Ownership Structure and Economic Growth

Koki Okumura

UCLA

Ownership Structure $\Longrightarrow$ Economic Growth?

- Corporate ownership is highly concentrated (Backus et al., 2021)
  - BlackRock, Vanguard, and State Street exercise about 30% of the votes at S&P 500 firms

Share

Ownership Structure $\Longrightarrow$ Economic Growth?

- Corporate ownership is highly concentrated (Backus et al., 2021) Share
  - BlackRock, Vanguard, and State Street exercise about 30% of the votes at S&P 500 firms

- Such concentration has led to a large literature and policy debates on common ownership
  - Implications for innovation: Lopez and Vives (2019); Kini et al. (2024); Anton et al. (2025)
  - Merger Guidelines raise concerns about the impact of common ownership on R&D

  Merger Guidelines

Ownership Structure $\Longrightarrow$ Economic Growth?

- Corporate ownership is highly concentrated (Backus et al., 2021) Share
  - BlackRock, Vanguard, and State Street exercise about 30% of the votes at S&P 500 firms
- Such concentration has led to a large literature and policy debates on common ownership
  - Implications for innovation: Lopez and Vives (2019); Kini et al. (2024); Anton et al. (2025)
  - Merger Guidelines raise concerns about the impact of common ownership on R&D

    Merger Guidelines
- Common ownership facilitates the internalization of inter-firm externalities
  - Rotemberg (1984); Azar and Vives (2021); Ederer and Pellegrino (2024)

Ownership Structure $\Longrightarrow$ Economic Growth?

- Corporate ownership is highly concentrated (Backus et al., 2021) Share
  - BlackRock, Vanguard, and State Street exercise about 30% of the votes at S&P 500 firms
- Such concentration has led to a large literature and policy debates on common ownership
  - Implications for innovation: Lopez and Vives (2019); Kini et al. (2024); Anton et al. (2025)
  - Merger Guidelines raise concerns about the impact of common ownership on R&D

    Merger Guidelines
- Common ownership facilitates the internalization of inter-firm externalities
  - Rotemberg (1984); Azar and Vives (2021); Ederer and Pellegrino (2024)
- Two inter-firm externalities of innovation (Aghion and Howitt, 1992; Bloom et al., 2013):

  − Business-stealing effect

  + Technology spillover effect

Ownership Structure $\Longrightarrow$ Economic Growth?

- Corporate ownership is highly concentrated (Backus et al., 2021) Share
  - BlackRock, Vanguard, and State Street exercise about 30% of the votes at S&P 500 firms
- Such concentration has led to a large literature and policy debates on common ownership
  - Implications for innovation: Lopez and Vives (2019); Kini et al. (2024); Anton et al. (2025)
  - Merger Guidelines raise concerns about the impact of common ownership on R&D
    Merger Guidelines
- Common ownership facilitates the internalization of inter-firm externalities
  - Rotemberg (1984); Azar and Vives (2021); Ederer and Pellegrino (2024)
- Two inter-firm externalities of innovation (Aghion and Howitt, 1992; Bloom et al., 2013):
  − Business-stealing effect
  + Technology spillover effect
- The aggregate effects of common ownership on R&D allocation and growth remain unknown

Quantitative Endogenous Growth Model with Ownership Structure

- Common ownership and technology spillovers span across industries $\Longrightarrow$ Firms internalize intra- and inter-industry externalities
  - Innovation networks: Scherer (1982); Acemoglu et al. (2016); Liu and Ma (2024)

Quantitative Endogenous Growth Model with Ownership Structure

- Common ownership and technology spillovers span across industries $\Longrightarrow$ Firms internalize intra- and inter-industry externalities
  - Innovation networks: Scherer (1982); Acemoglu et al. (2016); Liu and Ma (2024)

- In canonical endogenous growth models, each industry is infinitesimally small $\Longrightarrow$ if any, strategic interactions occur only within an industry
  - Monopolistic competition: Romer (1990); Klette and Kortum (2004)
  - Oligopoly with 2–4 firms in each industry: Aghion et al. (2001); Cavenaile et al. (2023)

Quantitative Endogenous Growth Model with Ownership Structure

- Common ownership and technology spillovers span across industries $\Longrightarrow$
  Firms internalize intra- and inter-industry externalities
  - Innovation networks: Scherer (1982); Acemoglu et al. (2016); Liu and Ma (2024)

- In canonical endogenous growth models, each industry is infinitesimally small $\Longrightarrow$
  if any, strategic interactions occur only within an industry
  - Monopolistic competition: Romer (1990); Klette and Kortum (2004)
  - Oligopoly with 2–4 firms in each industry: Aghion et al. (2001); Cavenaile et al. (2023)

- My framework is based on the endogenous growth model by Hopenhayn and Okumura (2025)
  - Hundreds or thousands of oligopolists engage in a dynamic R&D game
  - Product market rivalry networks (Pellegrino, 2024) and innovation networks
  - LQ differential game avoids the curse of dimensionality

Quantitative Endogenous Growth Model with Ownership Structure

- Common ownership and technology spillovers span across industries $\Longrightarrow$ Firms internalize intra- and inter-industry externalities
  - Innovation networks: Scherer (1982); Acemoglu et al. (2016); Liu and Ma (2024)

- In canonical endogenous growth models, each industry is infinitesimally small $\Longrightarrow$ if any, strategic interactions occur only within an industry
  - Monopolistic competition: Romer (1990); Klette and Kortum (2004)
  - Oligopoly with 2–4 firms in each industry: Aghion et al. (2001); Cavenaile et al. (2023)

- My framework is based on the endogenous growth model by Hopenhayn and Okumura (2025)
  - Hundreds or thousands of oligopolists engage in a dynamic R&D game
  - Product market rivalry networks (Pellegrino, 2024) and innovation networks
  - LQ differential game avoids the curse of dimensionality

- This paper incorporates ownership networks into Hopenhayn and Okumura (2025) $\Longrightarrow$ Overlap of networks determines the internalization of the two externalities

Model Environment

- Continuous time

Model Environment

- Continuous time
- Many granular firms

Model Environment

- Continuous time
- Many granular firms
- Markov perfect equilibrium

Model Environment

- Continuous time
- Many granular firms
- Markov perfect equilibrium
- Each firm produces a single differentiated product and engages in Cournot competition

Model Environment

- Continuous time
- Many granular firms
- Markov perfect equilibrium
- Each firm produces a single differentiated product and engages in Cournot competition
- Each firm invests in R&D to accumulate knowledge capital $z_{i,t}$

Model Environment

- Continuous time
- Many granular firms
- Markov perfect equilibrium
- Each firm produces a single differentiated product and engages in Cournot competition
- Each firm invests in R&D to accumulate knowledge capital $z_{i,t}$
- Strategic interaction through three (exogenous) inter-firm networks

Network	Notation	Measurement
Ownership	$\boldsymbol{K} = [\kappa_{ij}]$	Weight firm i places on firm j's value
Product market	$\boldsymbol{\Sigma} = [\sigma_{ij}]$	Substitutability between firms i and j's products
Innovation	$\boldsymbol{\Omega} = [\omega_{ij}]$	Technology spillover through $z_{i,t}$ and $z_{j,t}$

Key Properties of the Model

- (Stochastic) Balanced growth path with endogenous growth rate

Network	Notation	Measurement
Ownership	$\boldsymbol{K} = [\kappa_{ij}]$	Weight firm i places on firm j's value
Product market	$\boldsymbol{\Sigma} = [\sigma_{ij}]$	Substitutability between firms i and j's products
Innovation	$\boldsymbol{\Omega} = [\omega_{ij}]$	Technology spillover through $z_{i,t}$ and $z_{j,t}$

Key Properties of the Model

- (Stochastic) Balanced growth path with endogenous growth rate
- More overlap in $\boldsymbol{K}$ and $\boldsymbol{\Sigma} \Longrightarrow$ internalize business-stealing effects $\Longrightarrow$ R&D $\downarrow$

Network	Notation	Measurement
Ownership	$\boldsymbol{K} = [\kappa_{ij}]$	Weight firm i places on firm j's value
Product market	$\boldsymbol{\Sigma} = [\sigma_{ij}]$	Substitutability between firms i and j's products
Innovation	$\boldsymbol{\Omega} = [\omega_{ij}]$	Technology spillover through $z_{i,t}$ and $z_{j,t}$

Key Properties of the Model

- (Stochastic) Balanced growth path with endogenous growth rate
- More overlap in $\boldsymbol{K}$ and $\boldsymbol{\Sigma} \Longrightarrow$ internalize business-stealing effects $\Longrightarrow$ R&D $\downarrow$
- More overlap in $\boldsymbol{K}$ and $\boldsymbol{\Omega} \Longrightarrow$ internalize technology spillovers $\Longrightarrow$ R&D $\uparrow$

Network	Notation	Measurement
Ownership	$\boldsymbol{K} = [\kappa_{ij}]$	Weight firm i places on firm j's value
Product market	$\boldsymbol{\Sigma} = [\sigma_{ij}]$	Substitutability between firms i and j's products
Innovation	$\boldsymbol{\Omega} = [\omega_{ij}]$	Technology spillover through $z_{i,t}$ and $z_{j,t}$

Identification of Networks

- Identify networks for publicly listed patenting firms in the U.S. (>700 firms)

Network	Notation	Measurement
Ownership	$\boldsymbol{K} = [\kappa_{ij}]$	Institutional investor shareholdings
Product market	$\boldsymbol{\Sigma} = [\sigma_{ij}]$	Business descriptions (Hoberg and Phillips, 2016)
Innovation	$\boldsymbol{\Omega} = [\omega_{ij}]$	Patent classifications (Jaffe, 1986)

Impact of Common Ownership on R&D and Production

Production ownership structure	Dispersed	Dispersed	Common
R&D ownership structure	Dispersed	Common	Common
Total Output (Dispersed: 100)	100	100	97.3
Total R&D (Dispersed: 100)	100	69.8	86.4
Economic Growth Rate (%)	1.32	1.20	1.29
CE Welfare (Dispersed: 100)	100	99.4	97.3
Firm Value Share (%)	26.6	27.2	34.1

- Internalization of business-stealing > technology spillovers

Impact of Common Ownership on R&D and Production

Production ownership structure	Dispersed	Dispersed	Common
R&D ownership structure	Dispersed	Common	Common
Total Output (Dispersed: 100)	100	100	97.3
Total R&D (Dispersed: 100)	100	69.8	86.4
Economic Growth Rate (%)	1.32	1.20	1.29
CE Welfare (Dispersed: 100)	100	99.4	97.3
Firm Value Share (%)	26.6	27.2	34.1

- Internalization of business-stealing $>$ technology spillovers
- Less product market competition $\Longrightarrow$ Private return on R&D $\uparrow$

Impact of Common Ownership on R&D and Production

Production ownership structure	Dispersed	Dispersed	Common
R&D ownership structure	Dispersed	Common	Common
Total Output (Dispersed: 100)	100	100	97.3
Total R&D (Dispersed: 100)	100	69.8	86.4
Economic Growth Rate (%)	1.32	1.20	1.29
CE Welfare (Dispersed: 100)	100	99.4	97.3
Firm Value Share (%)	26.6	27.2	34.1

- Internalization of business-stealing $>$ technology spillovers
- Less product market competition $\Longrightarrow$ Private return on R&D $\uparrow$
- Internalization of business-stealing $>$ technology spillovers $+$ less product market competition

Conclusion

- Quantitative Schumpeterian growth model with ownership structure
  - Utilizes micro data and computational capabilities
- Common ownership in the U.S.:
  1. Internalization of business-stealing effect $\Longrightarrow g \downarrow\downarrow$
  2. Internalization of technology spillover effect $\Longrightarrow g \uparrow$
- Potential applications:
  - M&A / FDI
  - Conglomerate / Cross-shareholdings (e.g. Japan, Korea, Germany, AI companies AI)

Related Literature

- Competition and Innovation:
  d'Aspremont and Jacquemin (1988); Kamien et al. (1992); Ericson and Pakes (1995); Aghion et al. (2001, 2005); Acemoglu and Akcigit (2012); Aghion et al. (2013); Bloom et al. (2013); Lopez and Vives (2019); Peters (2020); Akcigit and Ates (2021, 2023); Cavenaile et al. (2023), **Hopenhayn and Okumura (2025)**
  Endogenous growth model with ownership networks

- Common Ownership:
  Rubinstein and Yaari (1983); Rotemberg (1984); Gutierrez and Philippon (2017); He and Huang (2017); Azar et al. (2018, 2022); Azar and Vives (2021); Anton et al. (2023), **Kini et al. (2024); Anton et al. (2025)**
  Macroeconomic implications of common ownership for R&D allocation and growth

- Oligopoly / Hedonic Demand:
  Lancaster (1966); Rosen (1974); Berry et al. (1995); Nevo (2001); Neary (2003); Atkeson and Burstein (2008); Autor et al. (2020), **Pellegrino (2024); Ederer and Pellegrino (2024)**
  Dynamic general equilibrium model / R&D / technology spillovers

Preference and Production Technology (1/2)

- Continuous time
- Risk-neutral representative household:

$$U_t = \int_t^{\infty} \exp\left(-\rho(s-t)\right) C_s ds$$

- Production labor is inelastically supplied
- Final goods are used for consumption and R&D
- Firm $i \in \{1, \ldots, n\}$ produces a single differentiated intermediate good
- Linear-quadratic aggregator (Pellegrino, 2024):

$$Y_t = \boldsymbol{q}_t^T \boldsymbol{b}_t - \frac{1}{2} \boldsymbol{q}_t^T \boldsymbol{\Sigma} \boldsymbol{q}_t$$

  - $\boldsymbol{b}_t = [b_{1,t}, \ldots, b_{n,t}]^T$: product quality vector (endogenous)
  - $\boldsymbol{\Sigma} = \left[\sigma_{ij}\right]$: product-market rivalry matrix (exogenous) $(\sigma_{ii} = 1)$

Preference and Production Technology (2/2)

- Final goods price is normalized to 1
- Linear inverse demand:

$$p_{i,t} = b_{i,t} - \sum_{j \neq i} \sigma_{ij} q_{j,t} - q_{i,t}$$

- CRS intermediate-good production technology:

$$q_{i,t} = a_{i,t} l_{i,t}$$

- Each firm i has knowledge capital $z_{i,t}$
- Firms allocate knowledge capital to improve labor productivity and product quality:

$$\zeta a_{i,t} + b_{i,t} = z_{i,t}$$

Law of Motion of Knowledge Capital

$$\dot{\boldsymbol{z}}_t = \underbrace{\boldsymbol{\Omega} \boldsymbol{z}_t}_{\text{Tech Spillover}} + \underbrace{\mu \boldsymbol{x}_t}_{\text{R\&D}} - \underbrace{\delta \boldsymbol{z}_t}_{\text{Depreciation}}$$

- $\boldsymbol{\Omega} = \left[\omega_{ij}\right]$: technology spillover matrix / innovation networks
- $x_{i,t} = \sqrt{d_{i,t}}$
  - $d_{i,t}$: R&D input in terms of final good
  - Innovation elasticity $d \log \text{(firm value)} / d \log \text{(R\&D cost)} = 0.5$
- μ, δ: positive scalars
- Can incorporate (idiosyncratic / aggregate) shocks (not today)

Market Clearing

- Final good market clearing:

$$Y_t = C_t + \underbrace{\sum_i d_{i,t}}_{\text{R\&D input}}$$

- Inelastic production labor supply:

$$L = \sum_i l_{i,t}$$

Ownership Networks: Common Ownership Weights

- $\boldsymbol{K} = [\kappa_{ij}]$: common ownership weights that firm i places on the value of firm j $\quad (\kappa_{ii} = 1)$
- More overlapping ownership between firms i and $j \implies$ higher κ_{ij}
- $\boldsymbol{K} = \boldsymbol{I}$: dispersed ownership (each firm maximizes its own value)
- $\boldsymbol{K} = \mathbf{1}_{n\times n}$: monopoly (maximizes total producer surplus)

Proportional Influence (Rotemberg, 1984)

- Baseline corporate governance assumption to map shareholding data to κ_{ij}
- $o \in \{1, 2, \dots, n_o\}$: owners
- s_{io}: the proportion of shares in firm i owned by owner o where $\sum_o s_{io} = 1$
- $\widehat{V}_i$: value of firm i
- $\widetilde{V}_o \equiv \sum_i s_{io} \widehat{V}_i$: value of owner o
- Firm i's objective:

$$\sum_o s_{io} \widetilde{V}_o \propto \sum_j \kappa_{ij} \widehat{V}_j$$

where

$$\kappa_{ij} \equiv \frac{\boldsymbol{s}_i^T \boldsymbol{s}_j}{\boldsymbol{s}_i^T \boldsymbol{s}_i} = \cos\left(\boldsymbol{s}_i, \boldsymbol{s}_j\right) \sqrt{\frac{\text{Investor HHI}_j}{\text{Investor HHI}_i}} \quad \text{where} \quad \boldsymbol{s}_i \equiv \left[s_{i1}, \dots, s_{io}, \dots, s_{in_o}\right]^T$$

Markov Perfect Equilibrium

- Given other firms' strategies, firm i chooses $\left\{a_{i,t}, b_{i,t}, q_{i,t}, x_{i,t}\right\}_{t\geq 0}$ to maximize

$$\max_{\left\{a_{i,t}, b_{i,t}, q_{i,t}, x_{i,t}\right\}_{t\geq 0}} V_i\left(z_0\right) \equiv \int_0^\infty \exp\left(-\rho t\right) \sum_j \kappa_{ij} \left(\underbrace{\pi_{j,t}}_{\text{Gross Profit}} - \underbrace{d_{j,t}}_{\text{R\&D Cost}} \right) dt$$

- Markov perfect equilibrium can be solved by the following steps:
  1. Static Game: For each t, choose $\left\{a_{i,t}, b_{i,t}, q_{i,t}\right\}$ to maximize $\sum_j \kappa_{ij}\pi_{j,t}$.
  2. Dynamic Game: Given the static strategy profile, choose $\{x_{i,t}\}$ to maximize $V_i\left(z_0\right)$

Static Cournot Game

- Firm i's static objective is given by:

$$\sum_j \kappa_{ij}\pi_{j,t}$$

where the profit (before R&D cost) of firm i is given by:

$$\pi_{i,t} = p_{i,t}q_{i,t} - w_t l_{i,t} = q_{i,t}\left(b_{i,t} - \sum_{j\neq i}\sigma_{ij}q_{j,t} - q_{i,t} - \frac{w_t}{a_{i,t}}\right)$$

Assumption

Given w_t, $z_{i,t}$, and $\{a_{j,t}, b_{j,t}, q_{j,t}\}_{j\neq i}$ and $\zeta a_{i,t} + b_{i,t} = z_{i,t}$, firm i chooses $a_{i,t}$, $b_{i,t}$, and $q_{i,t}$ to maximize $\sum_j \kappa_{ij}\pi_{j,t}$

Dynamic R&D Game $\Longrightarrow$ Linear-Quadratic Differential Game

- Given other firms' R&D $\{x_{j,t}\}_{j\neq i,\, t\geq 0}$, firm i chooses R&D $\{x_{i,t}\}_{t\geq 0}$ to maximize

$$\max_{\{x_{i,t}\}_{t\geq 0}} \quad V_i(\boldsymbol{z}_0) \equiv \int_0^{\infty} \exp(-\rho t) \sum_j \kappa_{ij} \left(\pi_{j,t} - d_{j,t}\right) dt$$

  - Gross profit: $\sum_j \kappa_{ij} \pi_{j,t} = \boldsymbol{z}_t^T \boldsymbol{Q}^i \boldsymbol{z}_t$ Q
  - R&D cost: $\sum_j \kappa_{ij} d_{j,t} = \sum_j \kappa_{ij} x_{j,t}^2$
  - Law of motion: $\dot{\boldsymbol{z}}_t = \boldsymbol{\Omega} \boldsymbol{z}_t + \mu \boldsymbol{x}_t - \delta \boldsymbol{z}_t$

- Firm i's HJB equation:

$$\rho V_i(\boldsymbol{z}) = \max_{x_i} \left\{ \boldsymbol{z}^T \boldsymbol{Q}^i \boldsymbol{z} - \sum_j \kappa_{ij} x_j^2 + V_{\boldsymbol{z}}^i(\boldsymbol{z}) \left[\boldsymbol{\Omega} \boldsymbol{z} + \mu \boldsymbol{x} - \delta \boldsymbol{z} \right] \right\}$$

HJB Equations $\Longrightarrow$ Riccati Equations

- Guess and verify $V_i(z) = z^T X^i z$ (for any z)
- X^i is the solution of stacked algebraic Riccati equations

  Riccati Equations

- Public & patenting firms in the U.S. in our dataset > 700 firms $\Longrightarrow$
  $\underbrace{700 \times 700}_{\text{size of } X^i} \times \underbrace{700}_{n} = 343$ million undetermined coefficients (< 1 min on my laptop)

Schumpeterian growth model with oligopolistic competition	Computation time	# of firms in each game	Productivity space
Cavenaile et al. (2023)	$O(2^n)$	4	6 grid
HO (2025), This paper	$O(n^4)$	>700	Continuous

Transition

BGP

- Linear R&D strategy: $x_t = \mu \widetilde{X} z_t$ where $\widetilde{X} = \left[X_1^1 \ \cdots \ X_n^n \right]^T$ and X_i^i is the ith column of X^i
- The law of motion is rewritten as $\dot{z}_t = \Phi z_t$ where

$$\Phi \equiv \underbrace{\Omega}_{\text{Tech Spillover}} + \underbrace{\mu^2 \widetilde{X}}_{\text{R\&D}} - \underbrace{\delta I}_{\text{Depreciation}}$$

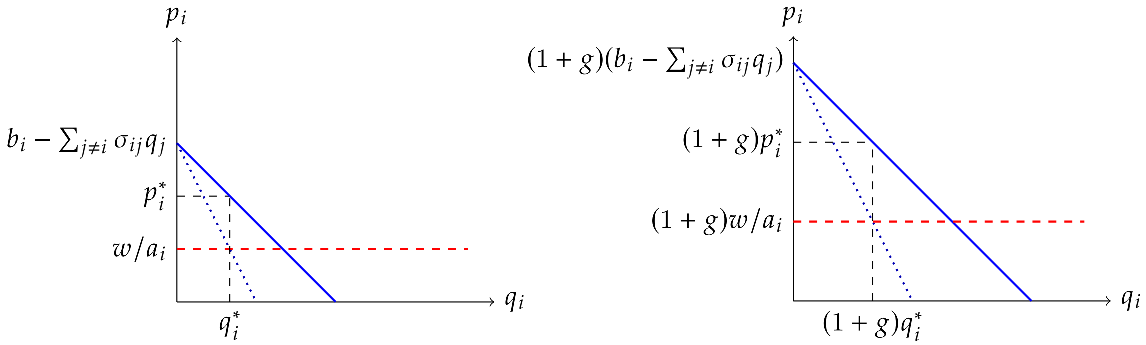
Theorem

If Φ is irreducible, then:
(i) There exists a largest positive eigenvalue of Φ, g, and an associated positive eigenvector, z^*.
(ii) There exists a globally stable BGP such that the knowledge capital growth rate of all firms is g, and the knowledge capital distribution is a scalar multiple of z^*.

- Proof: Perron–Frobenius Theorem
- “Φ is irreducible” $\Longleftrightarrow$ “All firms are directly or indirectly connected technologically”

Symmetric Example

CES on BGP despite Non-CES Demand



- a_i, b_i, $q_i (= a_i l_i)$, p_i, and w/a_i grow at the same rate g
- (i) (consumer surplus / producer surplus) and (ii) markup stay the same
- Demand elasticity is constant on BGP despite linear demand

Lifetime Utility

- Lifetime utility is expressed in quadratic form:

$$\int_t^\infty \exp\left(-\rho s\right) C_s ds = \boldsymbol{z}_t^T X \boldsymbol{z}_t$$

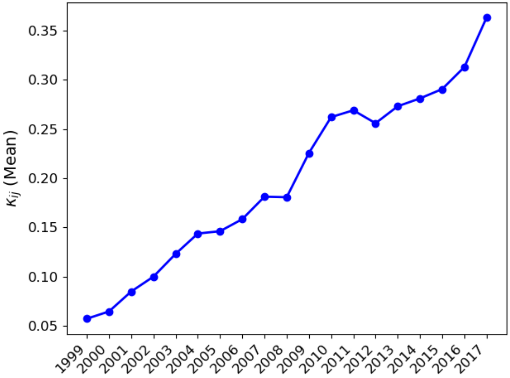
X

- Solve the equilibrium once $\Longrightarrow$ we can compute lifetime utility for any initial z_t
- This property holds for expected utility even if we introduce (idiosyncratic / aggregate) shocks
- In the exercise, we focus on the transition dynamics starting from the observed initial z_t

Common Ownership Weights K

- Backus et al. (2021) construct a dataset on institutional investors' holdings based on Form 13F
- Baseline: proportional influence (Rotemberg, 1984)

Proportional Influence



Product-Market Rivalry Σ

- Hoberg and Phillips (2016) estimates product proximity using business descriptions in 10-K
- Pellegrino (2024) estimates α to align with the cross-price elasticity of demand

$$\underbrace{\sigma_{ij}}_{\text{substitutability}} = \alpha \times \text{product proximity between } i \text{ and } j \quad (i \neq j)$$

micro estimates

Technological Proximity $\widetilde{\mathbf{\Omega}}$

- Technological profile of firm i
  - The vector of the share of patents held by firm i in each technology class
  - Baseline: group-level patent classifications (≈ 4000), five years window
- Jaffe (1986) technological proximity measure $\tilde{\omega}_{ij}$:
  - Cosine similarity of the technological profiles between firms i and j
  - Impose $\sum_{j \neq i} \tilde{\omega}_{ij} = 1$ for each i

Distribution of Knowledge Capital z_t

Variables	Identification
$\pi_{i,t}$	Gross profit (before R&D cost) = Revenue − Cost of goods sold
$\boldsymbol{q}_t$	$\pi_{i,t} = \sum_j \kappa_{ij}\,\sigma_{ij}\,q_{i,t}\,q_{j,t}$
ζ/L	Matches sample firms' cost share (average markup)
$\boldsymbol{z}_t$	$\boldsymbol{z}_t = \left\{2\frac{\zeta}{L}\mathbf{1}_{n\times n} + \boldsymbol{\Sigma} + \boldsymbol{K}\circ\boldsymbol{\Sigma}\right\}\boldsymbol{q}_t$

- Observed z_t is used to
  1. estimate the law of motion of knowledge capital, and
  2. identify the initial distribution of knowledge capital

Technology Spillover $\mathbf{\Omega} = \beta \times$Technological Proximity $\widetilde{\mathbf{\Omega}}$ First Stage

$$\log z_{i,t+1} - \log z_{i,t} = \beta \sum_{j \neq i} \tilde{\omega}_{ij,t} \frac{z_{j,t}}{z_{i,t}} + \text{Controls}_{i,t} + \epsilon_{i,t}$$

	(1)	(2)	(3)
	$\log z_{i,t+1} - \log z_{i,t}$	$\log z_{i,t+1} - \log z_{i,t}$	$\log z_{i,t+1} - \log z_{i,t}$
$\sum_{j \neq i} \tilde{\omega}_{ij,t} \frac{z_{j,t}}{z_{i,t}}$	0.026**	0.024**	0.073*
	(0.010)	(0.010)	(0.038)
$\frac{x_{i,t}}{z_{i,t}}$		0.514***	
		(0.063)	
Firm & Year FEs	✓	✓	✓
Controls	✓	✓	✓
IV			✓
Observations	14,576	14,576	14,576

SEs clustered by years and 4-digit NAICS industries are reported in parentheses. Control variables include $\log z_{i,t}$, firm fixed effects, and year fixed effects. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

- IV: User cost of R&D, driven by federal and state-specific rules variations (Bloom et al., 2013)

Identification: Summary

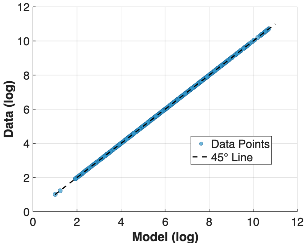
- Publicly available data + Compustat

Notation	Description	Value	Source
$\boldsymbol{\Sigma}$	Product proximity		Form 10-K, Hoberg and Phillips (2016)
$\widetilde{\boldsymbol{\Omega}}$	Technological proximity		USPTO, Patent classification
$\boldsymbol{K}$	Common ownership weights		Form 13F, Backus et al. (2021)
α	Product proximity $\longrightarrow$ Substitutability	0.120	Pellegrino (2024)
β	Technological proximity $\longrightarrow$ Spillovers	0.024	Estimated from the law of motion
ζ/L	Labor-augmenting efficiency	0.004	Compustat, Cost of goods sold
ρ	Discount rate	0.100	
μ	R&D efficiency	0.066	2.6% R&D share (moment match)
δ	Depreciation rate	0.017	1.2% economic growth rate (moment match)

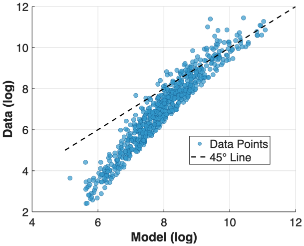
Network Correlation

Model vs. Data: Firm-level Profits, Sales, and R&D

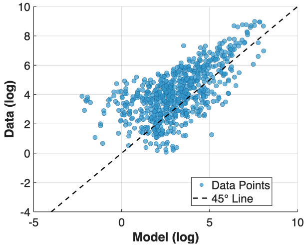
- Comparison of firm-level model-generated values (x-axis) with observed data (y-axis)



(a) Log of Profit (Targeted)



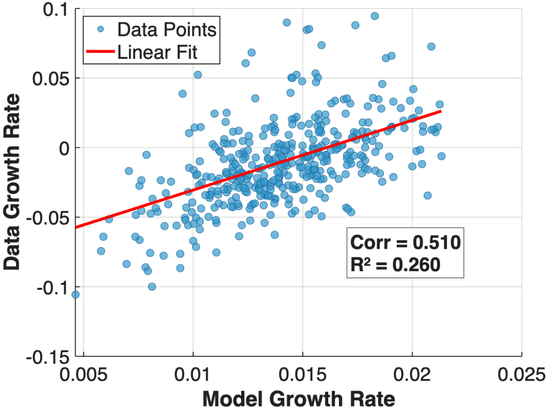
(b) Log of Sales



(c) Log of R&D Expenditure

Model vs. Data: Firm-level Growth Rates

- Data: Average growth rate of $z_{i,t}$ between 2010 and 2017
- Model: Networks and initial knowledge capital in 2010



Model vs. Data: Comparison with Anton et al. (2025)

- Anton et al. (2025) estimates the effect of interaction b/w common ownership and technology/product proximity on R&D

$$\log\left(1+\text{R\&D}_{it}/A_{it}\right) = \gamma_1 \log\left(\sum_{j\neq i}\kappa_{ijt}\text{tech proximity}_{ijt}G_{jt}\right) + \gamma_2 \log\left(\sum_{j\neq i}\kappa_{ijt}\text{product proximity}_{ijt}G_{jt}\right) + \text{Controls}_{it} + \text{Firm FEs}_i + \text{Year FEs}_t + \varepsilon_{ijt}$$

	$\text{R\&D}_{it}$	A_{it}	G_{it}	Sample period
Anton et al. (2025)	Observed R&D	Assets	R&D stocks	1985–2015
Our model	Model-generated R&D	Knowledge capital	Knowledge capital	1999–2017

	Anton et al. (2025)	Our model
$\log\left(\sum_{j\neq i}\kappa_{ijt}\text{tech proximity}_{ijt}G_{jt}\right)$	0.00513^{**} (0.00226)	0.00194^{***} (0.000272)
$\log\left(\sum_{j\neq i}\kappa_{ijt}\text{product proximity}_{ijt}G_{jt}\right)$	-0.00457^{**} (0.00222)	-0.00547^{***} (0.000693)

Counterfactual Ownership Structures

Ownership Structure	Description
Baseline	Observed common ownership structure in 2017
Mean=1999	$\kappa_{ij,2017}^{M1999} = \text{const} \times \kappa_{ij,2017}$ and $\boldsymbol{E}\left[\kappa_{ij,2017}^{M1999}\right] = \boldsymbol{E}\left[\kappa_{ij,1999}\right]$ for $j \neq i$
Dispersed	$\boldsymbol{K}^{D} = \boldsymbol{I}$
Monopoly	$\boldsymbol{K}^{M} = \mathbf{1}_{n\times n}$

Total R&D Expenditure

- For the moment, assume that ownership structure only affects R&D decisions
  - Product-market competition: firms maximize gross profits (dispersed ownership)

Total R&D in 2017 (Optimal R&D: 100)	Ownership Structure			
	Dispersed	Mean=1999	Baseline	Monopoly
Both	40.5	38.7	28.3	21.4
Only Business Steal $\mathbf{\Omega} = [0]$	52.0	49.7	36.4	30.7
Only Tech Spill $\mathbf{\Sigma} = \boldsymbol{I},\ \zeta/L = 0$	13.6	14.3	19.3	27.8

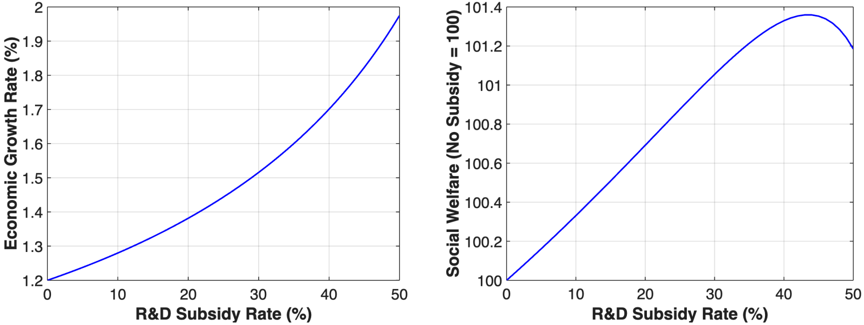
- Internalization of business-stealing $>$ internalization of technology spillovers

Total R&D, Growth Rate, Social Welfare, Firm Value Share

	Ownership Structure			
	Dispersed	Mean=1999	Baseline	Monopoly
Total R&D (Optimal R&D: 100)	40.5	38.7	28.3	21.4
Economic Growth Rate (%)	1.32	1.31	1.20	1.11
CE Welfare (Optimal R&D: 100)	94.9	94.9	94.4	93.5
Firm Value Share (%)	26.6	26.7	27.2	27.8

- The rise of common ownership from 1999 to 2017 $\Longrightarrow g \downarrow$ by 0.11 p.p., CE welfare $\downarrow$ by 0.54%

Optimal Uniform R&D Subsidy



(a) Economic Growth (b) Social Welfare

- Optimal rate is $s = 43\%$, which increases g by 0.57 pp and CE welfare by 1.4%
- c.f. Welfare gains from optimal R&D allocation: 6.0%

Which Firms' R&D Should be Subsidized?

	Private R&D x	Social / Private value of R&D
Initial knowledge capital z	0.12***	-0.00021
	(0.00085)	(0.00016)
Product market centrality	-16***	-1.1***
	(0.29)	(0.053)
Technology spillover centrality	5.5***	1.5***
	(0.42)	(0.079)
Ownership structure centrality	-7.2***	0.58***
	(0.24)	(0.045)
Intercept	-22***	0.90***
	(0.26)	(0.048)
Observations	740	740
R^2	0.98	0.56

Alternative Corporate Governance Models

1. Dispersed onwership: $\kappa_{ij}^{D} = 0 \quad (i \neq j)$
2. Baseline proportional influence: $\kappa_{ij} = \frac{\sum_o s_{io} s_{jo}}{\sum_o s_{io}^2}$
3. Super-proportional influence: $\kappa_{ij}^{SP} = \frac{\sum_o \gamma_{io} s_{io} s_{jo}}{\sum_o \gamma_{io} s_{io}^2}$ where $\gamma_{io} = \sqrt{s_{io}}$
4. Blockholder influence: $\kappa_{ij}^{BH} = \frac{\sum_o b_{io} s_{io} s_{jo}}{\sum_o s_{io}^2} \quad (i \neq j)$, where $b_{io} = 1$ if $s_{io} > 5\%$
5. Structural estimation in the airline industry by Azar and Ribeiro (2021): $\kappa_{ij}^{AR} = \tau_i \kappa_{ij} \quad (i \neq j)$
   - 5.1 Uniform: $\tau = 0.29$
   - 5.2 Firm-specific: $\tau_i = \frac{\exp[\theta_0 + \log(\text{Investor HHI}_i)]}{1 + \exp[\theta_0 + \log(\text{Investor HHI}_i)]}$ where $\theta_0 = 2.68$

Alternative Corporate Governance Models

	Ownership Structure					
	Dispersed Ownership	Baseline: Proportional Influence	Super Proportional Influence	Blockholder Influence	AR Uniform	AR Firm-Specific
Total R&D Expenditure	100	69.8	69.0	77.5	90.3	90.4
Growth Rate (%)	1.32	1.20	1.19	1.23	1.29	1.29
CE Welfare	100	99.4	99.4	99.6	99.9	99.9
Firm Value Share (%)	26.6	27.2	27.2	27.1	26.8	26.8

- Internalization of business-stealing > internalization of technology spillovers

Share of Top 5 Shareholders in Largest Market Cap Firms

Back

Microsoft	
Vanguard	9.20%
Blackrock	7.75%
Steven Ballmer	4.48%
State Street	3.97%
Fidelity	2.66%

Nvidia	
Vanguard	8.93%
BlackRock	7.74%
Fidelity	4.12%
State Street	3.97%
Jensen Huang	3.80%

Apple	
Vanguard	9.29%
Blackrock	7.48%
State Street	3.96%
Fidelity	2.27%
Geode Capital	2.26%

Google	
Vanguard	7.36%
Blackrock	6.47%
State Street	3.39%
Fidelity	3.01%
Sergey Brin	2.99%

Amazon	
Jeffrey Bezos	8.58%
Vanguard	7.77%
Blackrock	6.50%
State Street	3.44%
Fidelity	3.10%

Meta	
Vanguard	7.55%
Blackrock	6.50%
Fidelity	5.38%
Accel IX LP	3.88%
State Street	3.40%

Merger Guidelines

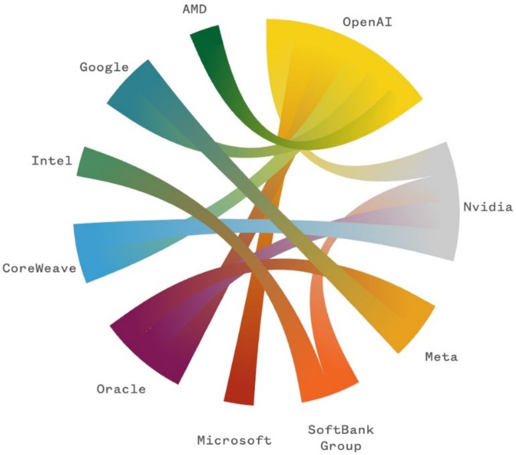
Back

"For example, the partial owner may decide not to develop a new product feature to win market share from the firm in which it has acquired an interest, because doing so will reduce the value of its investment in its rival."

2023 Merger Guidelines by the U.S. Department of Justice and the Federal Trade Commission

Cross Shareholdings among AI Companies

Back



Source: Wallstreetcn.com

Technology & Product Proximity: Example

Tesla vs. Ford	
Technology Proximity	0.11
Product Proximity	0.15

Apple vs. Intel	
Technology Proximity	0.57
Product Proximity	0.00

Empirical Literature: Common Ownership $\Longrightarrow$ R&D

- Anton et al. (2025):
  - Dependent variables: R&D, citation-weighted patents, market value of patents
    - $+$ Interaction term between common ownership and technology proximity
    - $-$ Interaction term between common ownership and product proximity
- Kini et al. (2024): DiD that exploits mergers between financial institutions
  - Dependent variables: Investments, new product development
    - $+$ Post (merger) $\times$ treatment (common owner) $\times$ technology proximity

R&D Externalities

1. Business-stealing effect
   - Innovators steal the business (profits) of other firms
2. Technology spillover effect
   - Innovation improves the productivity of other firms
3. Appropriability effect (market power)
   - Innovators cannot appropriate the entire consumer surplus

Generalized Hedonic-Linear Demand (Pellegrino, 2024)

- $i \in \{1, 2, ..., n\}$: firms / products
- 1 unit of product i provides
  - 1 unit of idiosyncratic characteristic $k \in \{1, 2, ..., n\}$
  - $\psi_{k,i}$ unit of shared characteristic $k \in \{n+1, n+2, ..., n+n_k\}$ where $\sum_k \psi_{k,i}^2 = 1$
- Aggregate each characteristic:

$$y_{k,t} = \begin{cases} q_{k,t} & k = 1, 2, ..., n \\ \sum_i \psi_{k,i} q_{i,t} & k = n+1, n+2, ..., n+n_k \end{cases}$$

- Linear-quadratic aggregator over characteristics:

$$Y_t = (1-\alpha) \sum_{k=1}^{n} \left(\underbrace{\hat{b}_{k,t} y_{k,t} - \frac{1}{2} y_{k,t}^2}_{\text{idiosyncratic characteristic}} \right) + \alpha \sum_{k=n+1}^{n+n_k} \left(\underbrace{\hat{b}_{k,t} y_{k,t} - \frac{1}{2} y_{k,t}^2}_{\text{shared characteristic}} \right)$$

Generalized Hedonic-Linear Demand (Pellegrino, 2024)

- Quality:

$$b_i = (1-\alpha)\,\hat{b}_i + \alpha \sum_{k=n+1}^{n+n_k} \psi_k \hat{b}_k$$

- Inverse demand:

$$\frac{\boldsymbol{p}}{P} = \boldsymbol{b} - \boldsymbol{\Sigma}\boldsymbol{q}$$

- Inverse cross-price elasticity of demand:

$$\frac{\partial \log p_i}{\partial \log q_j} = -\frac{q_j}{p_i} \cdot \sigma_{ij}$$

- Cross-price elasticity of demand:

$$\frac{\partial \log q_i}{\partial \log p_j} = -\frac{p_j}{q_i} (\boldsymbol{\Sigma}^{-1})_{ij}$$

Static Profits

- Firms choose labor productivity and product quality: $\zeta a_{i,t} = \sqrt{\zeta w_t}$, $b_{i,t} = z_{i,t} - \sqrt{\zeta w_t}$
- Labor market clearing: $L = \sum_i \frac{q_{i,t}}{a_{i,t}} \implies \sqrt{\zeta w_t} = \frac{\zeta}{L} \sum_i q_{i,t}$
- $\boldsymbol{q}_t = \boldsymbol{N} \boldsymbol{z}_t$ where $\boldsymbol{N} \equiv \left\{ 2\frac{\zeta}{L} \mathbf{1}_{n\times n} + \boldsymbol{\Sigma} + \boldsymbol{K} \circ \boldsymbol{\Sigma} \right\}^{-1}$
- $\boldsymbol{N}_i$: the ith row of $\boldsymbol{N}$
- Ownership weighted profit:

$$\sum_j \kappa_{ij} \frac{\pi_{j,t}}{P_t} = \sum_j \kappa_{ij} \sum_h \kappa_{jh} \sigma_{jh} q_{j,t} q_{h,t} = \boldsymbol{z}_t^T \boldsymbol{Q}^i \boldsymbol{z}_t$$

where

$$\boldsymbol{Q}^i = \frac{1}{2} \sum_j \kappa_{ij} \sum_h \kappa_{jh} \sigma_{jh} \left(N_j^T N_h + N_h^T N_j \right)$$

Back

Intuition of Externality

- Assume firms choose static variables $\{a_{i,t}, b_{i,t}, q_{i,t}\}$ to maximize static profits
- Equilibrium quantity $q_i = \frac{1}{2} z_i - \frac{1}{2} \sum_{k \neq i} \sigma_{ik} q_k - \sqrt{\zeta w_t}$ and profit $\pi_i = q_i^2$

Tech Spillover Externalities: $\dfrac{\partial \dot{z}_j}{\partial z_i} = \omega_{ij}, \quad \dfrac{\partial \pi_j}{\partial z_j} = 2 q_j \dfrac{\partial q_j}{\partial z_j} = q_j$

$$z_i \uparrow \quad \underbrace{\Longrightarrow}_{\text{strong if } \omega_{ij} \text{ is large}} \quad z_j \uparrow \quad \Longrightarrow \quad \pi_j \uparrow$$

Business Stealing Externalities: $\dfrac{\partial \pi_j}{\partial z_i} = 2 q_j \dfrac{\partial q_j}{\partial z_i} = 2 q_j \left(-\dfrac{1}{2} \sigma_{ji} \dfrac{\partial q_i}{\partial z_i} \right) = -\dfrac{1}{2} \sigma_{ji} q_j$

$$z_i \uparrow \quad \Longrightarrow \quad q_i \uparrow \quad \underbrace{\Longrightarrow}_{\text{strong if } \sigma_{ij} \text{ is large}} \quad q_j \downarrow \quad \Longrightarrow \quad \pi_j \downarrow$$

Riccati Equations

- $V_i\left(\boldsymbol{z}\right) = \boldsymbol{z}^T \boldsymbol{X}^i \boldsymbol{z}$ where $\boldsymbol{X}^i$ is the solution of the stacked Riccati equation

$$0 = \boldsymbol{Q}^i - \mu^2 \sum_j \kappa_{ij} \boldsymbol{X}_j^j \left(\boldsymbol{X}_j^j\right)^T + \left(\boldsymbol{\Phi} - \frac{1}{2}\left(\rho - \gamma^2\right)\boldsymbol{I}\right)^T \boldsymbol{X}^i + \boldsymbol{X}^i \left(\boldsymbol{\Phi} - \frac{1}{2}\left(\rho - \gamma^2\right)\boldsymbol{I}\right)$$

  - $\boldsymbol{X}_i^i \equiv$ the ith column of $\boldsymbol{X}^i$
  - $\boldsymbol{\Phi} \equiv \boldsymbol{\Omega} + \mu^2 \begin{bmatrix} \boldsymbol{X}_1^1 & \cdots & \boldsymbol{X}_n^n \end{bmatrix}^T$

- Algorithm: Given $\begin{bmatrix} \boldsymbol{X}_\tau^1 & \cdots & \boldsymbol{X}_\tau^n \end{bmatrix}$, update $\begin{bmatrix} \boldsymbol{X}_{\tau-\Delta}^1 & \cdots & \boldsymbol{X}_{\tau-\Delta}^n \end{bmatrix}$ by

$$-\frac{\boldsymbol{X}_\tau^i - \boldsymbol{X}_{\tau-\Delta}^i}{\Delta} = \boldsymbol{Q}^i - \mu^2 \sum_j \kappa_{ij} \boldsymbol{X}_{j,\tau}^j \left(\boldsymbol{X}_{j,\tau}^j\right)^T + \left(\boldsymbol{\Phi}_\tau - \frac{1}{2}\left(\rho - \gamma^2\right)\boldsymbol{I}\right)^T \boldsymbol{X}_\tau^i + \boldsymbol{X}_\tau^i \left(\boldsymbol{\Phi}_\tau - \frac{1}{2}\left(\rho - \gamma^2\right)\boldsymbol{I}\right)$$

Back

Summary of Equilibrium

Description	Expression
Production strategy	$\boldsymbol{q}_t = \boldsymbol{N}\boldsymbol{z}_t$
R&D strategy	$\boldsymbol{x}_t = \mu\tilde{\boldsymbol{X}}\boldsymbol{z}_t$
Law of motion	$d\boldsymbol{z}_t = \left(\boldsymbol{\Omega}\boldsymbol{z}_t + \mu\boldsymbol{x}_t\right)dt + \gamma\boldsymbol{z}_t dW_t$
Profit of final producers	$\Pi_t^F/P_t = \boldsymbol{q}_t^T\left(\frac{1}{2}\boldsymbol{\Sigma}\right)\boldsymbol{q}_t$
Total operating profit of firms	$\Pi_t/P_t = \boldsymbol{q}_t^T\left(\frac{1}{2}\boldsymbol{\Sigma}\circ\left(\boldsymbol{K}+\boldsymbol{K}^T\right)\right)\boldsymbol{q}_t$
Labor income	$w_t L/P_t = \boldsymbol{q}_t^T\left(\frac{\zeta}{L}\mathbf{1}_{n\times n}\right)\boldsymbol{q}_t$
Output	$Y_t = \boldsymbol{q}_t^T\left(\frac{\zeta}{L}\mathbf{1}_{n\times n} + \frac{1}{2}\boldsymbol{\Sigma} + \frac{1}{2}\boldsymbol{\Sigma}\circ\left(\boldsymbol{K}+\boldsymbol{K}^T\right)\right)\boldsymbol{q}_t$
Consumption	$C_t = Y_t - \boldsymbol{x}_t^T\boldsymbol{x}_t$

Back

Example: Symmetric Equilibrium

Assumption

- Symmetric product substitutability, technology spillover, and ownership structure:
  $\sigma_{ij} = \sigma, \omega_{ij} = \omega, \kappa_{ij} = \kappa \quad \forall i \neq j$

- R&D strategy: $x^*_{i,t} = \mu \left(\tilde{x}_1 z_{i,t} + \tilde{x}_2 \sum_{j \neq i} z_j \right)$
  - $\tilde{x}_1$: market size effect (> 0)
  - $\tilde{x}_2$: strategic substitutability (< 0) / complementarity (> 0)

- Growth rate: $g = \underbrace{(n-1)\omega}_{\text{Tech Spillover}} + \underbrace{\mu^2 \left(\tilde{x}_1 + (n-1)\tilde{x}_2\right)}_{\text{R\&D}}$

- Stability (irreducibility) requires $\omega + \mu^2 \tilde{x}_2 > 0$
  - Tech spillover (ω) must be strong relative to strategic substitutability ($\tilde{x}_2 < 0$)

Back

Output and Expected Utility

- Output: $Y_t = \boldsymbol{q}_t^T \boldsymbol{Q} \boldsymbol{q}_t$ where

$$\boldsymbol{Q} = \frac{\zeta}{L}\mathbf{1}_{n\times n} + \frac{1}{2}\boldsymbol{\Sigma} + \frac{1}{2}\boldsymbol{\Sigma} \circ \left(\boldsymbol{K} + \boldsymbol{K}^T\right)$$

- Expected utility:

$$V(\boldsymbol{z}_t) \equiv \boldsymbol{E}_t\left[\int_t^\infty \exp\left(-\rho s\right) C_s ds \middle| \boldsymbol{z}_t\right] = \boldsymbol{z}_t^T \boldsymbol{X} \boldsymbol{z}_t$$

where $\boldsymbol{X}$ is the solution of the Lyapunov equation (obtained from households' HJB equation):

$$0 = \boldsymbol{Q} - \mu^2 \tilde{\boldsymbol{X}}^T \tilde{\boldsymbol{X}} + \boldsymbol{X}\left(\boldsymbol{\Phi} - \frac{1}{2}\left(\rho - \gamma^2\right)\boldsymbol{I}\right) + \left(\boldsymbol{\Phi} - \frac{1}{2}\left(\rho - \gamma^2\right)\boldsymbol{I}\right)^T \boldsymbol{X}$$

Back

Social Optimum

- Static optimal allocation: $\boldsymbol{q}_t^* = \boldsymbol{N}^* \boldsymbol{z}_t$ where $\boldsymbol{N}^* \equiv \left\{2\frac{\zeta}{L}\mathbf{1}_{n\times n} + \boldsymbol{\Sigma}\right\}^{-1}$
- Optimal output: $Y_t^* = \boldsymbol{z}_t^T \boldsymbol{Q}^* \boldsymbol{z}_t$ where $\boldsymbol{Q}^* = \frac{1}{2}\boldsymbol{N}^*$
- Optimal expected utility:

$$V^*(\boldsymbol{z}_t) \equiv \boldsymbol{E}_t\left[\int_t^{\infty} \exp(-\rho s)\, C_s ds \middle| \boldsymbol{z}_t\right] = \boldsymbol{z}_t^T \boldsymbol{X}^* \boldsymbol{z}_t,$$

  where $\boldsymbol{X}^*$ is the solution of the Riccati equation (obtained from planner's HJB equation):

$$0 = \boldsymbol{Q}^* - \mu^2 (\boldsymbol{X}^*)^2 + \boldsymbol{X}^* \left(\boldsymbol{\Phi}^* - \frac{1}{2}(\rho - \gamma^2)\boldsymbol{I}\right) + \left(\boldsymbol{\Phi}^* - \frac{1}{2}(\rho - \gamma^2)\boldsymbol{I}\right)\boldsymbol{X}^*$$

- Optimal R&D: $\boldsymbol{x}_t^* = \mu \boldsymbol{X}^* \boldsymbol{z}_t$
- Optimal technology transition matrix: $\boldsymbol{\Phi}^* = \boldsymbol{\Omega} + \mu^2 \boldsymbol{X}^*$

Back

Property of BGP

- On the BGP, $\boldsymbol{a}_t$, $\boldsymbol{b}_t$, $\boldsymbol{z}_t$, and $\boldsymbol{q}_t$ grow at the same rate

Knowledge Capital:	$\zeta a_{i,t} + b_{i,t} = z_{i,t}$
Linear Production Technology:	$q_{i,t} = a_{i,t} l_{i,t}$
Inelastic Labor Supply:	$L = \sum_i l_{i,t}$

- The linear and quadratic terms in $\boldsymbol{q}_t$ of output grow at the same rate:

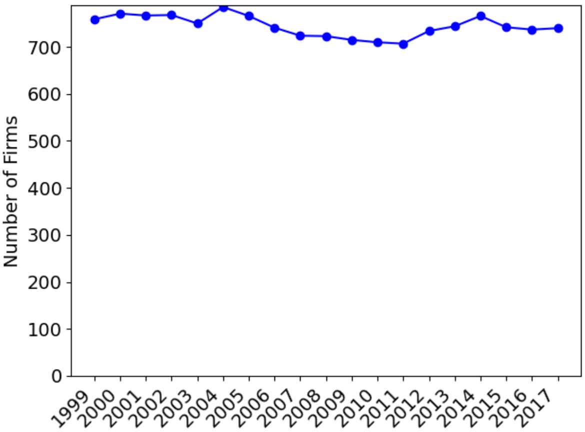
$$Y_t = \boldsymbol{q}_t^T \boldsymbol{b}_t - \frac{1}{2} \boldsymbol{q}_t^T \boldsymbol{\Sigma} \boldsymbol{q}_t$$

Growth Decomposition

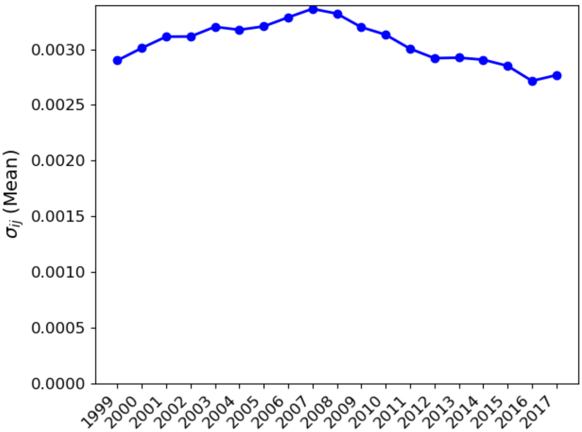
- Aggregate output: $Y_t = \boldsymbol{z}_t^T \boldsymbol{Q} \boldsymbol{z}_t$
- $d\boldsymbol{z}_t / dt = \boldsymbol{\Phi} \boldsymbol{z}_t$ where $\boldsymbol{\Phi} = \boldsymbol{\Omega} + \mu^2 \widetilde{\boldsymbol{X}} - \delta \boldsymbol{I}$

$$\frac{d \log Y_t}{dt} = \underbrace{\frac{\boldsymbol{z}_t^T \left(\boldsymbol{Q}\boldsymbol{\Omega} + \boldsymbol{\Omega}\boldsymbol{Q}\right) \boldsymbol{z}_t}{Y_t}}_{\text{Tech Spillover}} + \underbrace{\frac{\mu^2 \boldsymbol{z}_t^T \left(\boldsymbol{Q}\widetilde{\boldsymbol{X}} + \widetilde{\boldsymbol{X}}^T \boldsymbol{Q}\right) \boldsymbol{z}_t}{Y_t}}_{\text{R\&D}} - \underbrace{2\delta}_{\text{Depreciation}}$$

Number of Sample Firms

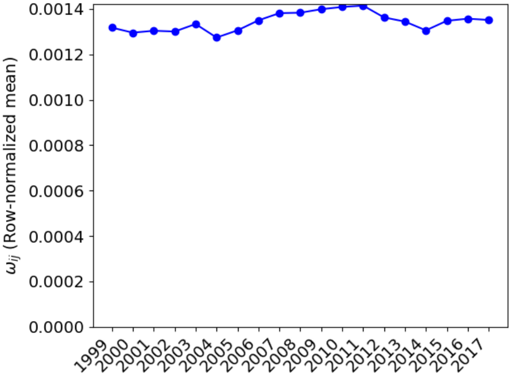


Trend of Product Substitutability



Technological Proximity

- Merge USPTO data with Compustat firms using DISCERN 2 dataset (Arora et al., 2024)
- Jaffe measure, group-level patent classification, stacked over 5 years



Correlation Across Networks

	K	Σ	Ω
K	1.0000	-0.0035	0.0115
Σ	-0.0035	1.0000	0.2542
Ω	0.0115	0.2542	1.0000

- K: Ownership network
- Σ: Product substitutability network
- Ω: Technological proximity network

Back

Microeconometric Estimates vs. GHL (Pellegrino, 2024) (1/2)

Market	Firm i	Firm j	Micro Estimate	GHL
Auto	Ford	Ford	-4.320	-5.197
Auto	Ford	General Motors	0.034	0.056
Auto	Ford	Toyota	0.007	0.017
Auto	General Motors	Ford	0.065	0.052
Auto	General Motors	General Motors	-6.433	-4.685
Auto	General Motors	Toyota	0.008	0.005
Auto	Toyota	Ford	0.018	0.025
Auto	Toyota	General Motors	0.008	0.008
Auto	Toyota	Toyota	-3.085	-4.851

Back

Microeconometric Estimates vs. GHL (Pellegrino, 2024) (2/2)

Market	Firm i	Firm j	Micro Estimate	GHL
Cereals	Kellogg's	Kellogg's	-3.231	-1.770
Cereals	Kellogg's	Quaker Oats	0.033	0.023
Cereals	Quaker Oats	Kellogg's	0.046	0.031
Cereals	Quaker Oats	Quaker Oats	-3.031	-1.941
Computers	Apple	Apple	-11.979	-8.945
Computers	Apple	Dell	0.018	0.025
Computers	Dell	Apple	0.027	0.047
Computers	Dell	Dell	-5.570	-5.110

Back

First Stage Back

	R&D
	(1)
State tax credit component of R&D user cost	-1.16^{***}
	(0.29)
Federal tax credit component of R&D user cost	-34.29^{***}
	(3.64)
Firm fixed effects	✓
Year fixed effects	✓
No. of observations	16197

SEs clustered by years and 4-digit NAICS industries are reported in parentheses.

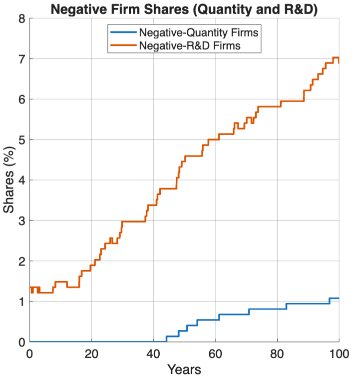
- IV: User cost of R&D, driven by federal and state-specific rules variations (Wilson, 2009; Bloom et al., 2013)

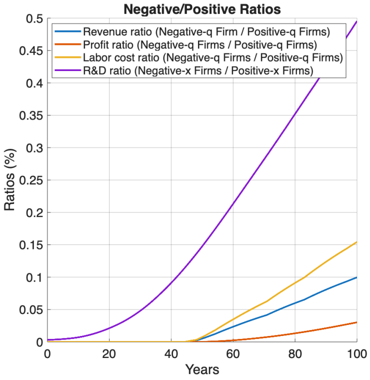
Negative R&D and Output

- Issue with the model: negative output and R&D
  - Inada condition is not satisfied
  - Non-negativity constraint makes model intractable

Negative R&D and Quantity

- Firms with negative values are negligible along the transition path
- The weight on values 100 years and beyond is 0.005% when $\rho = 0.1$





Back

Acemoglu, Daron, and Ufuk Akcigit. 2012. “Intellectual Property Rights Policy, Competition and Innovation.” *Journal of the European Economic Association* 10 (1): 1–42.

Acemoglu, Daron, Ufuk Akcigit, and William R Kerr. 2016. “Innovation network.” *Proceedings of the National Academy of Sciences of the United States of America* 113 (41): 11483–11488.

Aghion, P, N Bloom, R Blundell, R Griffith, and P Howitt. 2005. “Competition and Innovation: An Inverted-U Relationship.” *The Quarterly Journal of Economics* 120 (2): 701–728.

Aghion, Philippe, Christopher Harris, Peter Howitt, and John Vickers. 2001. “Competition, Imitation and Growth with Step-by-Step Innovation.” *The Review of Economic Studies* 68 (3): 467–492.

Aghion, Philippe, and Peter Howitt. 1992. “A Model of Growth Through Creative Destruction.” *Econometrica: journal of the Econometric Society* 60 (2): 323–351.

Aghion, Philippe, John Van Reenen, and Luigi Zingales. 2013. “Innovation and Institutional Ownership.” *American Economic Review* 103 (1): 277–304.

Akcigit, Ufuk, and Sina T Ates. 2021. “Ten Facts On Declining Business Dynamism and Lessons From Endogenous Growth Theory.” *American Economic Journal: Macroeconomics* 13 (1): 257–298.

Akcigit, Ufuk, and Sina T Ates. 2023. “What Happened to US Business Dynamism?” *The Journal of Political Economy* 131 (8): 2059–2124.

Anton, Miguel, Florian Ederer, Mireia Gine, and Martin Schmalz. 2023. “Common Ownership, Competition, and Top Management Incentives.” *The journal of political economy* 131 (5): 1294–1355.

Anton, Miguel, Florian Ederer, Mireia Gine, and Martin Schmalz. 2025. “Innovation: The Bright Side of Common Ownership?” *Management science*.

Arora, Ashish, Sharon Belenzon, Larisa Cioaca, Lia Sheer, Hyun Moh (john) Shin, and Dror Shvadron. 2024. “DISCERN 2: Duke innovation & SCientific Enterprises Research Network.”

Atkeson, Andrew, and Ariel Burstein. 2008. “Pricing-to-Market, Trade Costs, and International Relative Prices.” *The American Economic Review* 98 (5): 1998–2031.

Autor, David, David Dorn, Lawrence F Katz, Christina Patterson, and John Van Reenen. 2020. “The Fall of The Labor Share and The Rise of Superstar Firms.” *The Quarterly Journal of Economics* 135 (2): 645–709.

Azar, Jose, Martin C Schmalz, and Isabel Tecu. 2018. “Anticompetitive Effects of Common Ownership.” *The Journal of Finance* 73 (4): 1513–1565.

Azar, Jose, and Xavier Vives. 2021. “General Equilibrium Oligopoly and Ownership Structure.” *Econometrica* 89 (3): 999–1048.

Azar, José, Sahil Raina, and Martin Schmalz. 2022. “Ultimate ownership and bank competition.” *Financial management* 51 (1): 227–269.

Azar, José, and Ricardo Ribeiro. 2021. “Estimating oligopoly with shareholder voting models.” *SSRN Electronic Journal*.

Backus, Matthew, Christopher Conlon, and Michael Sinkinson. 2021. “Common Ownership in America: 1980-2017.” *American Economic Journal. Microeconomics* 13 (3): 273–308.

Berry, Steven, James Levinsohn, and Ariel Pakes. 1995. "Automobile Prices in Market Equilibrium." *Econometrica* 63 (4): 841.

Bloom, Nicholas, Mark Schankerman, and John VAN Reenen. 2013. "Identifying Technology Spillovers and Product Market Rivalry." *Econometrica* 81 (4): 1347–1393.

Cavenaile, Laurent, Murat Alp Celik, and Xu Tian. 2023. "Are Markups Too High? Competition, Strategic Innovation, and Industry Dynamics."

d'Aspremont, Claude, and A Jacquemin. 1988. "Cooperative and noncooperative R&D in duopoly with spillovers." *The American Economic Review* 78 (5): 1133–1137.

Ederer, Florian, and Bruno Pellegrino. 2024. "A Tale of Two Networks: Common Ownership and Product Market Rivalry."

Ericson, Richard, and Ariel Pakes. 1995. "Markov-perfect industry dynamics: A framework for empirical work." *The Review of Economic Studies* 62 (1): 53.

Gutierrez, German, and Thomas Philippon. 2017. "Investmentless Growth: An Empirical Investigation." *Brookings Papers on Economic Activity* 89–169.

He, Jie (jack), and Jiekun Huang. 2017. "Product Market Competition in a World of Cross-Ownership: Evidence from Institutional Blockholdings." *The Review of Financial Studies* 30 (8): 2674–2718.

Hoberg, Gerard, and Gordon Phillips. 2016. "Text-Based Network Industries and Endogenous Product Differentiation." *The Journal of Political Economy* 124 (5): 1423–1465.

Hopenhayn, Hugo, and Koki Okumura. 2025. "Dynamic Oligopoly and Innovation: A Quantitative Analysis of Technology Spillovers and Product Market Competition."

Jaffe, Adam B. 1986. "Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value." *The American economic review* 76 (5): 984–1001.

Kamien, Morton I, Eitan Muller, and Israel Zang. 1992. "Research Joint Ventures and R&D Cartels." *The American Economic Review* 82 (5): 1293–1306.

Kini, Omesh, Sangho Lee, and Mo Shen. 2024. "Common Institutional Ownership and Product Market Threats." *Management Science* 70 (5): 2705–2731.

Klette, Tor Jakob, and Samuel Kortum. 2004. "Innovating firms and aggregate innovation." *The journal of political economy* 112 (5): 986–1018.

Lancaster, Kelvin J. 1966. "A New Approach to Consumer Theory." *The Journal of Political Economy* 74 (2): 132–157.

Liu, Ernest, and Song Ma. 2024. "Innovation networks and R&D allocation."

Lopez, Angel L, and Xavier Vives. 2019. "Overlapping Ownership, R&D Spillovers, and Antitrust Policy." *The Journal of Political Economy* 127 (5): 2394–2437.

Neary, J Peter. 2003. "Globalization and market structure." *Journal of the European Economic Association* 1 (2-3): 245–271.

Nevo, Aviv. 2001. "Measuring Market Power in the Ready-to-Eat Cereal Industry." *Econometrica* 69 (2): 307–342.

Pellegrino, Bruno. 2024. "Product Differentiation and Oligopoly: A Network Approach." *The American Economic Review*.

Peters, Michael. 2020. "Heterogeneous Markups, Growth, and Endogenous Misallocation." *Econometrica* 88 (5): 2037–2073.

Romer, Paul M. 1990. "Endogenous Technological Change." *The journal of political economy* 98 (5, Part 2): S71–S102.

Rosen, Sherwin. 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *The Journal of Political Economy* 82 (1): 34–55.

Rotemberg, Julio. 1984. "Financial transaction costs and industrial performance."

Rubinstein, Ariel, and Menahem E Yaari. 1983. "The Competitive Stock Market as Cartel Maker: Some Examples." *STICERD - Theoretical Economics Paper Series*.

Scherer, F M. 1982. "Inter-industry technology flows and productivity growth." *The Review of Economics and Statistics* 64 (4): 627.

Wilson, Daniel J. 2009. "Beggar thy neighbor? The in-state, out-of-state, and aggregate effects of R&D tax credits." *The Review of Economics and Statistics* 91 (2): 431–436.