Product Differentiation and Oligopoly: a Network Approach

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Research Question

- **Motivation**: large dispersion in markups across firms
  - Rising level & dispersion (De Loecker, Eeckhout & Unger, 2020)
  - Rising industry concentration (Kwon et al. 2022)

- **Research Question**: what's behind this heterogeneity? What's driving these trends? What are the welfare implications?
  - Consumer surplus and deadweight loss **due to oligopoly**

- **Challenge**: IO question in a macroeconomic setting:
  - Standard IO tools are not available (scalability, lack of data)
  - No systematic, objective way to define product markets.

This Paper

- **Methodological contribution**: bring IO in macroeconomics.
- **Theory of oligopoly and markups in general equilibrium**
  - Forget about industries: in this model, oligopolistic firms compete in a network of product market rivalries.
  - New demand system: Generalized Hedonic-Linear (GHL).
- **Taken to the data** (and validated) for universe of US public firms, using product similarity data by Hoberg & Phillips (2016).
- **Decompose markups** into 2 forces: productivity and centrality.
- **Welfare measurement**: large, increasing oligopoly deadweight loss (12.7% of total surplus in 2019), major distributional effects.

Literature

- **Rising Markups and Industry Concentration**: De Loecker, Eeckhout & Unger (2020), Grullon, Larkin & Michaely (2019); Kwon, Ma & Zimmermann (2021), Eeckhout & Veldkamp (2022).
- **Distortions, Input/Output, Micro Origins of Aggregate TFP:** Gabaix (2011); Acemoglu, Carvalho, Ozdaglar, Tahbaz-Salehi (2012); Baqaee & Farhi (2020); Bigio & La'O (2020); Edmond, Midrigan & Xu (2019); Carvalho, Elliot & Spray (2022);
- **Hedonic Demand/Empirical IO**: Lancaster (1968); Rosen (1974); Epple (1987) Berry, Levinsohn & Pakes (1994); Nevo (2001)...
- **Network Games**: Ballester, Calvo-Armengol & Zenou (2006); Galeotti, Golub, Goyal, Talamer & Tamuz (2022).
- **Text Analysis/Product Similarity**: Hoberg & Phillips (2016).

Theory

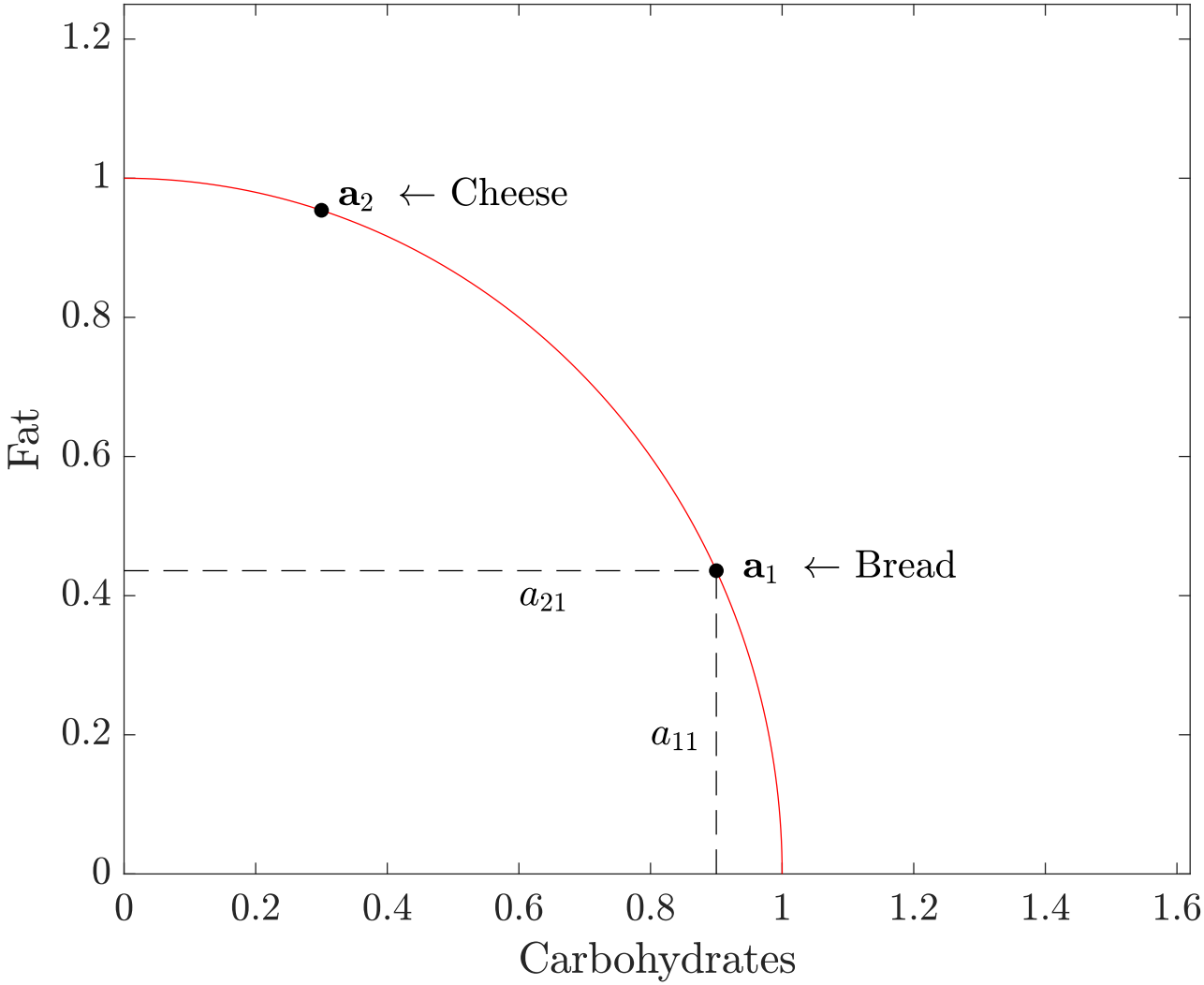
Generalized Hedonic-Linear Demand

- $i = 1,2,...,n$ firms that behave as oligopolists.

- **Hedonic demand**: each firm's product is a bundle of characteristics (Lancaster, 1968; Rosen, 1974; Epple, 1987, Berry, Levinsohn & Pakes 1994; etc.)

- 1 unit of product i provides:
  - 1 unit of an idiosyncratic characteristic i
  - a vector of k common characteristics $\mathbf{a}_i$ (length 1)

A basic example: 2 firms, 2 characteristics



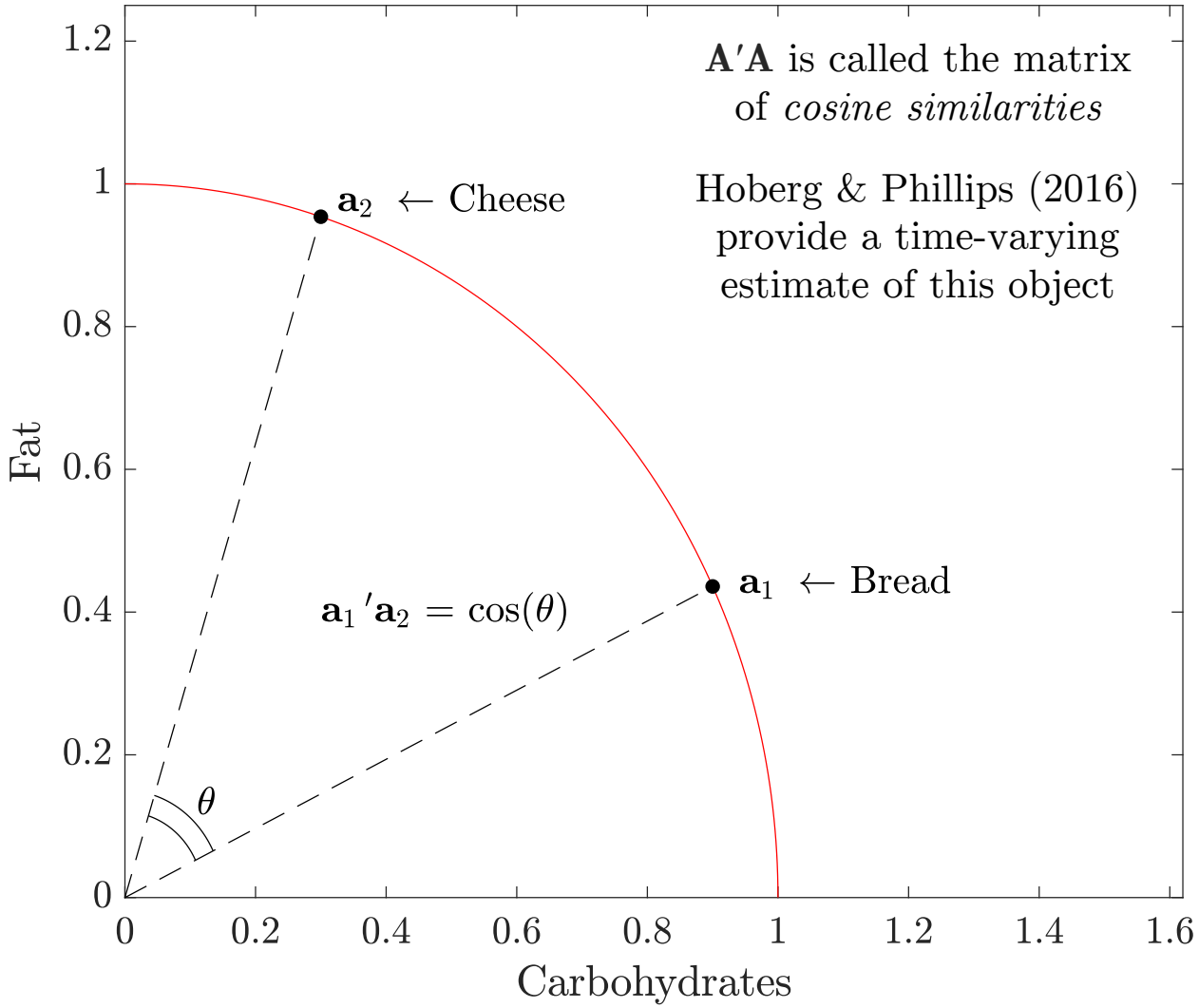
Aggregating common characteristics

Characteristics (Nutrient Intake)		**Matrix of Coordinates (Nutrition Facts)**	**Product Bundle**

$$\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_k \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{k1} & a_{k2} & \cdots & a_{kn} \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \\ \vdots \\ q_n \end{bmatrix}$$

$$\mathbf{x} = \mathbf{Aq}$$

Defining Cosine Similarity



Representative Consumer-Worker-Investor

- Quadratic utility $U(\mathbf{x},\mathbf{y},H) =$

$$\alpha \cdot \sum_{k=1}^{m} \left(b_k^x x_k - \frac{1}{2} x_k^2 \right) + (1-\alpha) \sum_{i=1}^{n} \left(b_i^y y_i - \frac{1}{2} y_i^2 \right) - H$$

- $H =$ hours worked – numeraire

- Consumer faces vector of prices $\mathbf{p}$ and chooses demand $\mathbf{q}$, subject to profits and labor income being $\geqslant \mathbf{p}'\mathbf{q}$.

Inverse Demand

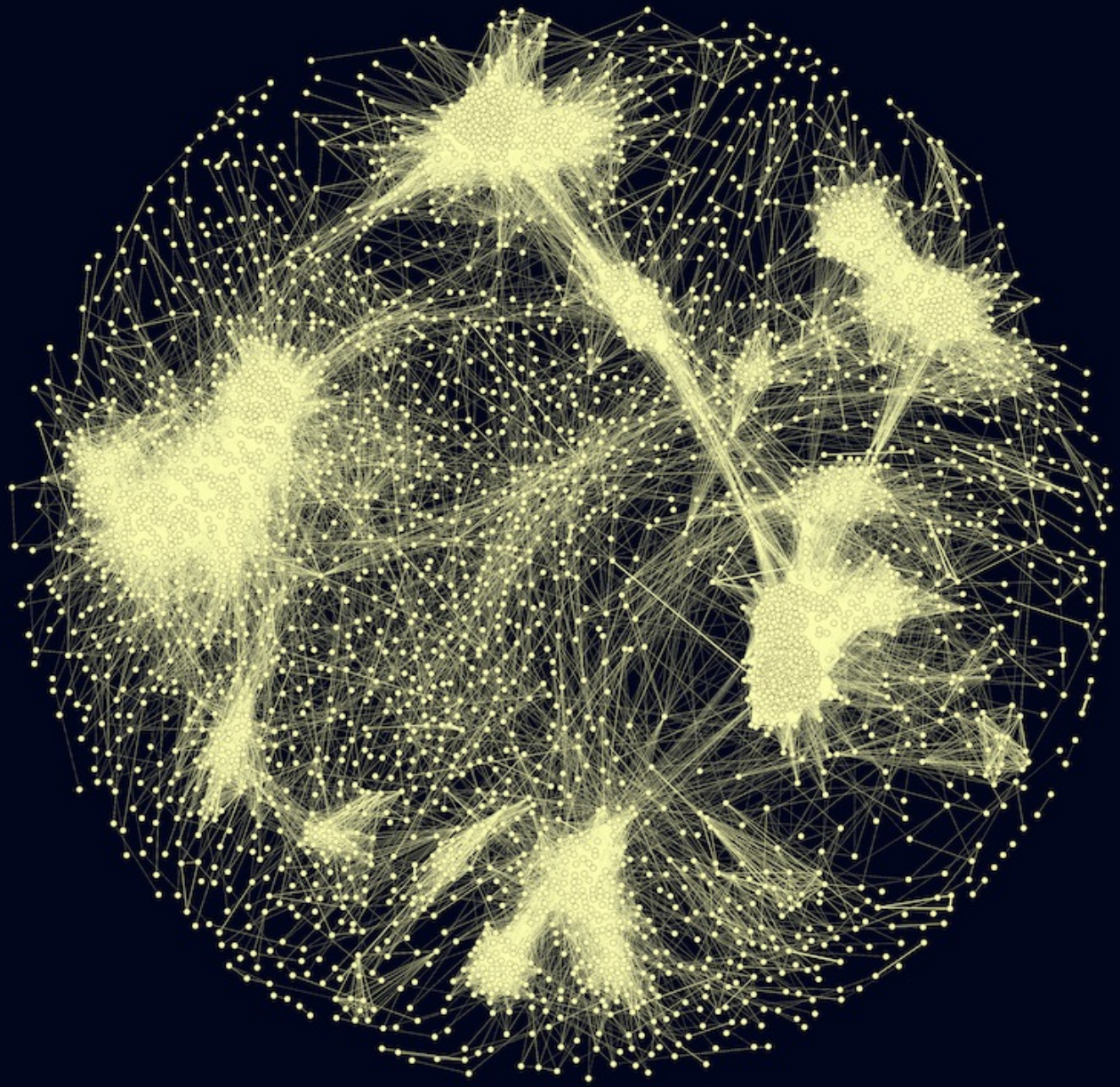
$$\mathbf{p} = \mathbf{b} - (\mathbf{I} + \mathbf{\Sigma})\,\mathbf{q}$$

where

$$\mathbf{\Sigma} \overset{\text{def}}{=} \alpha\,(\mathbf{A}'\mathbf{A} - \mathbf{I})$$

Cost Function and Competition

- Cost function (can be relaxed): $h_i = f_i + c_i^0 q_i + \frac{1}{2}\delta_i q_i^2$
- Cournot Competition: firm i chooses supply q_i to maximize profits function π_i (also quadratic)
- (Linear-quadratic) Network game
  - Ballester, Calvó-Armengol & Zenou, 2006
- Why? the matrix of cosine similarities $\mathbf{A}'\mathbf{A}$ (proportional to $\mathbf{\Sigma}$) can be thought of as an adjacency matrix of a network



Cournot-Nash Equilibrium

$$\mathbf{q} = (2\mathbf{I} + \boldsymbol{\Delta} + \boldsymbol{\Sigma})^{-1} \underbrace{(\mathbf{b} - \mathbf{c}^0)}$$

Scale Economies

Network Position

Marginal Surplus at $q_i = 0$

The expression above can be shown to be a measure of network centrality (Katz-Bonacich)

Hedonic-Adjusted Productivity

$$\omega_i \stackrel{\text{def}}{=} \frac{b_i}{c_i}$$

- Accounts for product quality
- Volumetric-invariant
- Comparable across widely-different firms

Decomposing Markups

Monopolistic Markup
$= (1 + \omega_i)/2$

$$\mu_i = \chi_i + (1 - \chi_i)\,\bar{\mu}_i$$

Product Market Centrality
Depends on the entire matrix of cosine similarities $\mathbf{A}'\mathbf{A}$. The profit share of surplus is a decreasing function of χ_i alone

Data and Validation

Hoberg & Phillips (2016 JPE) Product Similarity

- By law, every public corporation in the US has to file SEC form 10-K on a yearly basis.
- First 6-10 pages contain the "Business Description".
- HP created time-varying measures of cosine similarity between firms by text-mining these business descriptions.
- Solve long-standing problems with NAICS/SIC: static, binary do not reflect product market competition, can be manipulated.
- Highly incentive compatible - standard in finance: use of NAICS and SIC is no longer considered acceptable to capture product market rivalries, at least for top finance journals.

Construction

$$\mathbf{v}_i = \begin{bmatrix} v_{i,1} \\ v_{i,2} \\ \vdots \\ v_{i,61146} \end{bmatrix} \qquad \cos_{ij}^{\text{HP}} \overset{\text{def}}{=} \frac{\mathbf{v}_i' \mathbf{v}_j}{\sqrt{\|\mathbf{v}_i\| \, \|\mathbf{v}_j\|}}$$

Identification: bijective mapping words $\rightleftarrows$ characteristics, $\mathbf{a}_i$ and $\mathbf{v}_i$ are collinear up to permutation $\Rightarrow$ $\mathbf{a}_i' \mathbf{a}_j \equiv \cos_{ij}^{\text{HP}}$

Identification

- Compustat: Revenues ($p_i q_i$), COGS (TVC_i), SG&A (f_i).
- Assume $\delta_i{=}0$ (later relaxed). Only one free parameter: α.
- **Proposition**: $\partial \log p_i / \partial \log q_j$ is observed for firm pair (K,Q):

$$\alpha \;=\; -\frac{\varepsilon_{\mathrm{KQ}} \cdot p_{\mathrm{K}}\, q_{\mathrm{K}} + \varepsilon_{\mathrm{QK}} \cdot p_{\mathrm{Q}}\, q_{\mathrm{Q}}}{2 \cdot \cos^{\mathrm{HP}}_{\mathrm{KQ}} \cdot \sqrt{p_{\mathrm{K}} q_{\mathrm{K}} - \mathrm{TVC}_{\mathrm{K}}} \cdot \sqrt{p_{\mathrm{Q}} q_{\mathrm{Q}} - \mathrm{TVC}_{\mathrm{Q}}}}$$

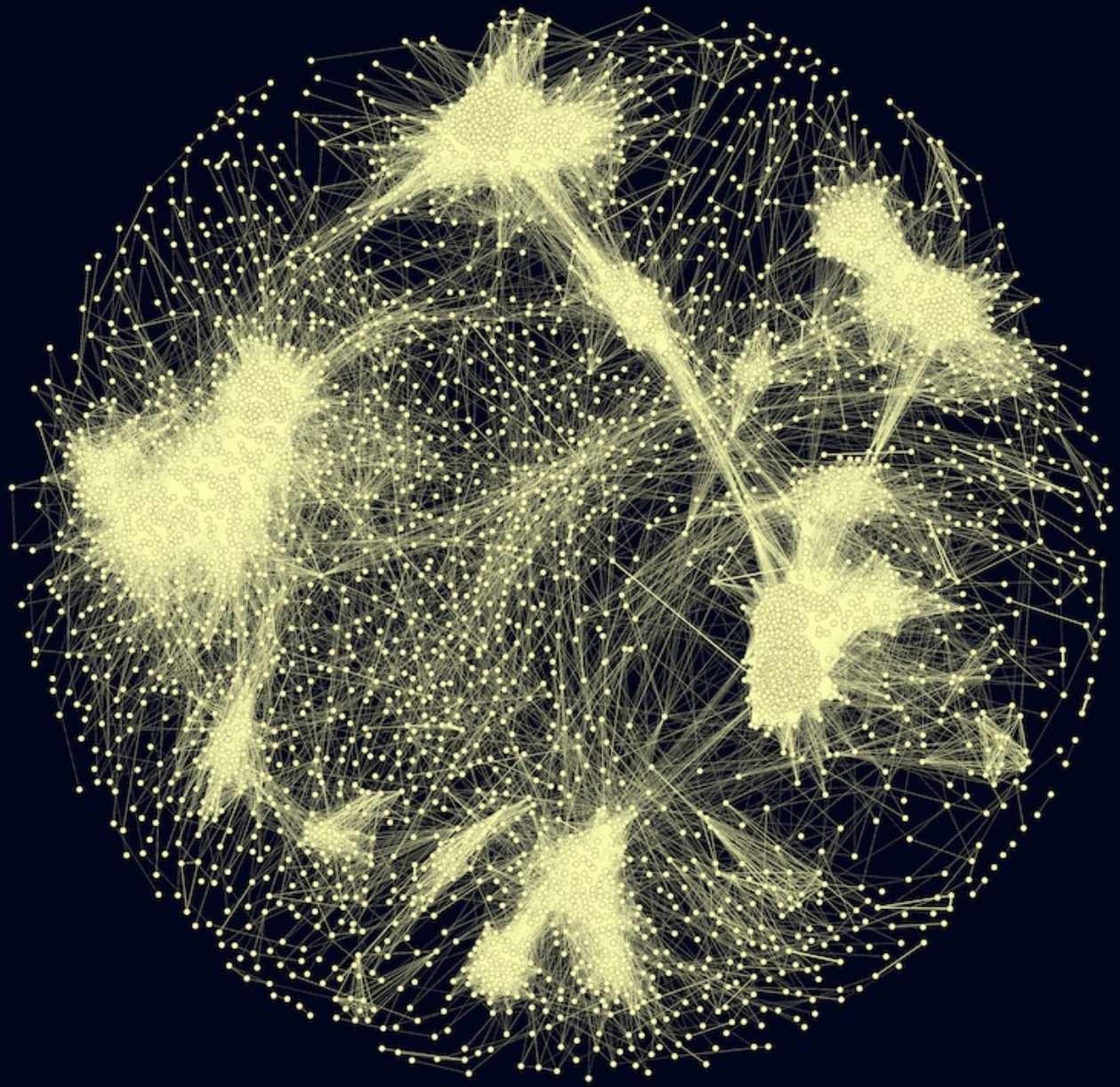
- Every other object is identified in closed form (correct units).

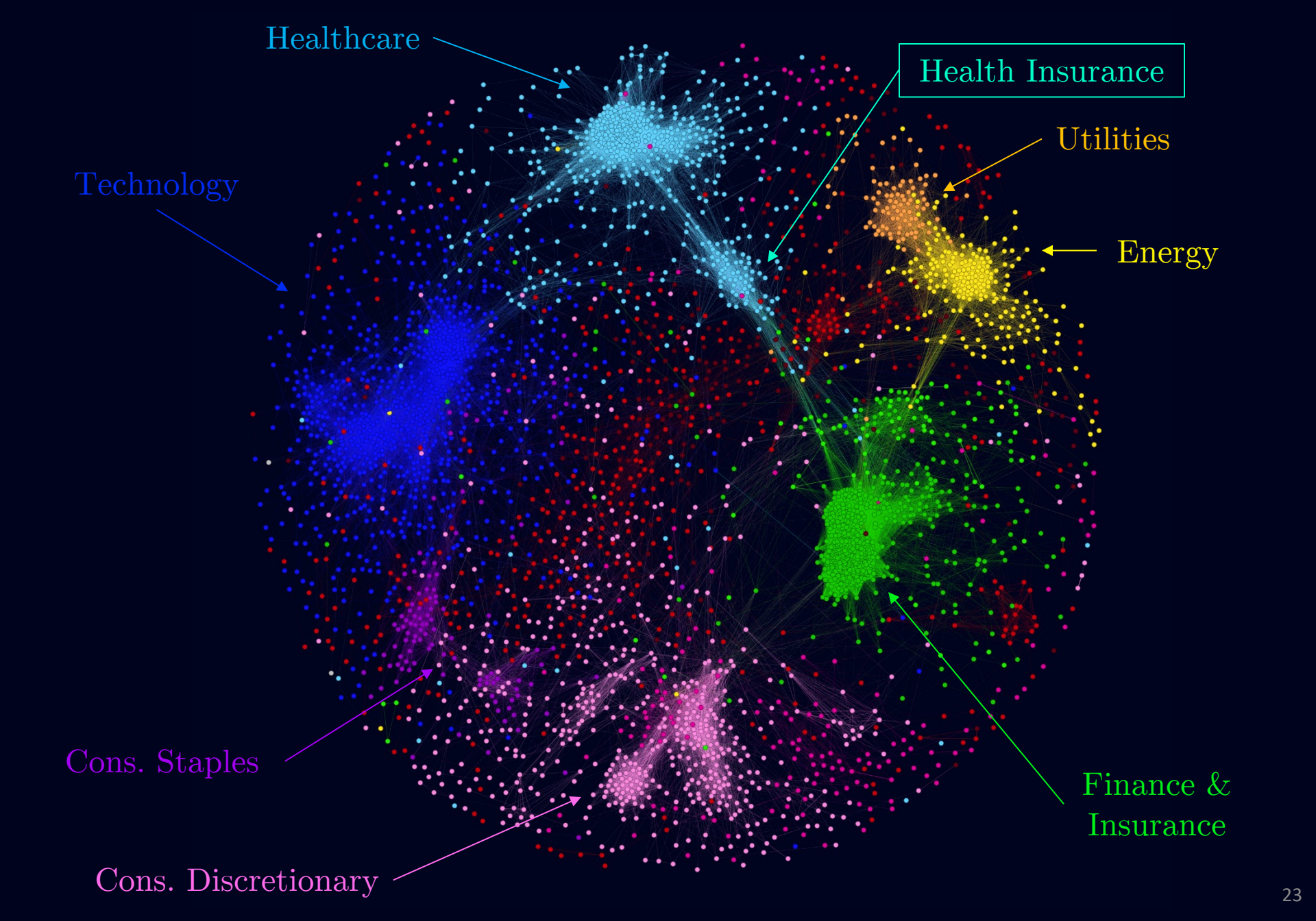
Identification

$$q_i = \sqrt{\pi_i}$$

$$c_i = \frac{\mathrm{TVC}_i}{q_i}$$

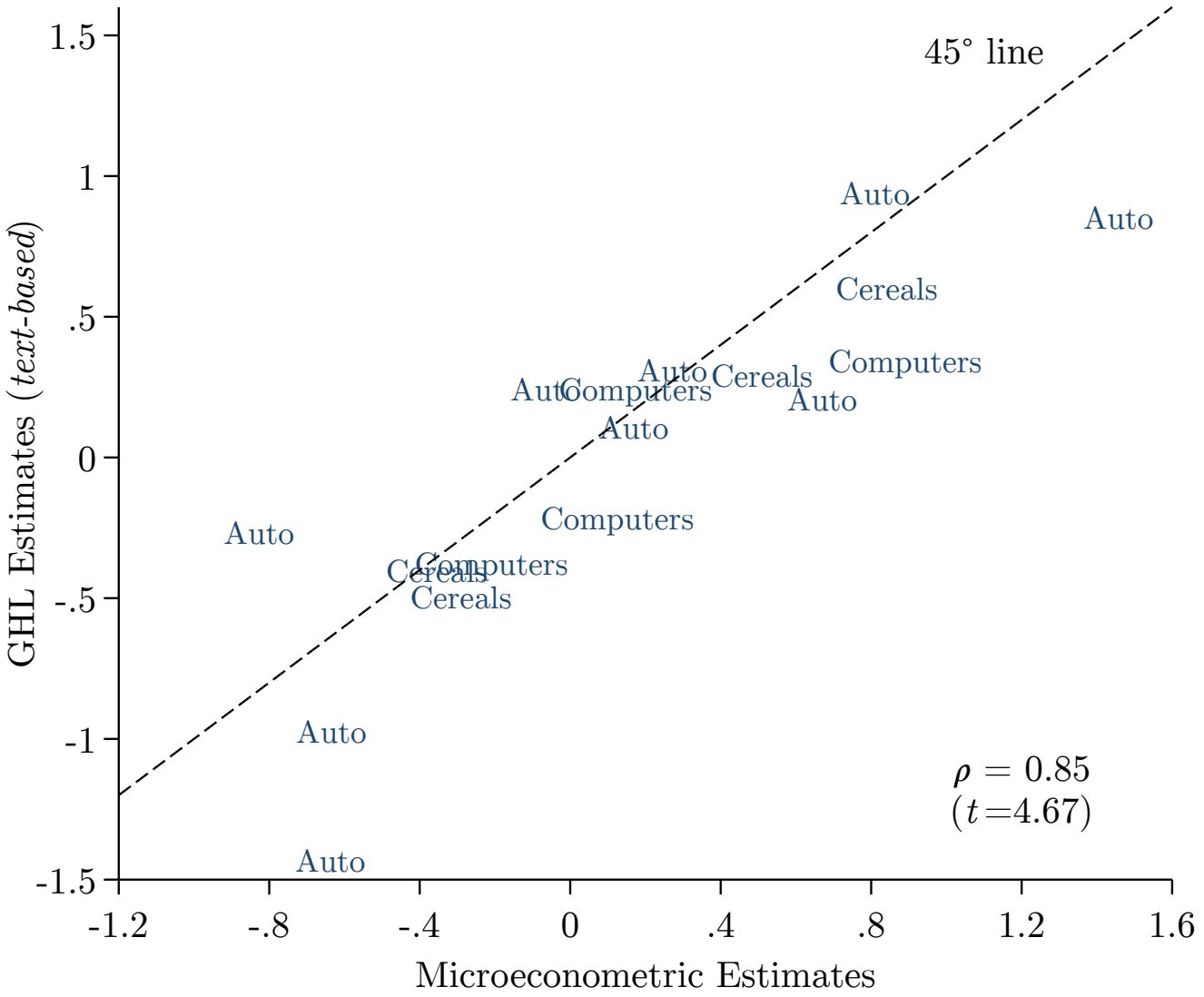
$$\mathbf{b} = (2\mathbf{I} + \mathbf{\Sigma})\,\mathbf{q} + \mathbf{c}$$



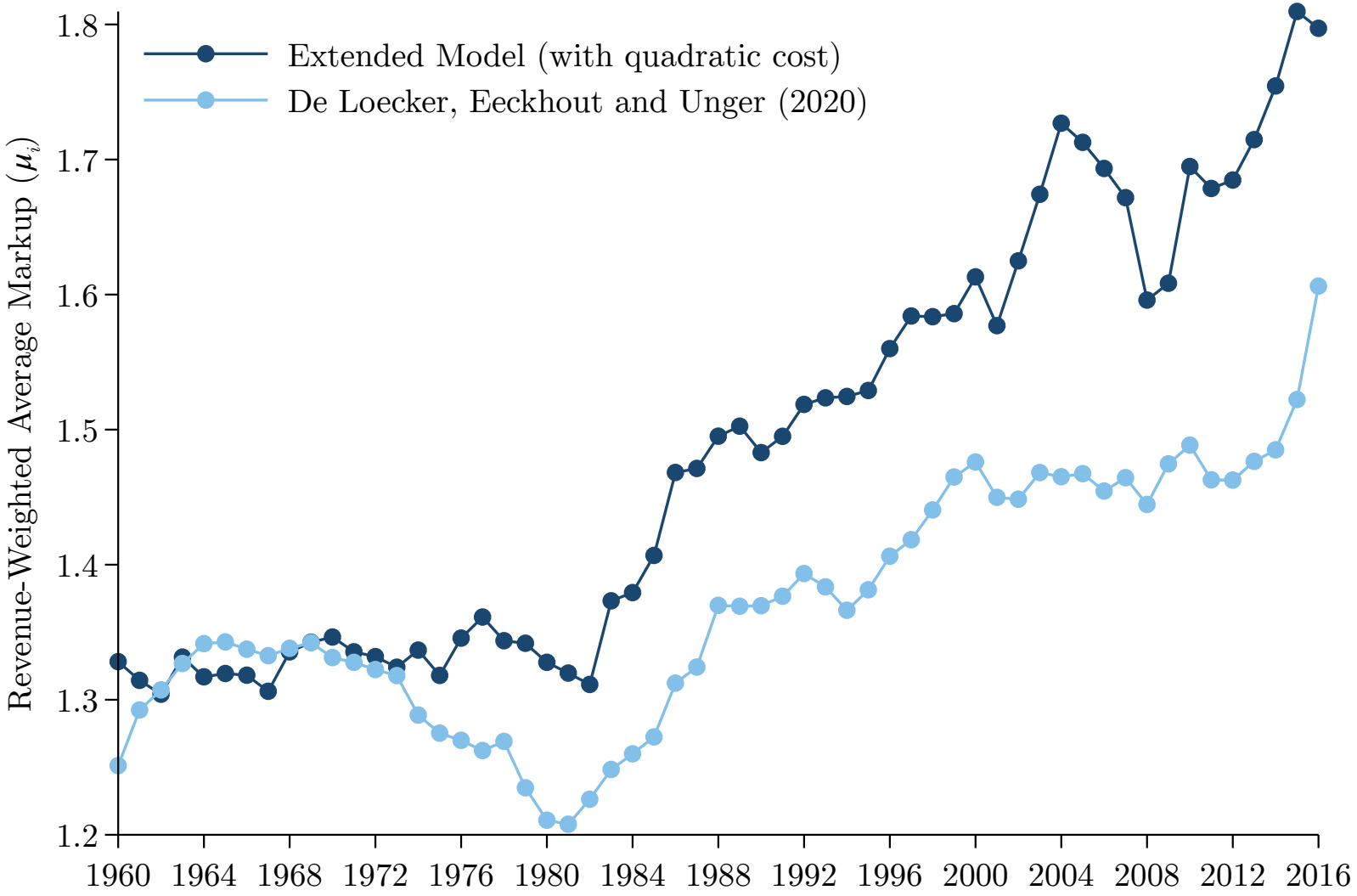

Healthcare
Health Insurance
Utilities
Technology
Energy
Cons. Staples
Finance &
Insurance
Cons. Discretionary

			Demand Elasticity $\left(\frac{\partial q_i}{\partial p_j} \cdot \frac{p_j}{q_i}\right)$	
Market	**Firm** i	**Firm** j	**Micro Estimate**	**GHL** (*text-based*)
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
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

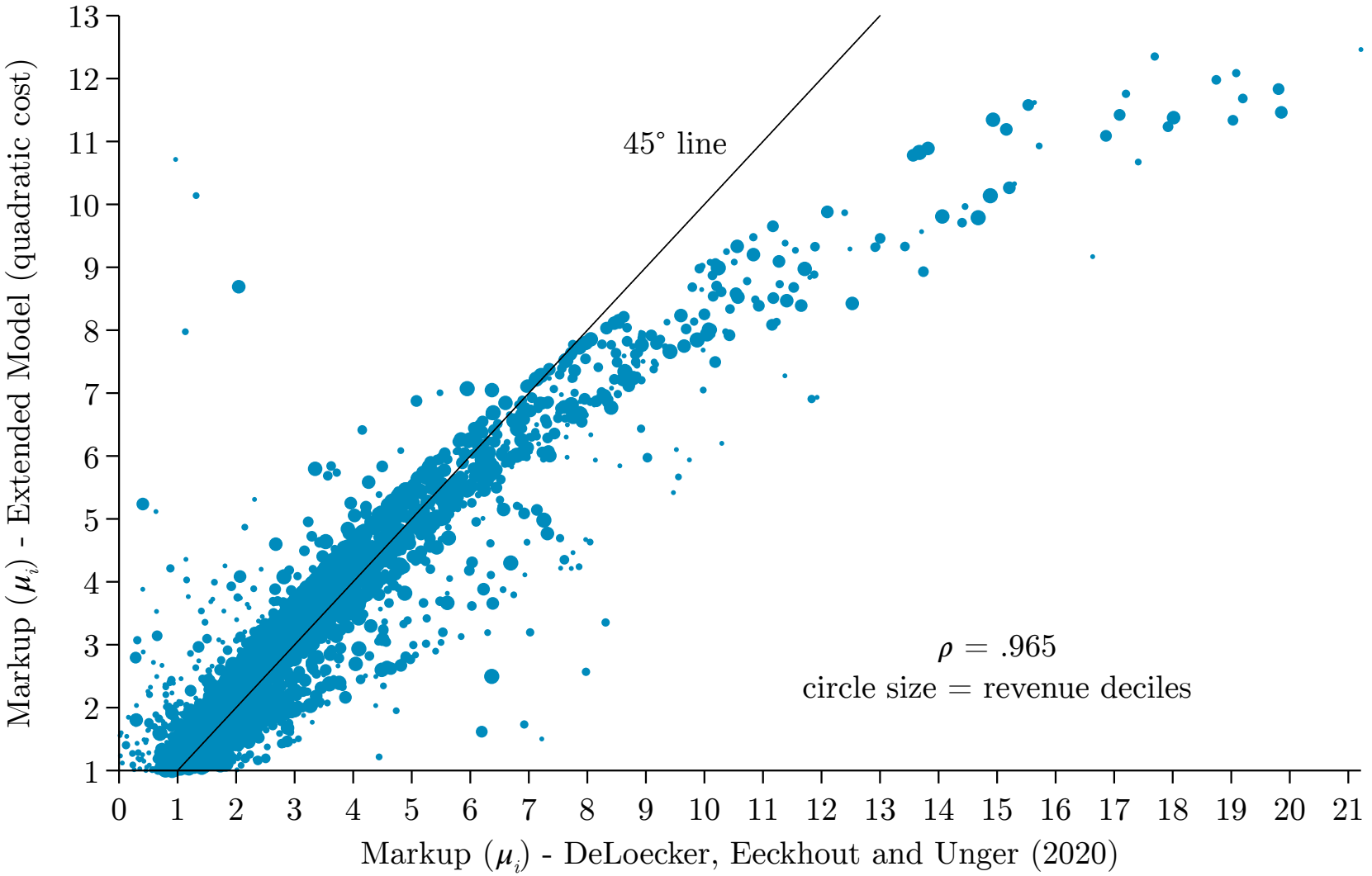
Variable: $\log\left|\frac{\partial q_i}{\partial p_j}\cdot\frac{p_j}{q_i}\right|$, *residualized on* $(i=j)$ *dummy and Market Fixed Effects*



Markups: Time Series

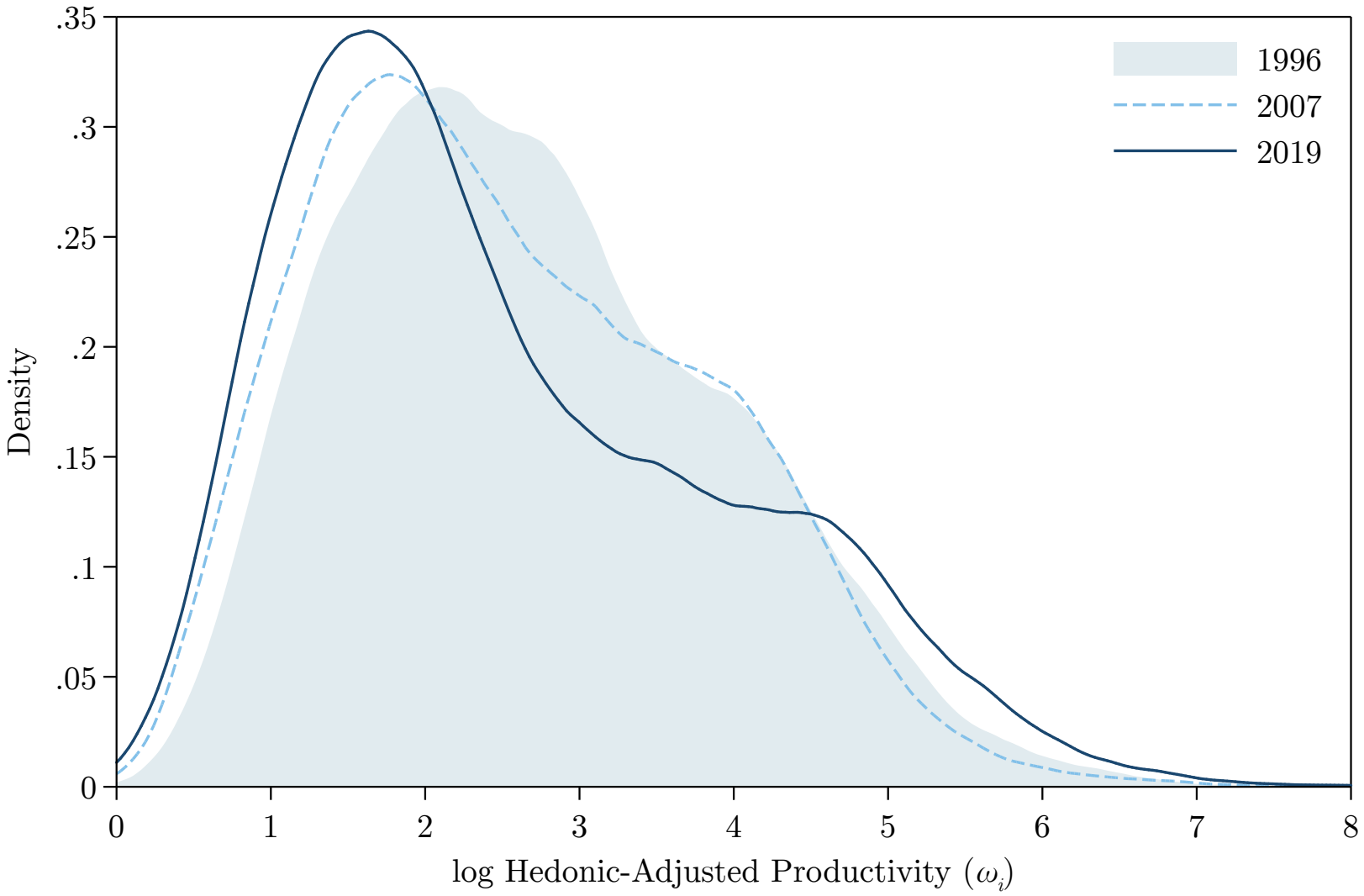


Markups: Cross-Section

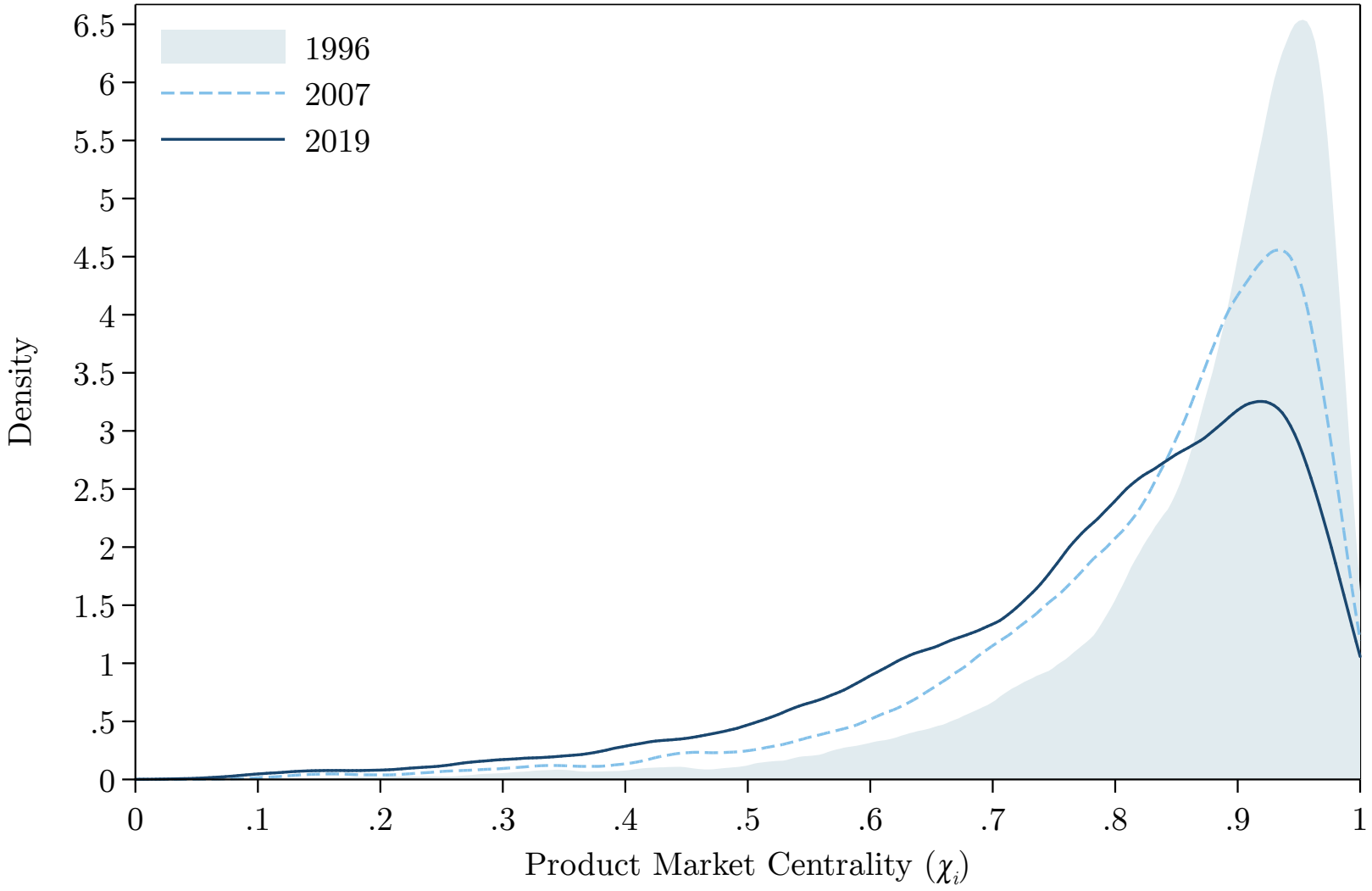


Empirics

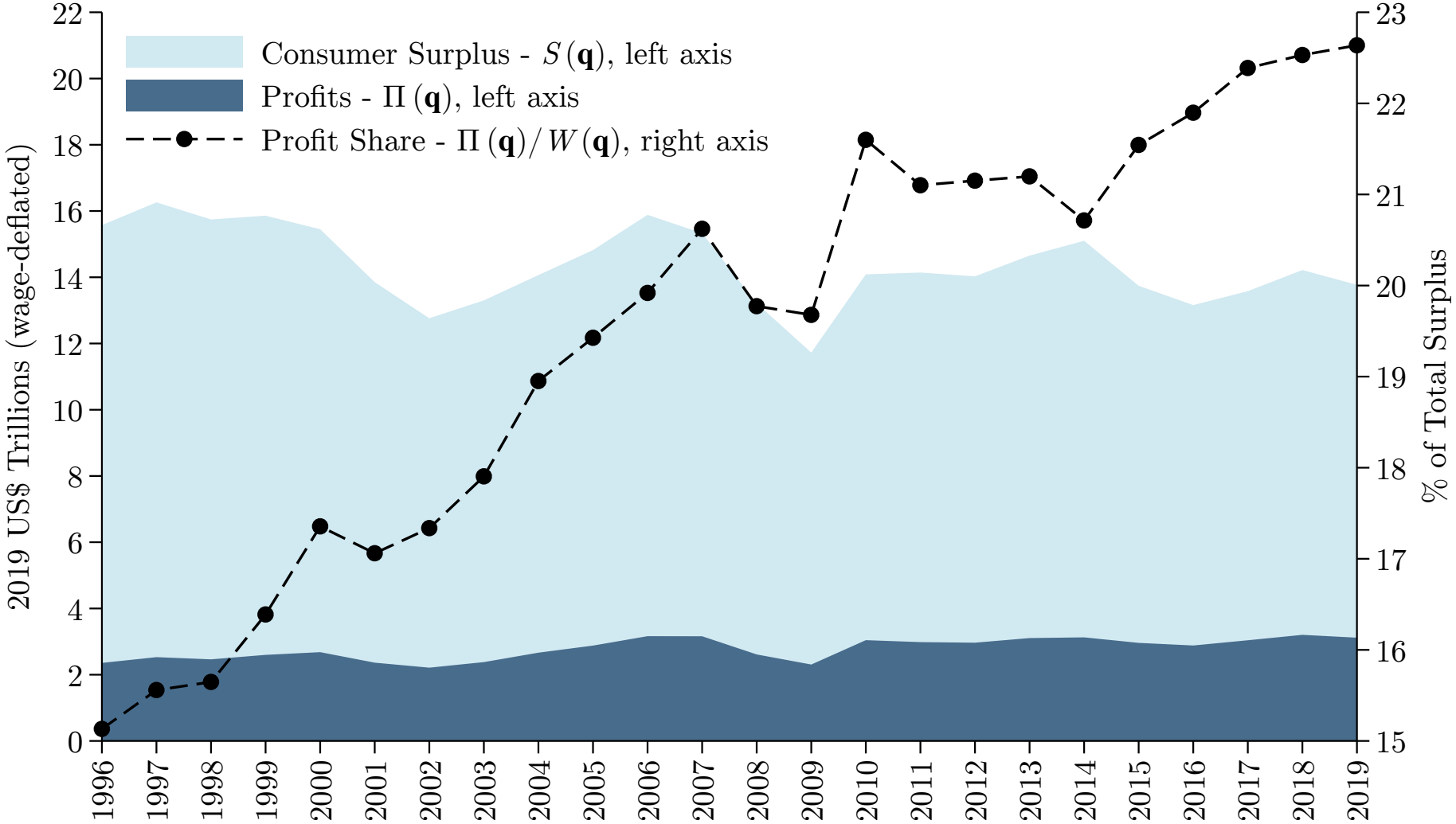
Distribution of Hedonic-Adjusted Productivity



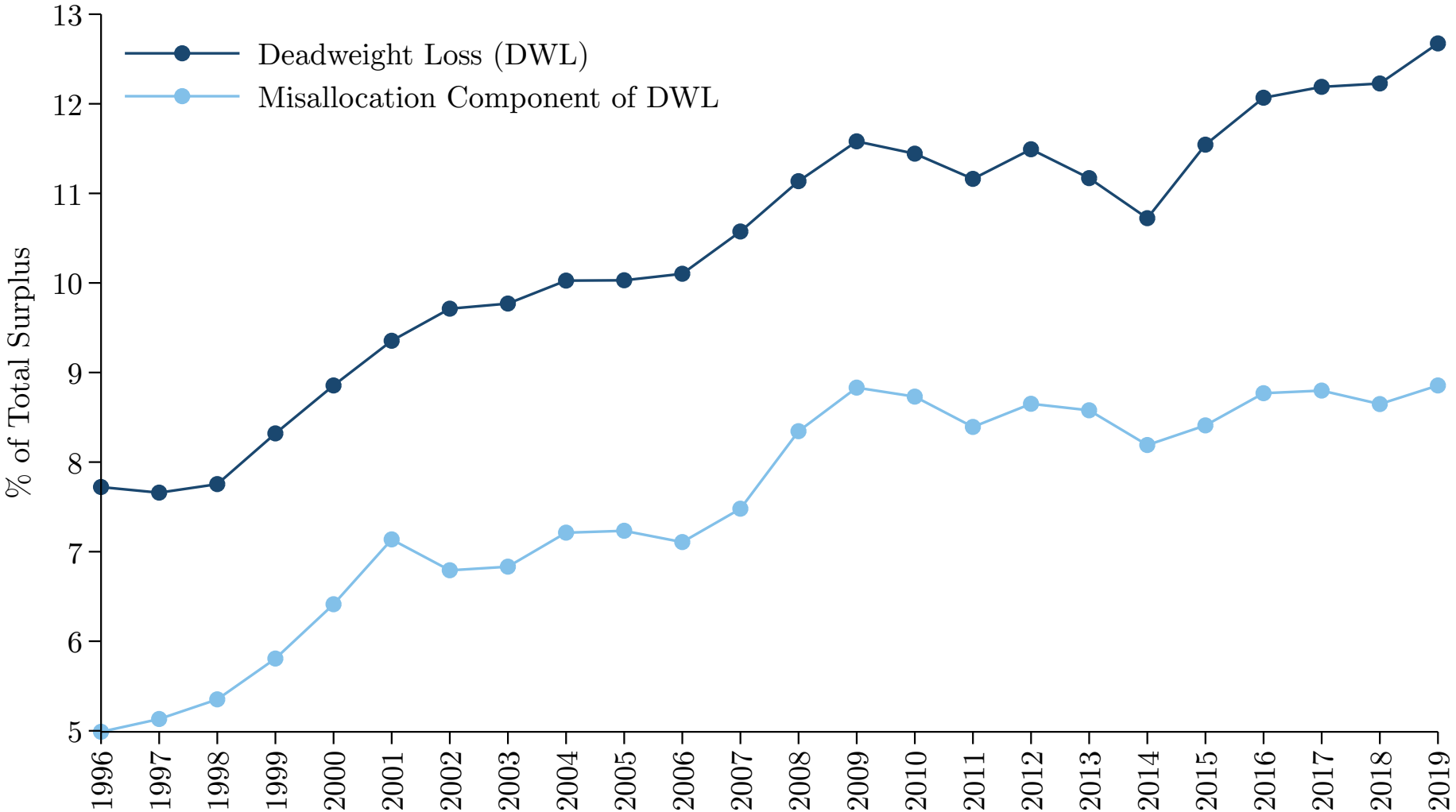
Distribution of Product Market Centrality



Total Surplus and its Distribution



Deadweight Loss from Oligopoly



Robustness & Extensions

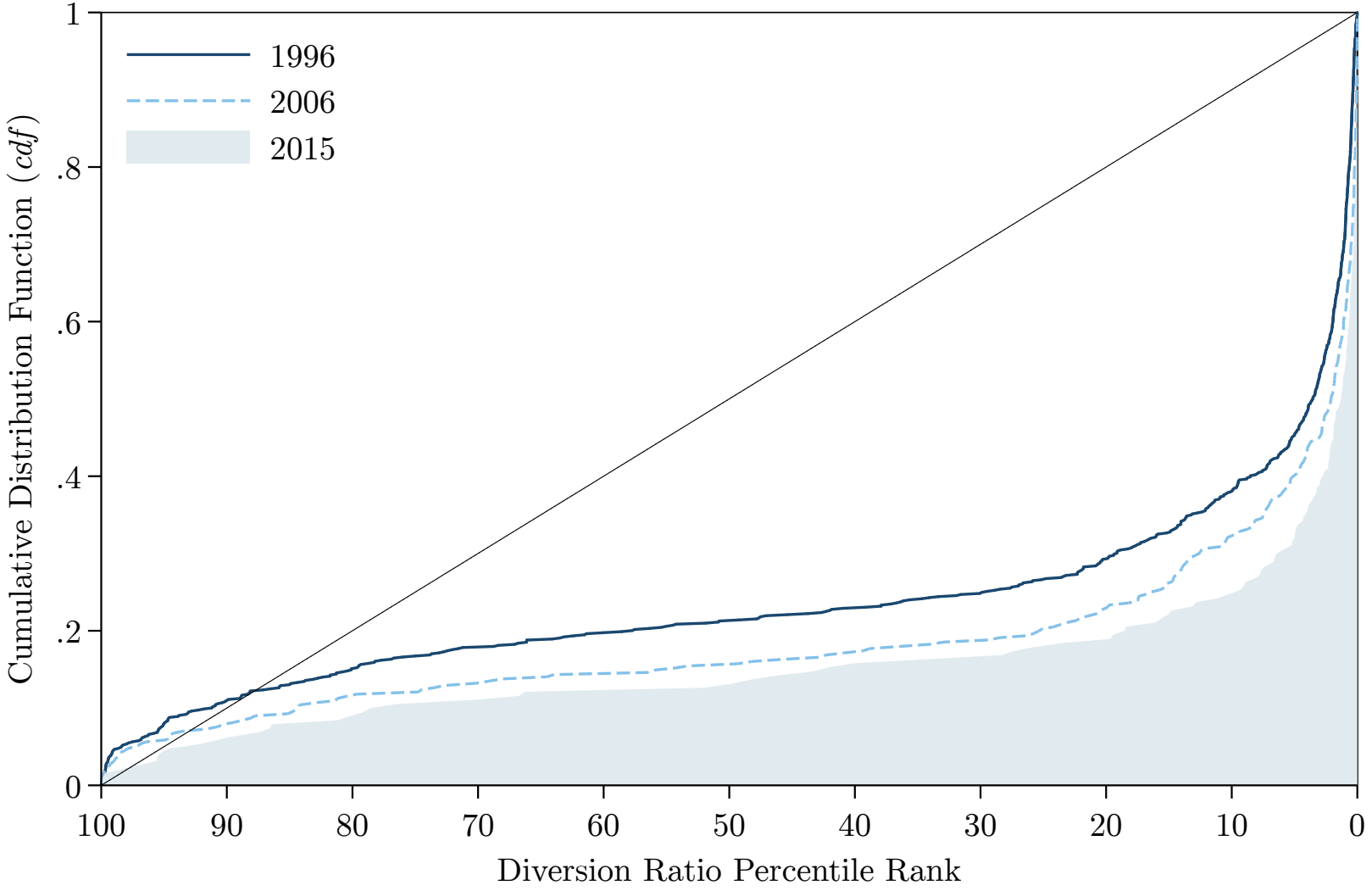
- Private and foreign firms, entry and exit
  - Aggregation result: add competitive fringes of atomistic firms in the form of a representative firms.
  - Can be located using firm-sector similarity from FHP.
- Non-flat marginal cost
- Exclude "non-tradable" industries
- Bertrand
- Multi-product firms (using Compustat Segments)
- Input-Output Linkages (using Atalay et al. 2011 IO data)

Diversion Ratio

To evaluate a merger's anti-competitive potential, the FTC-DOJ merger guidelines recommend looking at Diversion Ratios:

$$\text{Diversion Ratio}_{ij} \overset{\text{def}}{=} \frac{\partial q_i}{\partial p_j}\left(\frac{\partial q_j}{\partial p_j}\right)^{-1} = \frac{(\mathbf{I}+\mathbf{\Sigma})^{-1}_{ij}}{(\mathbf{I}+\mathbf{\Sigma})^{-1}_{jj}}$$

M&A Activity: Diversion Ratios



Take-aways

- A new GE theory of oligopoly with hedonic demand.
- Estimated for Compustat using 10-K product similarities.
- Distribution of markups is jointly determined by productivity and product market centrality.
  - Both have undergone significant changes
- Rising Oligopoly Power
  - increasing deadweight loss
  - lower consumer surplus share.

☞ I share the data! (elasticities, centrality, productivity...)

The Great Startup Sellout and the Rise of Oligopoly

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Yale SOM

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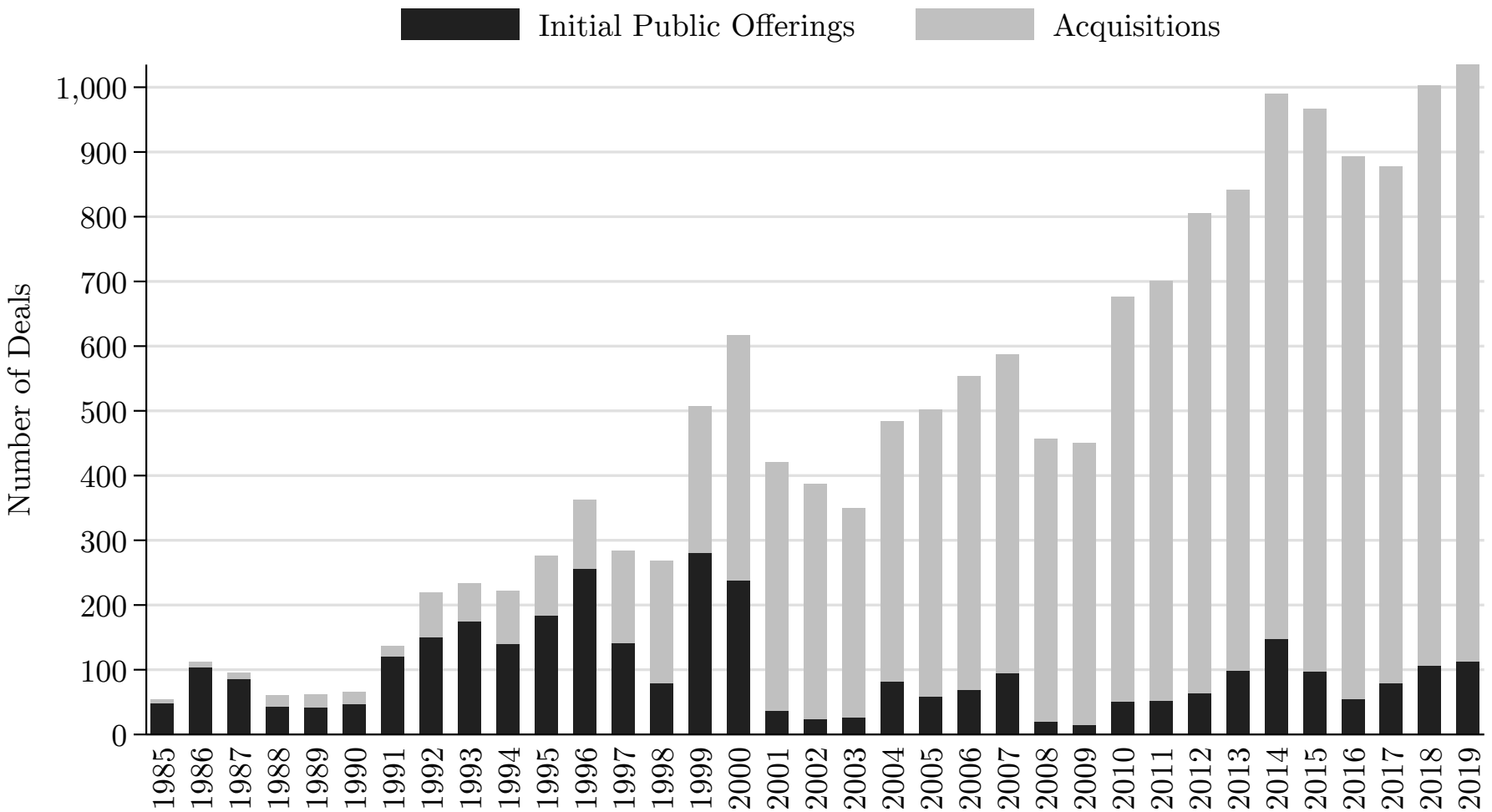
What is driving the increase in oligopoly?

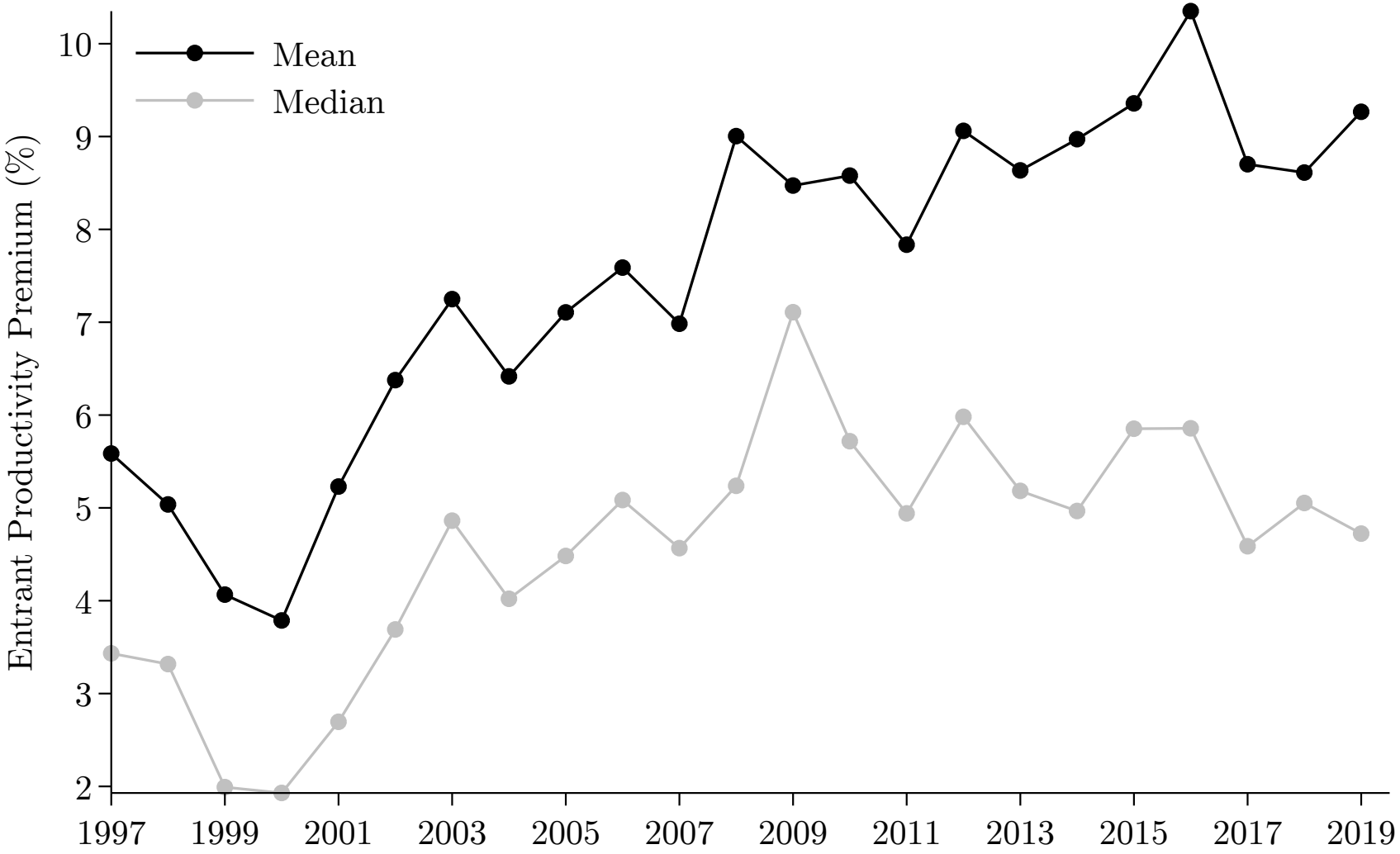
VC-backed startup exits (1985-2019)



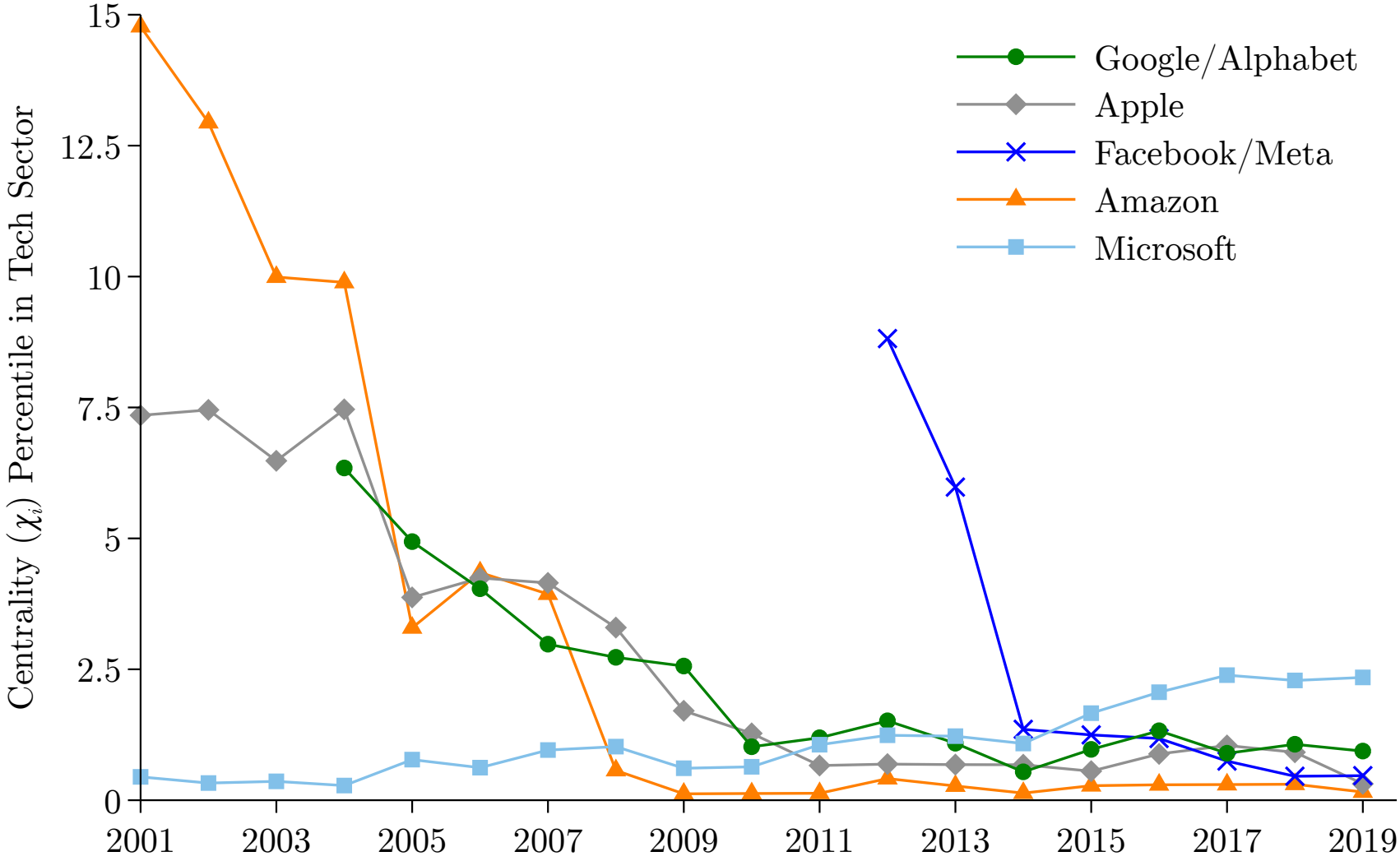
Entrant Productivity Premium

$$\text{EPP}_i = \frac{2q_i - \sqrt{f_i}}{b_i - c_i - 2q_i + \sqrt{f_i}}.$$

Entrant Productivity Premium



GAFAM Centrality



thank you