Product Differentiation and Oligopoly: a Network Approach

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Fifth Economic Networks and Finance Conference

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

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- **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

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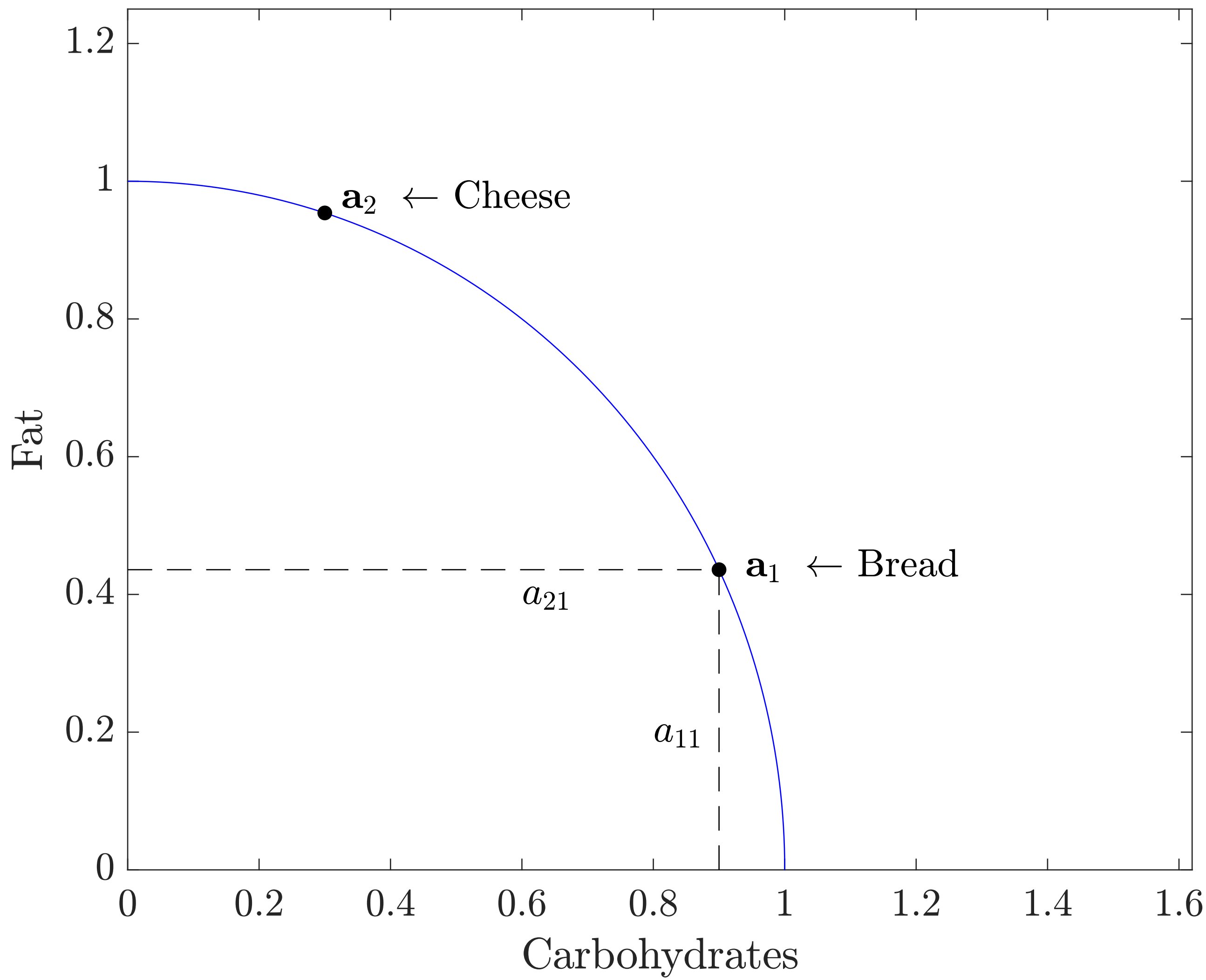
  - a vector of k common characteristics $\mathbf{a}_i$ (length 1)

A basic example: 2 firms, 2 characteristics



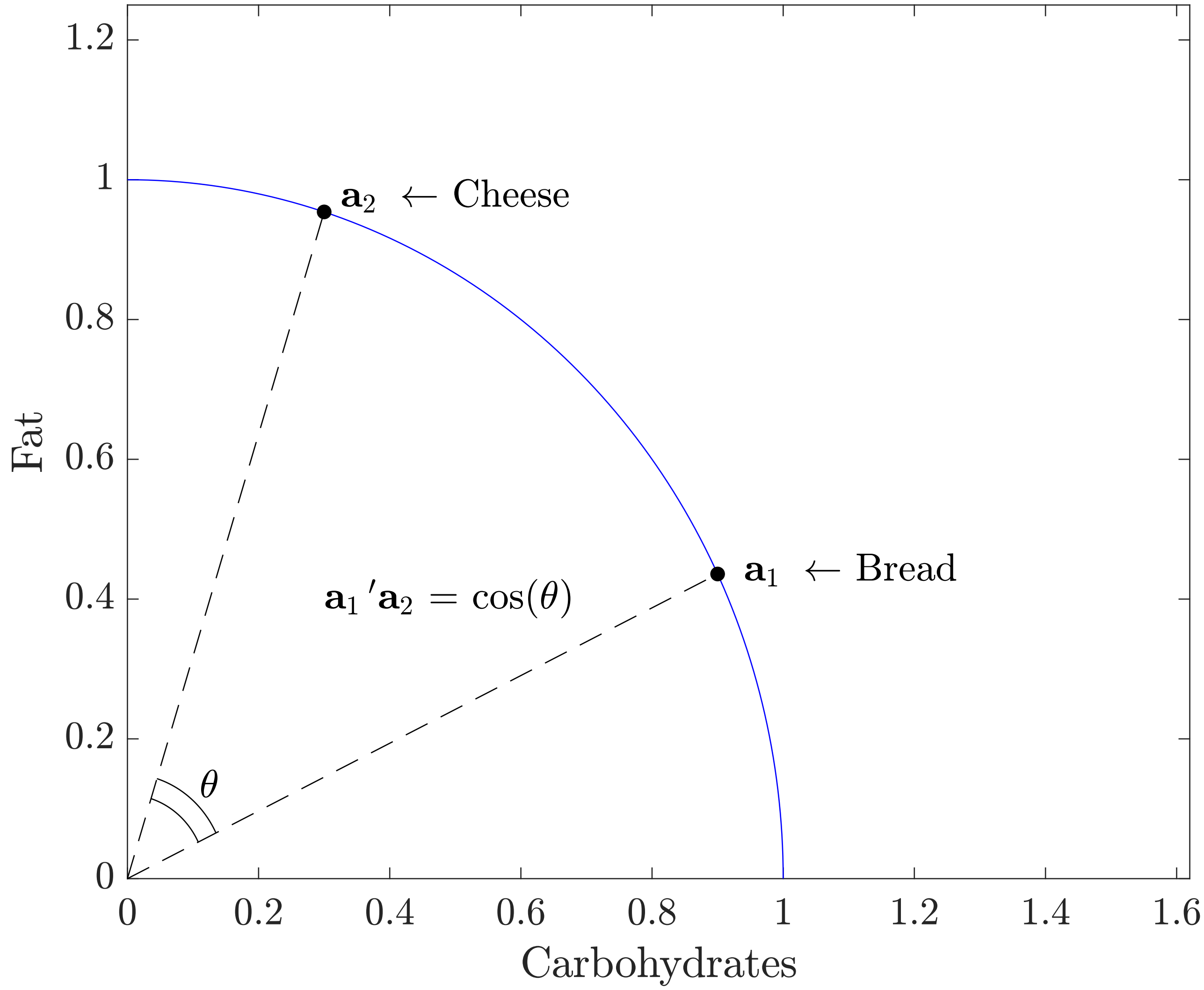
Aggregating common characteristics

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



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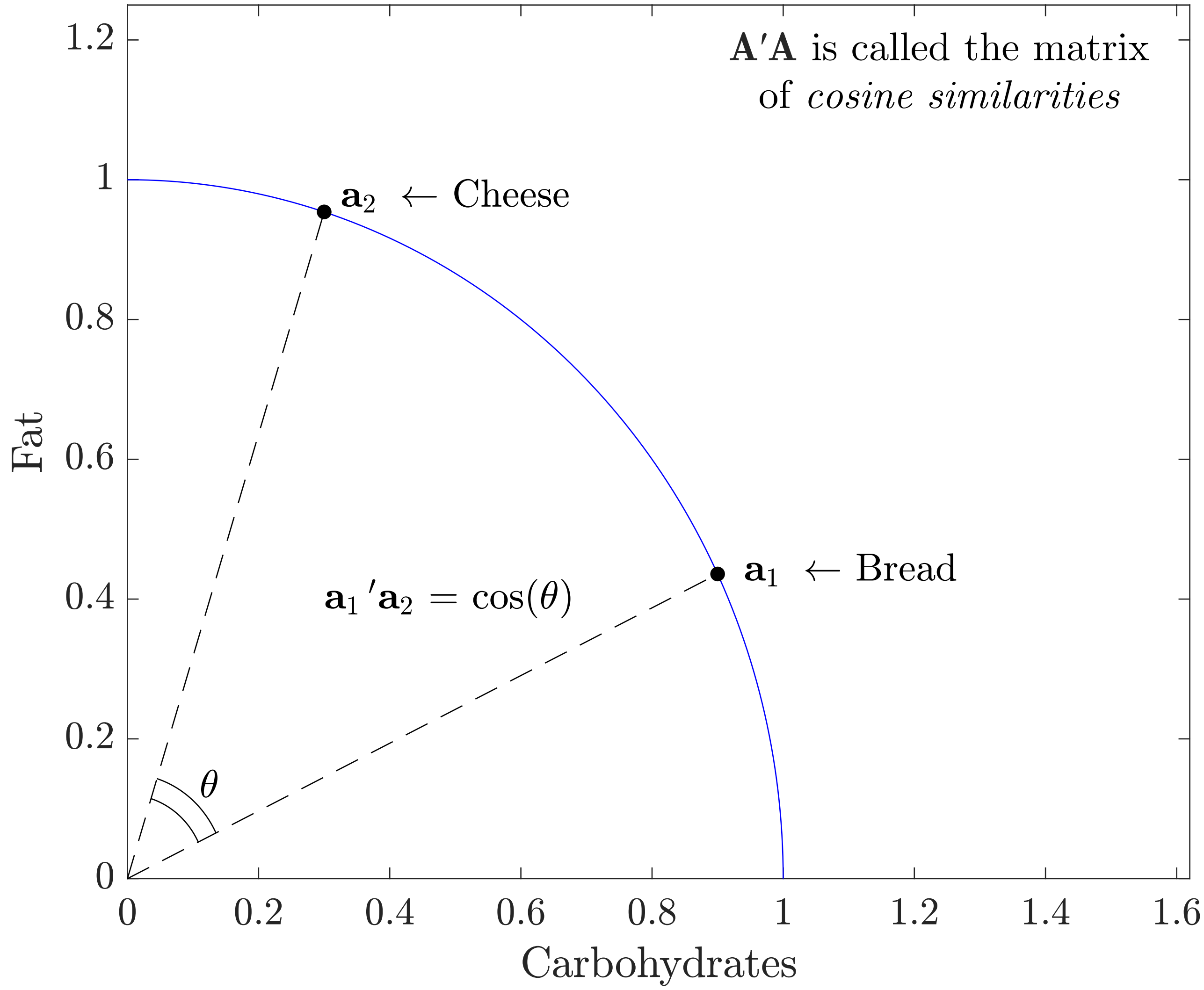

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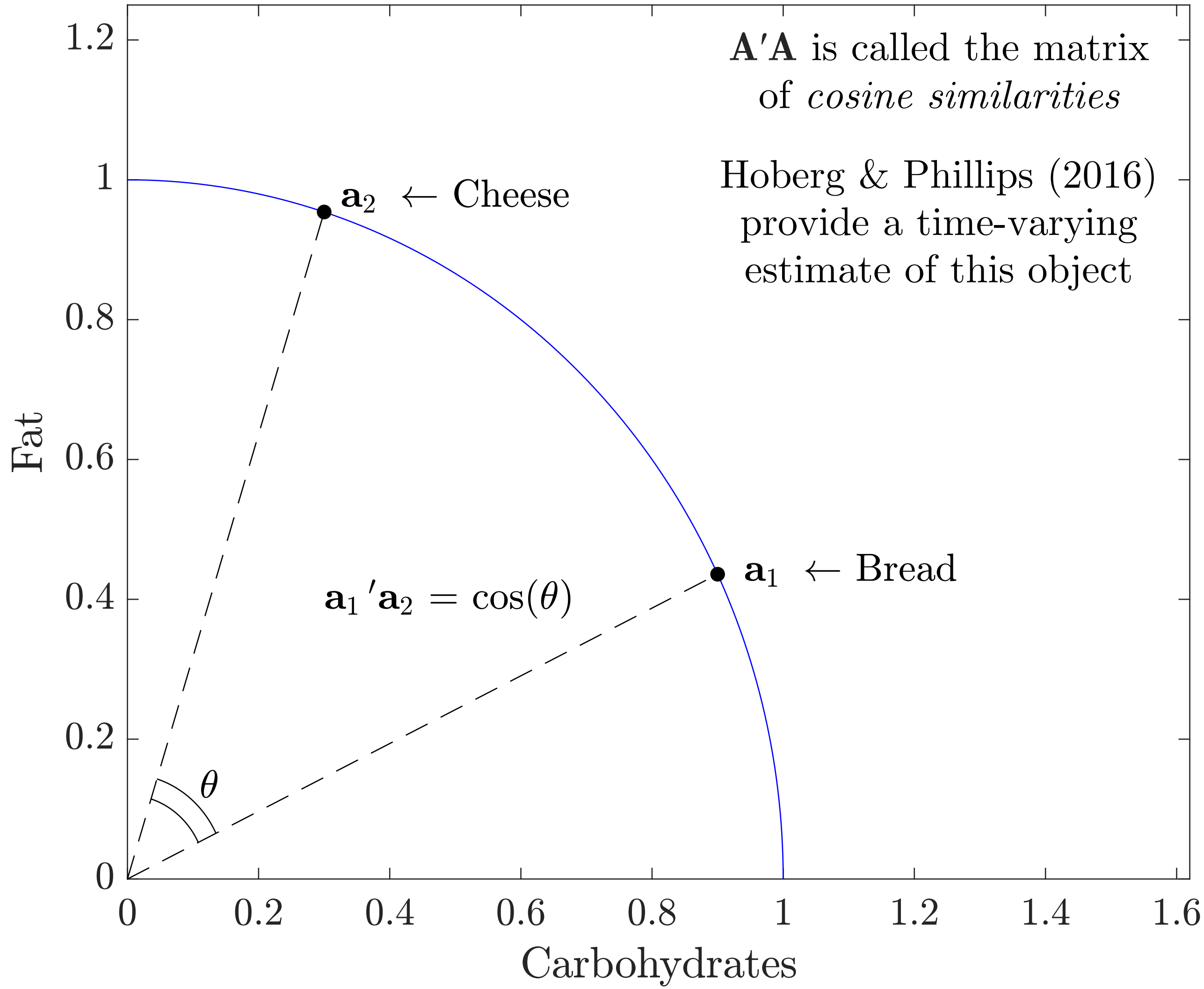

Representative Consumer-Worker-Investor

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

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

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- 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 and Conduct

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

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- Cournot Competition: firm i chooses supply q_i to maximize profits function π_i → (Linear-quadratic) Network game
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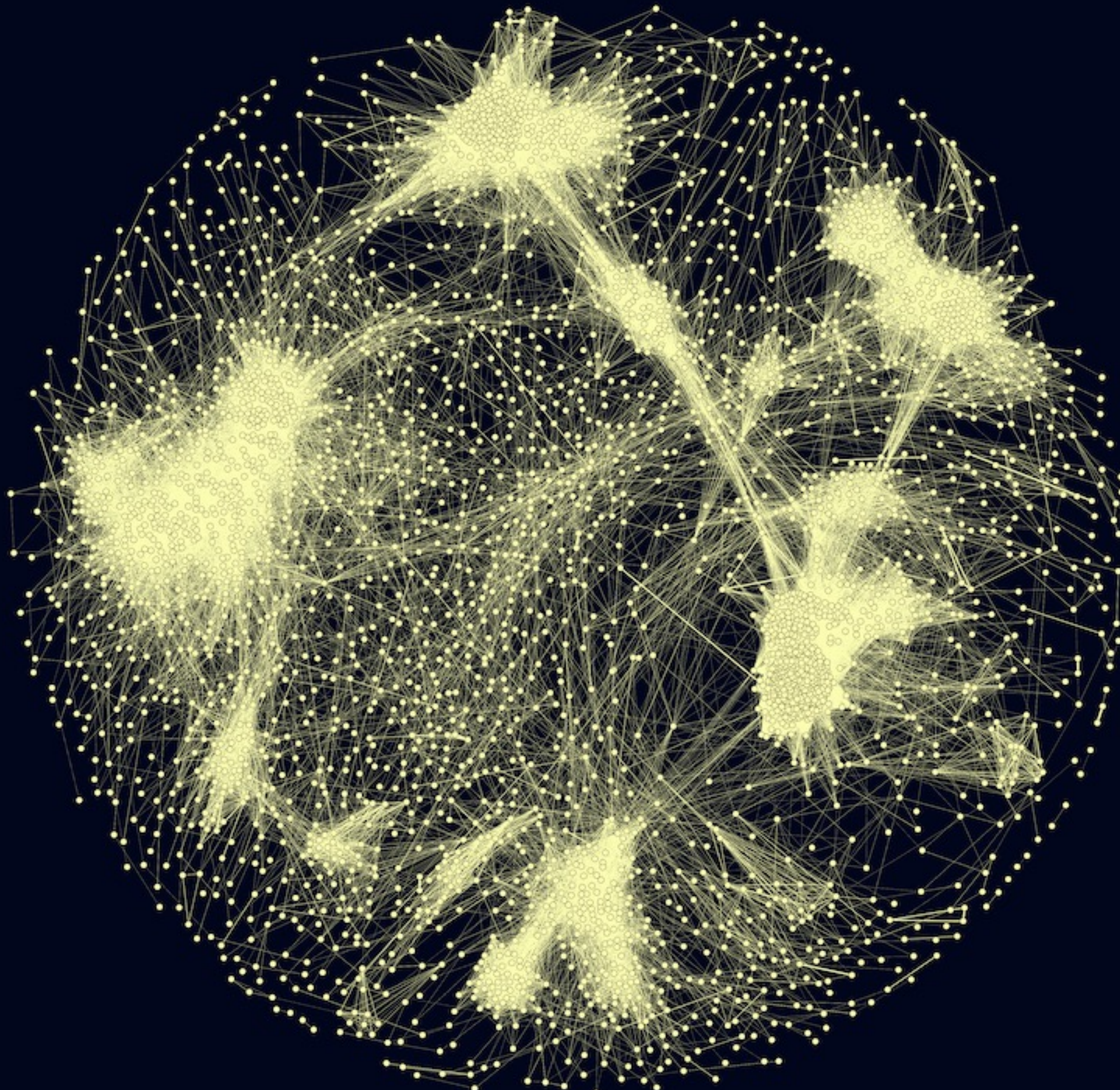
- Why? the matrix of cosine similarities $\mathbf{A}'\mathbf{A}$ (proportional to $\mathbf{\Sigma}$) can be thought of as an adjacency matrix of a network



Cournot-Nash Equilibrium

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

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Scale
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Cournot-Nash Equilibrium

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

Scale Economies → $\boldsymbol{\Delta}$

Network Position → $\boldsymbol{\Sigma}$

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- $\boldsymbol{\Delta}$: Scale Economies
- $\boldsymbol{\Sigma}$: Network Position
- $\left(\mathbf{b} - \mathbf{c}^0\right)$: Marginal Surplus at $q_i = 0$

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Scale Economies ($\boldsymbol{\Delta}$)

Network Position ($\boldsymbol{\Sigma}$)

Marginal Surplus at $q_i = 0$ ($\mathbf{b} - \mathbf{c}^0$)

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

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

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Monopolistic Markup

$= (1 + \omega_i)/2$

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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

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- Construction:

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

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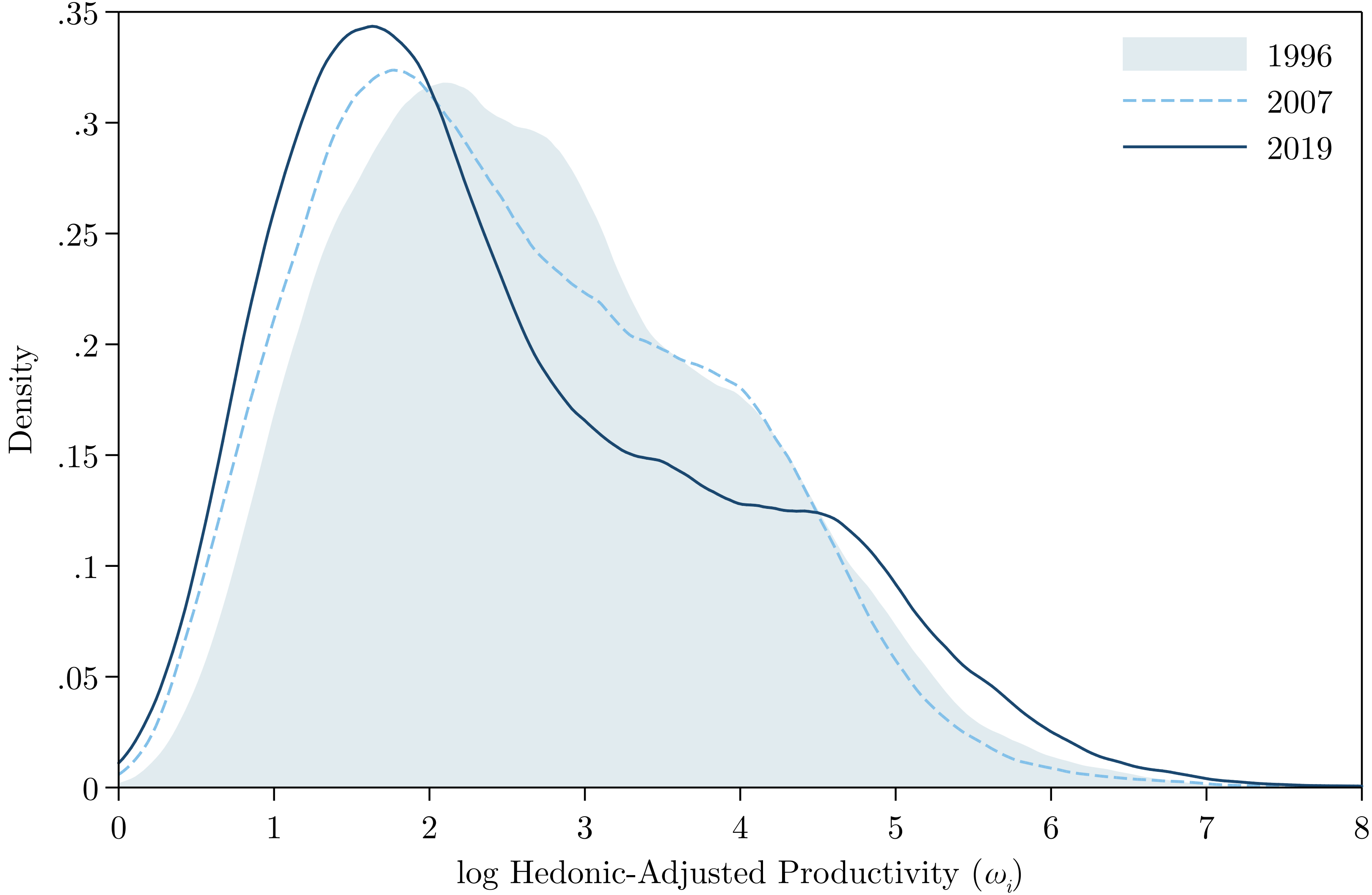
- **Identification**: $\mathbf{a}_i$ and $\mathbf{v}_i$ are collinear $\Rightarrow$ $\mathbf{a}_i{}'\mathbf{a}_j \equiv \cos_{ij}{}^{\text{HP}}$

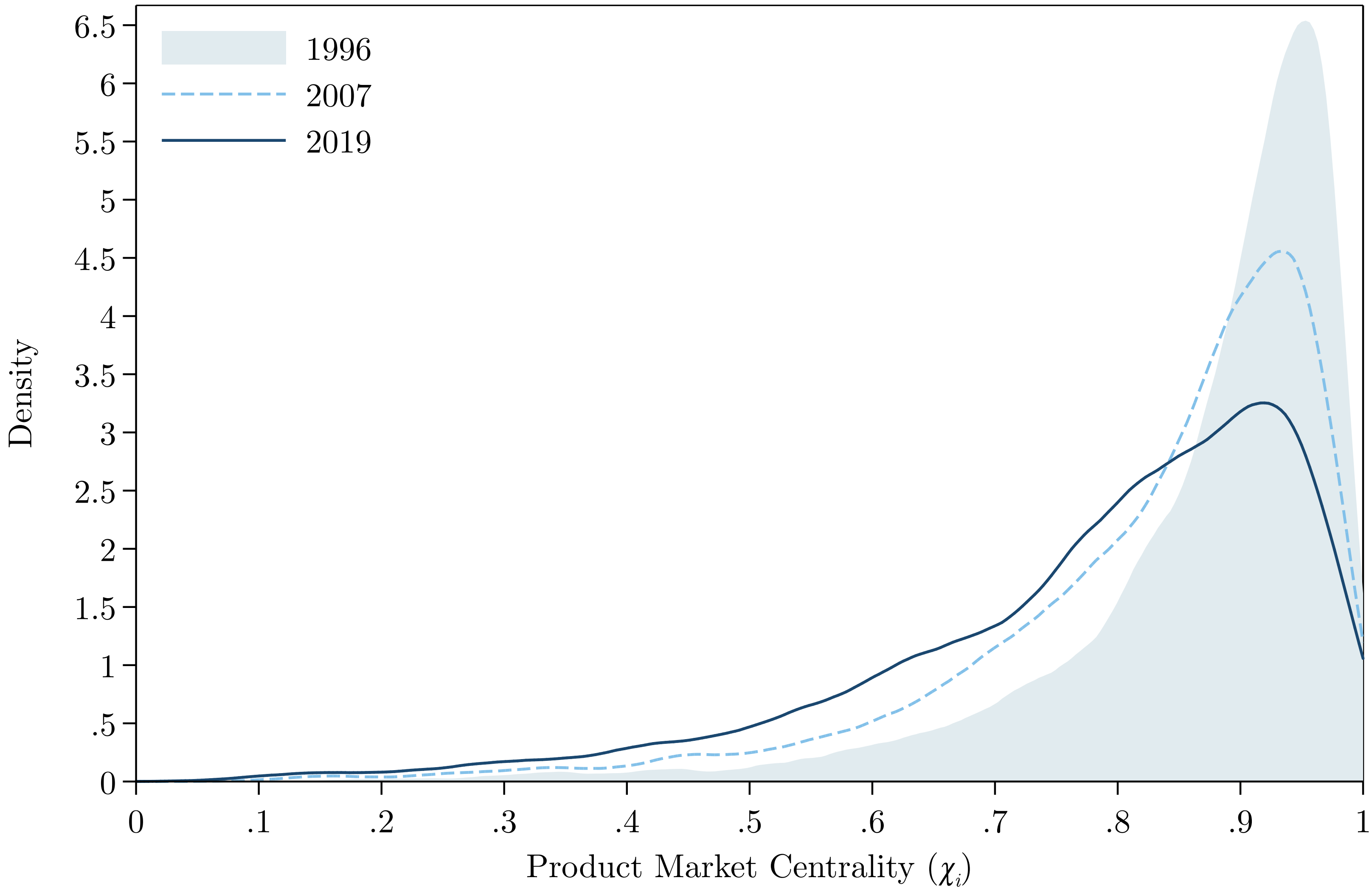
			Demand Elasticity $\left(\frac{\partial q_i}{\partial p_j}\cdot\frac{p_j}{q_i}\right)$	
Market	**Firm** i	**Firm** j	**Micro Estimate**	**GHL** (*text-based*)
Auto	Ford	Ford	-4.320	-5.197
Auto	Ford	General Motors	0.034	0.056
Auto	Ford	Toyota	0.007	0.017
Auto	General Motors	Ford	0.065	0.052
Auto	General 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

Empirics

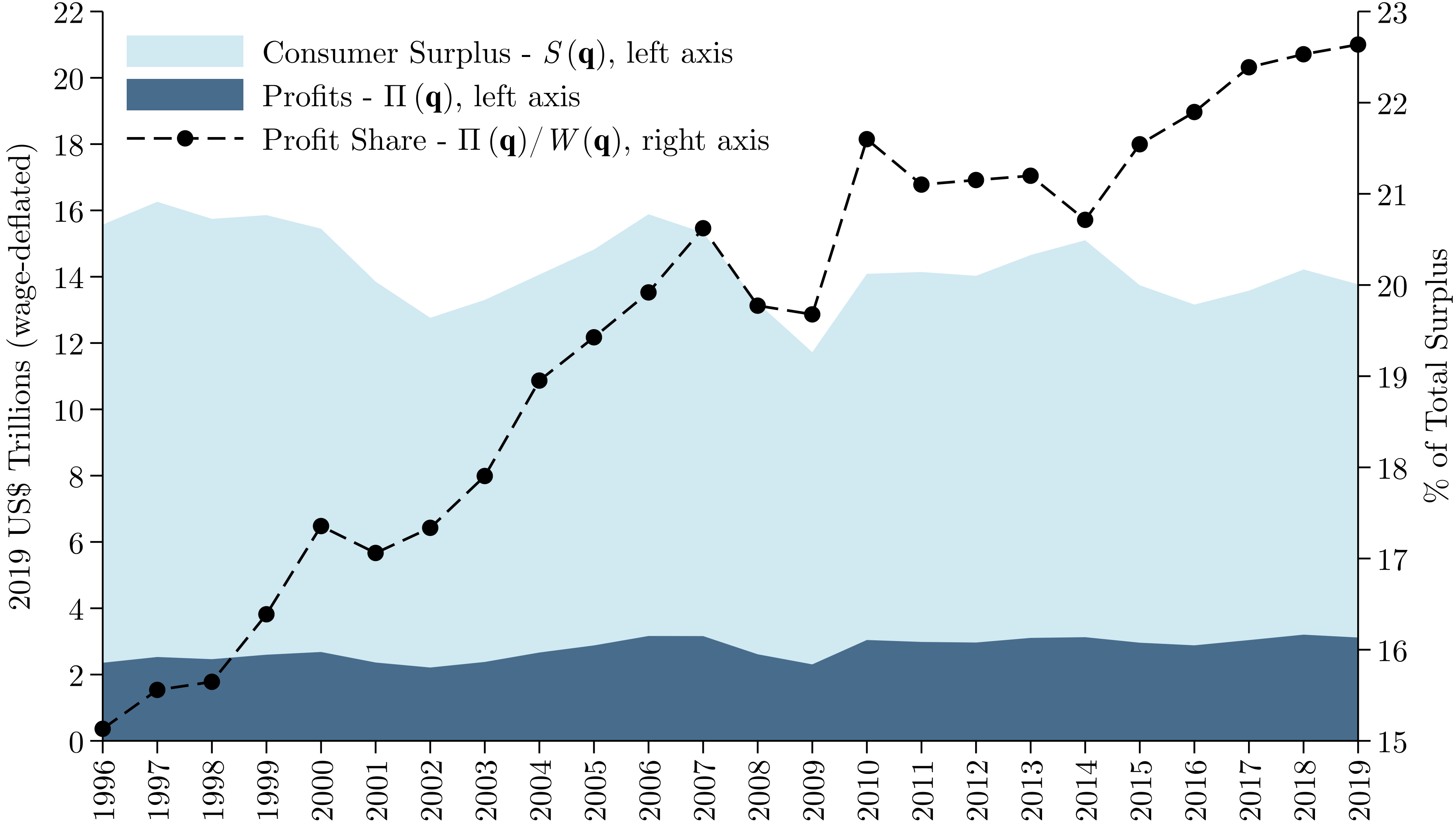
Distribution of Hedonic-Adjusted Productivity



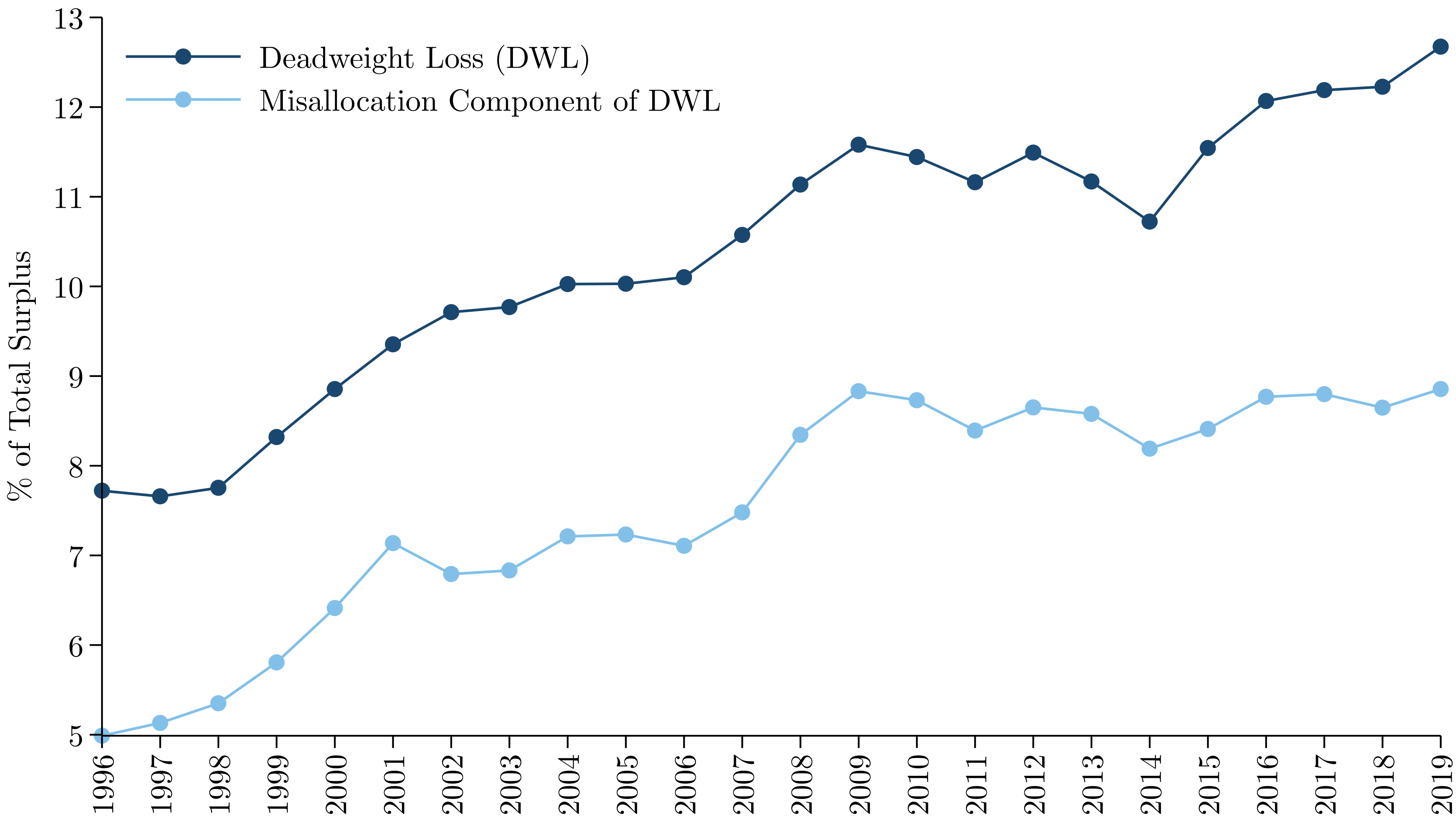
Distribution of Product Market Centrality



Total Surplus and its Distribution



Deadweight Loss from Oligopoly



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- Multi-product firms (using Compustat Segments)
- Input-Output Linkages (using Atalay et al. 2011 IO data)

A Tale of Two Networks:
Common Ownership and Product Market Rivalry

Florian Ederer
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Fifth Economic Networks and Finance Conference

Common Ownership

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- **Rising Common Ownership** (Gilje, Gormley & Levit 2020; Backus, Conlon & Sinkinson, 2021) → Huge policy/research interest:
  - Consolidation in asset management industry is putting stock ownership in the hands of a few large institutional investors.

Research Question

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→ Depends on ownership as well!

Common Ownership

- There are Z funds indexed by $z = 1,2,...,Z$. Fund z own shares s_{iz} in company i. Then fund z's total income is:

$$V_z \stackrel{\text{def}}{=} \sum_{i=1}^{n} s_{iz}\,\pi_i \qquad \text{and} \qquad \sum_{z=1}^{Z} s_{iz} = 1$$

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$$\phi_i \overset{\text{def}}{=} \sum_{z=1}^{Z} s_{iz}\,V_z$$

Profit Weights

- We can write i's objective function in terms of profit weights:

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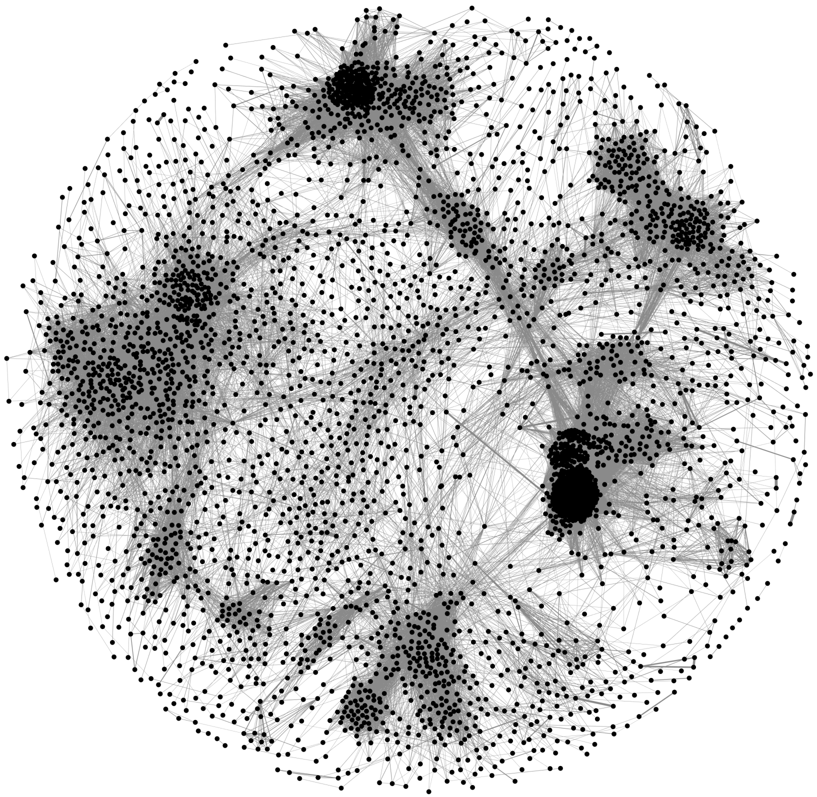
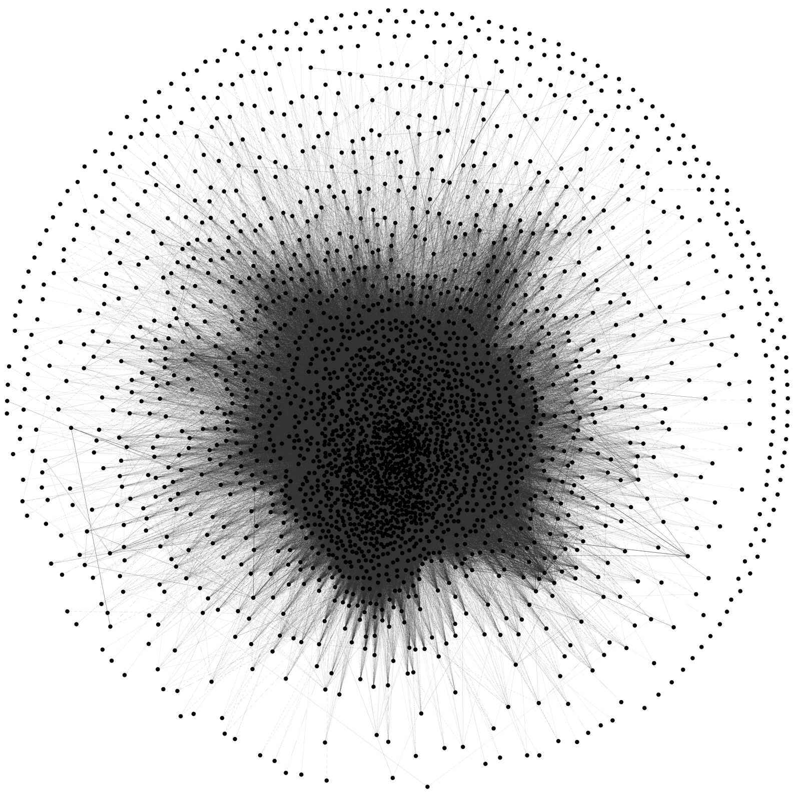
- Equilibrium:

$$\mathbf{q} \;= \left(2\mathbf{I} + \mathbf{\Delta} + \mathbf{\Sigma} + \mathbf{K} \circ \mathbf{\Sigma}\right)^{-1} \left(\mathbf{b} - \mathbf{c}\right)$$

A Tale of Two Networks

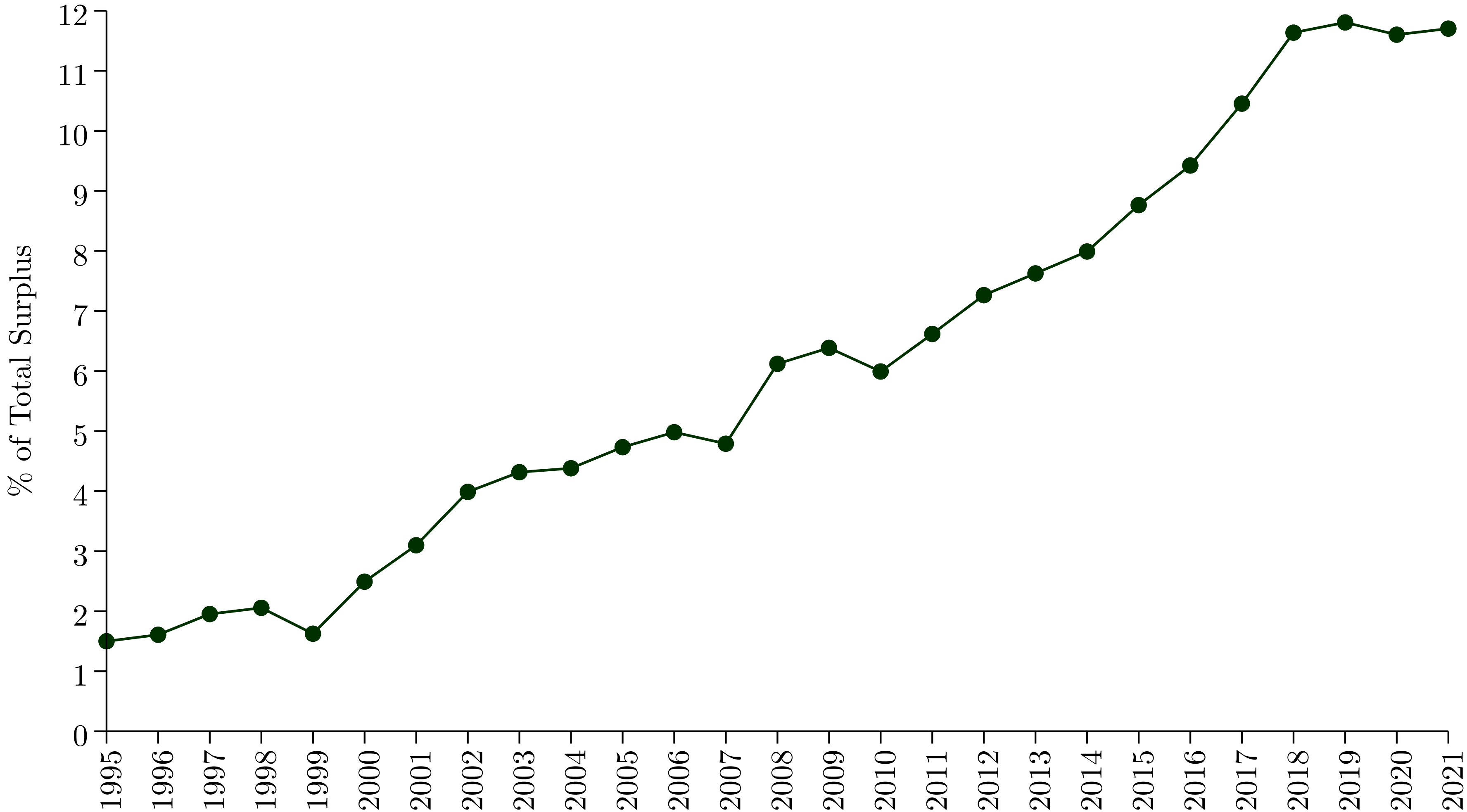


Product Market Similarity - $\mathbf{A'A}$
based on 10-K (Hoberg & Phillips, 2016)

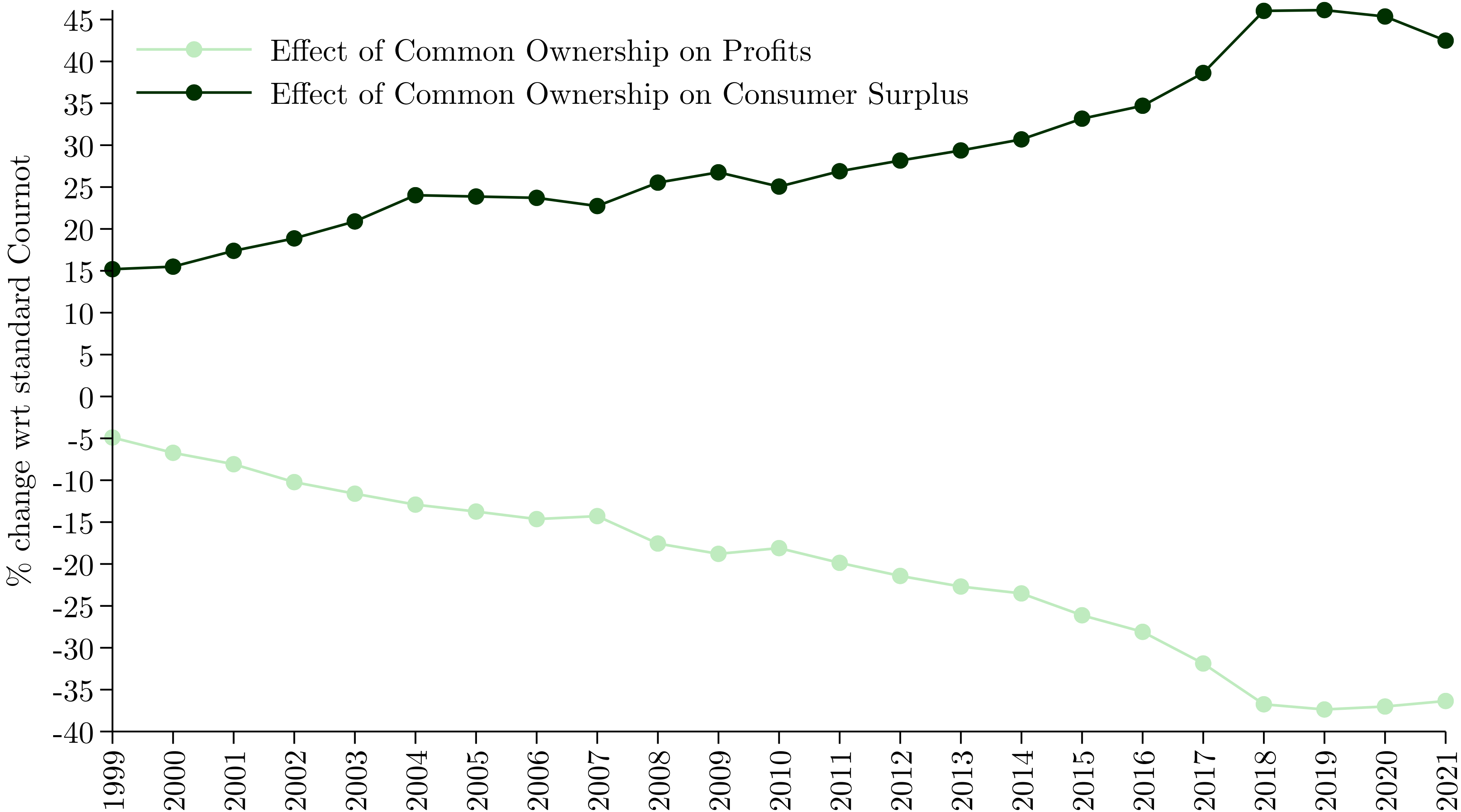


Common Ownership Weights – $\mathbf{K}$
based on 13-F data (Backus et al. 2021)

Deadweight Loss



Effect of CO on Profits and Consumer Surplus



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...)

thank you

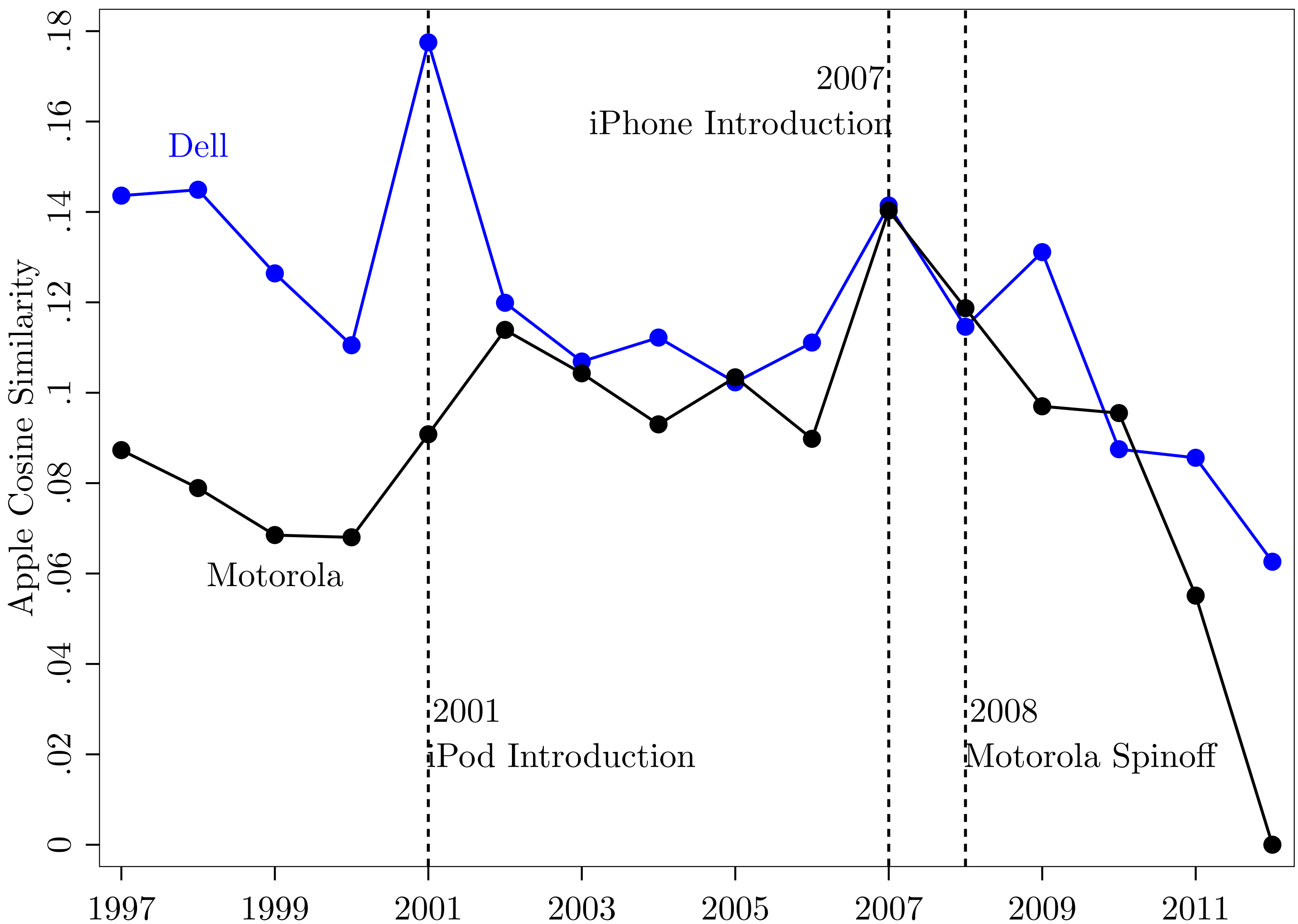
Product Market Centrality

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

$$= \frac{1}{2} \begin{bmatrix} 1-\chi_1 & 0 & \cdots & 0 \\ 0 & 1-\chi_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1-\chi_n \end{bmatrix} (\mathbf{b} - \mathbf{c})$$

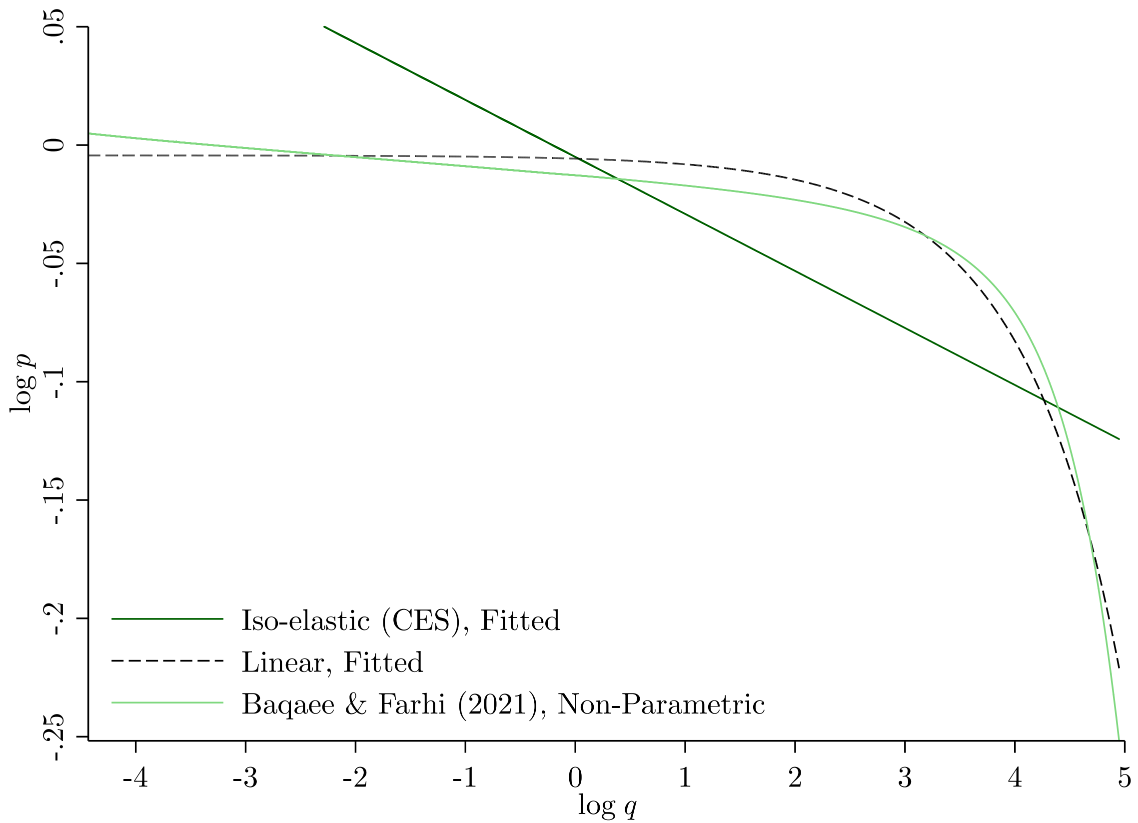
10-K-Based Classifications of Firms in Business Services (SIC-3 = 737)

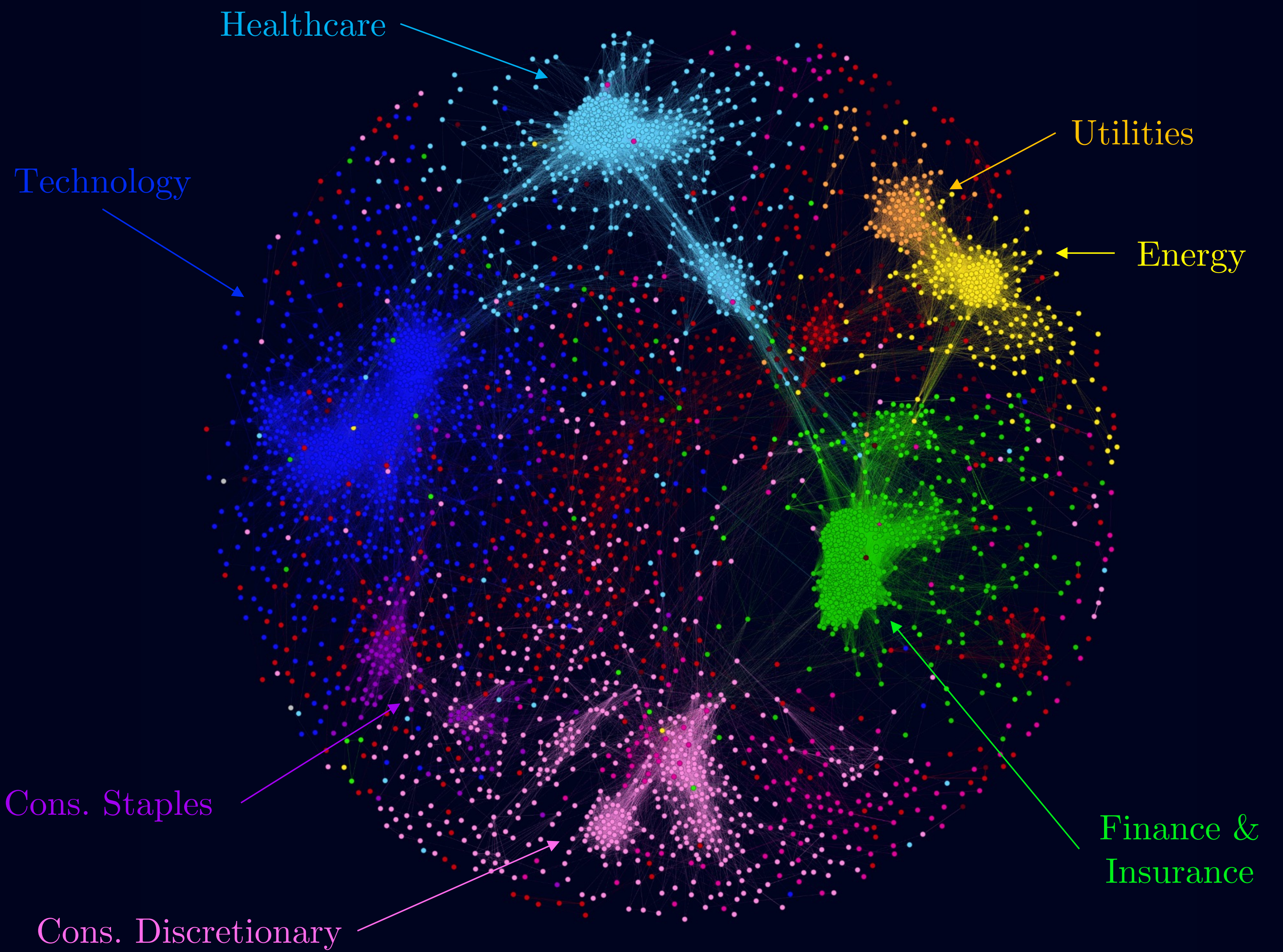
Submarket 1: Entertainment (Sample Focal Firm: Wanderlust Interactive)
43 rivals: Maxis, Piranha Interactive Publishing, Brilliant Digital Entertainment, Midway Games, Take Two Interactive Software, THQ, 3DO, New Frontier Media, . . .
SIC codes of rivals: computer programming and data processing [SIC-3 = 737] (24 rivals), motion picture production and allied services [SIC-3 = 781] (4 rivals), miscellaneous other (13 rivals)
Core words: entertainment (42), video (42), television (38), royalties (35), internet (34), content (33), creative (31), promotional (31), copyright (31), game (30), sound (29), publishing (29), . . .
Submarket 2: Medical Services (Sample Focal Firm: Quadramed Corp.)
66 rivals: IDX Systems, Medicus Systems, Hpr, Simione Central Holdings, National Wireless Holdings, HCIA, Apache Medical Systems, . . .
SIC codes of rivals: computer programming and data processing [SIC-3 = 737] (45 rivals), insurance agents, brokers, and service [SIC-3 = 641] (5 rivals), miscellaneous health services [SIC-3 = 809] (4 rivals), management and public relations services [SIC-3 = 874] (3 rivals), miscellaneous other (9 rivals)
Core words: client (59), database (54), solution (49), patient (47), copyright (47), secret (47), physician (47), hospital (46), health care (46), server (45), resource (44), functionality (44), billing (44), . . .

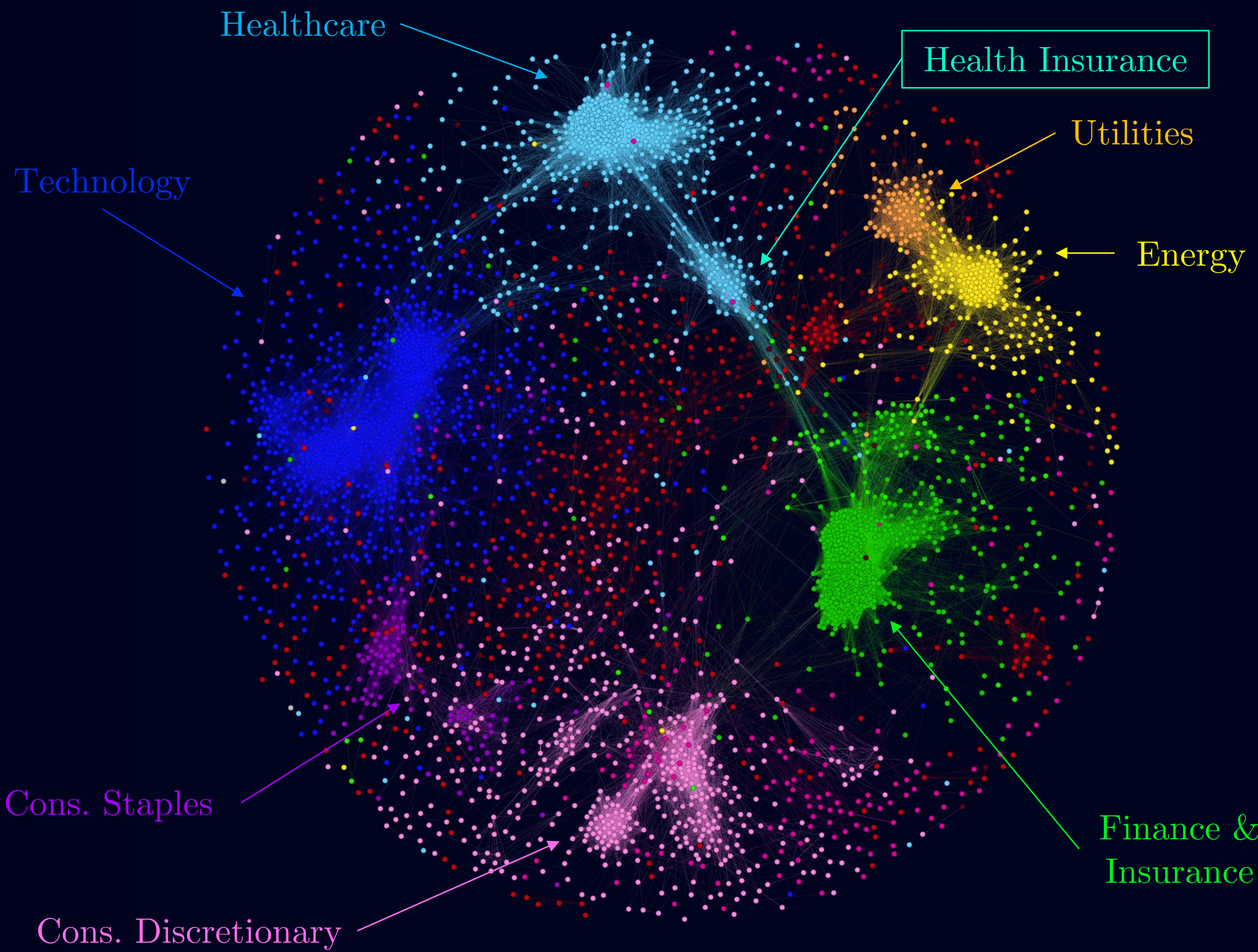

Apple Cosine Similarity
0
.02
.04
.06
.08
.1
.12
.14
.16
.18
1997
1999
2001
2003
2005
2007
2009
2011
Dell
Motorola
2007
iPhone Introduction
2001
iPod Introduction
2008
Motorola Spinoff

Linear Demand

1. Allows to write demand in terms of cosine similarity
2. Already standard in literature (see Syverson 2019 JEP review)
3. Data is begging you to use it




Healthcare
Utilities
Technology
Energy
Cons. Staples
Finance &
Insurance
Cons. Discretionary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Health Insurance
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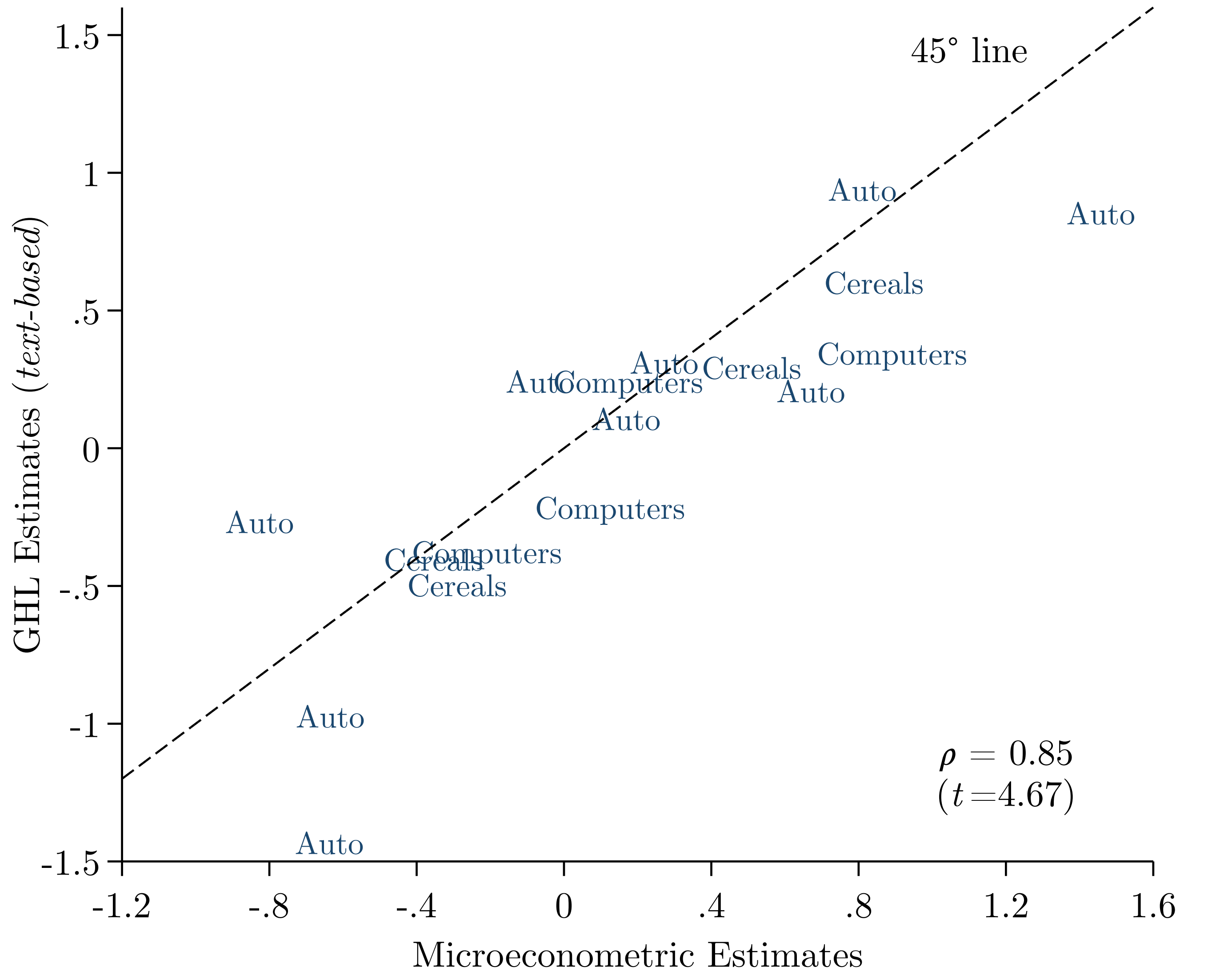
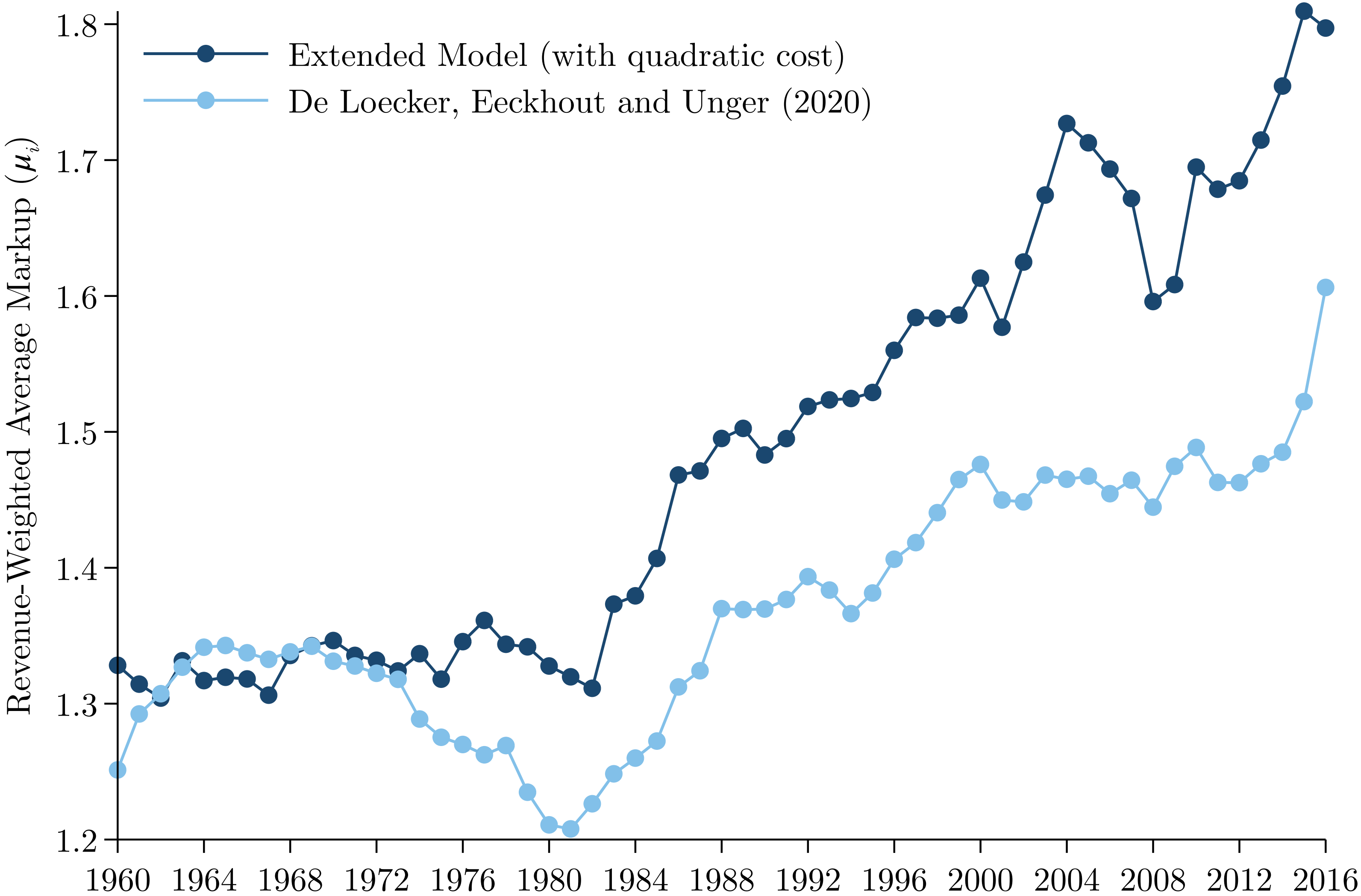
Variable: $\log\left|\frac{\partial q_i}{\partial p_j}\cdot\frac{p_j}{q_i}\right|$, *residualized on* $(i = j)$ *dummy and Market Fixed Effects*



Markups: Time Series



Profits, Potential and Welfare

$$\Pi(\mathbf{q}) = \mathbf{q}'\left(\mathbf{b}-\mathbf{c}^0\right) - \frac{1}{2}\cdot\mathbf{q}'\left(2\mathbf{I}+\boldsymbol{\Delta}+2\boldsymbol{\Sigma}\right)\mathbf{q} - F$$

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$$W(\mathbf{q}) = \mathbf{q}'\left(\mathbf{b}-\mathbf{c}^0\right) - \frac{1}{2}\cdot\mathbf{q}'\left(\mathbf{I}+\boldsymbol{\Delta}+\boldsymbol{\Sigma}\right)\mathbf{q} - F$$

where $\boldsymbol{\Delta} \overset{\text{def}}{=} \begin{bmatrix} \delta_1 & 0 & \cdots & 0 \\ 0 & \delta_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \delta_n \end{bmatrix}$ and $F \overset{\text{def}}{=} \sum_{i=1}^{n} f_i$

Identification

- Compustat: Revenues $(p_i q_i)$, COGS (TVC_i), SG&A (f_i).

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

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

Identification

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

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

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

Entry and Exit

The paper takes into account entry and exit in two ways.

- **Atomistic Firms** with quadratic cost and Pareto-distributed productivity that enter/exit endogenously, modelled through a representative firm. New aggregation result that allows for intensive and extensive margin. Results are virtually unchanged under this extension.

- **Granular Firms** have a choke price: when the social planner forces firms to price at marginal cost (Perfect Competition) some exit. Fewer firms compete much more aggressively (TS $\uparrow$)

Adding a representative competitive firm

Proposition 9. *Assume that there is a continuum of potential entrants that are indexed by a productivity parameter* $\zeta \in (\underline{\zeta}, \infty)$*, with* $\underline{\zeta} > 0$*, and that produce a homogeneous good using the following quadratic cost function:*

$$h(\zeta) = \frac{1}{2\zeta} \cdot q^2(\zeta) \tag{2.75}$$

Assume also that the firms face cost of entry equal to one unit of labor and that the probability density of type-ζ *potential entrants is given by*

$$pdf(\zeta) = \frac{\beta - 1}{\zeta^{\beta+1}} \tag{2.76}$$

implying that ζ *follows a Pareto distribution with shape parameter* β *and scale parameter* $\underline{\zeta} \stackrel{\text{def}}{=} [(\beta - 1)/\beta]^{\frac{1}{\beta}}$*.*[9] *Then, as the parameter* β *converges down to* 1*, the cost function of the corresponding aggregate representative firm is approximated by*

$$h_{n+1} = \frac{q_{n+1}^2}{2} \tag{2.77}$$

where and h_{n+1} *and* q_{n+1} *are, respectively, the labor input and the output of the representative firm, and the productivity cutoff for entry converges to* $\zeta_{\min} = \frac{1}{q_{n+1}}$*.*

Because employment and revenues are proportional to ζ, it follows that, if the assumptions above are respected, both the revenue and employment distribution of firms also approximate a Pareto distribution with shape parameter $\beta = 1$, sometimes called a Zipf Law.

Input-Output Linkages

- Leontief production function links intermediate/final output

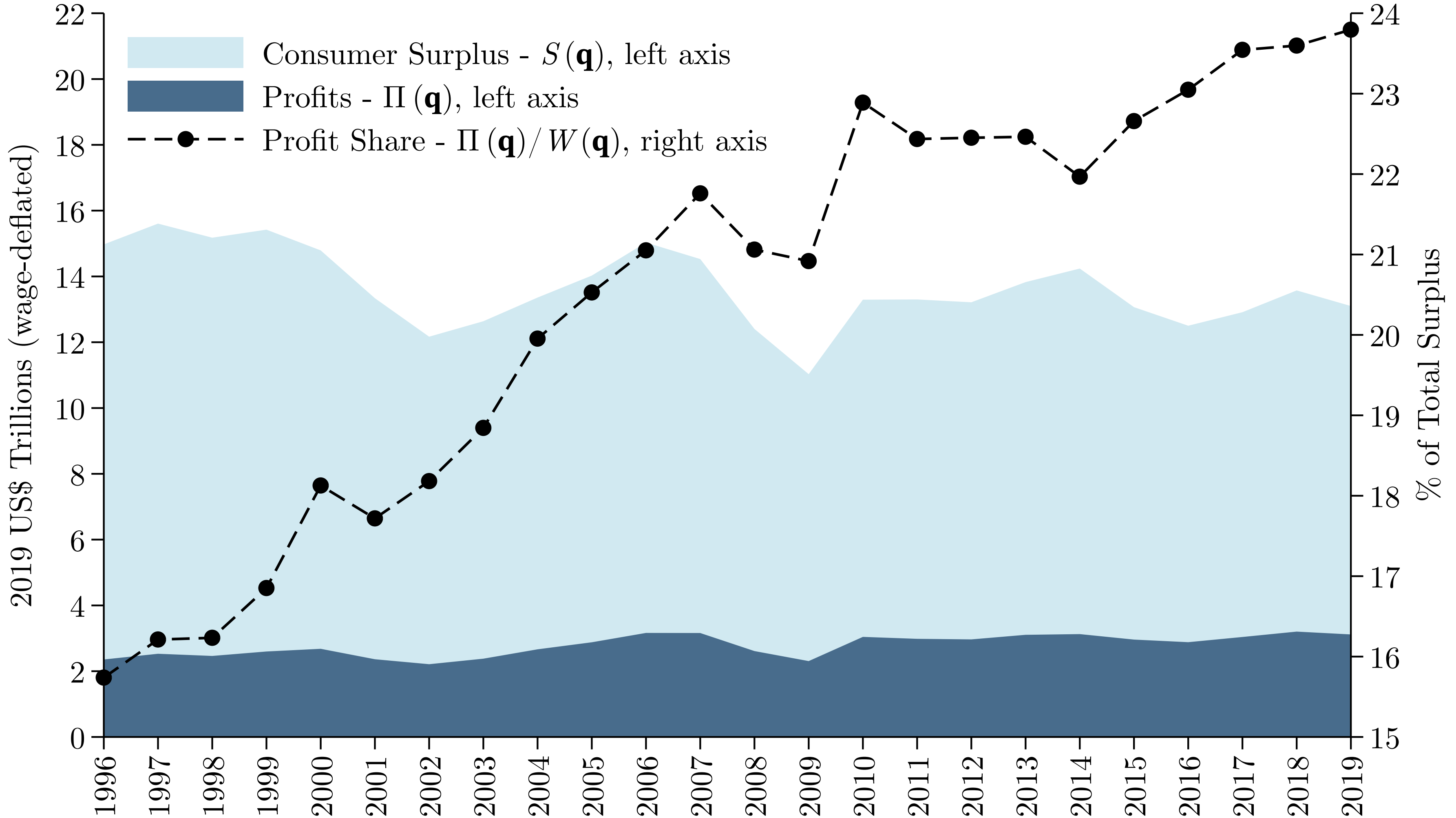
$$\mathbf{q}^{\mathrm{I}} = \mathbb{F}'\mathbf{q} \qquad \text{and} \qquad \mathbf{q}^{\mathrm{C}} = (\mathbf{I}-\mathbb{F})'\,\mathbf{q}$$

- Firms are price-takers in input markets - profit vector:

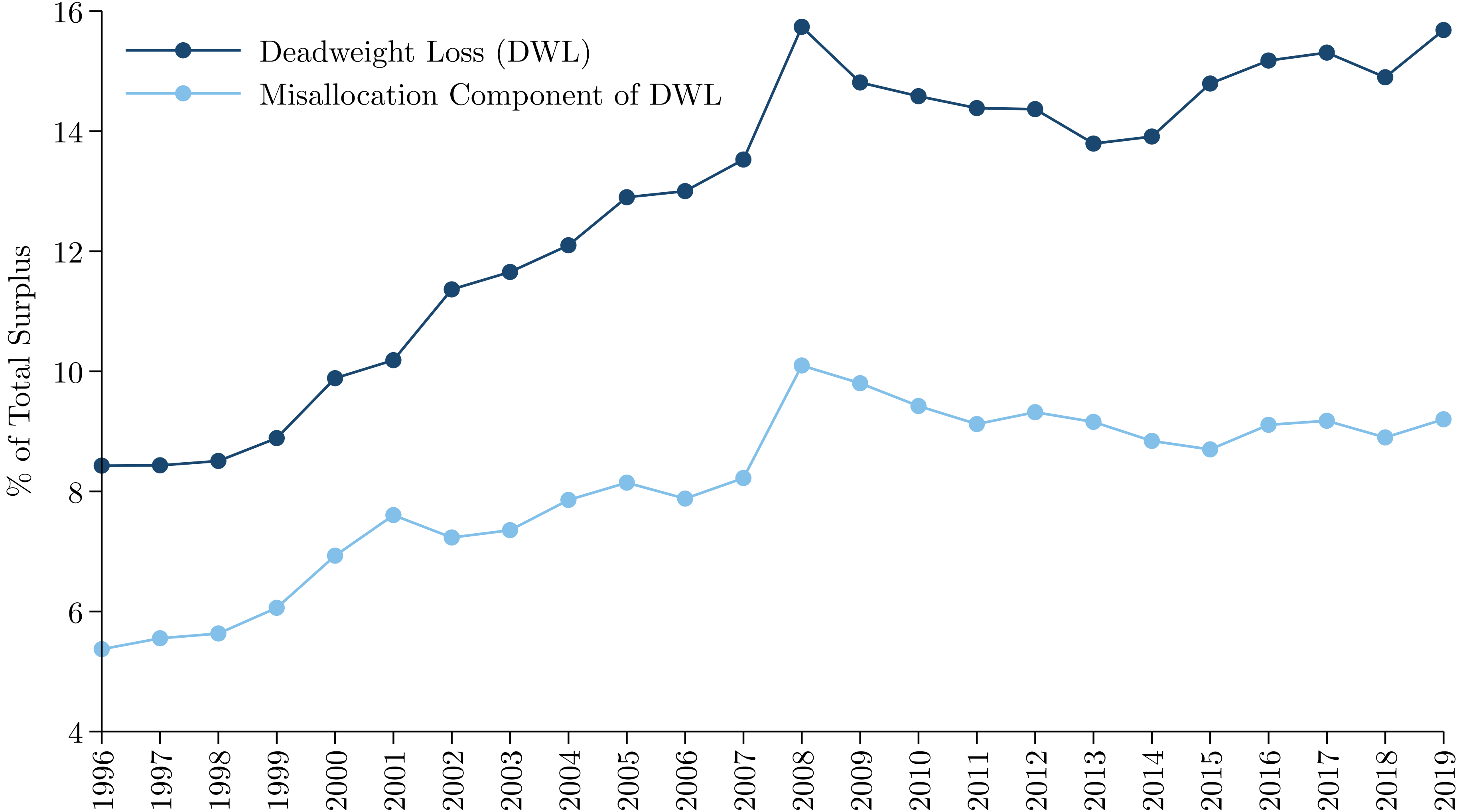
$$\boldsymbol{\pi} = \operatorname{diag}(\mathbf{q})\left(\mathbf{p}-\mathbf{c}^{0}-\mathbb{F}\mathbf{p}\right)-\mathbf{f}$$

$$\mathbf{q} = \left\{(\mathbf{I}+\mathbf{1}\mathbf{1}')\circ\left[(\mathbf{I}+\boldsymbol{\Sigma})(\mathbf{I}-\mathbb{F})'\right]\right\}^{-1}\left[(\mathbf{I}-\mathbb{F})\mathbf{b}-\mathbf{c}^{0}\right]$$

Total Surplus and its Breakdown (input-output)



Deadweight Loss (Input-Output)



Multi-Product Firms and Mergers

Company z maximizes the sum of profits over all product lines i where o_{iz} =1 if company z produces product i :

$$\varpi_z = \sum_{i=1}^{n} o_{iz}\pi_i$$

$$\mathbf{K} \equiv \begin{bmatrix} \kappa_{11} & \kappa_{21} & \cdots & \kappa_{1n} \\ \kappa_{12} & \kappa_{22} & \cdots & \kappa_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \kappa_{n1} & \kappa_{n2} & \cdots & \kappa_{nn} \end{bmatrix} \stackrel{\text{def}}{=} \mathbf{O}'\mathbf{O}$$

$$\mathbf{q}^{\Phi} = \left(2\mathbf{I} + \mathbf{\Delta} + \mathbf{\Sigma} + \mathbf{K} \circ \mathbf{\Sigma}\right)^{-1}\left(\mathbf{b} - \mathbf{c}^0\right)$$

Construction of Product Cosine Similarities

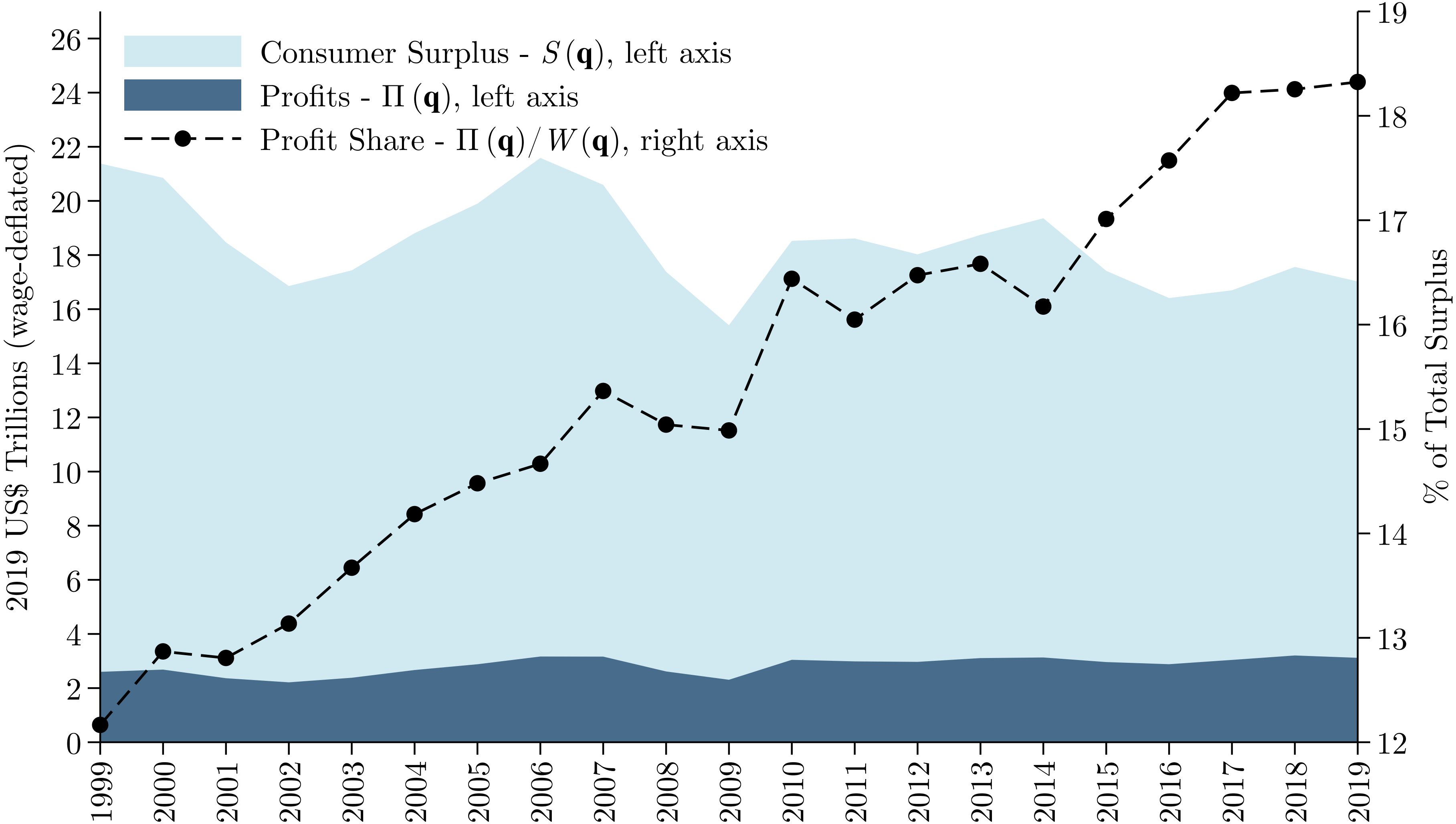
Company z maximizes the sum of profits over all product lines i where $[\mathbf{O}]_{iz} = 1$ if company z produces product i :

$$[\mathbb{Q}]_{i\mathcal{S}} = \begin{cases} 1 & \text{if} \quad i \in \mathcal{S} \\ 0 & \text{if} \quad i \notin \mathcal{S} \end{cases}$$

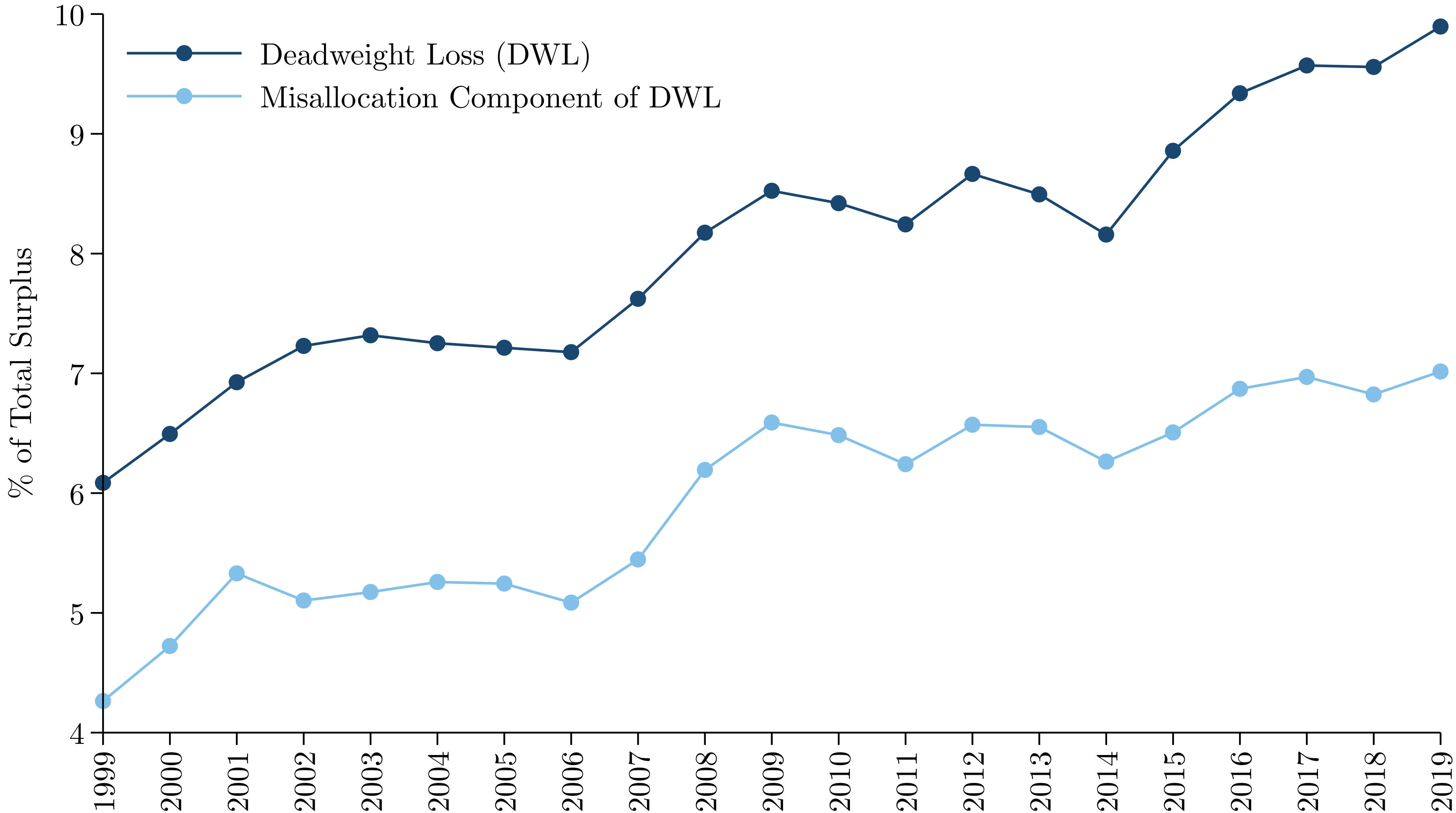
$$[\mathbb{S}]_{z\mathcal{S}} = z'\text{s share of SIC code } \mathcal{S} \text{ sales}$$

$$(\mathbf{A}'\mathbf{A})_{\mathrm{P}} = \frac{1}{2}\left[\mathbf{O}\,(\mathbf{A}'\mathbf{A})_{\mathrm{F}}\,\mathbf{O}' + \mathbb{Q}'\mathbb{S}'\,(\mathbf{A}'\mathbf{A})_{\mathrm{F}}\,\mathbb{S}\,\mathbb{Q}\right]$$

Total Surplus and breakdown (Multi-Product)



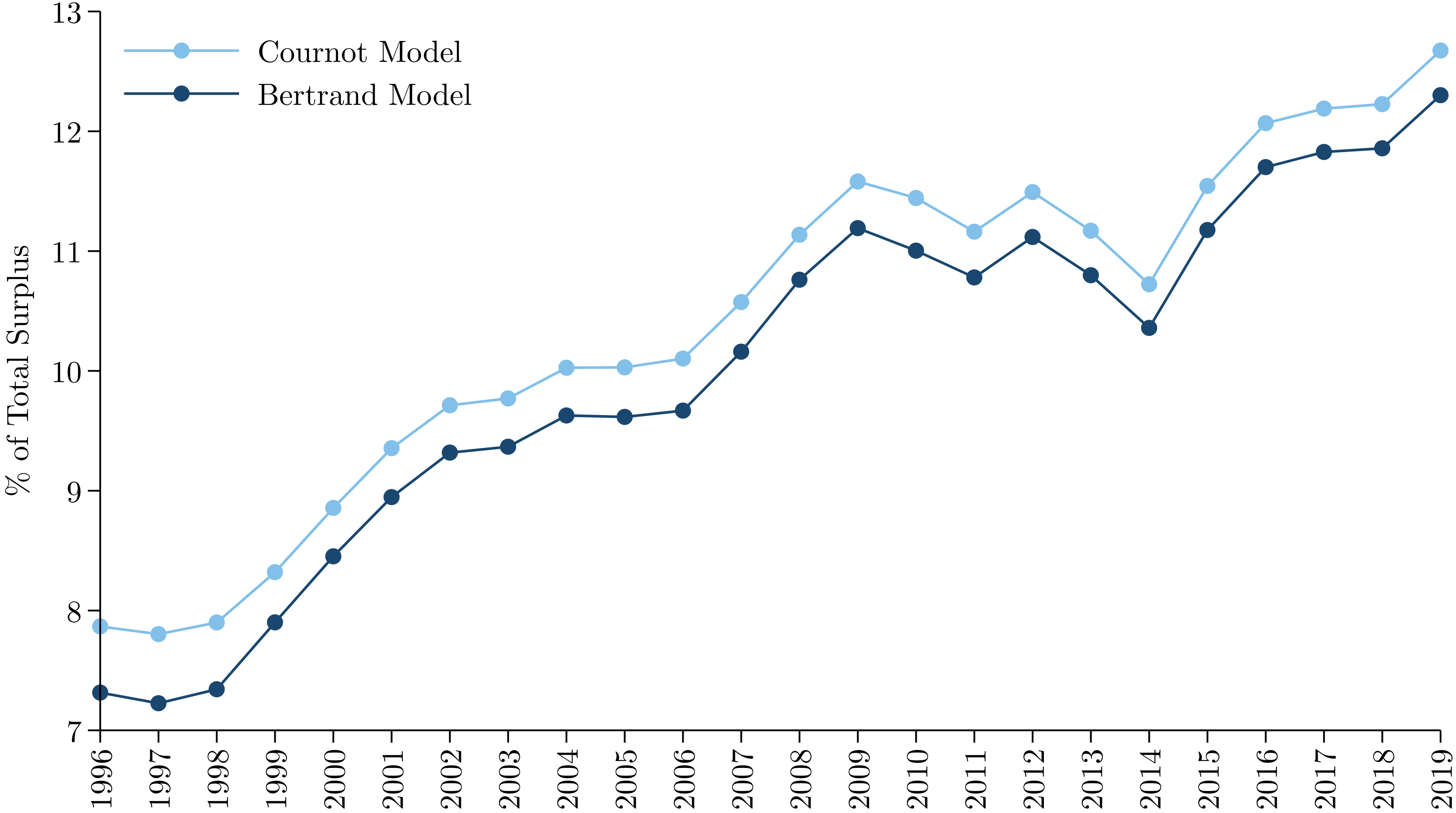
Deadweight Loss (Multi-Product)



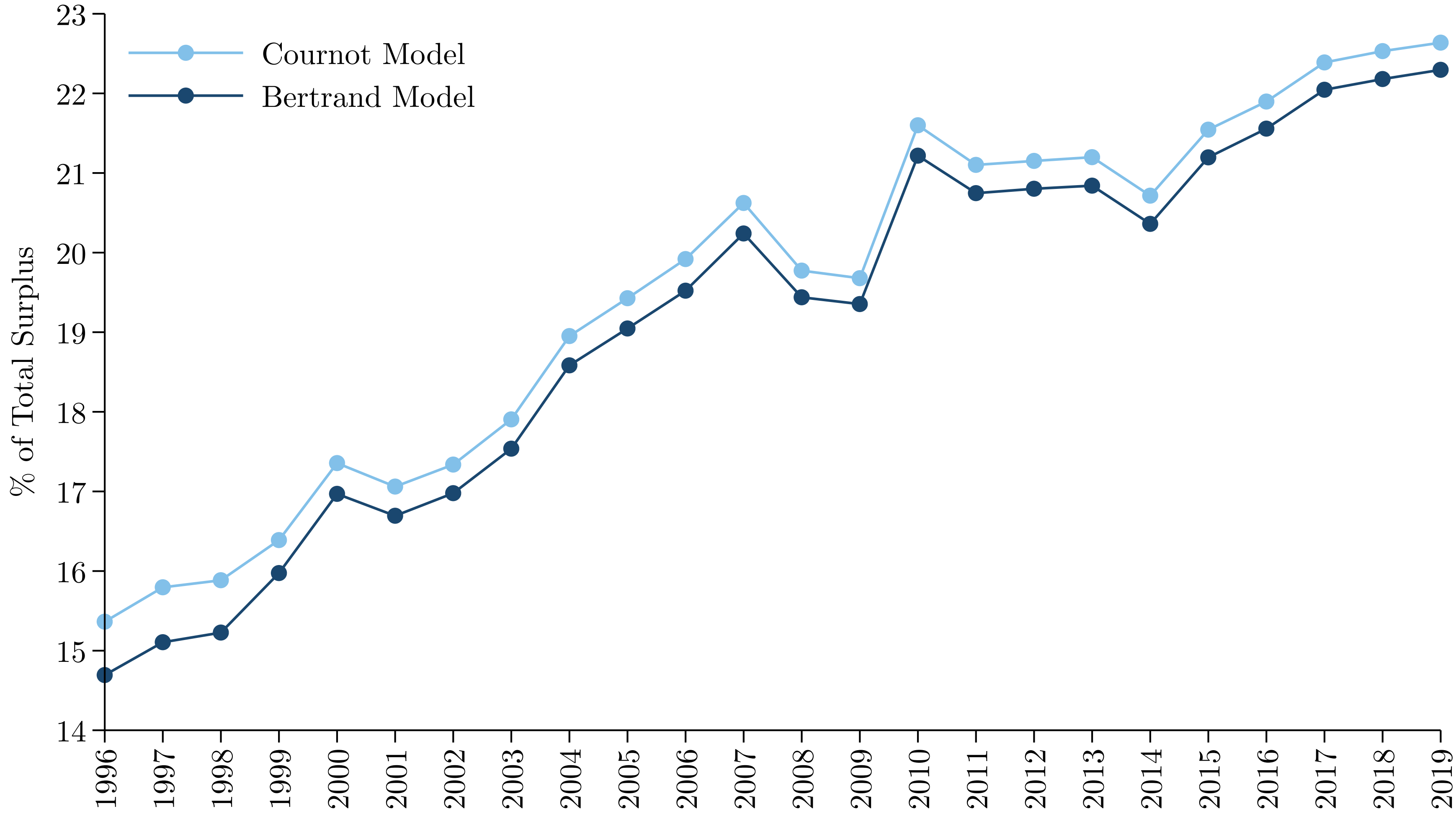
Bertrand Equilibrium (flat marginal cost)

$$\mathbf{q}^{\Psi} = \left(\mathbf{I} + \mathbb{D}^{-1} + \boldsymbol{\Sigma}\right)^{-1} (\mathbf{b} - \mathbf{c})$$

Deadweight Loss (Cournot v/s Bertrand)



Profit Share of Surplus (Cournot v/s Bertrand)



Take-aways

- A new GE theory of oligopoly with hedonic demand.

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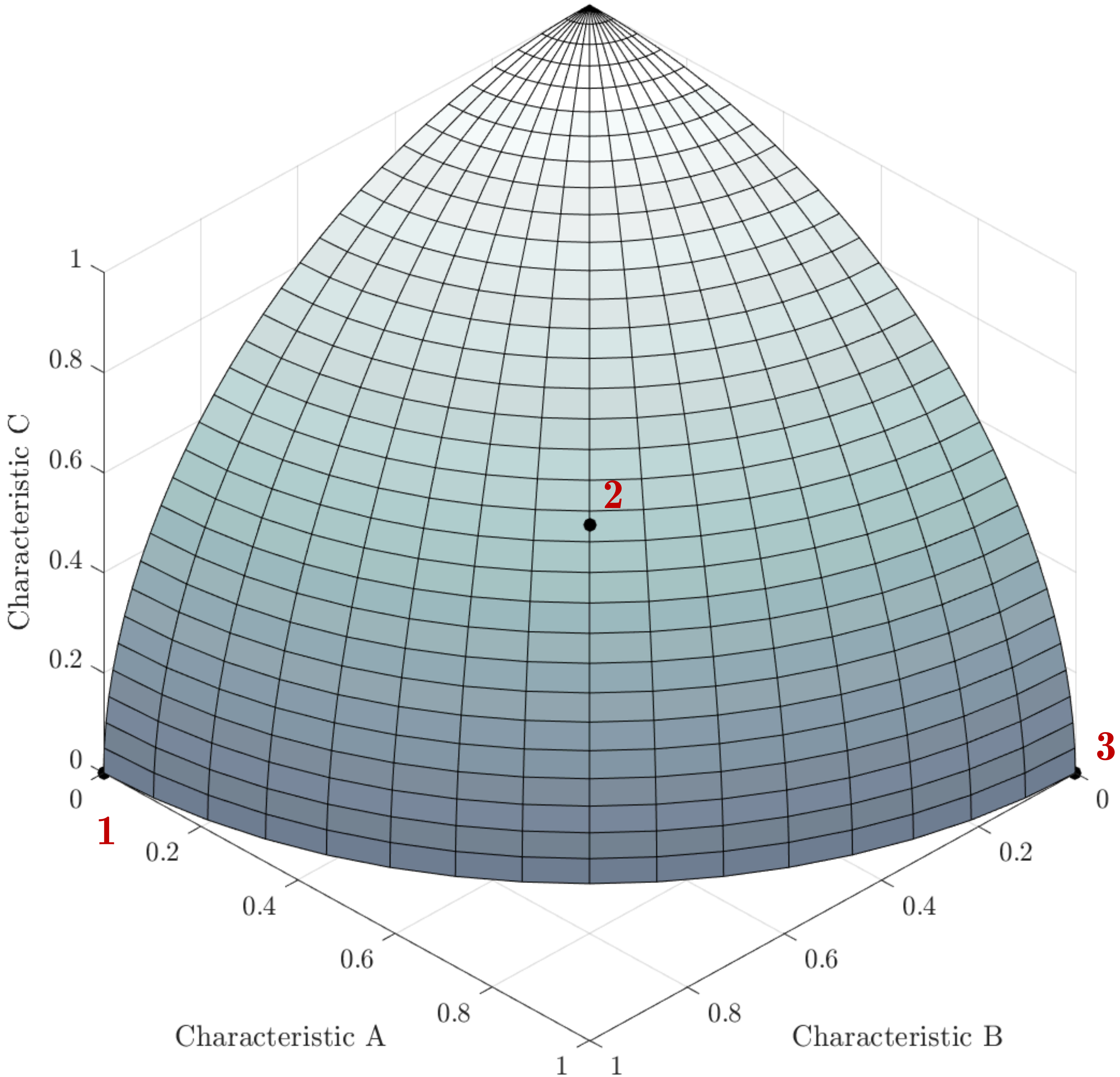
- Distribution of markups is jointly determined by productivity and product market centrality.
  - Both have undergone significant changes
- Rising Oligopoly Power
  - increasing deadweight loss
  - lower consumer surplus share.



$$\frac{\partial \mathbf{p}}{\partial \mathbf{q}} \equiv -(\mathbf{I}+\mathbf{\Sigma}) = \begin{bmatrix} -1 & -.58 & 0 \\ -.58 & -1 & -.58 \\ 0 & -.58 & -1 \end{bmatrix}$$

$$\frac{\partial \mathbf{q}}{\partial \mathbf{p}} \equiv -(\mathbf{I}+\mathbf{\Sigma})^{-1} = \begin{bmatrix} -2 & 1.73 & -1 \\ 1.73 & -3 & 1.73 \\ -1 & 1.73 & -2 \end{bmatrix}$$