  Romer (1987,1990), Aghion and Howitt (1992), Grossman and Helpman (1991)
- **R&D productivity and growth have fallen**
  Bloom et al. (2020), Fernald et al. (2014), Gordon (2016)
- **Concerns over inventors' misallocation**
  Acemoglu et al. (2018, 2021)



Source: Bloom et al. (2020)

This Paper

$\uparrow$ Concentration in some sectors $\Longrightarrow$ Attract inventors from competitive sectors

Are inventors misallocated? Yes!

- **Misallocation:** inventors employed by *incumbents* on *defensive R&D projects*

1. Data
   - Construct labor markets for inventors + inventor productivity
   - Product market concentration (NAICS 4-digit)
2. Empirical Results
   - Sectors with increasing concentration attracted more inventors
   - Fall in inventors' productivity
3. Schumpeterian model with *defensive innovation:*
   - Explain mechanism
   - Discuss policy

Related Literature

- *Trends in innovation and R&D productivity*

  Acemoglu et al. (2018, 2021), Akcigit and Ates (2020), Akcigit and Kerr (2018), Bloom et al. (2020)

- *Increasing Concentration and Profits*

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

- *Competition and Innovation*

  Aghion et al. (2005), Akcigit and Ates (2020), Argente et al. (2020), Autor et al. (2021)

- *Models of Schumpeterian and Defensive innovation*

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

Data Construction

Empirical Analysis Objectives

- Identify "knowledge markets": labor markets for inventors with same skills
  - Build a network of flows of inventors across sectors
  - Identify sets of product markets that hire the same type of inventors

- *Within knowledge markets:*
  - Analyze how concentration and product markets' share of inventors are related
  - Evaluate effects of increased concentration on R&D productivity

Data Sources

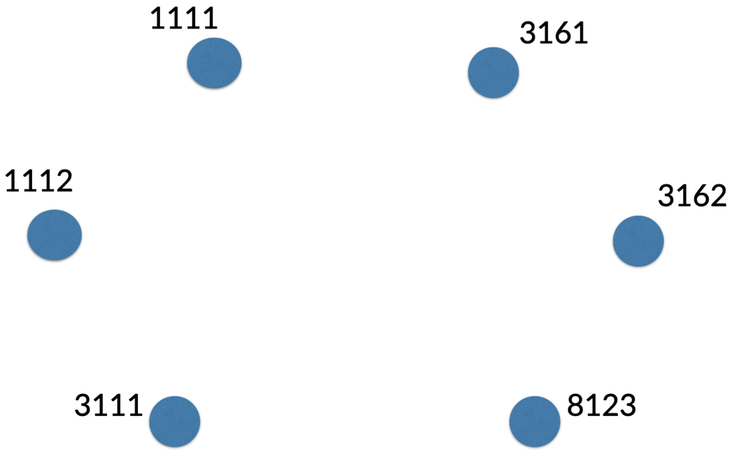
- USPTO (patent-year) and Goldschlag et al. (2016):
  - patent citation and disambiguated inventor id's, 1975-present;
  - Cooperative Patent Classification (CPC)
  - patent classification by NAICS of application (1978-2016)

- Economic Census and Keil (2017) (5-year-NAICS)
  - NAICS 4-digit concentration measure: HHI and HHI lower bound
  - 157 NAICS 4-digit sectors out of 304 business sectors
  - Most of manufacturing, retail, warehousing, telecommunications, publishing
  - Output per worker growth

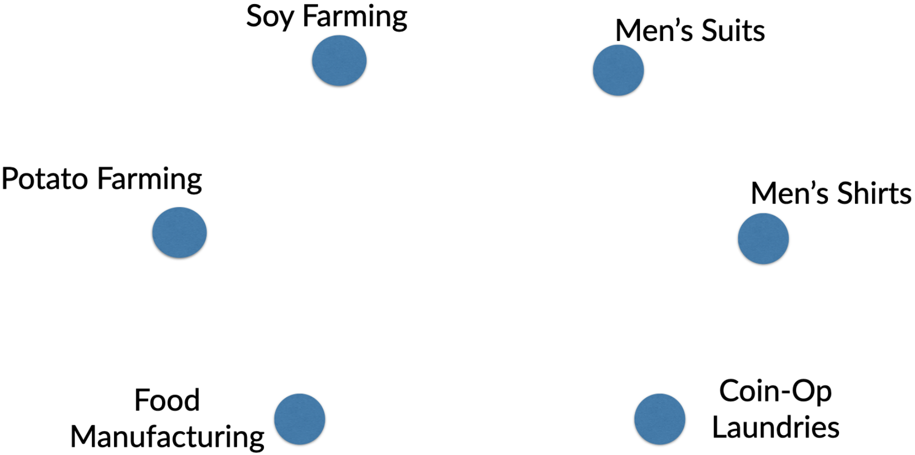
“Knowledge Markets”

- *Ideally*:
  - set of product markets with same *required knowledge* innovate
- *In practice:*
  - NAICS 4-digit sectors connected by flows of inventors
  - Identify flows from patents with disambiguated inventors
  - Group NAICS that have strongest connections

Building a Knowledge Market



Building a Knowledge Market



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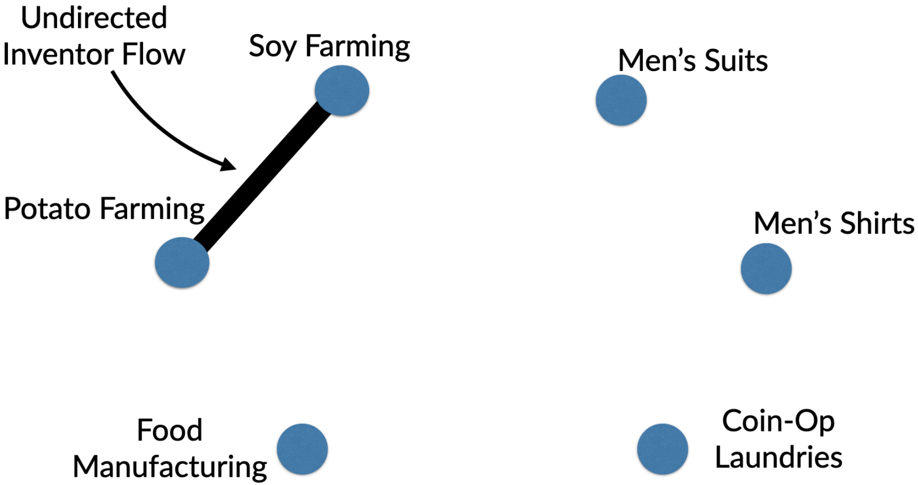

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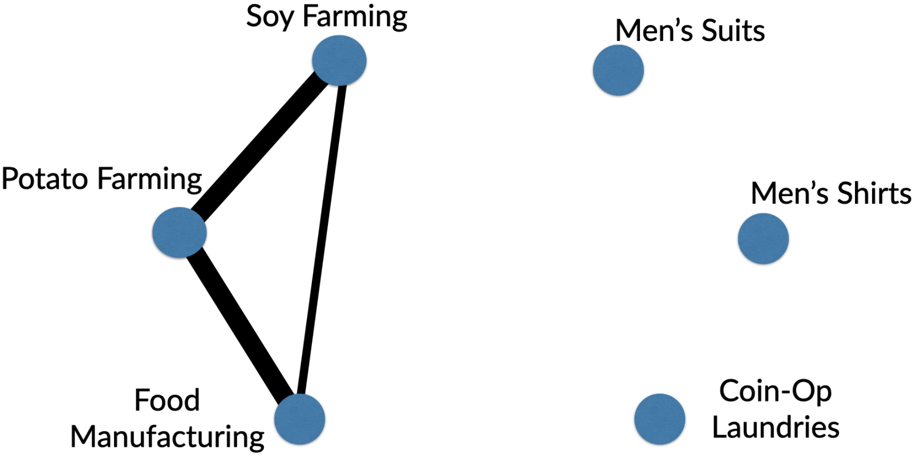

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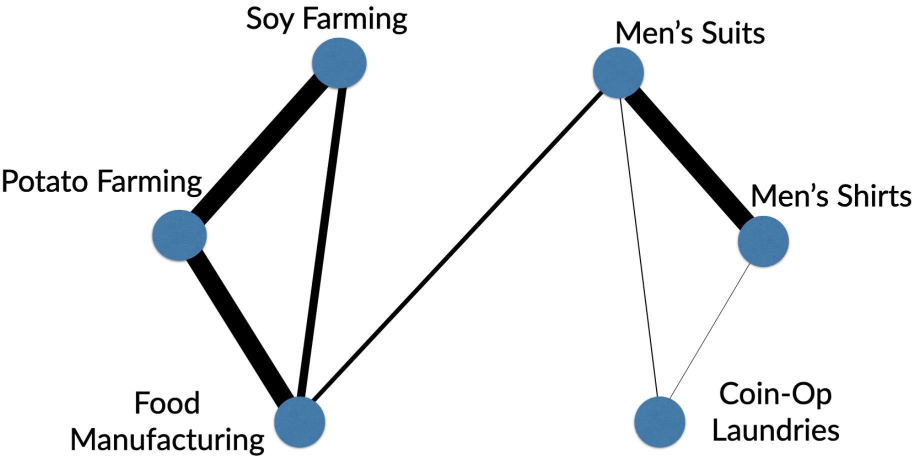

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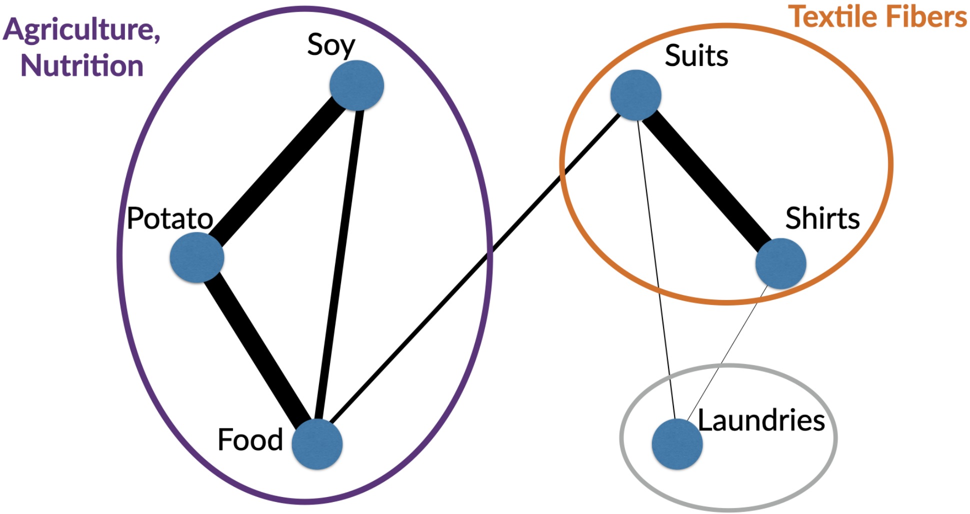

Constructing Inventor Flows

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

Constructing Inventor Flows

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US00001	00001-2	1112	1980
US00002	00001-1	3111	1981

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

NAICS 1	NAICS 2	Year	Total Flows
1111	1112	1980	2
1112	3111	1981	1

Weighting Flows: “Effective Inventors”

- Flows shall adjust for productivity of inventors who move
- *Effective inventors:*
  - "Productivity-adjusted" inventor. Fixed effect α_i in regression:

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

  - γ_{cft}: CPC class 1-digit, c, by firm (assignee), f, by year, t, fixed effect
  - Results robust to using raw number of inventors
- *Effective inventor flow from sector 1 to 2:*

$$\text{flow}_{1\to 2,t} = \sum_i \#\left\{i's \text{ transitions } 1 \to 2 \text{ in } t\right\} \cdot \alpha_i$$

Detecting Knowledge Markets: Network Weights

- Total undirected flows:

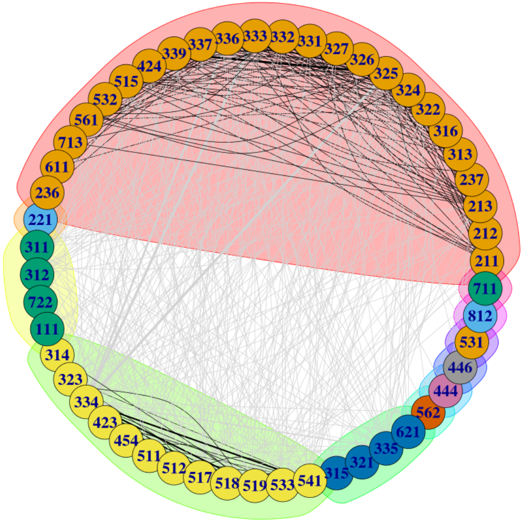
$$\text{flow}_{12} = \sum_t \left(\text{flow}_{1\to 2,t} + \text{flow}_{2\to 1,t}\right)$$

  used as network weights. Normalize to:
  - Avoid double-counting of inventors
  - Account for different sizes of sectors ▸ Details

Detecting Knowledge Markets: Algorithm

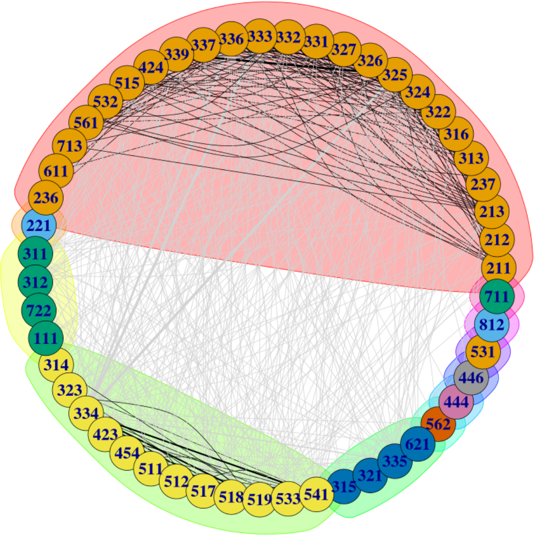
- Modularity maximization through Louvain community detection (Brodel et al., 2009). Formula and Algorithm
- Modularity: density of links *within* communities versus *between*
- Maximize over:
  - Number of communities $\mathbb{N}$ (Knowledge markets)
  - Assignment of nodes (sectors) to the $\mathbb{N}$ communities
- Result: 10 non-singleton sets of NAICS 4-digit that share inventors with non-missing HHI

Visualization at 3-digit NAICS



Features of Flows and Knowledge Markets

- Inventor flows between many different product markets!
- Orange: "Mining, Heavy Industry"
  Petroleum and Coal Products, Chemical, Machinery Manufacturing
- Green: "Food and Agriculture"
  Crop Production, Food Manufacturing, Beverage and Tobacco
- Yellow: "Communications, Electronics"
  Computer Products, Telecommunications, Data Processing



Empirical Analysis

Empirical Analysis Roadmap

- Merge knowledge market and inventor productivity data to sectors' concentration
- Look within *knowledge* markets, across products:
  - Regress inventors' share on product market concentration and controls
- Look within *product* markets:
  - Effect of increased concentration on inventors' productivity
  - Correlation between patent metrics and changes in inventors' share

Variable Definition

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

$$\text{Inventor Share}_{p,t} \equiv \frac{\sum_{p(i,t)=p} \alpha_i}{\sum_{k(i,t)=k} \alpha_i},$$

  - α_i are "effective inventors", or raw number of inventors
  - Averaged for 5 years *starting* in census years (same results with symmetric window)
- Market concentration: HHI
  - Economic Census only computes HHI for some sectors (80 in my sample)
  - But reports top 4, 8, 20, 50 firms' share for a majority (2/3)
  - Use $\underline{\text{HHI}}$: lower bound of HHI computed from top shares (Keil, 2017) Expression
- Size of sectors or firms: real sales, real sales per company (Economic Census)

Specification

- Long-difference 2012-1997 at NAICS 4-digit sector, p:

$$\Delta Share_{p,\,2012-1997} = f_k \mathbf{1}\{p \in k\} + \beta \Delta HHI_{p,\,2012-1997} + \gamma \Delta Size_{p,\,2012-1997} + \varepsilon_p,$$

- $f_k \mathbf{1}\{p \in k\}$: sector p belongs to knowledge market k
- $\Delta \mathrm{HHI}_p$: change in concentration
- $\Delta Size_{p,\,2012-1997}$: log-real sales of sector, per firm
- Weighted by sales, robust standard errors

Main Specification Results

▸ No Controls ▸ Census HHI ▸ Trim Outliers ▸ Raw Inventors

	Δ Inventor Share (pp)	
	(1)	(2)
$\Delta \underline{\text{HHI}}$	26.093*	22.509*
	(10.696)	(10.848)
Δ log Sales	0.914**	0.548*
	(0.278)	(0.243)
Knowledge Market FE		✓
Sample	Full Sample	Full Sample
Weight	Sales	Sales
Observations	157	153

Robust standard errors in parentheses, $+\ p < 0.1, ^{*}\ p < 0.05, ^{**}\ p < .01, ^{***}\ p < .001$

- $\Longrightarrow$1 s.d. increase in $\underline{\text{HHI}}$: .033 $\Longrightarrow \uparrow .858\text{pp}$ inventor share (.55 s.d.)
- Compares to average inventors' share of 1.16pp, median $.37\text{pp}$

Causality

Threats to causal interpretation:

- Inventors move towards expanding sectors/firms
  - Control for change in sales
  - Control for change in sales per company Table
- Reverse causality: increase in inventors drives higher concentration
  - Inventors' share computed on 5 years *starting* in Economic Census year
  - IV analysis using Mercatus regulation data Details

What Happens within Product 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

	Δ Growth/Inventor (pp)	
	(1)	(2)
$\Delta\underline{\text{HHI}}$	-0.332**	-0.292*
	(0.113)	(0.123)
Δ log Sales		-0.052*
		(0.021)
Knowledge Market FE	✓	✓
Sample	Full Sample	Full Sample
Weight	Sales	Sales
Observations	101	101

Robust standard errors in parentheses, $+$ $p < 0.1$,* $p < 0.05$,** $p < .01$,*** $p < .001$

Back-of-the-envelope Loss from Misallocation

- Median change in annual output per worker growth in sample : $-2.73\mathrm{pp}$
- Implied loss from misallocation for the median sector with Δ Inventor Share $>$ 0:

$$\Delta g = \frac{\Delta\left(\frac{g}{\mathrm{Inventor}}\right)}{\Delta\underline{\mathrm{HHI}}} \underbrace{\frac{\Delta\left(\frac{g}{\mathrm{Inventor}}\right)}{\Delta\underline{\mathrm{HHI}}}}_{\text{-.29}} \underbrace{\frac{\Delta\left(\frac{g}{\mathrm{Inventor}}\right)}{\Delta\underline{\mathrm{HHI}}}}_{\in[-.54,-.05]} \times \Delta\underline{\mathrm{HHI}} \times \underbrace{\Delta\underline{\mathrm{HHI}}}_{.0019} \times \mathrm{Inventors} \times \underbrace{\underline{\mathrm{Invent}}}_{1421}$$

- Misallocation would explain 28.6% of fall in growth (4.8% to 53%)
- 23% fall in output per worker growth for these sectors relative to 1997
- Similar results regressing of inventors' productivity on Δ Inventor Share

Recap of Key Results

- Within knowledge markets:
  - Sector that become more concentrated attract more inventors
- Within product markets, increasing concentration:
  - Lowers inventors' productivity (growth per inventor)
  - Increases share of inventors at top firms
  - Lowers forward citations

Model

Model Objectives

- Explain mechanism behind empirical facts
- Schumpeterian model *with defensive innovation*
  - Entrants give creative-destruction growth
  - Incumbents can engage in defensive innovation raising entrants' costs
- Empirical evidence of defensive innovation in Argente et al. (2020), model builds on Abrams et al. (2018)
- Calibrate two sectors, one knowledge market model to evaluate policy:
  - Optimal to subsidize entrants' R&D in concentrated sectors
  - Cost-neutral policy gives up to .28pp higher annual growth $(+10\%)$

Single-Sector: Market Structure ▸ Concentration v. Markup

Consumption good is C-D of intermediates:

$$\ln Y_t = \int_0^1 \ln y_t(i) di$$

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

- Incumbents' R&D gives:
  - a *patent wall* of size $\omega > 1$ w.p. 1, which raises entrants' costs,
  - an innovation w.p. $\lambda \in [0, 1]$.
- State of each market is the size of patent wall $\Omega \in \{1, \omega\}$
- Incumbents choose an innovation intensity x_I with costs:

$$C\left(x_I; w^{RD}\right) = \alpha_I \frac{x_I^\gamma}{\gamma} w^{RD}, \ \gamma > 1$$

- $\alpha_I \frac{x_I^\gamma}{\gamma}$ total incumbents' inventors
- Fix $w^{RD} = 1$ for now

Incumbents' Values

- Incumbents' normalized values $v = \frac{V(\Omega)}{Y}$ with constant output growth:

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

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

- $x_{e,1}, x_{e,\omega}$: total research intensity of entrants
- δ: depreciation of patent wall (patent protection)
- Gain from innovation depends on the difference between $x_{e,\omega}$ and $x_{e,1}$

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 $\zeta \times \Omega$:

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

- Finite demand IFF:

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

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):

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

One-Sector Equilibrium Proposition

Proposition

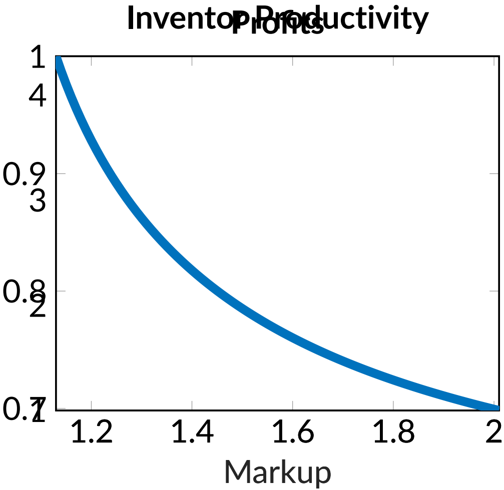
Consider the above model with a perfectly elastic production and R&D labor supply. Assume $\delta, \lambda = 0$, *and*

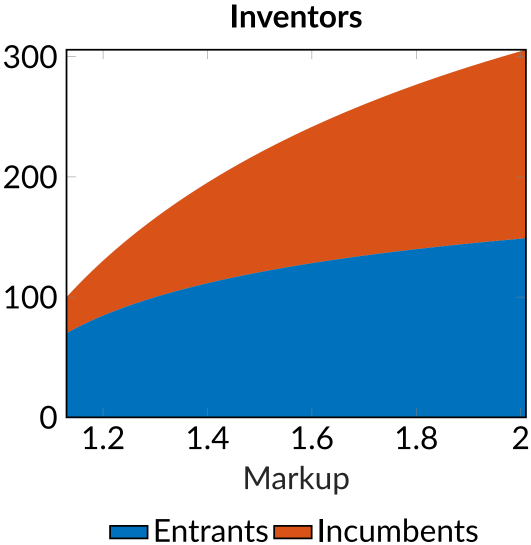
$$\sqrt{\frac{\phi - 1}{\phi}} \left(\frac{\alpha_I - \zeta\omega\left(\omega - 1\right)}{\alpha_I \zeta \omega} \right) > \rho.$$

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

- Sufficient conditions, holds for wider range of parameters in simulations

Single Sector Comparative Statics: Markup Increase





Calibration and Policy

Two-Sectors, Inventor Market Equilibrium

- Two Cobb-Douglas sectors as above:

$$\ln Y = \beta_1 \int_0^1 \ln y_{1,t}(i) di + (1 - \beta_1) \int_0^1 \ln y_{2,t}(i) di$$

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

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

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

External Calibration

Parameter Name	Symbol	Value	Source/Target
Discount rate	ρ	.04	4% annual real rate
Value Added Share	β	.5	Share of sectors with $\uparrow$ HHI
Average Sectors' Markup	ϕ	1.13	Incumbents' Relative Efficiency (Aghion et al., 2019)
Innovation Cost Curvature	γ	$1/.6$	Kortum (1993)
Patent Expiration Rate	δ	.05	Uruguay Round Agreements Act (1994)
Incumbent Innovation Probability	λ	.785	Internal patent share (Akcigit and Kerr, 2018)
Patent Wall Size	ω	1.469	Entry to patents elasticity (Hall and Helmers, 2015)

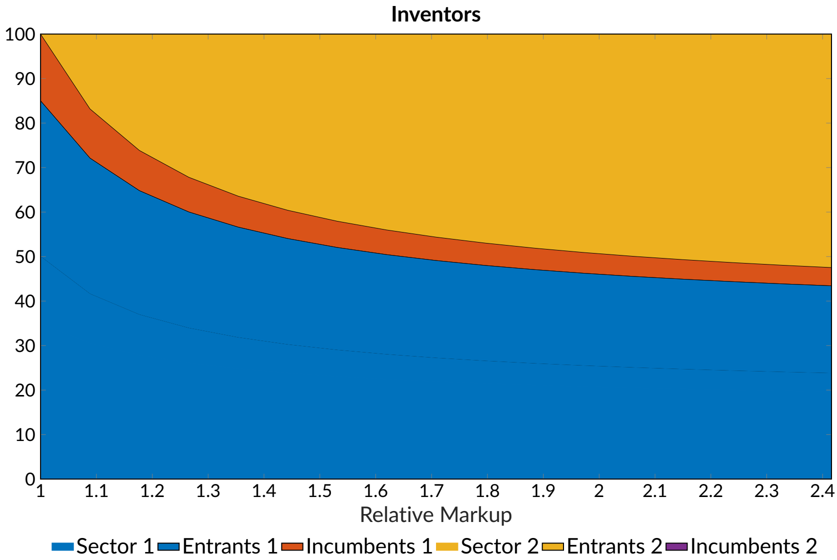
- τ, s: corp. tax 23% and R&D subsidy 19% (Akcigit et al., 2019)

Internal Calibration

- Internal calibration for α_I, ζ, η,
- Target R&D moments and average growth
- Lower fall in growth from misallocation than what implied by data (*about 1/5 of lower bound*)

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

CS: Increase in Sector 2 Markup



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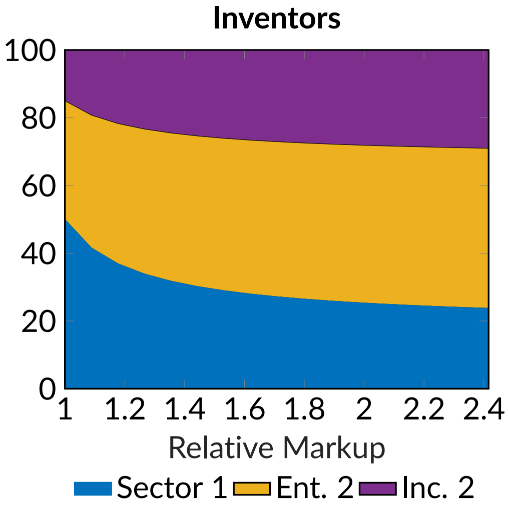

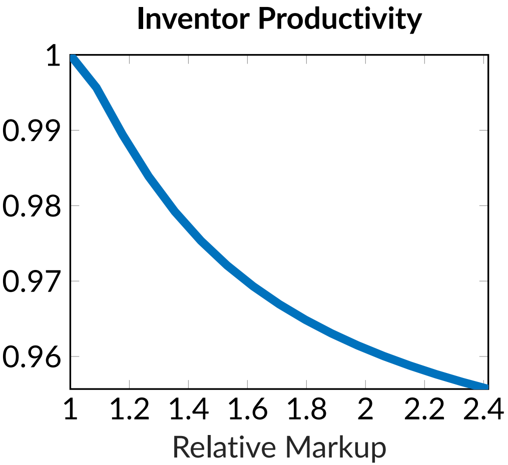

Growth-Maximizing Policy

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

Policy Results

	Baseline		Optimal Cost-Neutral		Cost-Neutral Sector		Cost-Neutral Entry	
	Sector 1 (1)	Sector 2 (2)	Sector 1 (3)	Sector 2 (4)	Sector 1 (5)	Sector 2 (6)	Sector 1 (7)	Sector 2 (8)
R&D Subsidies:								
s_I	19%	19%	0%	0%	41.90%	0%	0%	0%
s_e	19%	19%	0%	42.42%	41.90%	0%	28.25%	28.25%
Aggregates:								
L_I^{RD}	8.66	22.20	8.01	13.89	12.65	17.45	6.26	16.41
L_e^{RD}	27.36	41.78	26.44	51.66	32.42	37.47	30.61	46.72
L_{TOT}^{RD}	36.02	63.98	34.45	65.55	45.07	54.93	36.87	63.13
Sector Growth	1.91%	2.93%	1.85%	3.61%	2.27%	2.62%	2.14%	3.26%
GDP Growth	2.42%		2.73%		2.45%		2.7%	

$\Longrightarrow$ **Subsidizing entry** is the most effective policy: .28-.31pp higher growth

Conclusion

- Concentrating sectors attracted inventors away from competitive
- Incumbents increasingly deployed inventors to defensive projects
- Misallocation can explain 28.6% of 1997-2012 fall in annual output/worker growth
- Key model mechanism: *defensive innovation*
- Policy: entrant subsidies in *less competitive sectors*
- Cost-neutral entry subsidies give .28pp higher annual growth

Headlines

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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

Total Inventor Flows ▸ Back

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

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

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

$$\text{inflow}_{\text{NAICS}} = \sum_{n} \sum_{t} \sum_{i} \text{flow}_{n \to \text{NAICS},i,t},$$

Network Weights ▸ Back

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

$$share_{1\leftarrow 2} = \frac{\sum_t \sum_i flow_{2\rightarrow 1,i,t}}{inflow_1}$$

- Define weight:

$$W_{12} = W_{21} = \min\left\{\frac{share_{1\leftarrow 2} + share_{1\rightarrow 2}}{2}, \frac{share_{2\leftarrow 1} + share_{2\rightarrow 1}}{2}\right\}$$

- Average tends to overstate flows from small sectors to large

Problem: Maximize Modularity

Back

- Assigns sectors i to N *non-overlapping* communities c_i to maximize modularity

$$\max_{N} \max_{(c_1,\ldots,c_N)} Q \equiv \frac{1}{2\boldsymbol{W}} \sum_{ij} \left[W_{ij} - \frac{\boldsymbol{W}_i \boldsymbol{W}_j}{2\boldsymbol{W}} \right] \mathbb{1}\left\{ c_i = c_j \right\},$$

  - W_{ij}, weight of edge connecting node i to j
  - $\boldsymbol{W}_i = \sum_i W_{ik}$, sum of weights for edges with one end in node i, $\boldsymbol{W}$ sum of all weights in the graph
  - $\frac{\boldsymbol{W}_i \boldsymbol{W}_j}{2\boldsymbol{W}}$ is the expected number of weighted edges between nodes i and j

Louvain Algorithm ▸ Back

- Louvain method (Blodel et al., 2008). Assign each node to its own community. Then, repeat iteratively:
  1. Compute local deviations in modularity from reassigning the node to neighboring communities
  2. Move node in highest modularity direction
  3. Redefine a network with new communities as nodes

HHI Lower Bound

Back

- Keil, 2017:

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

- Coincides with actual if:
  - Sector has 50 or less firms
  - Shares are distributed equally between firms in brackets 0-4, 5-8, 9-20, 21-50
- Correlation with actual HHI is .93

IV Analysis: Regulation measure Back

- Regulation measure from Mercatus RegData 4.0
- Counts of regulation affecting NAICS 4d using text analysis
- Extended to all sectors with HHI using cosine-similarity between sector descriptions
- 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.

IV Regression: Reduced Form and First Stage

	Δ Inventor Share (pp)	$\Delta \underline{\mathrm{HHI}}$
	(1)	(2)
Δ log Restrictions	0.478*	0.016*
	(0.220)	(0.007)
Δ log Sales	0.539+	-0.000
	(0.274)	(0.005)
Knowledge Market FE	✓	✓
Sample	Full Sample	Full Sample
Weight	Sales	Sales
Observations	153	153

Robust standard errors in parentheses, $+ \ p < 0.1,^{*} \ p < 0.05,^{**} \ p < .01,^{***} \ p < .001$

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

Robust standard errors in parentheses, $+\ p < 0.1,^{*}\ p < 0.05,^{**}\ p < .01,^{***}\ p < .001$

No Controls Back

	Δ Inventor Share (pp)	
	(1)	(2)
$\Delta\underline{HHI}$	27.293*	
	(11.569)	
ΔHHI		22.399***
		(6.345)
Knowledge Market FE		
Sample	Full Sample	Full Sample
Weight	Sales	Sales
Observations	157	80

Robust standard errors in parentheses, $+\ p < 0.1$, $^{*}\ p < 0.05$, $^{**}\ p < .01$, $^{***}\ p < .001$

Main Specification: Actual HHI Back

	Δ Inventor Share (pp)					
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \underline{\mathrm{HHI}}$	27.293*		27.183*		27.326*	
	(11.569)		(11.941)		(11.620)	
$\Delta \mathrm{HHI}$		22.399***		22.399***		22.350***
		(6.345)		(6.345)		(6.343)
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

Robust standard errors in parentheses, $+ \; p < 0.1, ^{*} \; p < 0.05, ^{**} \; p < .01, ^{***} \; p < .001$

Main Specification: Robustness to Outliers

Back

	Δ Inventor Share (pp)					
	(1)	(2)	(3)	(4)	(5)	(6)
ΔHHI	26.093*	22.509*	25.904*	22.716*	26.111*	22.554*
	(10.696)	(10.848)	(11.124)	(10.948)	(10.725)	(11.019)
Δ log 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)
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

Robust standard errors in parentheses, $+\ p < 0.1,^{*}\ p < 0.05,^{**}\ p < .01,^{***}\ p < .001$

Robustness to Individual Firm Size ▸ Back

	Δ Inventor Share (pp)					
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \underline{HHI}$	35.230**	20.783+	35.230**	20.783+	35.154**	22.854*
	(12.759)	(10.615)	(12.759)	(10.615)	(12.647)	(11.197)
Δ log Size	0.175	-0.040	0.175	-0.040	0.300	-0.055
	(0.382)	(0.253)	(0.382)	(0.253)	(0.460)	(0.346)
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

Robust standard errors in parentheses, $+\ p < 0.1,^{*}\ p < 0.05,^{**}\ p < .01,^{***}\ p < .001$

Robustness to Raw Inventors ▸ Back

	Δ Inventor Share (pp)					
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\underline{\mathrm{HHI}}$	71.724+	67.160+	72.123+	67.736+	71.772+	68.398+
	(39.265)	(37.176)	(39.530)	(37.504)	(39.316)	(37.717)
Δ log 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)
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

Robust standard errors in parentheses, $+\ p < 0.1,^{*}\ p < 0.05,^{**}\ p < .01,^{***}\ p < .001$

Within-Sector Distribution ▸ Back

	Δ Top 10%/Bottom 50%	Δ Top 10%	Δ Bottom 50%
	(2)	(4)	(5)
$\Delta\underline{HHI}$	0.243*	0.018**	-0.008*
	(0.097)	(0.006)	(0.004)
Δ log Sales	0.328	0.026	0.005
	(0.294)	(0.020)	(0.007)
Knowledge Market FE	✓	✓	✓
Sample	Full Sample	Full Sample	Full Sample
Weight	Sales	Sales	Sales
Observations	118	118	118

Robust standard errors in parentheses, $+\ p < 0.1,^{*}\ p < 0.05,^{**}\ p < .01,^{***}\ p < .001$

Self-Citations ▸ Back

	Δ CPC group self-citations		Δ CPC subgroup self-citations	
	(1)	(2)	(3)	(4)
Δ Inventor Share (pp)	5.540**	5.244*	4.561***	4.110*
	(1.783)	(2.469)	(1.211)	(1.600)
Δ log Sales	-2.217	-2.099	-1.780	-1.780
	(1.879)	(1.976)	(1.287)	(1.265)
Knowledge Market FE		✓		✓
Sample	Full Sample	Full Sample	Full Sample	Full Sample
Weight				
Observations	145	144	145	144

Results for $\Delta \mathtt{Share}_p \in [-2, 2]$. Robust standard errors in parentheses, $+$ $p < 0.1$,* $p < 0.05$,** $p < .01$,*** $p < .001$

Forward Citations ▸ Back

	Δ log citations/patent		Δ patent generality
	(1)	(2)	(3)
Δ Inventor Share (pp)	-0.545***		-0.025*
	(0.113)		(0.012)
Δ log Sales	-0.232*		0.008
	(0.109)		(0.012)
4D Knowledge Market FE	✓		✓
Sample	Full Sample		Full Sample
Weight			
Observations	144		144

Results for $\Delta Share_p \in [-2, 2]$. Robust standard errors in parentheses, $+\ p < 0.1$, $^{*}\ p < 0.05$, $^{**}\ p < .01$, $^{***}\ p < .001$

Robustness for Inventor Productivity

Back

	Δ Growth/Inventor (pp)			
	(1)	(2)	(3)	(4)
$\Delta \underline{HHI}$	-0.332**	-0.292*	-0.332**	-0.290*
	(0.113)	(0.123)	(0.114)	(0.126)
Δ log Sales		-0.052*		-0.053*
		(0.021)		(0.022)
Knowledge Market FE	✓	✓	✓	✓
Sample	Full Sample	Full Sample	Mahalanobis 5%	Mahalanobis 5%
Weight	Sales	Sales	Sales	Sales
Observations	101	101	98	94

Robust standard errors in parentheses, $+\ p < 0.1,^{*}\ p < 0.05,^{**}\ p < .01,^{***}\ p < .001$

Lerner Index v. Concentration in Sample

Back

	Δ Lerner Index
	(2)
$\Delta\underline{\text{HHI}}$	1.652***
	(0.257)
Observations	258
R-squared	.14

Robust standard errors in parentheses, $+\ p < 0.1,^{*}\ p < 0.05,^{**}\ p < .01,^{***}\ p < .001$

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:

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

and output grows at a constant rate, g.

Stationary Distribution

Back

LOM:

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

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

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