

Industry shakeouts after an innovation breakthrough

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What happens after a technological revolution or breakthrough?

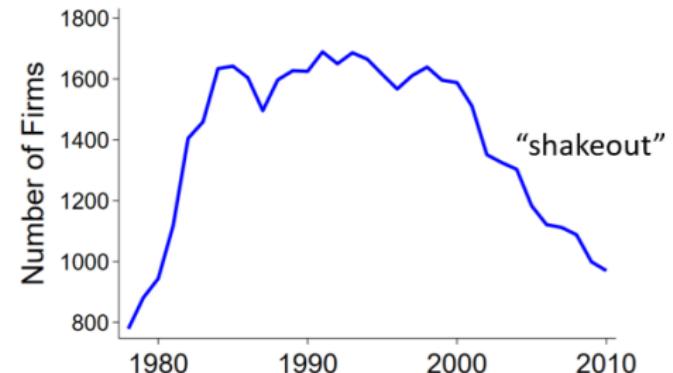
1970



1974



Computer
Manufacturing



After a breakthrough, do industries across the economy shake out and why?

► Literature documents striking pattern at industry-level

- **Prominent theory:** After a breakthrough, firm numbers explode; Then firm numbers fall, rapidly & dramatically – a "shakeout"

Klepper Graddy, 1990; Jovanovich MacDonald, 1994; Horvath et al., 2001

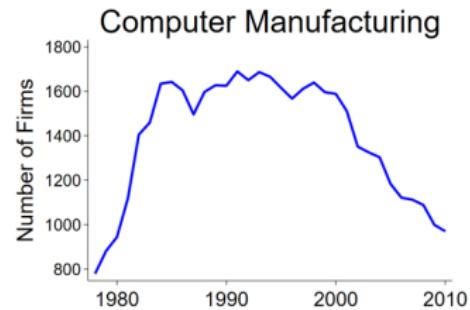
► Are shakeouts representative of breakthroughs?

- Concern about limited data & how breakthroughs are selected
- Literature relies on narrative evidence & patentable innovations
⇒ Selection bias towards salient consumer goods

Gort and Klepper, 1982; Bloom et al., 2024; Kelly et al., 2021

► In fact, shakeouts are the exception, not the rule!

- a statistical procedure to select breakthroughs
- new facts → conventional view on shakeouts is incorrect
- a model that answers why industries shake out or do not



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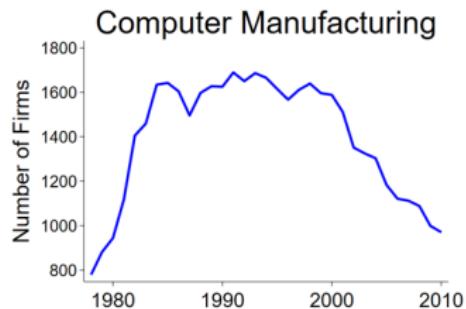
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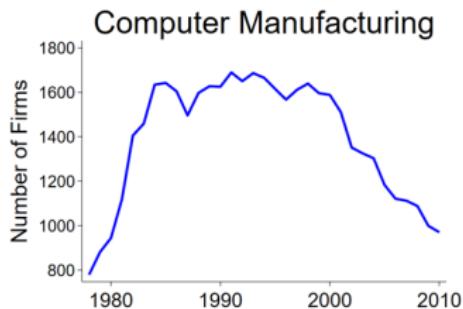
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What do I do? First, a statistical strategy to select breakthroughs

- ▶ **The commercial emergence of a breakthrough is detected via:**
 - ▶ After filtering out noise, search for periods of sustained deviations in the net entry rate
 - ▶ Motivated by empirical evidence of explosive post-breakthrough entry
- ▶ The strategy is **useful** for studying **industry dynamics** after a breakthrough
 - ▶ Historical validation: potential breakthroughs coincide with narrative evidence
 - ▶ Consistent with alternative measures
 - ▶ Robust: not sensitive to minor changes in the strategy's threshold
 - ▶ Large disparities between selected vs non-selected industries, even in long run
 - ▶ Since purely statistical, easy to apply to all industries in the economy

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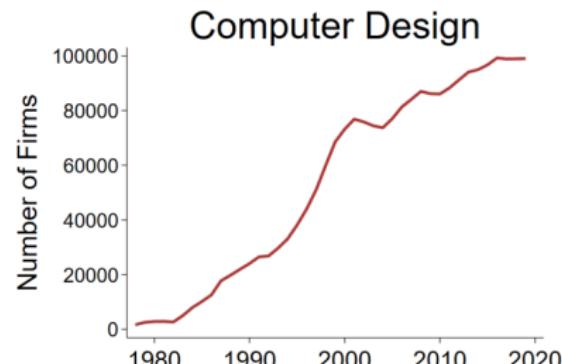
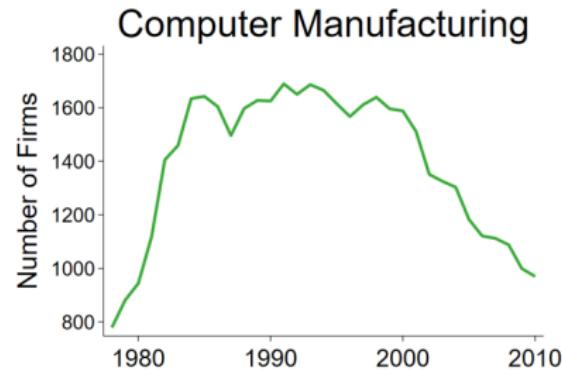
Second, most industries in the economy do not shake out

► Background on the conventional wisdom

- ▶ **Rapid entry** of firms after breakthrough
- ▶ Then output rises and prices fall
- ▶ Large number of firms exit – **a shakeout**
 - ▶ Who exits? Less efficient firms exit
 - ▶ When does the shakeout happen?
16 years (Jovanovich and MacDonald)

► Main result: Most industries do not shakeout

- ▶ Three-fifth's of industries experience no large decline in the total number of firms (within 40 years)
 - ▶ Longitudinal Business Database follows 288 industries in US between 1978-2019
- ▶ Five novel facts on industries after a breakthrough



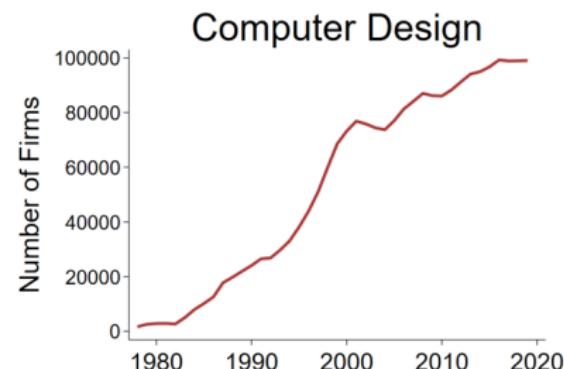
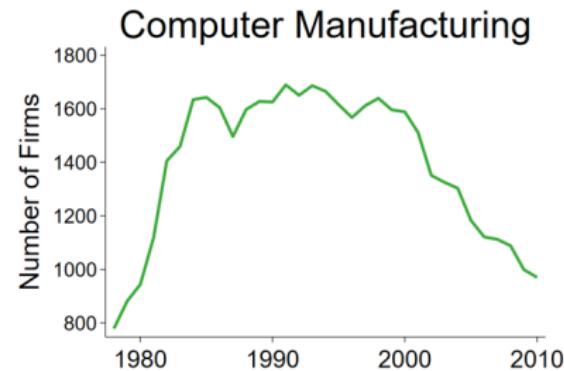
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Third, why do some industries see a shakeout, whereas others do not?

Three periods: before, during, after the breakthrough

- ▶ Competitive industry within each period:
 - ▶ Number of active firms is an equilibrium outcome
 - ▶ Firms are het. in productivity but take industry price as given
- ▶ **The breakthrough is an unanticipated one-time shock:** Lit
 - ▶ Increases potential productivity for post-breakthrough entrants
 - ▶ Once they become older firms; Pre-breakthrough firms unaffected

Why are there equilibria with shakeouts vs no shakeouts?

- ▶ Learning curve determines short-run overshoot in firm entry
 - ▶ Short-run: Young unproductive firms enter betting on long-term gains
 - ▶ Long-run: Can market support number of firms (now old) that entered?

Why do industries vary in shakeout size?

- ▶ High returns to scale amplify shakeouts by toughening competition

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2000: \$2,500-2800



2015: \$1,200-1800



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I fill the gap in the literature in three ways

► **Narrative and patent-based identification of breakthroughs**

- ▶ Klepper (1982, 1990), Bloom Hassan Kalyani Lerner Tahoun (2021), Kelly Papanikolaou Seru Taddy (2021)

I do statistical detection of breakthroughs

► **Empirical evidence of breakthrough dynamics in a handful of industries (<50 industries)**

- ▶ Wang (2008), Horvath Schivardi Woywode (2001), Klepper (1996, 2000, 2005)

I give evidence across the economy (288 industries)

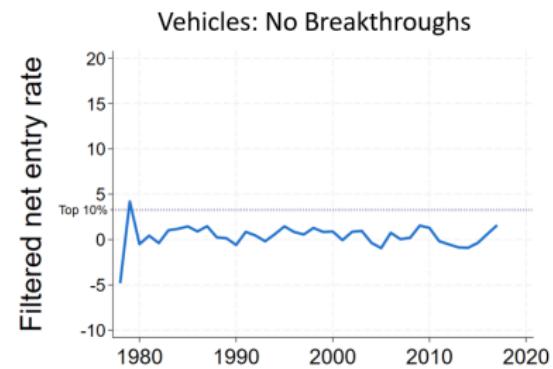
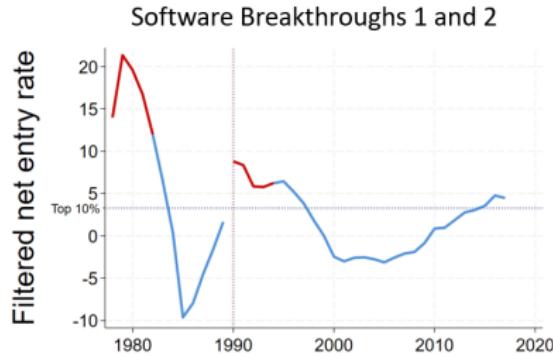
► **Firm-level or product-level innovations**

- ▶ Klette Kortum (2004), Garcia-Macia Hsieh Klenow (2019), Akcigit Kerr (2019), Argente Lee Moreira (2023)

I study industry aggregate variables after industry-wide innovations

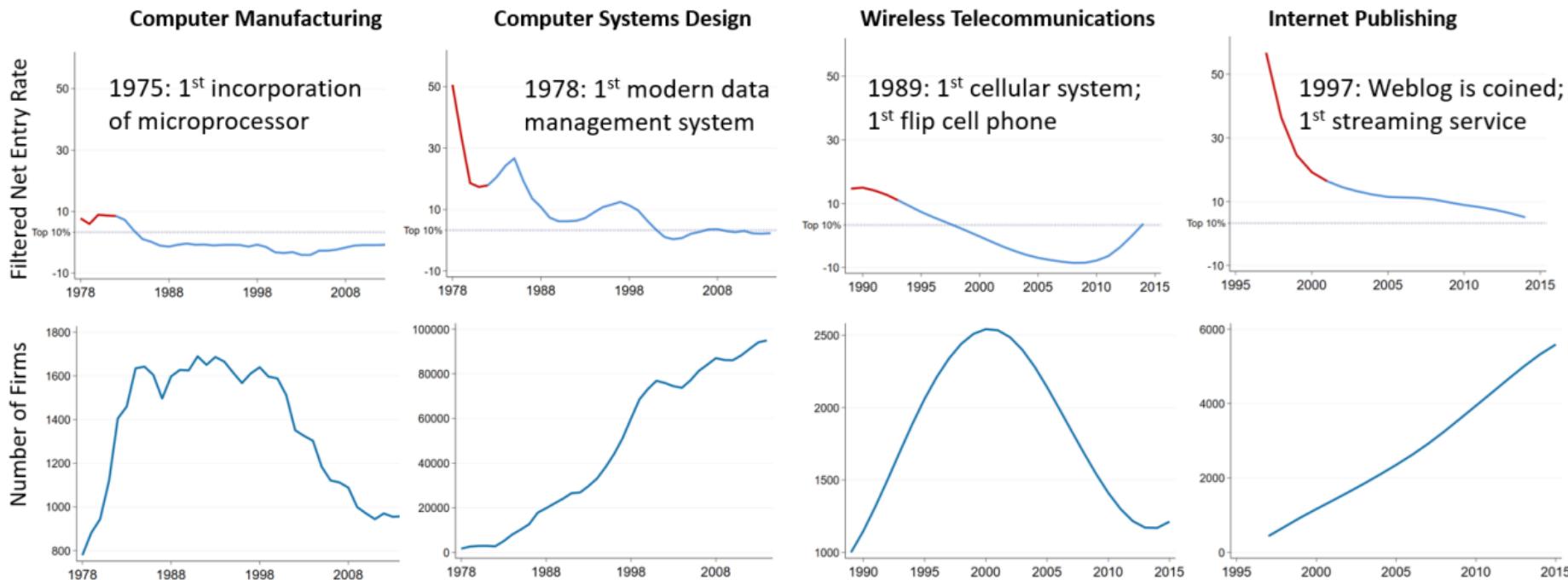
My statistical strategy selects outlier industries using net entry rate

1. Annual net firm entry relative to 6-digit NAICS industry
2. **Filter out noise from the economy**
 - ▶ Remove year and sector FE; smooth the raw net entry rates
 - ▶ Extract smoothed cross-sectional deviation
3. Search for **sustained periods** (5 years) where **industry crosses a threshold** (ex. 5%)
 - ▶ The threshold is relative across time and across industries
4. A breakthrough industry begins with a sustained period during which the threshold is crossed
5. An industry can experience **more than one breakthrough**



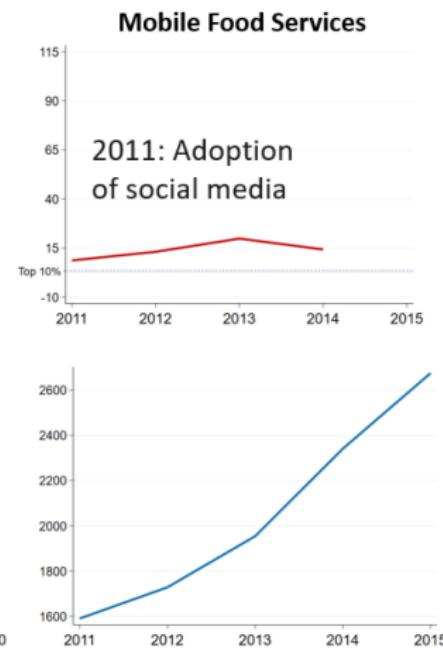
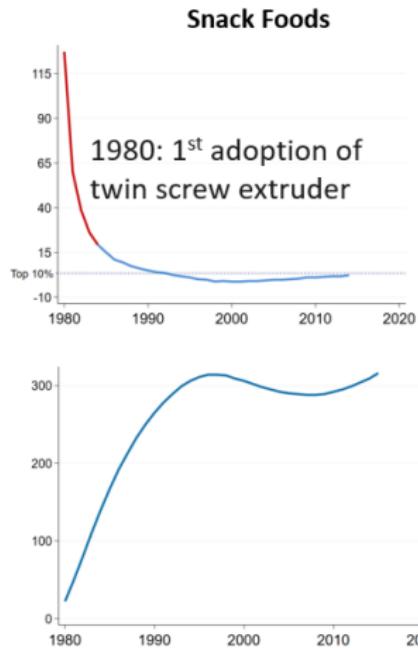
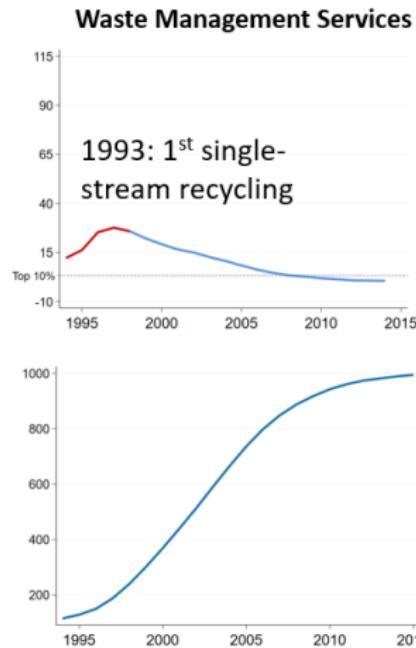
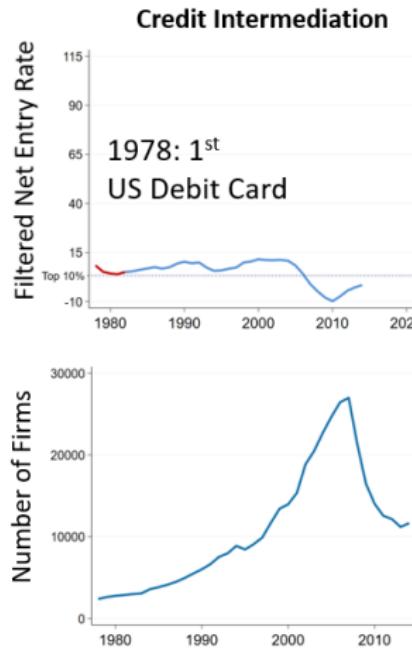
In math

Illustration of procedure with 4 obvious breakthroughs: two do not shake out



Details

4 less obvious breakthroughs selected through my procedure

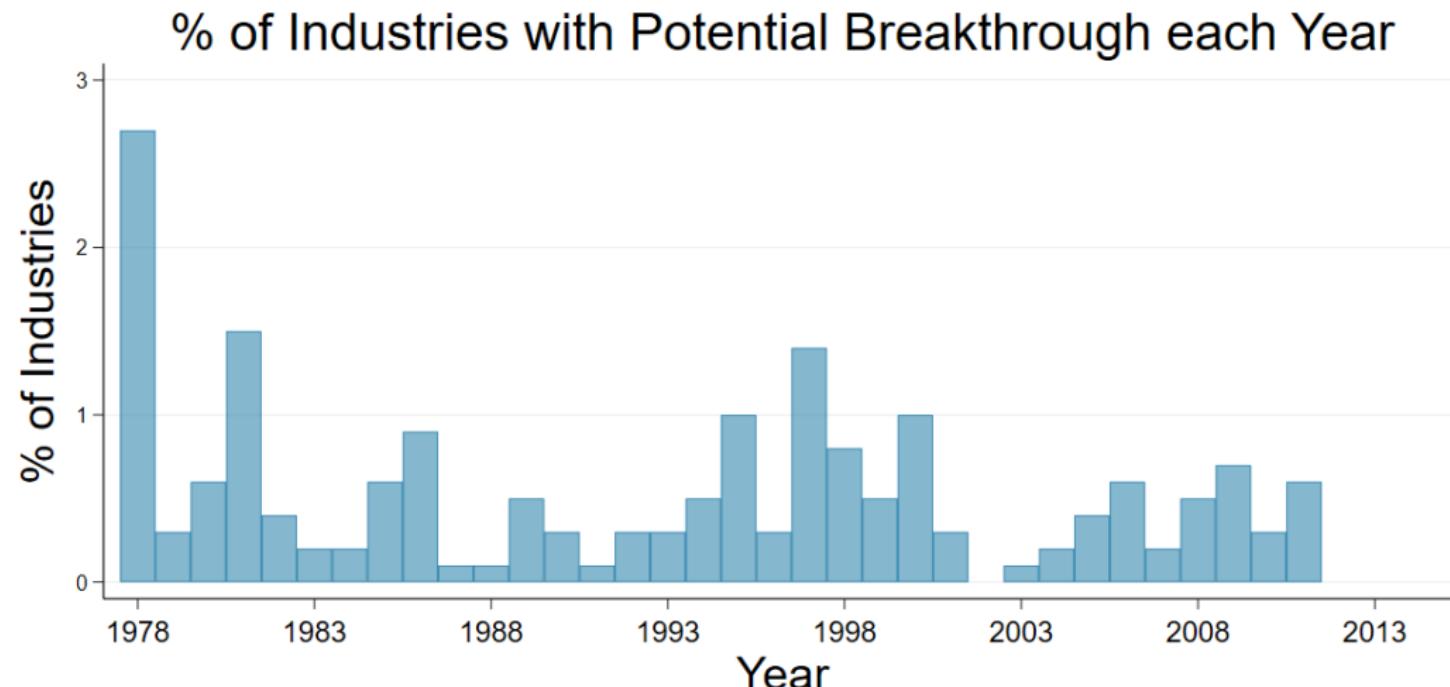


Details

Breakthrough selection strategy selects a small number of industries

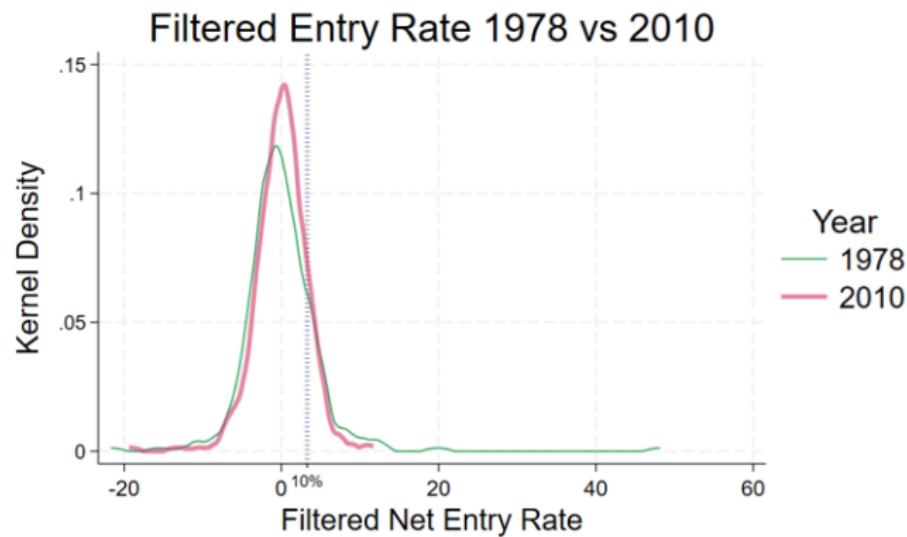
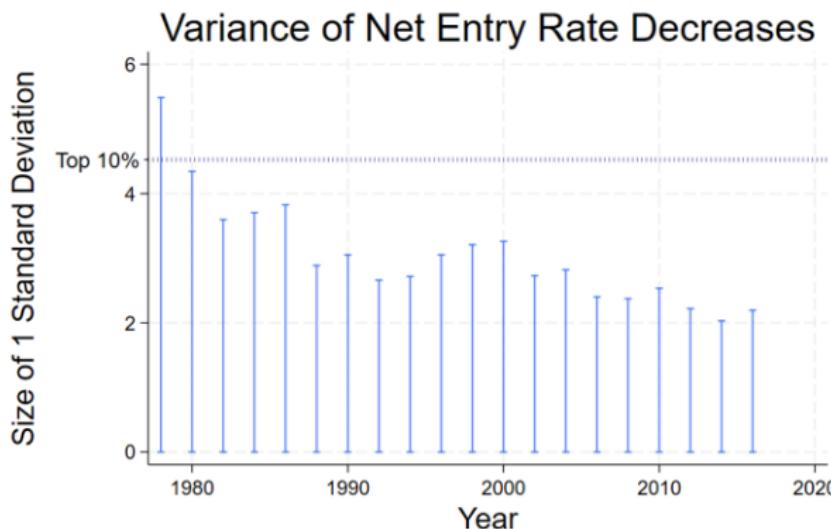
- Scope of the selected shock is concorded LBD Naics6 definition of an industry
- ~150 out of the total of 1,012 industries are selected from 1978-2014

Every breakthrough in 1978 What if I start in 1980? 1990? 2000?



New fact: Breakthroughs have been decreasing for the last forty years

- ▶ Previous plot \implies Number of breakthrough industries decrease across time
 - ▶ Reason: the **variance** of the net entry rate across industries have been decreasing across time
 - ▶ Literature has not documented variance of net entry rate
(Levels documented in Akcigit and Ates, 2021; Decker, Haltiwanger, Jarmin, Miranda, 2016)



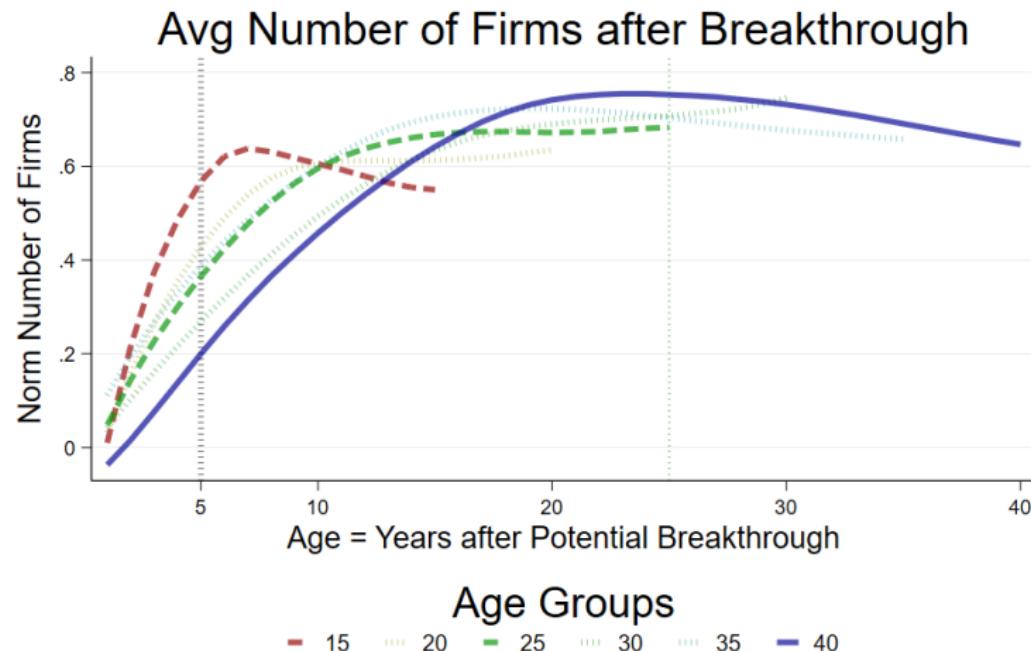
Fact 1: On average, industries do not shake out, with enormous heterogeneity

- ▶ Recall: Literature says after an industry-wide breakthrough, firm numbers boom then shake out
- ▶ Jovanovich MacDonald 1994: auto tire industry shakeout 16 years after invention of rubber tires
- ▶ To make industries comparable,
 - ▶ Normalize number of firms
 - ▶ For industry s ,

Normalized Num. of Firms_{st}

$$= \frac{\text{Firms}_{st} - \text{Min Firms}_s}{\text{Max Firms}_s - \text{Min Firms}_s}$$

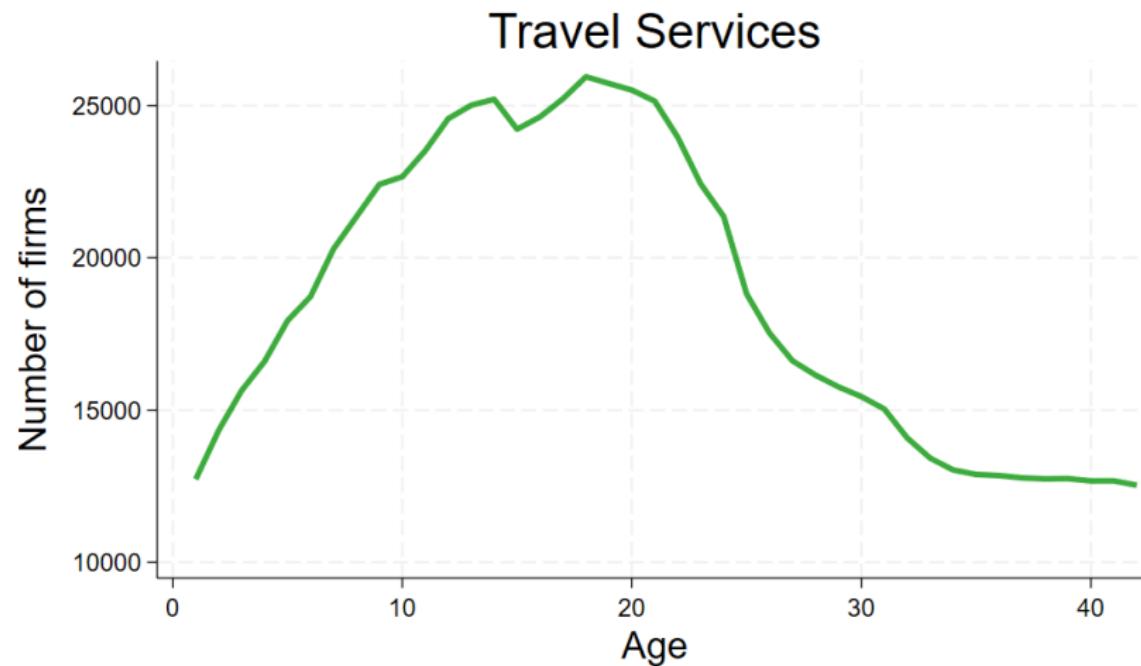
$$= \frac{\text{Offset Factor}}{\text{Normalization Factor}}$$



Distribution of net entry rates

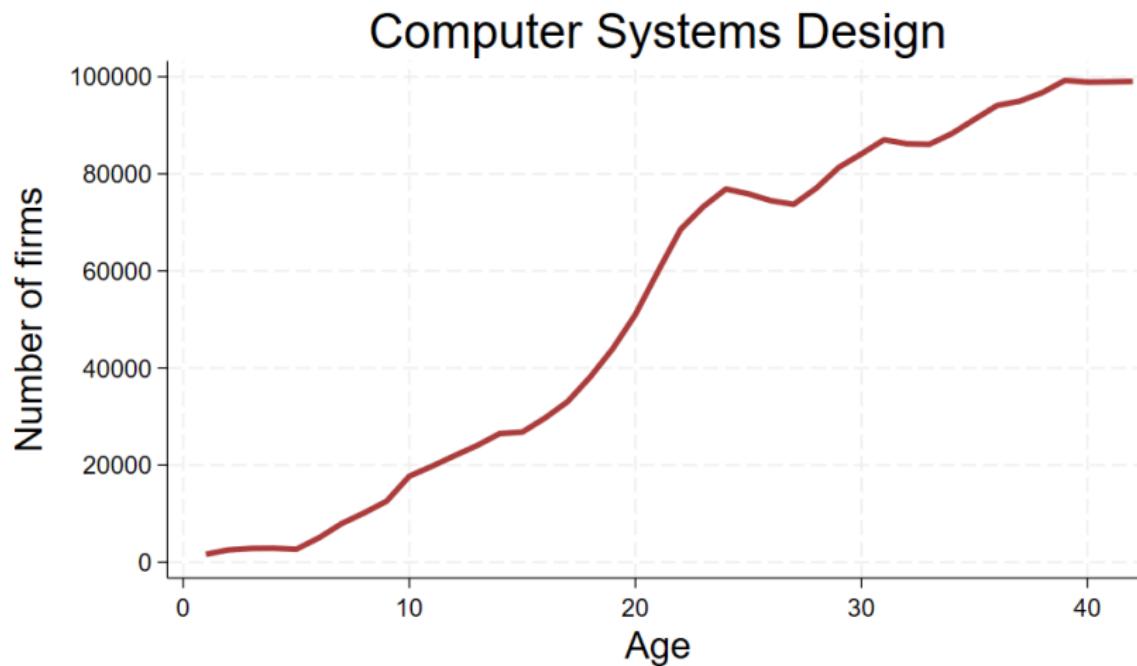
The quintessential shakeout

- ▶ Exhibits patterns closely aligned with Jovanovich MacDonald 1994's model
 - ▶ High initial entry followed by a significant shakeout



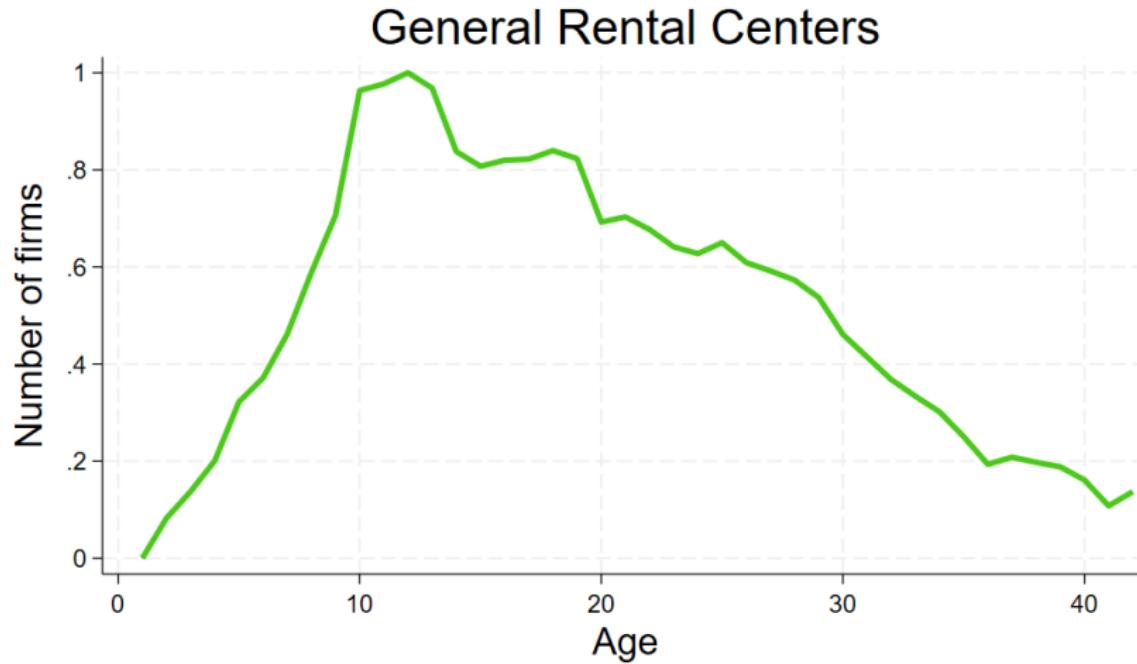
Some industries do not shake out

- ▶ Despite high initial entry, doesn't follow the typical shakeout pattern
 - ▶ Demonstrates the variability in industry life cycles



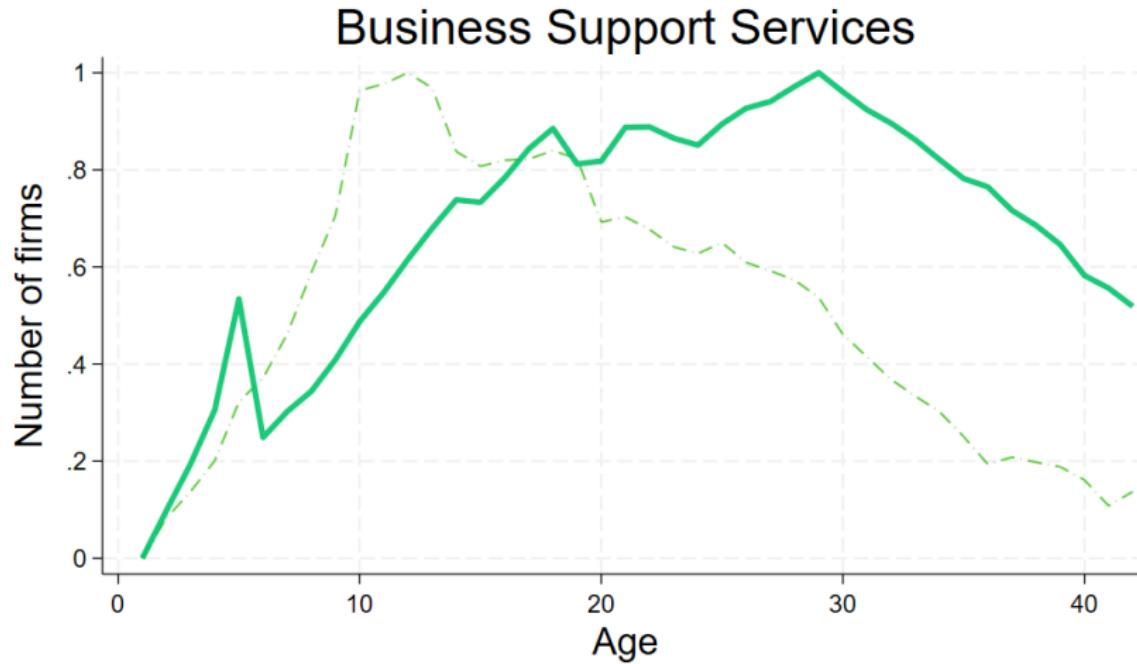
Industries in-between: the diversity of shakeouts

- ▶ While some industries closely follow Jovanovich MacDonald's model, others diverge significantly



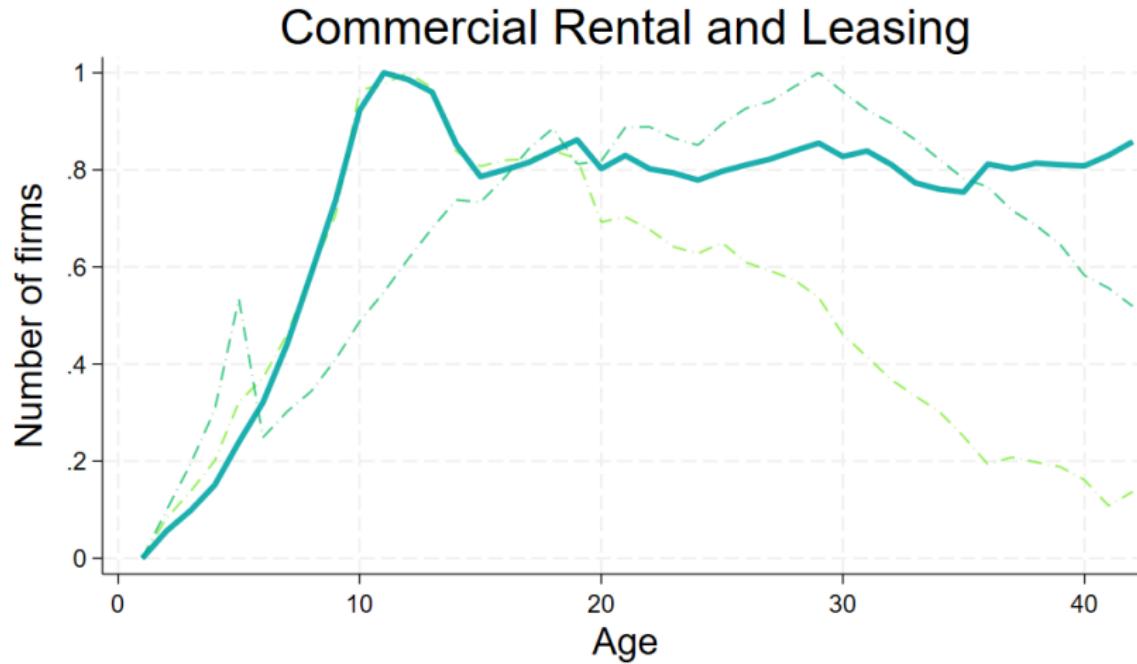
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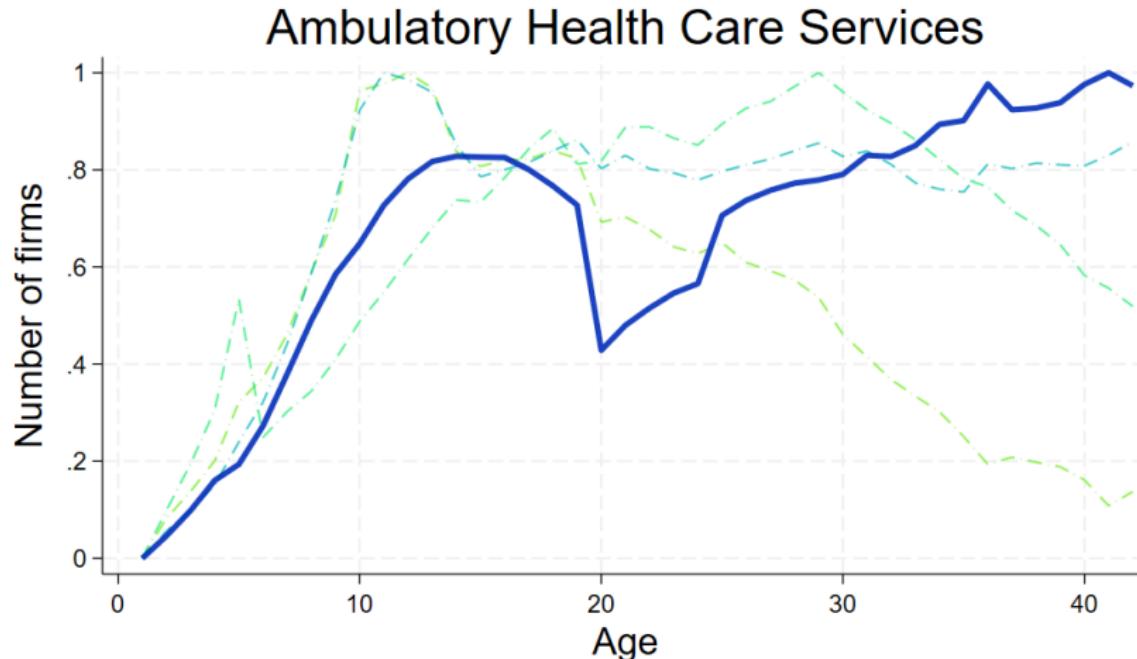
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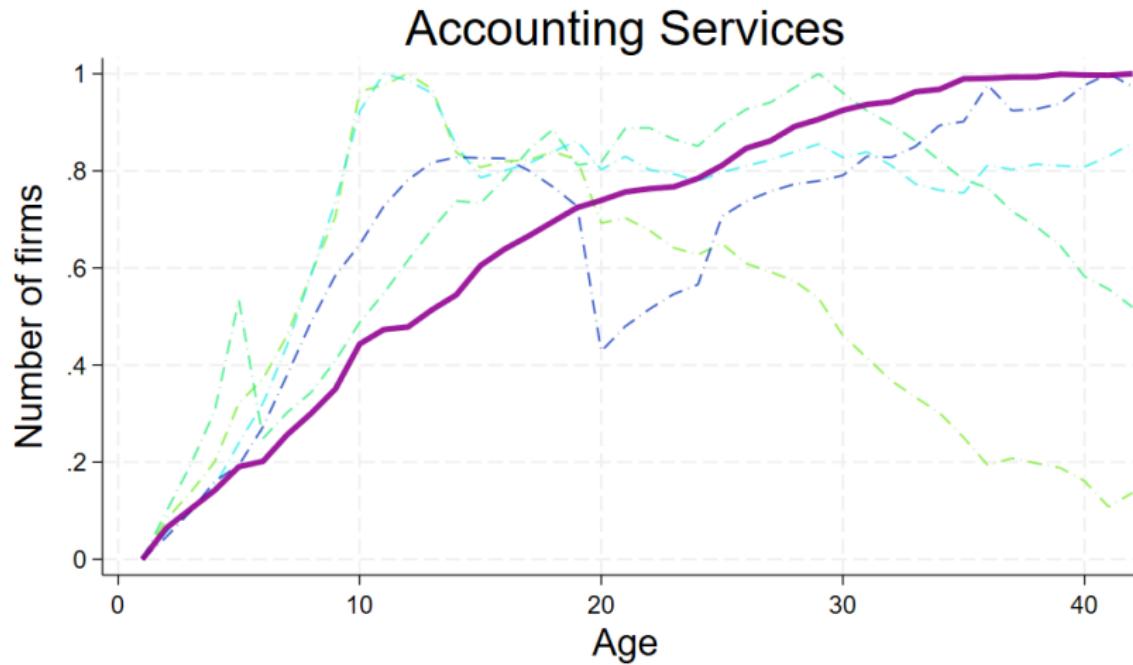
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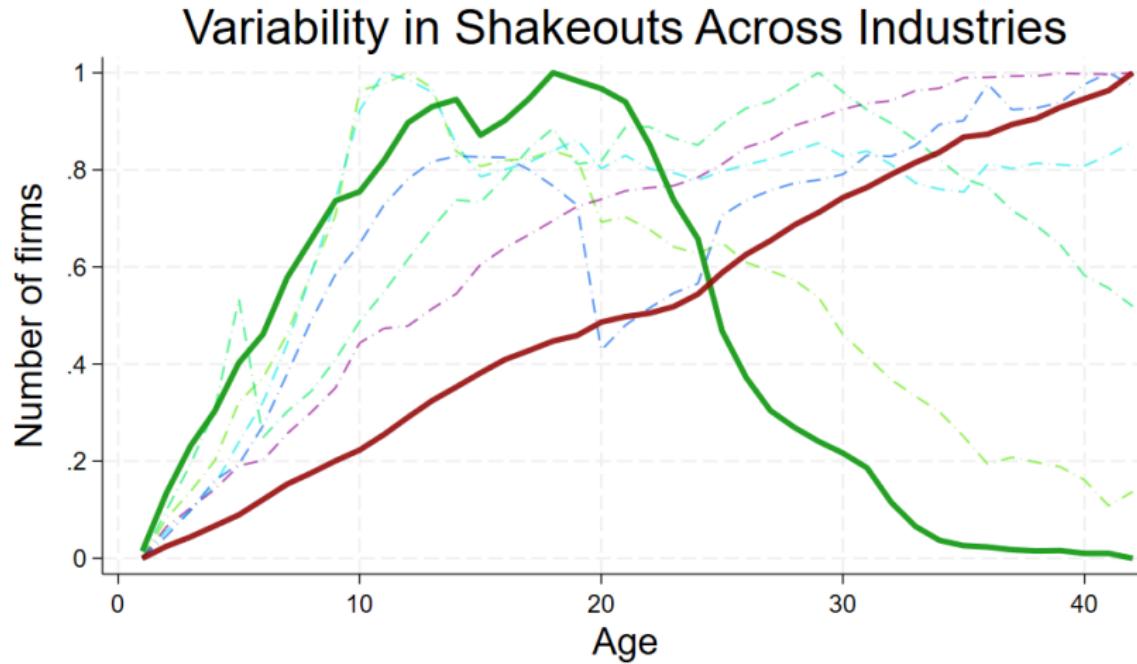
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Fact 2: Most of the breakthrough industries do not shake out

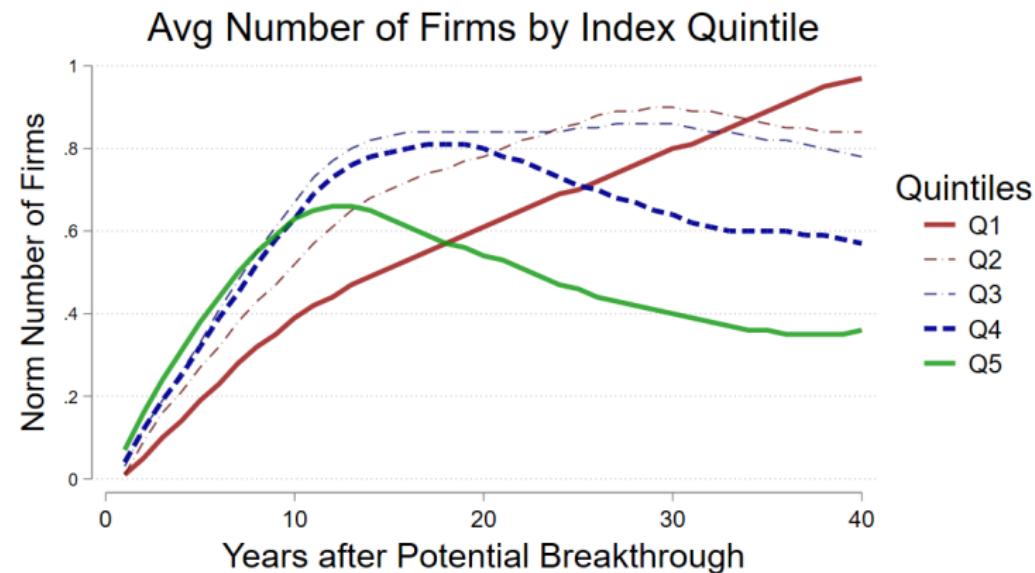
- ▶ Define a **shakeout index** that depends on the relative size of the decline in firms

$$\text{Index} = \text{Adjustment} \cdot \% \text{ Decline}$$

- ▶ Adjustment = $\frac{1}{\text{Cumul.entry} \cdot \text{Decline duration}}$
- ▶ Shakeout index falls within (0,1)
- ▶ Fact 2 is robust to adjustments in the breakthrough filter robustness

Visual assessments Index within sectors Distribution of index

Index with math Median Emp. weighted



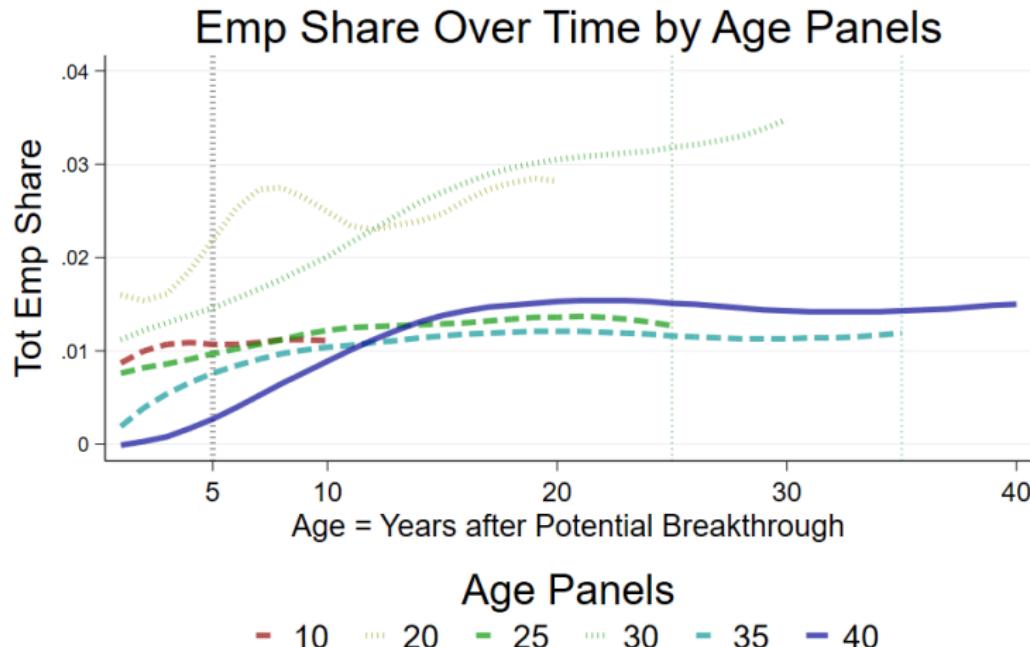
Fact 3: Labor reallocates toward breakthrough industries

- ▶ The breakthrough industries absorb economy's labor, contrasting non-breakthrough industries
- ▶ Year t , emp. share in industry i

$$\text{EmpShare}_{it} = \frac{\text{Emp}_{it}}{\text{TotEmp}_t}$$

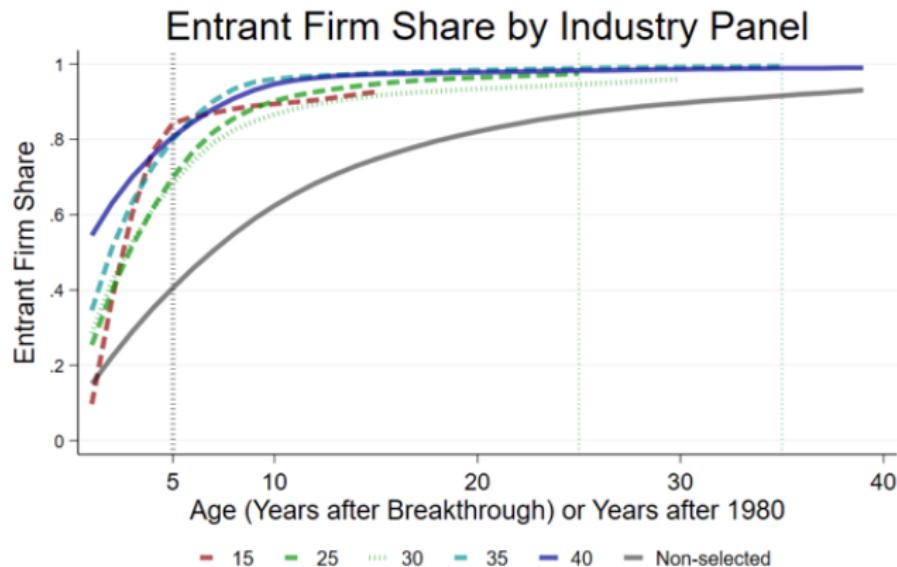
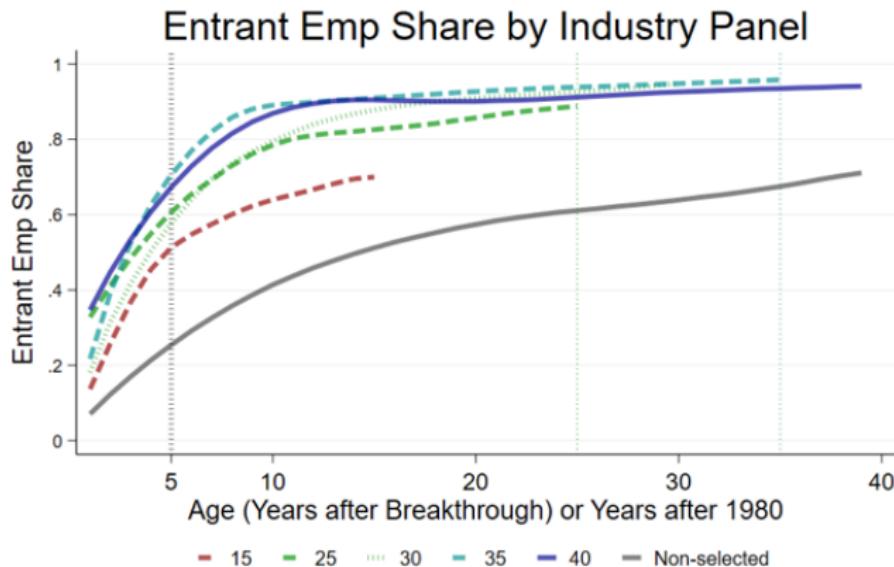
- ▶ Emp_{it} is the level of employment in industry i
- ▶ TotEmp_t is year t total employment in economy

Employment share for 5 non-selected industries



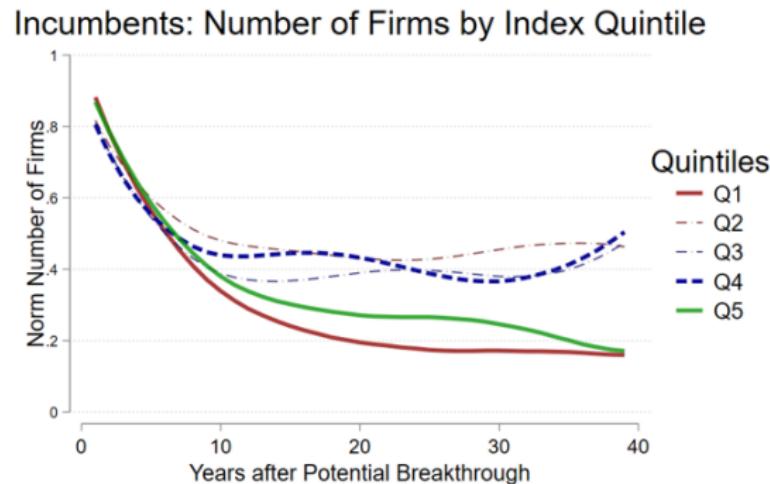
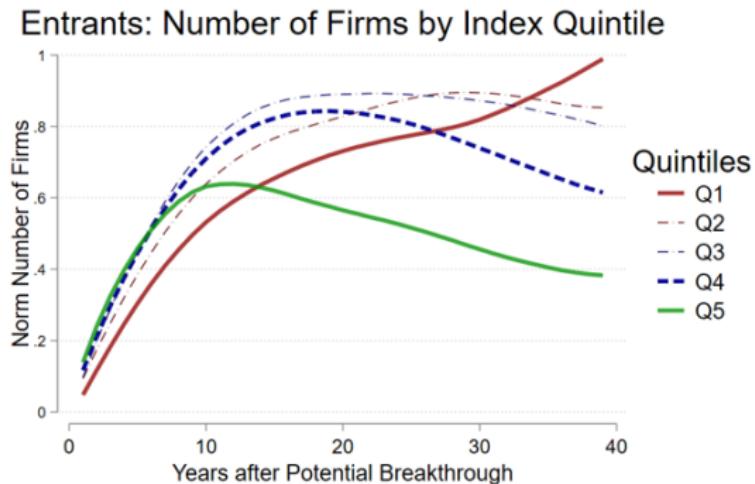
Fact 4: Labor in breakthrough industries reallocates toward entrants

- ▶ The firms that enter after the breakthrough drastically out-compete firms that enter before
- ▶ This result contrasts non-breakthrough industries and is persistent



Fact 5: Inter-industry shakeout differences are driven by entrants

- ▶ Firms that enter after the breakthrough (entrants) determine the future of industry dynamics
- ▶ Incumbents = Firms that entered before the breakthrough



Robustness: The breakthrough detection procedure is reliable and representative

► Validation with existing literature

- ▶ Prominent breakthrough industries align with previous anecdotal and patent-based methods:
 - ▶ Kalyani, Bloom, Lerner, Melo, Tahoun (2024) & Kelly, Papanikolaou, Seru, Taddy (2021) Method Common
- ▶ Stylized facts remain robust among commonly selected industries: most industries do not shake out Common
- ▶ Strengths of my procedure: Sectoral representation; empirical consistency Sectors Uncommon

► Stylized facts remain robust across parameter variations and subsample restrictions

- ▶ Varying parameters in the procedure: Smoothing, observation start, thresholds, industry scope Details
- ▶ Robustness across subsamples: Industries assigned new codes; post-breakthrough demand shifts Naics Price

► Two experiments to illustrate the null outcome & faulty strategy

- ▶ Null outcome \implies Selected industries display patterns indistinguishable from the broader economy
 - ▶ Randomly selected industries display patterns indistinguishable from economy, contrasting Facts 3-5 Details
- ▶ Faulty strategy \implies Non-prominent breakthroughs diverge from prominent breakthroughs
 - ▶ Prominent demand shock industries contrast Facts 3-5; Non-prominent breakthrough industries do not Details

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Two key industry parameters drive the absence and size of shakeouts

Ingredients of the Model

- ▶ **The Breakthrough (Shock):** benefits post-breakthrough entrants
 - ▶ Microcomputer breakthrough: entrants adopt microprocessor tech
 - ▶ Older mainframe firms unaffected
- ▶ **Short-run:** Entry of young, less productive firms (long-run profit potential)
- ▶ **Long-run:** Old, more productive firms drive price ↓

1980: \$4,000-9,000



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Two Key Drivers of Shakeouts

- ▶ **Old-Young Productivity Gap z_h/z :** causes short-run overshoot
 - ▶ Short-run: excess entry of young firms betting on long-run profits
 - ▶ Long-run: old, productive firms saturate the market ($\downarrow P \uparrow$ competition)
- ▶ **Industry-Specific Returns to Scale α :** Higher scale amplifies shakeouts
 - ▶ Large firms decrease the available profits in the market

The number of active firms is an equilibrium outcome in the model

- ▶ **Production:** Firm i produces output using labor l & firm-specific productivity z : $y_{it} = z_{it} l_{it}^\alpha$
 - ▶ Labor supply is elastic \Rightarrow constant wages \Rightarrow normalize to 1
 - ▶ Optimal labor choice: $l_{it} = (\alpha P_t z_{it})^{\frac{1}{1-\alpha}}$
 - ▶ Let $\mu_t(z)$ be productivity distribution for active firms \Rightarrow aggregate output is $Y_t^s = N_t \int y(z) \mu_t(z) dz$
 - ▶ Define the industry's average productivity:

$$\tilde{z}_t \equiv \left(\int z_t^{\frac{1}{1-\alpha}} \mu_t(z) dz \right)^{1-\alpha} \quad (1)$$

- ▶ **Demand:** industry consumer demand Y_t given the price P_t is

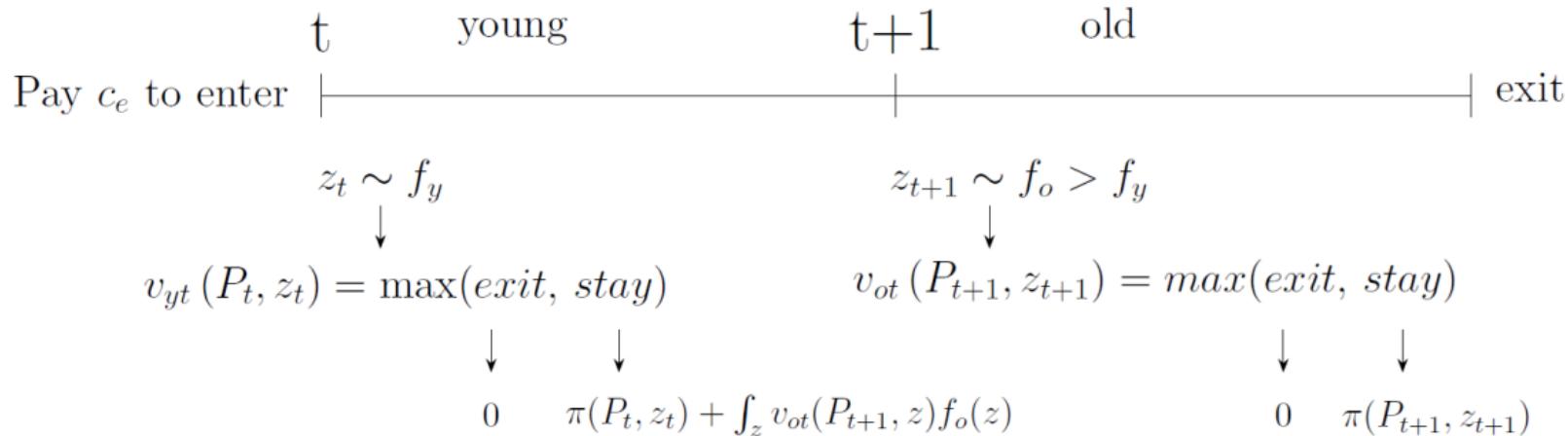
$$Y_t^d = \left(\frac{P_t}{\mathcal{P}} \right)^{-\sigma} \mathcal{Y}, \quad \sigma > 1 \quad (2)$$

- ▶ Assume economy output \mathcal{Y} and price \mathcal{P} are constant; σ = inter-industry elasticity of substitution
- ▶ **Market clearing:** output equals demand ($Y^s = Y^d$) implies the equilibrium number of firms N_t

$$P_t^{\sigma + \frac{\alpha}{1-\alpha}} = \mathcal{Y} \mathcal{P}^\sigma \left(\alpha^{\frac{\alpha}{1-\alpha}} N_t \tilde{z}_t^{\frac{1}{1-\alpha}} \right)^{-1} \quad (3)$$

Old firms are more productive than young firms

- Upon entry, firms live for 2 periods: in the 1st period they are young, in the 2nd period they are old:



- The total number of firms in period t is the sum of number of young & old firms:

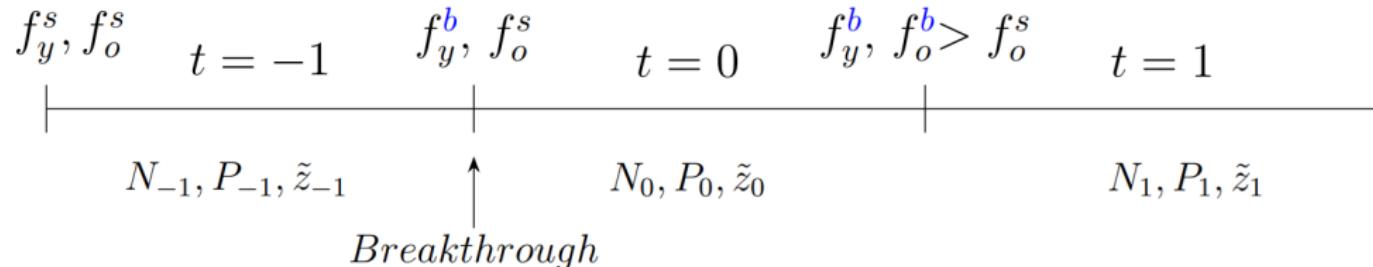
$$N_t = N_{yt} + N_{ot} \tag{4}$$

- Industry avg productivity \tilde{z}_t is the weighted average of young and old:

$$\tilde{z}_t = \left(\frac{N_{yt}}{N_t} \tilde{z}_{yt}^{\frac{1}{1-\alpha}} + \frac{N_{ot}}{N_t} \tilde{z}_{ot}^{\frac{1}{1-\alpha}} \right)^{1-\alpha} \tag{5}$$

First, an example of an equilibrium where a shakeout occurs

- The breakthrough improves productivity in old age, for future cohorts of firms



- An example where shakeouts occur

- Suppose pre and post breakthrough young productivity distributions are identical:

$$f_y^s(z) = f_y^b(z) = \begin{cases} \frac{z}{\gamma} \text{ w.p. } \gamma \\ 0 \text{ w.p. } 1 - \gamma \end{cases}$$

- The breakthrough improves productivity distribution in old age, for future cohorts:

$$f_o^s(z) = \begin{cases} \frac{z}{\lambda} \text{ w.p. } \lambda \\ 0 \text{ w.p. } 1 - \lambda \end{cases} < f_o^b(z) = \begin{cases} z_h > z \text{ w.p. } \lambda \\ 0 \text{ w.p. } 1 - \lambda \end{cases}$$

In this example, shakeouts occur: the number of firms rises and then falls

Proposition: The number of firms rises at the breakthrough, $N_0 > N_{-1}$ [proof](#)

$$\frac{N_0}{N_{-1}} = \left(\frac{P_{-1}}{P_0} \right)^{\sigma + \frac{\alpha}{1-\alpha}} = \left(\frac{\gamma + \lambda \left(\frac{z_h}{z} \right)^{\frac{1}{1-\alpha}}}{\gamma + \lambda} \right)^{\sigma(1-\alpha)+\alpha} > 1 \quad (6)$$

- The rise in the number of firms is proportional to decrease in price, $\tilde{z}_0 = \tilde{z}_{-1}$ and $P_0 < P_{-1}$ [details](#)

Proposition: The number of firms eventually falls, $N_1 < N_0$ [proof](#)

$$\frac{N_1}{N_0} = \left(\frac{\tilde{z}_0}{\tilde{z}_1} \right)^{\frac{1}{1-\alpha}} = \left(\frac{1 + \lambda}{1 + \lambda \frac{z_h}{z}} \right)^{\frac{1}{1-\alpha}} < 1 \quad (7)$$

- The decline in the number of firms is proportional to increase in avg productivity, $\tilde{z}_1 > \tilde{z}_0$ and $P_1 = P_0$

Extension: \leq^b

Size of the shakeout depends on learning curve and returns to scale

- ▶ Using Shakeout Index from empirical strategy,

$$\text{Shakeout Index} = 1 - \frac{N_1}{N_0} = 1 - \left(\frac{1 + \lambda}{1 + \lambda \frac{z_h}{\underline{z}}} \right)^{\frac{1}{1-\alpha}}$$

- ▶ As returns to scale (α) \uparrow , size of shakeout \uparrow ,

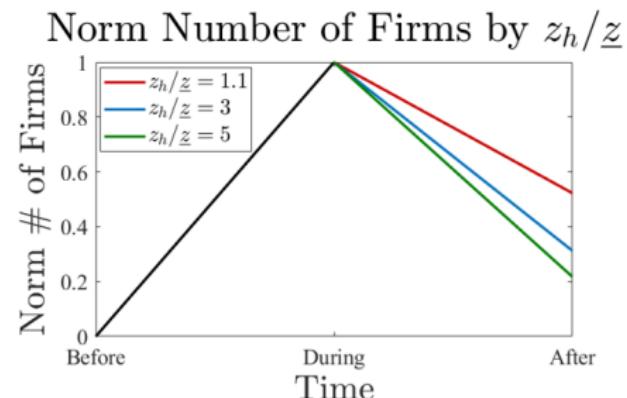
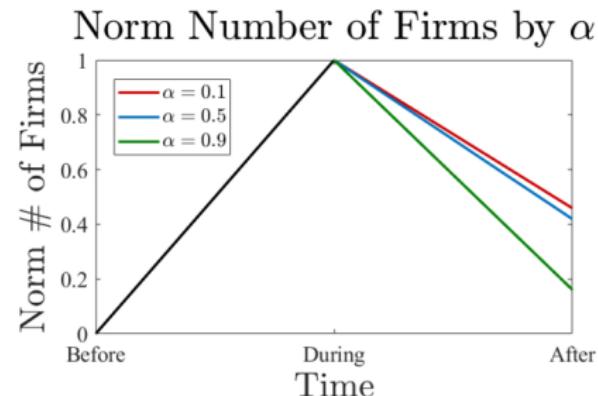
$$\lim_{\alpha \rightarrow 1} \text{Shakeout Index} = 1$$

$$\lim_{\alpha \rightarrow 0} \text{Shakeout Index} = 1 - \frac{1 + \lambda}{1 + \lambda \frac{z_h}{\underline{z}}} < 1$$

- ▶ As learning curve (z_h/\underline{z}) \uparrow , size of shakeout \uparrow ,

$$\lim_{z_h/\underline{z} \rightarrow \infty} \text{Shakeout Index} = 1$$

$$\lim_{z_h/\underline{z} \rightarrow 1} \text{Shakeout Index} = 0$$



Second, an example of an equilibrium where NO shakeout occurs

- ▶ Consider a breakthrough with no learning curve

- ▶ Young firms operate with the same productivity as old firms

$$f_y^b(z) = \begin{cases} z_h > \underline{z} \text{ w.p. } \gamma \\ 0 \text{ w.p. } 1 - \gamma \end{cases}, \quad f_o^b(z) = \begin{cases} z_h > \underline{z} \text{ w.p. } \lambda \\ 0 \text{ w.p. } 1 - \lambda \end{cases}$$

- ▶ Period 0 equilibrium identical to Period 1 [conditions](#)

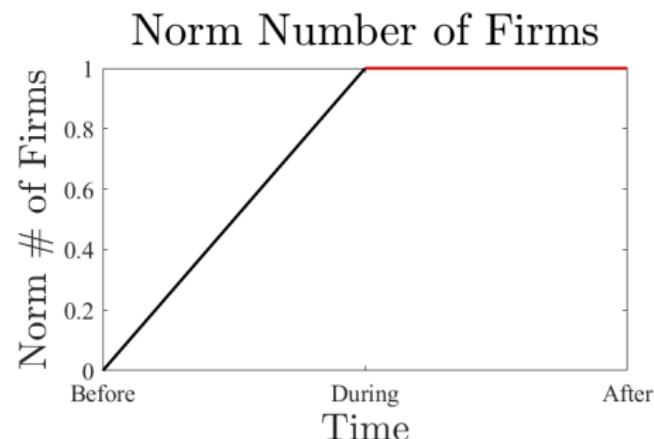
- ▶ No learning curve means no shakeouts

- ▶ Because the number of firms will rise monotonically

- ▶ The result is driven by $\tilde{z}_0 = \tilde{z}_1$

$$\frac{N_1}{N_0} = 1, \quad \frac{N_1}{N_{-1}} = \left(\frac{z_h}{\underline{z}} \right)^{\sigma-1} > 1 \text{ as long as } \sigma > 1$$

⇒ Model aligns with the five stylized facts [details](#)



Takeaways and future research

Takeaways from my paper

- ▶ Most breakthrough industries do not shake out
- ▶ The number of breakthroughs have been decreasing across time
- ▶ Industries display differences in shakeouts due to
 - ▶ Differences in returns to scale
 - ▶ Differences in the productivity gap between old and young firms

Next we can research

- ▶ What is the effect of breakthroughs on industry concentration?
- ▶ Why is the number of breakthroughs decreasing?
- ▶ What are the aggregate welfare implications of breakthroughs in the short vs long run?
- ▶ How might industrial subsidies affect the answers to the questions above?

Literature that links breakthroughs and regime-shift back

The basic invention offers the first possibility for commercial application — that is, low-tech innovation — leading to the opening of the product market at $t = 1$

Jovanovich MacDonald (1994)

Scientific revolutions are inaugurated by a growing sense, again often restricted to a narrow subdivision of the scientific community, that *an existing paradigm has ceased to function adequately* in the exploration of an aspect of nature to which that paradigm itself had previously led the way. In both political and scientific development the sense of malfunction that can lead to crisis is prerequisite to evolution (emphasis added)

Thomas Kuhn (1962)

The distinguishing feature of the technology as an input is that it is neither a conventional good nor a public good; it is a nonrival, partially excludable good

Romer (1990)

The breakthrough selection strategy is robust

[back to strategy](#)[back to index](#)

- ▶ Industry i in year t has net entry rate r_{it}

1. Remove year fixed effects and extract the residual ε_{it}

$$r_{it} = \alpha + \beta_t I_t + \varepsilon_{it}$$

2. Smooth over 5 years: main result is robust to adjustments in smoothing [No smoothing](#) [Smooth over 2 years](#)

$$\hat{\varepsilon}_{it} = \frac{1}{5} \sum_{k=-2}^2 \varepsilon_{i(t+k)}$$

3. Append 1978 and 1979: result is robust to not appending 1978 and 1979 [Start from 1979](#) [Start from 1980](#)

$$\tilde{\varepsilon}_{it} = \begin{cases} \hat{\varepsilon}_{it} & \text{for } t \geq 1980 \\ \varepsilon_{it} & \text{for } t = 1978, 1979 \end{cases}$$

- ▶ Let E be the set of all pairs (i, t) such that $\tilde{\varepsilon}_{it}$ is in the 90th percentile of all pooled $\tilde{\varepsilon}_{it}$

- ▶ Result is robust to using cross-sectional instead of pooled $\tilde{\varepsilon}_{it}$ [Cross-section](#)

- ▶ A breakthrough is a sequence $\{(i, t), (i, t+1), \dots, (i, t+5)\} \in E$

- ▶ **1978: Software packages separate from hardware**
 - ▶ What firms entered? Microsoft (1975), Oracle, Adobe, Symantec, VisiCorp, Lotus
- ▶ **1990: Birth of Gaming industry in Software**
 - ▶ Release of Windows 3.0 by Microsoft, with a user-friendly graphical user interface (GUI)
 - ▶ Who entered? id Software (1st first person shooter games), Rogue Entertainment, Epic Games (Fortnite)
- ▶ **1989: Wireless Telecommunications**
 - ▶ First cellular system, Qualcomm's CDMA, and the first flip phone, Motorola's MicroTAC
- ▶ **1997: Internet publishing**
 - ▶ Launch of Weblogs and RealPlayer, the first online media sharing content and streaming platform, respectively

► Credit intermediation

- ▶ 1978: issuance of the first debit card by the First National Bank of Seattle
- ▶ What firms entered? Ameriquest, Discover Financial Services, MBNA, The Blackstone Group

► Waste Management services

- ▶ First large-scale recycling facility for commingled materials (MRF) began operation in 1993

► Snack Foods

- ▶ 1980: adoption of twin-screw extrusion technology enabled the production of snacks with distinct textures, shapes, and flavors that older methods could not achieve, leading to the emergence of modern snacks like Doritos, Cheetos, and Ritz Crackers

► Mobile Food Services

- ▶ Social media platforms like Twitter, Facebook, and Instagram served as a breakthrough in how the industry operated and attracted customers: broadcasting their locations, menus, and schedules in real-time; and attracting a larger customer base through promotion of foodie culture

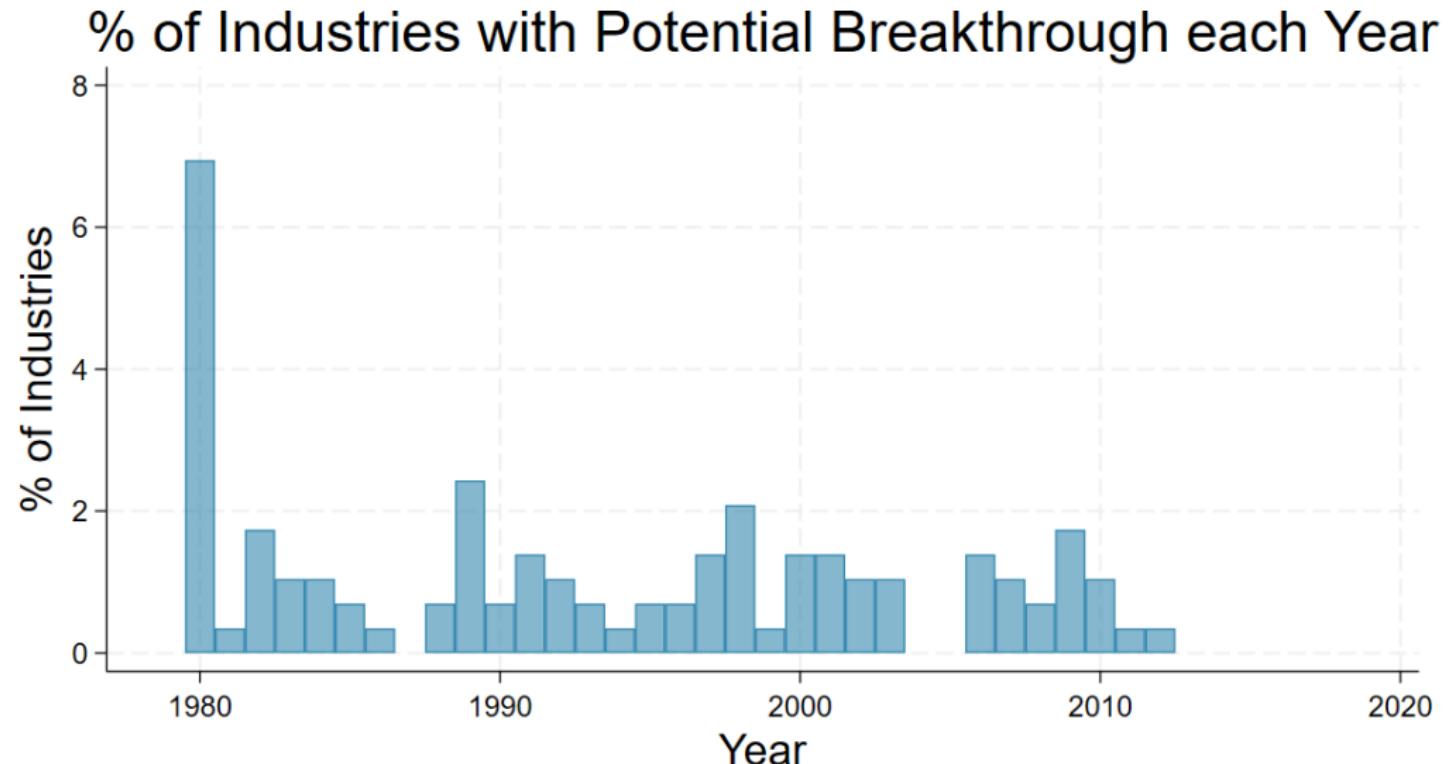
Every selected industry in 1978

[back](#)

Industry	Breakthrough	Entrants
Computer Manufacturing	1st PC: Apple II, TRS-80	Compaq, Epson America, Apple (1976)
Software Publishers	Software packages separate from hardware	Microsoft (1975), Oracle, Adobe, Symantec, VisiCorp
Sound Recording	Compact Disc	Sub Pop, Metal Blade, Rhino
Satellite Telecommunications	1st GPS satellite: NAVSTAR 1	EchoStar, PanAmSat
Credit Intermediation	1st US debit card, MBS (1981)	Ameriquest, Discover, Blackstone
Rental Centers	1st video rental store	Family Video, Blockbuster Video
Equipment Rental	DIY movement	Sunbelt Rentals, Rent-A-Center
Accounting Services	Electronic data interchange	Intuit Inc., Accounting Micro Systems
Design Services	Graphic design/postmodernism	Hovey-Kelley Design (later IDEO), Frog Design, Pentagram
Computer Systems Design	Network operating system	Sun Microsystems, Silicon Graphics, Novell
Business Support Services	Outsourcing, specialization	Sykes, TeleTech, Aerotek
Travel Agencies	Computerized reservation systems	Pleasant Holidays, Vacations To Go
Security Services	1st electronic keycard is installed	
Other Support Services	Automated packaging	Uline
Offices of Other Health Practitioners	Alternative medicine	CSHS, Upledger Institute, Bastyr University
Home Health Care Services	Telehealth (STARPAHC + CT scanner)	Almost Family Inc, Lincare Holdings Inc
Ambulatory Services	Ambulatory surgery centers	Surgicare of Manhattan, Blue Ridge Surgery Center
Disability and Abuse Facilities	Community care (Ira Burnim)	Local REM ICF facilities
Independent Artists	Independent record labels	Dischord Records, Alternative Tentacles, Sub Pop

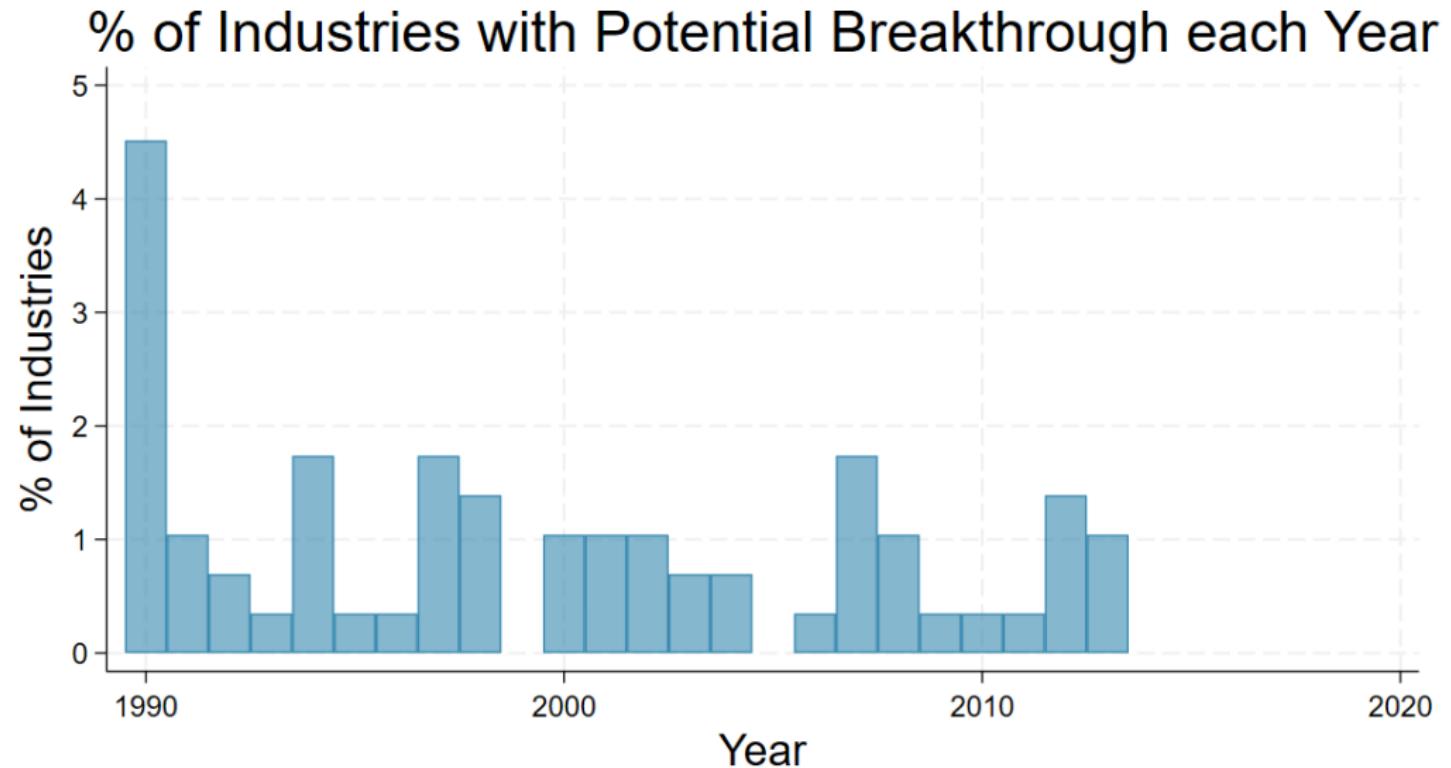
What if I started observing the data starting in 1980? [back](#)

- The industries below are selected with a cross-sectional threshold of 10%



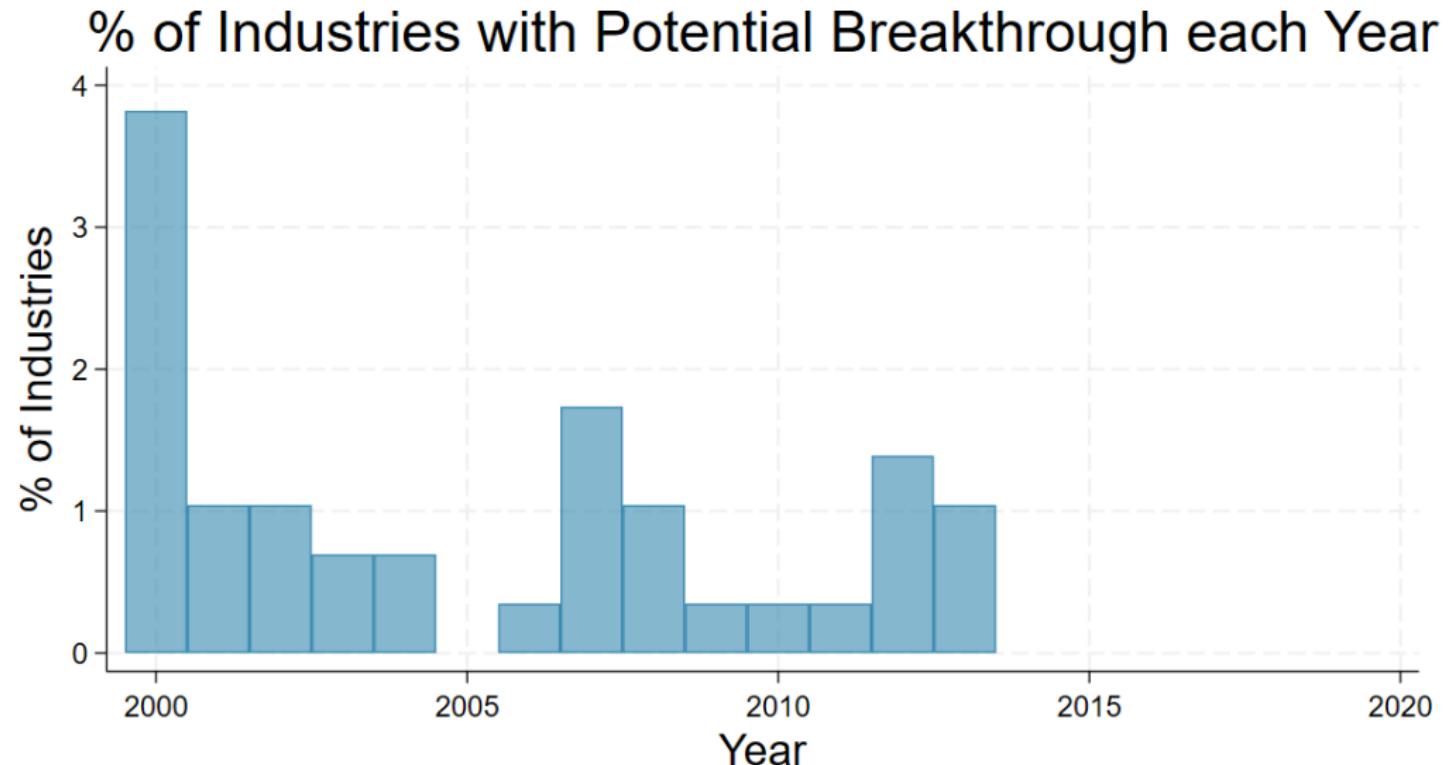
What if I started observing the data starting in 1990? [back](#)

- The industries below are selected with a cross-sectional threshold of 10%



What if I starting observing the data starting in 2000? [back](#)

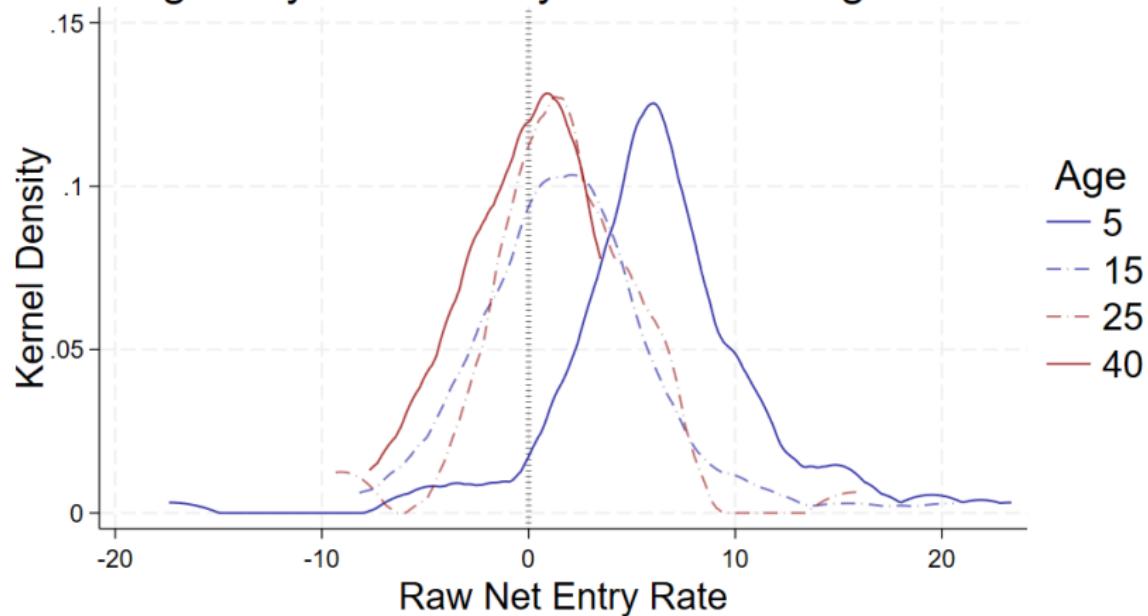
- The industries below are selected with a cross-sectional threshold of 10%



While net entry rate decreases, some industries shake out and others do not

back

Heterogeneity of Net Entry in Breakthrough Industries



Major sector descriptions

- ▶ **A** - Administrative and Support and Waste Management Services
- ▶ **F** - Finance, Insurance, and Real Estate
- ▶ **H** - Educational Services, Health Care and Social Assistance
- ▶ **I** - Information, Professional, Scientific, and Technical Services
- ▶ **M** - Manufacturing
- ▶ **T** - Trade, Transportation and Warehousing
- ▶ **O** - Other
 - ▶ Agriculture, Forestry, Fishing and Hunting
 - ▶ Mining, Quarrying, and Oil and Gas Extraction
 - ▶ Arts, Entertainment, and Recreation
 - ▶ Other Services (except Public Administration)

[back](#)

How is the shakeout index computed and normalized?

back

► Case 1. An interior global maxima exists

- Let T be the oldest age of the industry

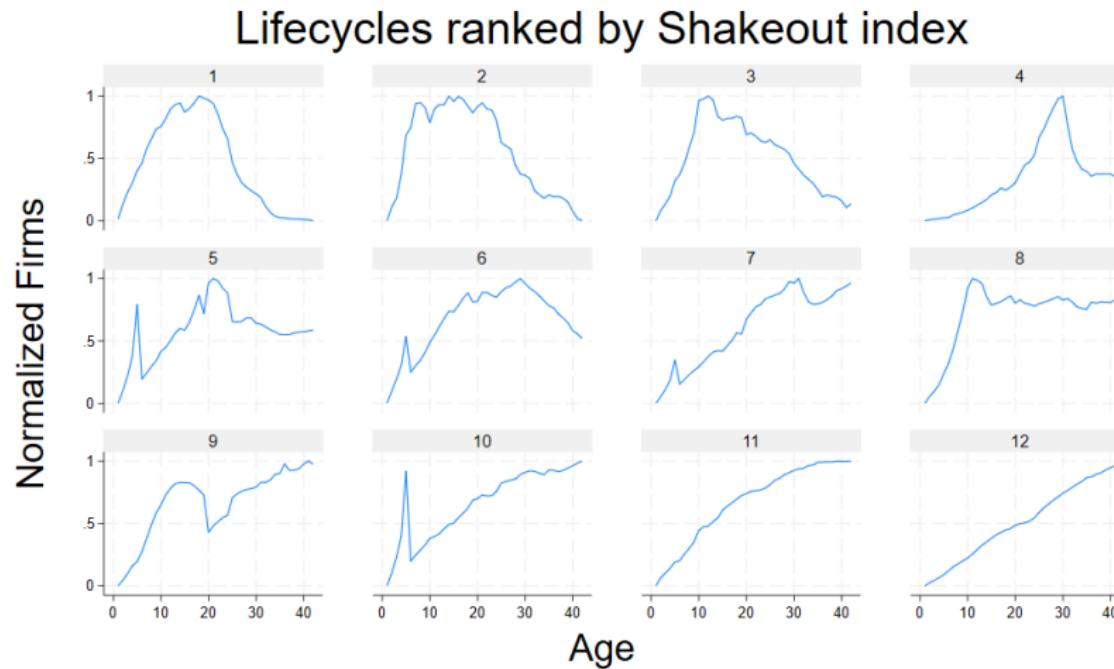
$$\begin{aligned}\widetilde{RD} &= 1 - \frac{\text{Firms at trough}}{\text{Firms at max}} \\ \widetilde{DD} &= \frac{(\text{Age at trough}) - (\text{Age at max})}{\text{Lifespan}} \\ \widetilde{EI} &= \frac{\text{Firms at } T}{\text{Firms at age 1}}\end{aligned}$$

- Firms at max = number of firms at the industry's peak (global maximum)
 - Firms at trough = local minimum observed after the peak (before any subsequent breakthrough)
 - Normalize DD with $\frac{1}{1+e^{-x}}$
 - For $X = RD, DD, EI$ let $X = \tilde{X} + 1$
- Case 2. An exterior global maxima exists on the right boundary. Then mechanically $\widetilde{RD} = 0$
- I set $\widetilde{DD} = 0$

Shakeout Index aligns with visual assessments of shakeouts

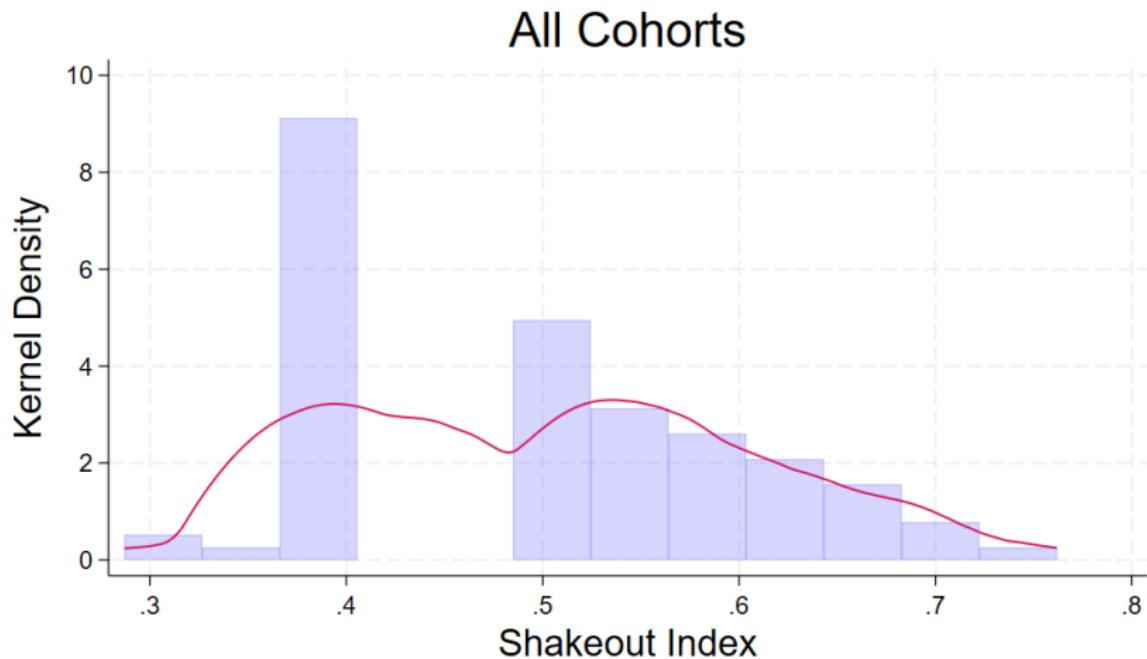
[back](#)

- ▶ Plot below shows the top ranked 12 industries in the oldest cohort

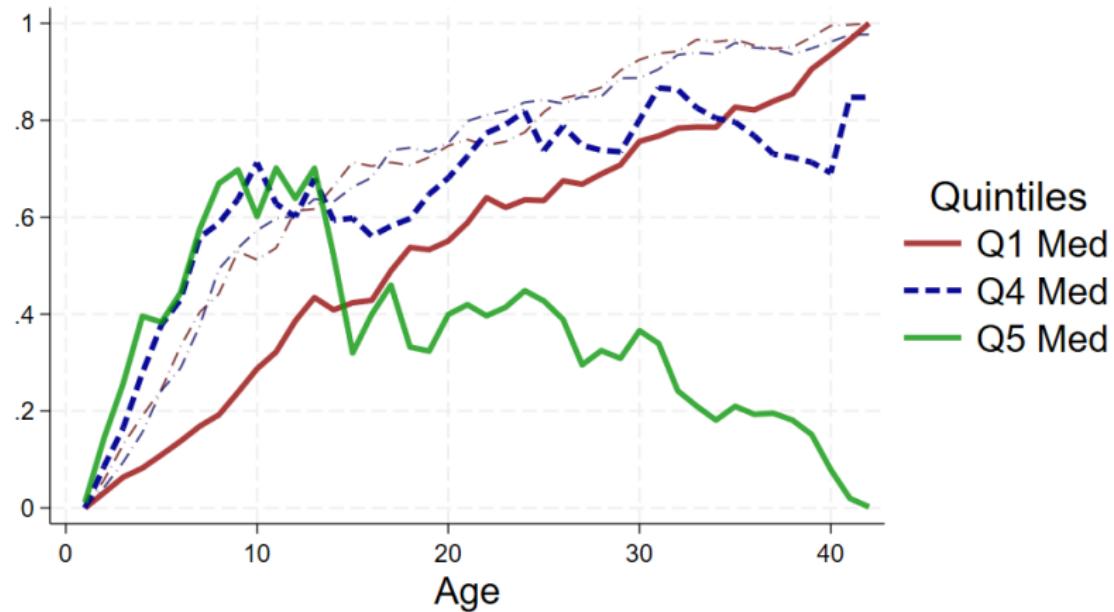


Distribution of the shakeout index

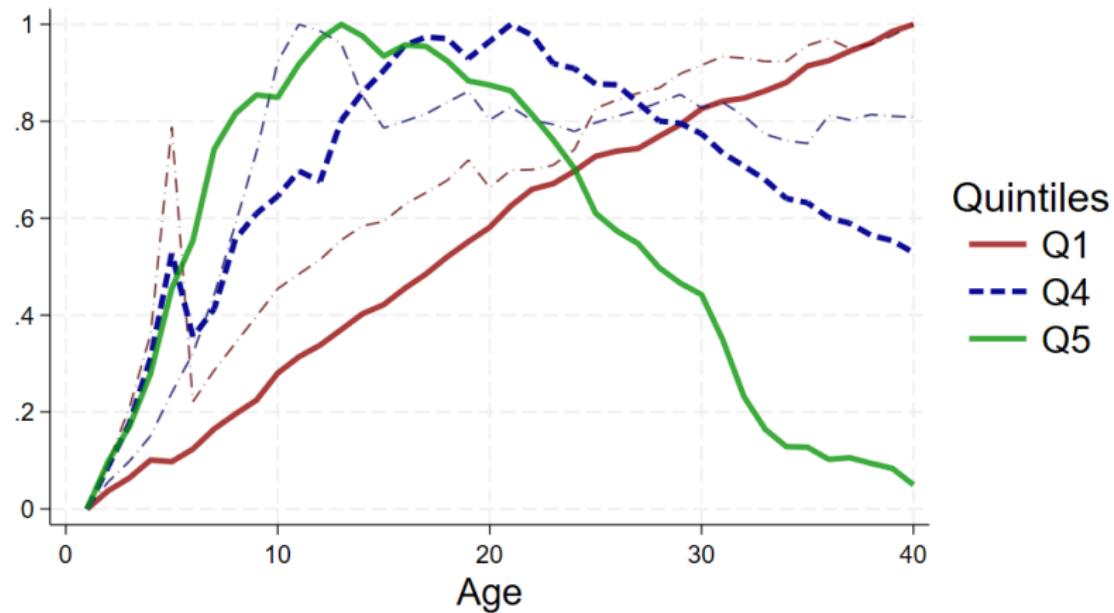
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Normalized Firms



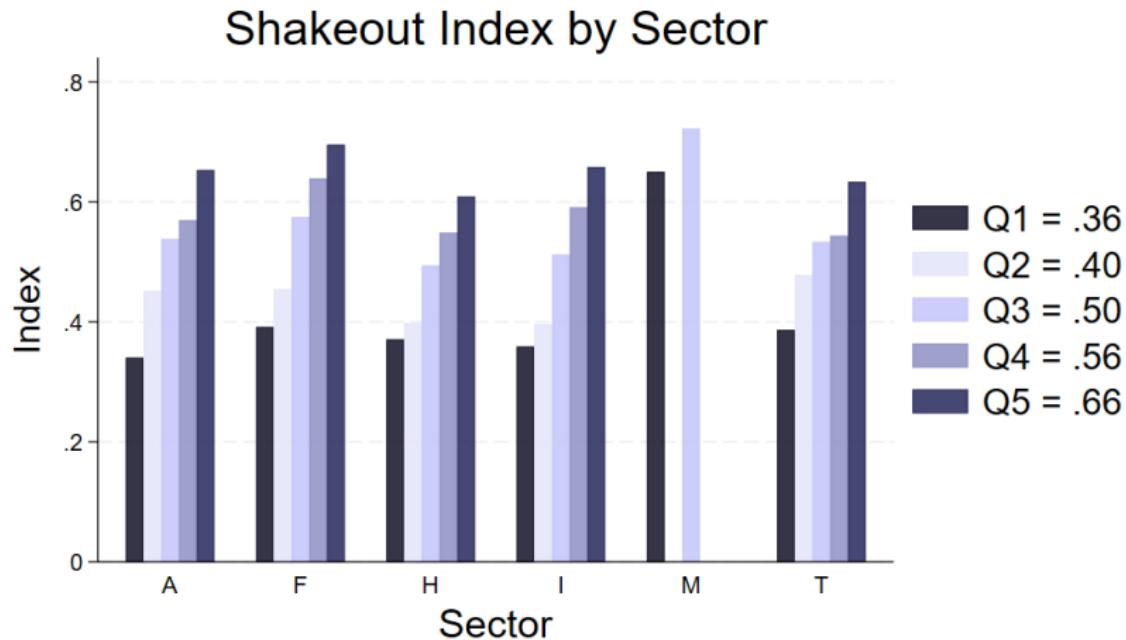
Normalized Firms



Shakeouts are heterogeneous within industries

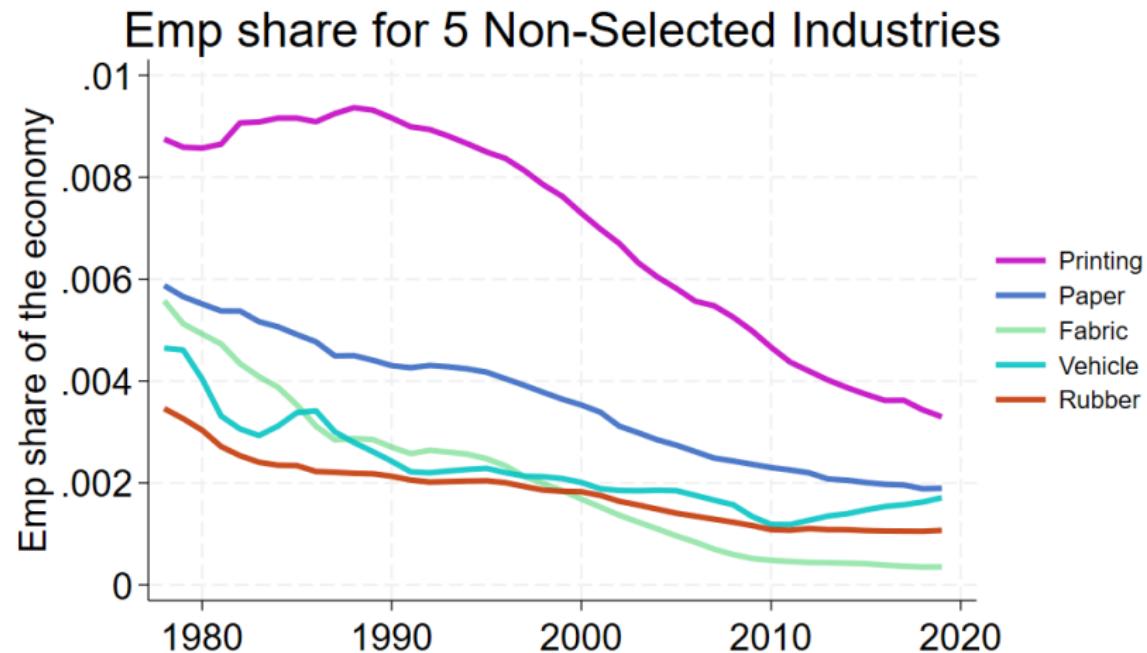
[back](#)

- ▶ Across sectors, the top quintile shakes out, whereas the bottom does not
- ▶ Manufacturing: an exception, shown for Jovanovich MacDonald comparison



Employment share decreases for 5 non-selected industries

back



- ▶ KBLMT (2023) selects “disruptive technologies” to study the effects on job creation and displacement
 1. Look for novel phrases “bigrams”/“trigrams” in US patent data
 2. Match these selected technological phrases with Wikipedia pages
 3. Cross-reference phrases with online job postings and earnings conference calls
 4. A breakthrough is a sustained growth in the mention of the phrases in associated patents
 5. The breakthrough date is the first year a technology reaches 100 citation-weighted patents with 10% annual growth for 5 years
- ▶ KPST (2021) selects breakthrough innovations through a measure of patent significance
 1. Textual analysis on the full text of patent documents to assess the content of each patent
 2. Assess novelty “Backward similarity”: Evaluating the patent’s textual dissimilarity to existing patents
 3. Assess impact “Forward similarity”: Examining the patent’s textual similarity to future patents
 4. Significance score of the patent: the ratio of forward similarity over backward similarity
 5. Breakthrough patents are in the top 10% of significance scores
 6. The date of the breakthrough patent is determined by the filing date

Comparison of commonly selected industries with KBLMT (2023)

back

Description	My Breakthrough	Anecdote	KBLMT (2023)
Support Activities for Mining	1979, 2005	Tertiary recovery (1972), Shale revolution (2003)	Coiled tubing (1988)
Computer Manufacturing	1978	1st PC: Apple II, TRS-80 (1977)	Hard disk drive (1980); Fiberoptic cable (1980); Pattern recognition (1980); +200 other techs, not listed
Software Publishers	1978, 1990	Microsoft's 1st product (1978); 1st graphics interface (1990)	Data type (1985); Input device (1985); Software architecture (1986); + 107 other techs, not listed
Information Services	1998	Google is founded (1998)	Cell site (2002); + 8 techs, not listed
Credit Intermediation	1978	1st US debit card (1978); 1st mortgage-backed security (1981)	Financial instrument (1993); Debit card (1994); Payment card (2003)
Lessors of Nonfinancial Intangible Assets	1989	TRIPS agreement (1986-1994), amendments to US patent act	Controllerpilot data link communications (2004)
Computer Systems Design	1978	Berkeley Software Distribution: Modern operating system (1978)	Predictive modelling (1990); Gunfire locator (1990); Digital mapping (1992); +6 other techs, not listed
Management, Scientific, and Technical Consulting Services	1984, 1994	1st IBM PC released (1981) - Management systems PC era; Andersen Consulting: 1st digital management system (1992)	Data validation (1992); Client computing (1993); Amazon relational database service (1993); User activity monitoring (1993); + 50 other techs, not listed
Office Admin Services	1992, 2002	The "Kodak effect" Advent of outsourcing (1989); Salesforce: 1st online customer management (1999)	Intensive care unit (1991)
Electronic Shopping and Mail-Order Houses	1997	Amazon launches 1st distribution network (1997)	Web query (1994); Client computing (2005)

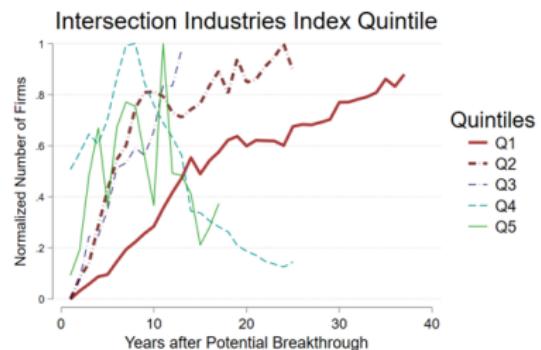
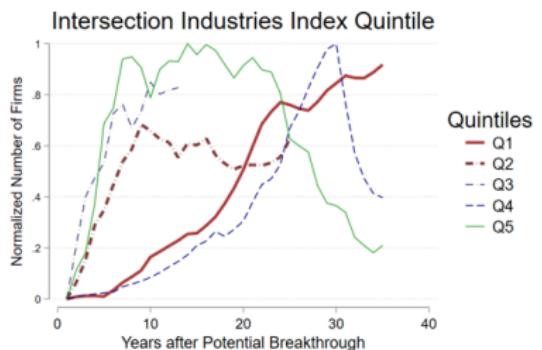
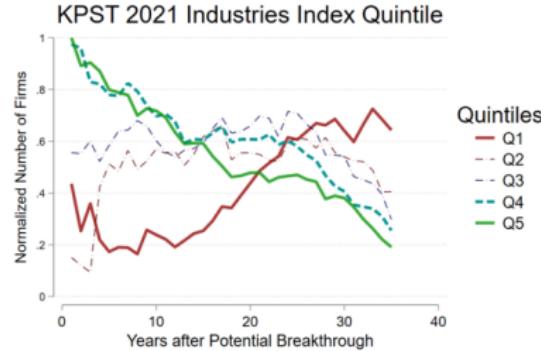
Comparison of commonly selected industries with KPST (2021)

back

Description	My Breakthrough	Anecdote	KBLMT (2023)
Timber Tract Operations	2011	Forest management software (GIS)	1995
Hunting and Trapping	1989, 1997	Population monitoring; Sustainable hunting practices	1975
Support Activities for Mining	1979, 2005	Tertiary recovery (1972), Shale revolution (2003)	1975
Grain and Oilseed Milling	2008	Biofuel production	1975
Sugar Manufacturing	2010	Alternative sweeteners	1975
Dairy Product Manufacturing	2009	Ultra-high-temperature (UHT) processing	1975
Bakeries Manufacturing	2010	Automation in baking	1975
Other Food Manufacturing	2001	Functional food products	1975
Beverage Manufacturing	2001	Craft brewing movement	1975, 1993
Tobacco Manufacturing	2009	E-cigarettes	1975
Fabric Finishing	1989	Synthetic performance fabrics	1975
Nonmetallic Mineral Products	2002	Advancements in composite materials	1975
Iron and Steel Manufacturing	1980, 1998	Continuous casting (1980), Electric arc furnaces (1998)	1975
Semiconductors	1980	Flash memory	1975
Railroad Rolling Stock	2007	High-speed Rail	1991
Residential Care Facilities	1978	Community-based care	1975
Gambling Industries	1989	Online gambling platforms	1975

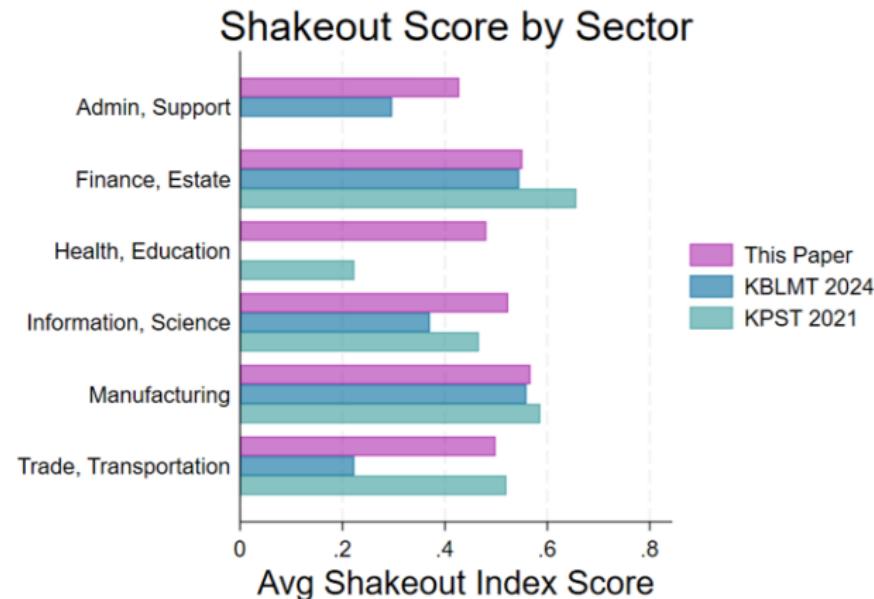
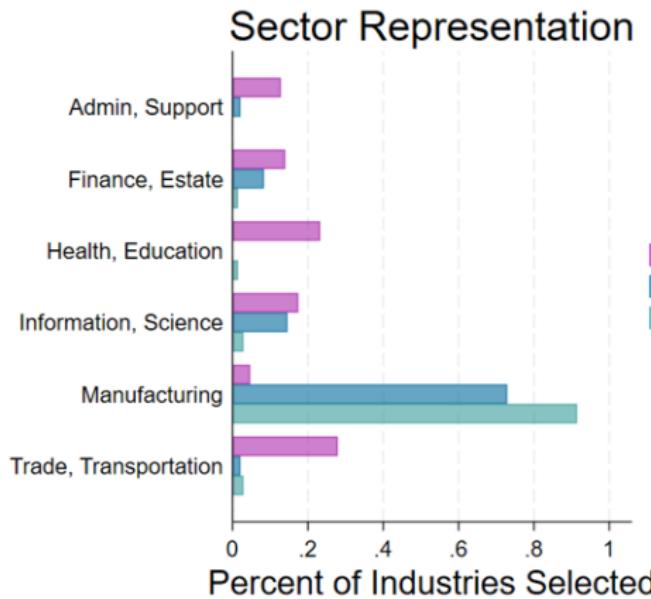
Among commonly selected industries, most industries do not shake out

[back](#)



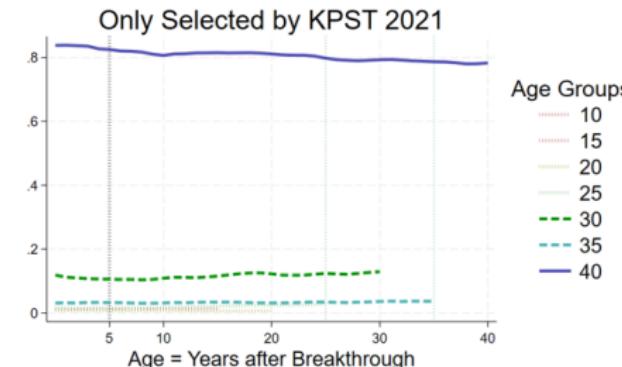
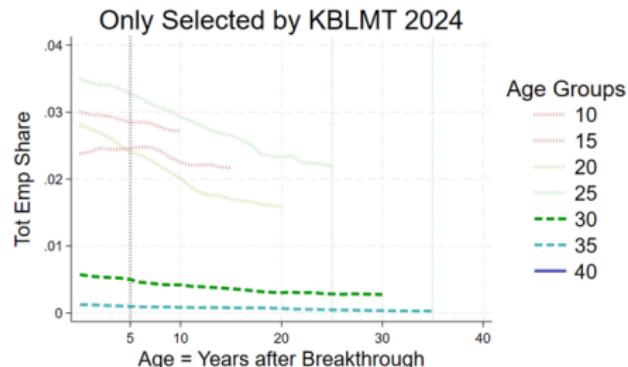
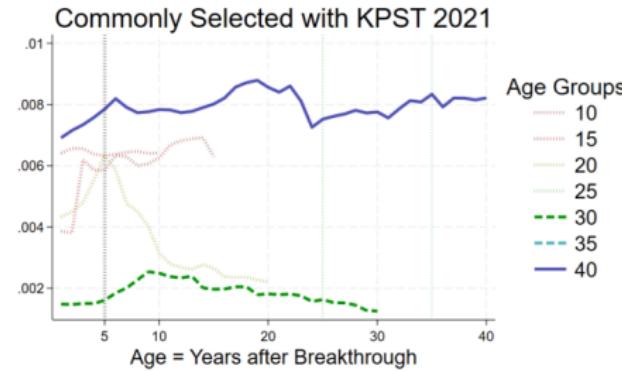
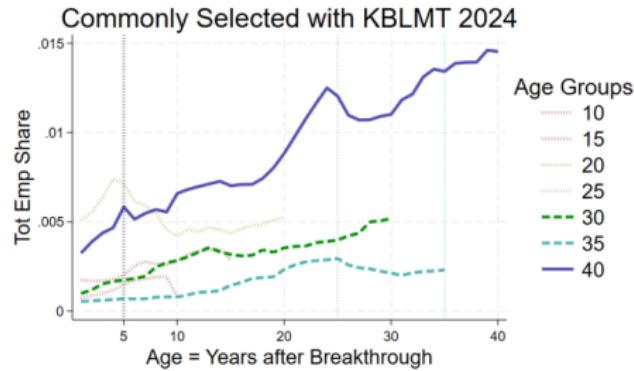
Sector representation drives shakeout differences with previous studies

[back](#)



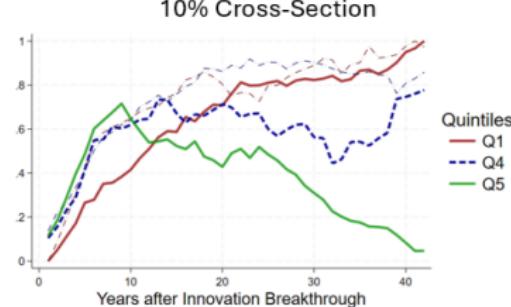
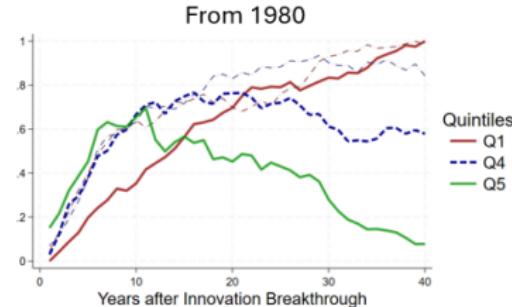
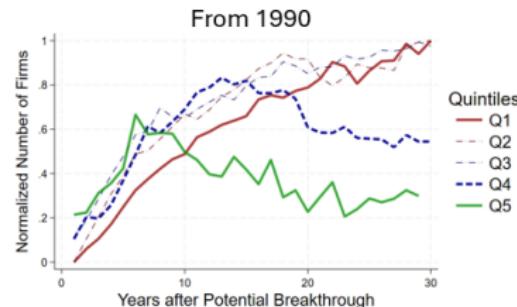
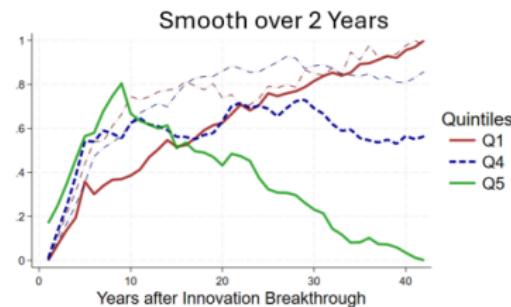
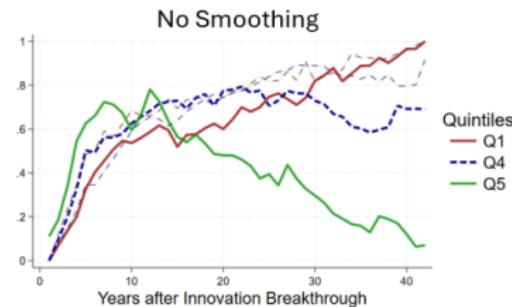
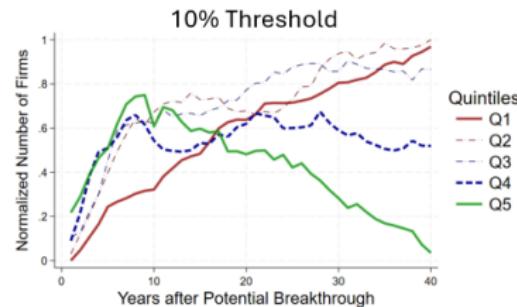
Employment share declines for industries not selected by my procedure

[back](#)



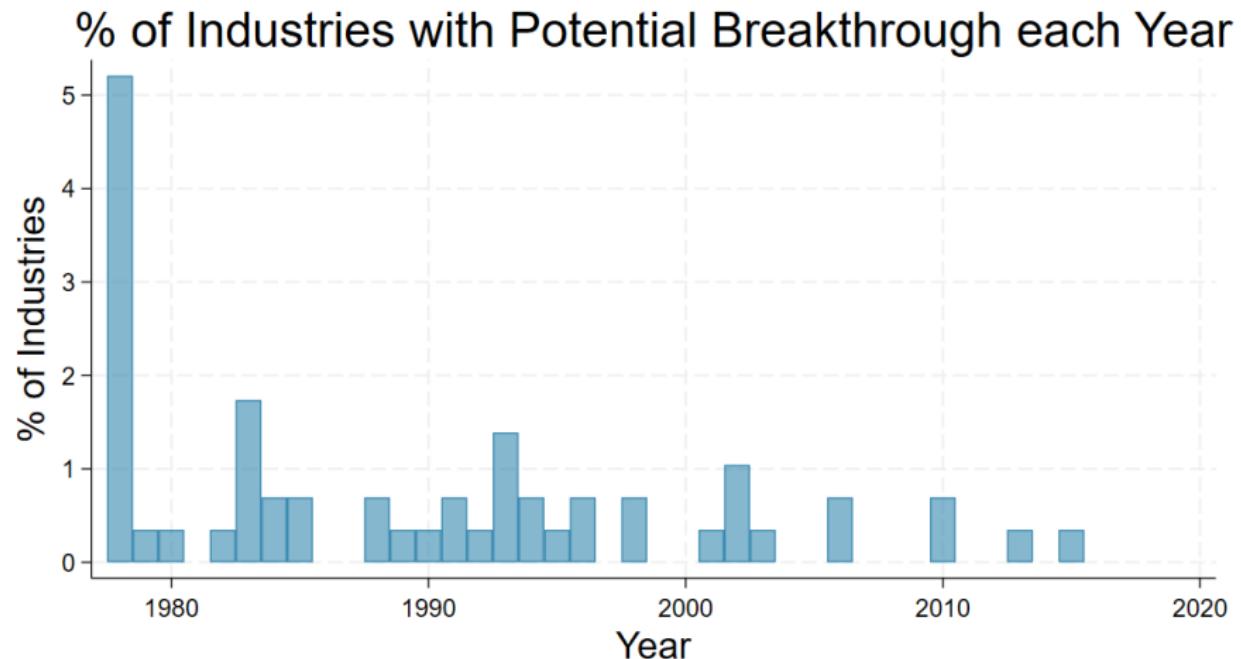
Shakeouts result remains robust to varying parameters in detection procedure

[back](#)



Main result is robust to not smoothing net entry rates [back](#)

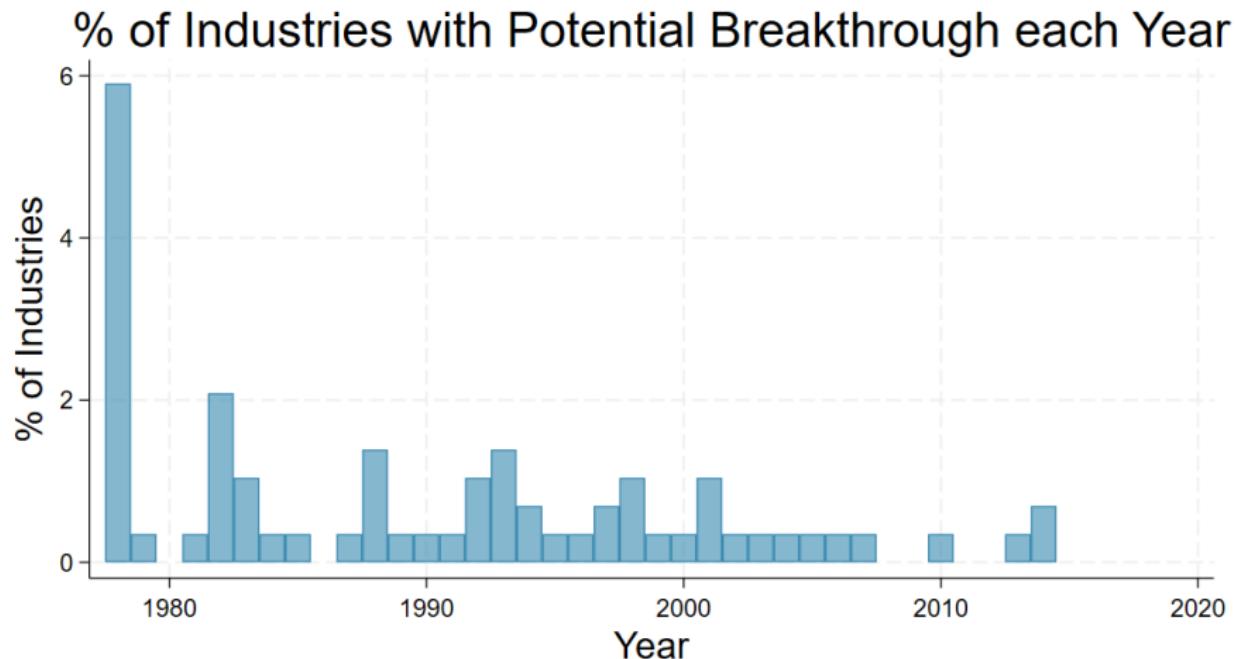
- ▶ Main result holds: Most industries do not shake out
- ▶ 42 out of the total 288 LBD Naics4 industries are selected



Main result is robust to smoothing net entry rates over 2 years

[back](#)

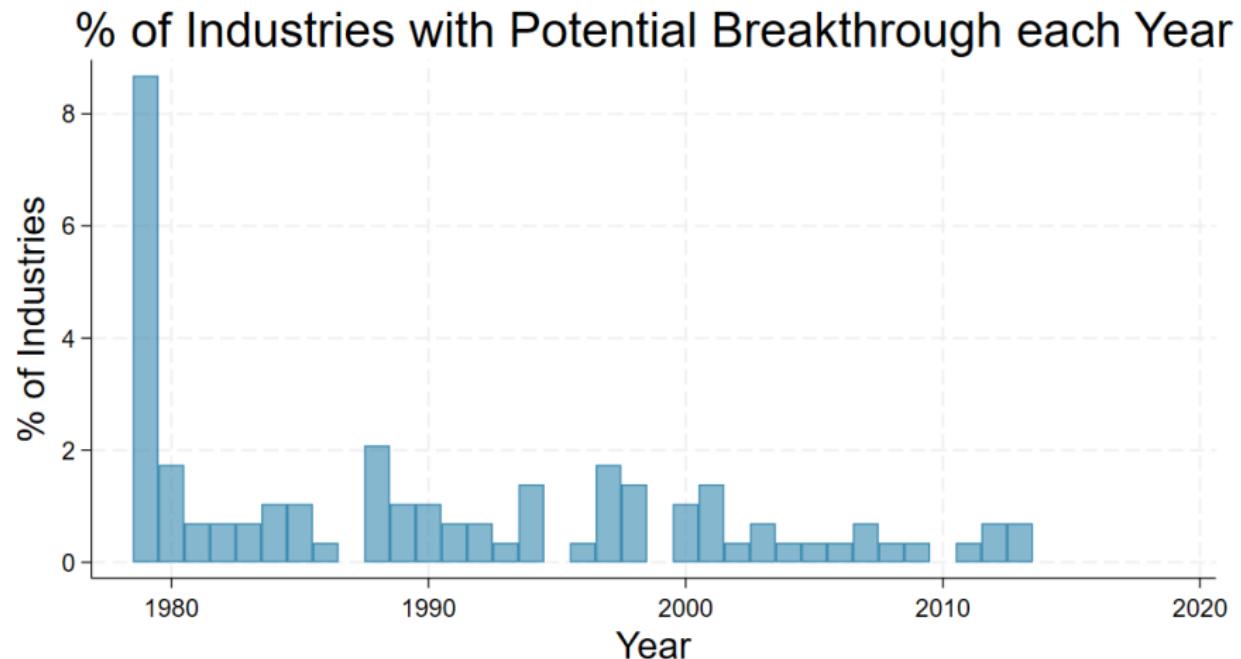
- ▶ Main result holds: Most industries do not shake out
- ▶ 53 out of the total 288 LBD Naics4 industries are selected



Main result is robust to excluding 1978

[back](#)

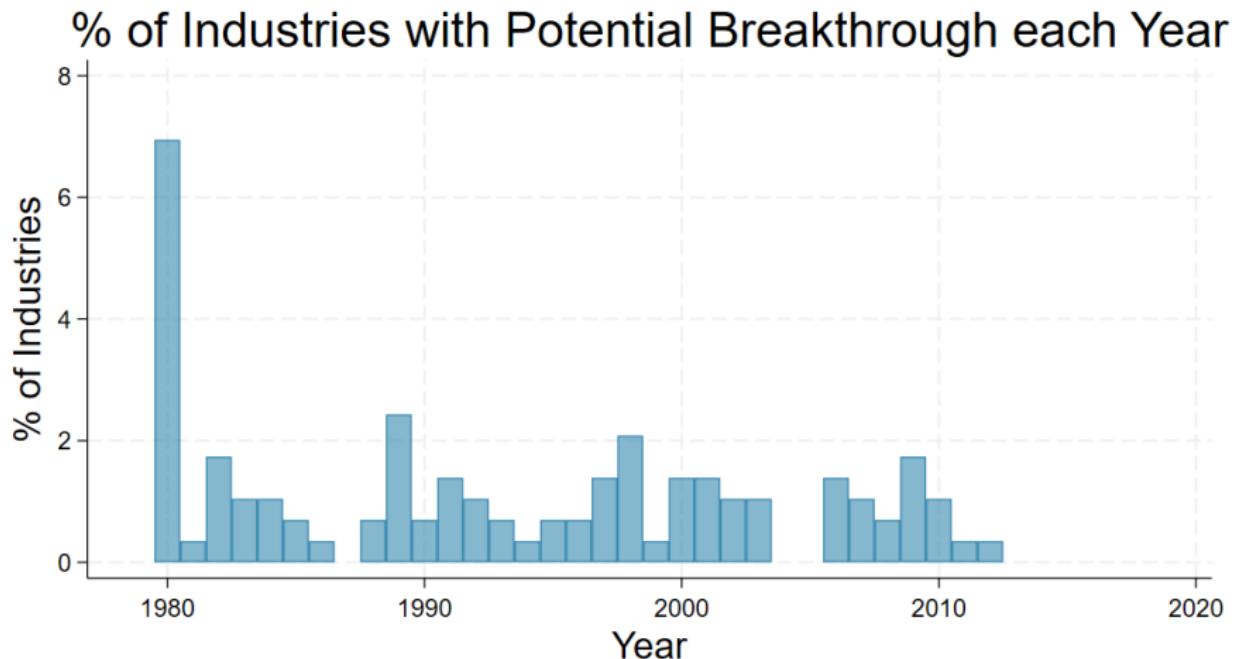
- ▶ Main result holds: Most industries do not shake out
- ▶ 75 out of the total 288 LBD Naics4 industries are selected



Main result is robust to starting from 1980

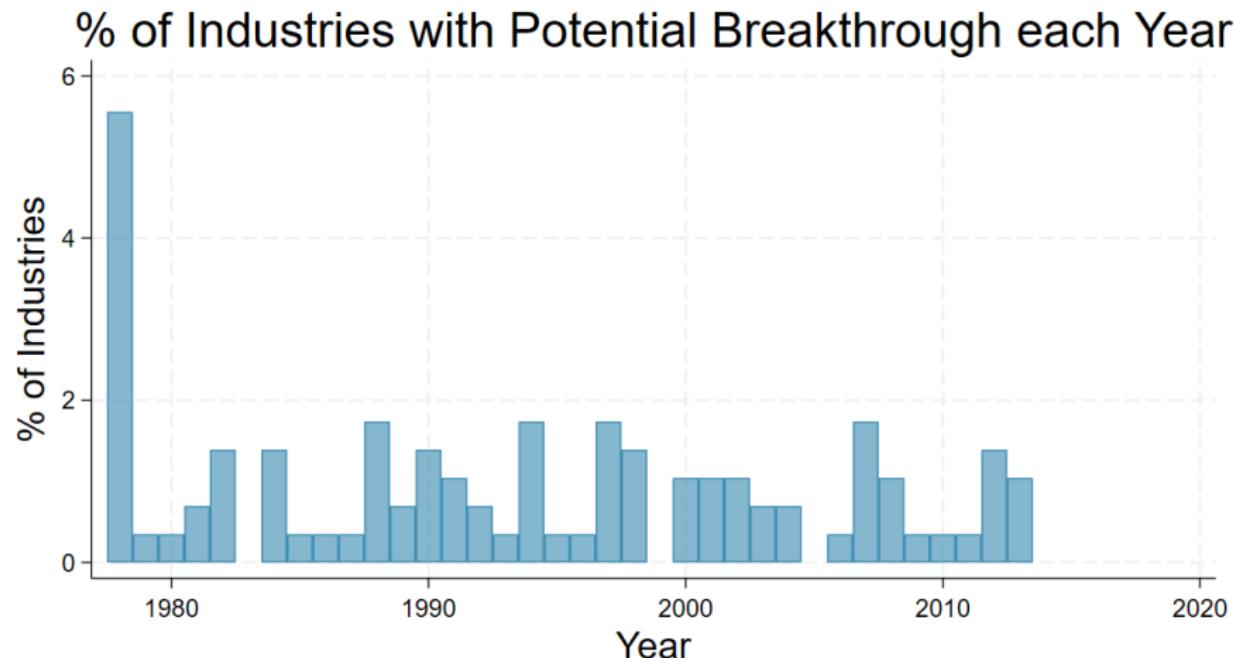
[back](#)

- ▶ Main result holds: Most industries do not shake out
- ▶ 70 out of the total 288 LBD Naics4 industries are selected



Main result is robust to a slightly different threshold: Top 10% cross-section [back](#)

- ▶ Threshold: net entry rate (FE removed) is in the top 10% of each year, instead of pooled across time
- ▶ 73 out of the total 288 LBD Naics4 industries are selected; 9 industries are different from original filter
 - ▶ Original filter selects 76 industries



New Naics codes lag multiple years behind the date of the breakthrough

back

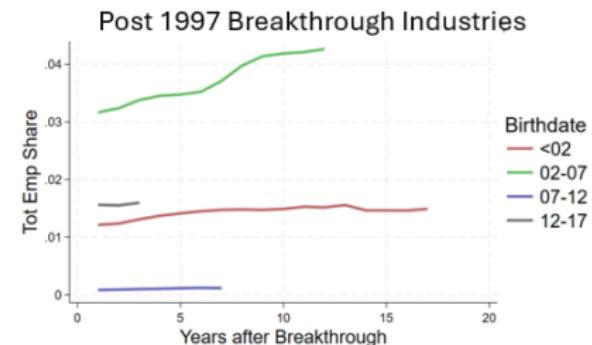
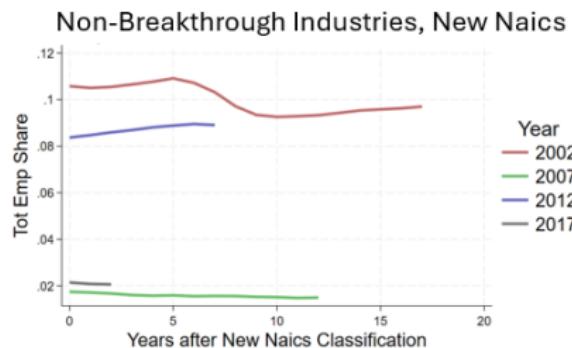
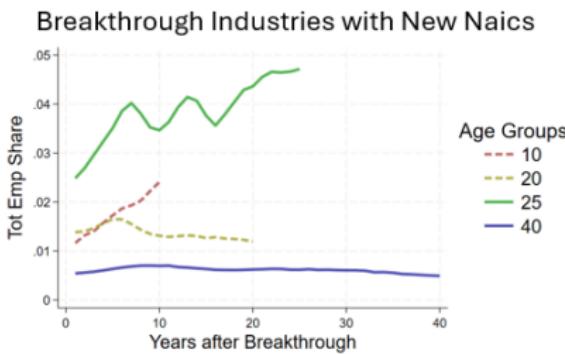
- ▶ New Naics Code Date is a Naics code that did not exist in the 1997 Naics code classification

Industry	Breakthrough Date(s)	New Naics Date	Breakthrough
Satellite Telecommunications	1978, 1993	2002	1978 - 1st GPS satellite (NAVSTAR 1); 1993 - 1st standard positioning service
Photographic Equipment	1980	2002	1981 - 1st electronic camera unveiled (Sony Mavica)
Executive Search Services	1984, 1994	2007	1984 - Computerized applicant tracking systems; 1994 - Online job boards (Monster.com, CareerBuilder)
Telecommunications Resellers	1991	2002	1991 - 1st GSM phone call, ie transition from analog to digital cellular networks
Data Processing and Hosting Services	1997	2002	1st Web hosting services (GeoCities, Tripod.com)
Wired Telecommunications Carriers	1998	2002	Rollout of Digital subscriber lines (DSL)
Internet Publishing and Web Search Portals	1998	2002	1997 - Google Search is launched; 1998 - PageRank Algorithm is designed

Statistical procedure is more empirically consistent than using new Naics codes

[back](#)

- ▶ Robustness check with 4 digit Naics codes; 6 digit Naics codes disclosure TBD



Demand shifts alone do not explain the observed variation in shakeout patterns

back

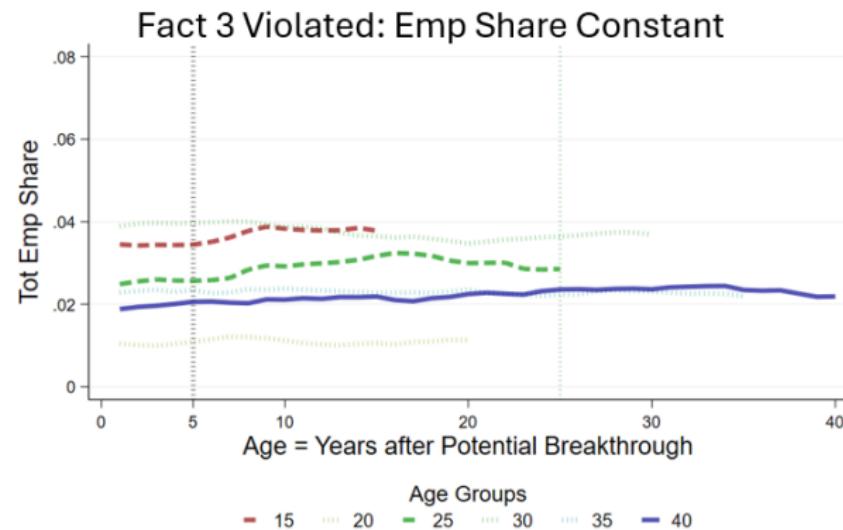
- ▶ Industries in which average prices decline post-breakthrough are consistent with stylized facts
 - ▶ Most industries do not shake out
 - ▶ Average price declines reflect little to no demand shifts in the industry

[TBD, redacted]

Facts 3-5 Violated among Random Selection of Industries

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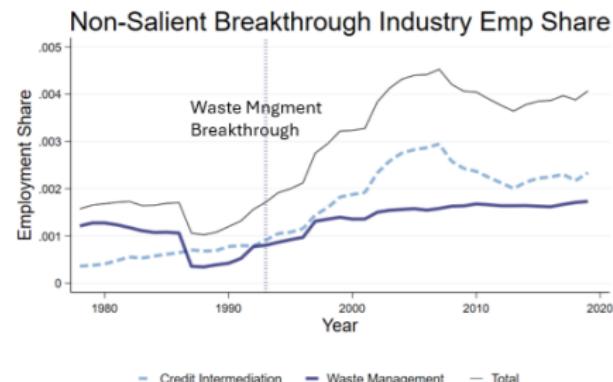
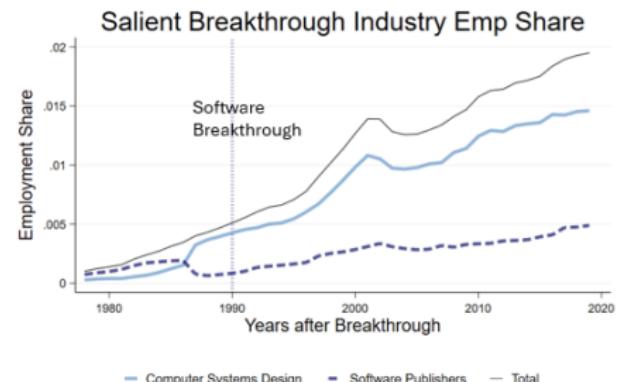
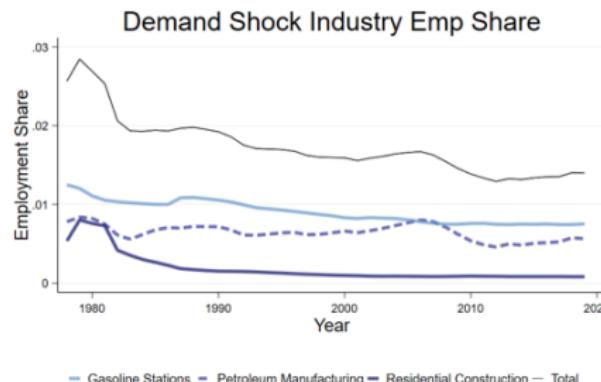
- ▶ Experiment: randomly select the same number of industry-year pairs as in the original procedure
 - ▶ Fact 3 violated; Facts 4-5 TBD (redacted)



Facts 3-5 Violated among Prominent Demand Shock Industries

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- ▶ Declining employment share in demand shock industries contrast breakthrough industries
 - ▶ Breakthrough detection procedure did not select demand shock industries (regardless of parameters)
 - ▶ Facts 4-5 TBD (redacted)



- ▶ A pattern was observed in 77 case studies in Clayton Christensen's career (Christensen et al., 1998; Rosenbloom and Christensen, 1994)
 - ▶ When an innovation emerged that improved performance on dimensions that customers *historically* valued, incumbents tended to lead commercialization and to maintain their market position
 - ▶ When an innovation emerged that did not improve performance along this customer-preference trajectory but introduced a *unique constellation of attributes* new entrants led development while incumbents languished or failed
- ▶ Also documented by Henderson 2006, Adner Zemsky 2005, King and Baatartogtokh 2015
 - ▶ "Across industries ranging from computers to retail to steel, leading firms failed to remain dominant in their respective markets. These apparently well-managed firms were widely lauded by analysts and the business press, and yet each of them overlooked something important that precipitated a decline"

Extension: Number of firms rises at the breakthrough and then falls [back](#)

- ▶ Suppose breakthrough firms when young are less productive than pre-breakthrough firms

$$f_y^b(z) = \begin{cases} \underline{z}^b < \underline{z} \text{ w.p. } \gamma \\ 0 \text{ w.p. } 1 - \gamma \end{cases}$$

- ▶ The number of firms rises at the breakthrough, $N_0 > N_{-1}$

- ▶ The result is driven by two mechanisms, $\tilde{z}_0 < \tilde{z}_{-1}$ and $P_0 < P_{-1}$

$$\frac{N_0}{N_{-1}} = \left(\frac{P_{-1}}{P_0} \right)^{\sigma + \frac{\alpha}{1-\alpha}} \left(\frac{\tilde{z}_{-1}}{\tilde{z}_0} \right)^{\frac{1}{1-\alpha}} = \left(\frac{\gamma + \lambda \left(\frac{z_h}{z^b} \right)^{\frac{1}{1-\alpha}}}{(\gamma + \lambda)} \right)^{\sigma(1-\alpha)+\alpha} \underbrace{\left(\frac{\underline{z}^b}{\underline{z}} \right)^{\sigma + \frac{\alpha}{1-\alpha}}}_{<1 \text{ if } \underline{z}^b < \underline{z}} \underbrace{\left(\frac{N_{y0}}{N_0} \frac{\underline{z}^b}{\underline{z}} + \frac{N_{o0}}{N_0} \right)^{-1}}_{>1 \text{ if } \underline{z}^b < \underline{z}} > 1 \quad (8)$$

- ▶ The number of firms eventually falls, $N_1 < N_0$

- ▶ The result is driven by two mechanisms, $\tilde{z}_1 > \tilde{z}_0$ and $P_1 = P_0$

$$\frac{N_1}{N_0} = \left(\frac{\tilde{z}_0}{\tilde{z}_1} \right)^{\frac{1}{1-\alpha}} = \left(\frac{1 + \lambda}{1 + \lambda \frac{z_h}{z^b}} \right)^{\frac{1}{1-\alpha}} \underbrace{\left(\frac{N_{y0}}{N_0} + \frac{\underline{z}^b}{\underline{z}} \frac{N_{o0}}{N_0} \right)^{\frac{1}{1-\alpha}}}_{>1 \text{ if } \underline{z}^b < \underline{z}} < 1 \quad (9)$$

Derivation details for equilibrium with shakeouts

[back](#)

- ▶ Equilibrium number of firms

$$N_t = \mathcal{Y}P^\sigma \left(\alpha^{\frac{\alpha}{1-\alpha}} P_t^{\sigma + \frac{\alpha}{1-\alpha}} \underline{z}_t^{\frac{1}{1-\alpha}} \right)^{-1}$$

- ▶ Entry decision for Period 0

$$c_e = \gamma \left(A \underline{z}^{\frac{1}{1-\alpha}} P_0^{\frac{1}{1-\alpha}} - c \right) + \lambda \left(A z_h^{\frac{1}{1-\alpha}} P_1^{\frac{1}{1-\alpha}} - c \right) \quad (10)$$

- ▶ Profits in each period are $\pi(P_t, z) = AP_t^{\frac{1}{1-\alpha}} z^{\frac{1}{1-\alpha}} - c$, $A = \alpha^{\frac{\alpha}{1-\alpha}} (1 - \alpha)$
- ▶ Let the given \underline{z} satisfy the following continuation values and exit conditions in equilibrium:

$$\pi(P_{-1}, 0) + \lambda \pi(P_{-1}, \underline{z}) < 0$$

$$\pi(P_{-1}, \underline{z}) + \lambda \pi(P_{-1}, \underline{z}) \geq 0$$

$$\pi(P_{-1}, 0) < 0$$

$$\pi(P_{-1}, \underline{z}) > 0$$

- ▶ These conditions are satisfied as long as $c > \frac{\lambda}{\lambda + \gamma} c_e$ and $c_e > 0$

Derivation details for burst of entry

[back](#)

- ▶ First show $P_{-1} > P_1$ from setting Period -1 and 1 entry conditions equal:

$$P_1 = \left(\frac{\gamma + \lambda}{\gamma + \lambda \left(\frac{z_h}{z} \right)^{\frac{1}{1-\alpha}}} \right)^{1-\alpha} P_{-1} \quad (11)$$

- ▶ Therefore $P_{-1} > P_0 = P_1$ as well
- ▶ Next, plug in for the equilibrium equations for N ,

$$\begin{aligned} \frac{N_0}{N_{-1}} &= \frac{\gamma P^\sigma \left(\alpha^{\frac{\alpha}{1-\alpha}} P_0^{\sigma + \frac{\alpha}{1-\alpha}} \tilde{z}_0^{\frac{1}{1-\alpha}} \right)^{-1}}{\gamma P^\sigma \left(\alpha^{\frac{\alpha}{1-\alpha}} P_{-1}^{\sigma + \frac{\alpha}{1-\alpha}} \tilde{z}_{-1}^{\frac{1}{1-\alpha}} \right)^{-1}} \\ &= \left(\frac{P_{-1}}{P_0} \right)^{\sigma + \frac{\alpha}{1-\alpha}} \end{aligned}$$

- ▶ Finally, use equation 11 and the result follows immediately

Derivation details for shakeouts

[back](#)

- Use $P_0 = P_1, \tilde{z}_1 = \frac{N_{y,1}}{N_1} z + \frac{N_{o,1}}{N_1} z_h, N_1/N_{y1} = 1 + \lambda$
- The last equation follows from: for $t = -1, 1$ we have

$$\begin{aligned} N_t &= N_{y,t} + N_{o,t} \\ &= N_{y,t} + \lambda N_{y,t} \\ &= (1 + \lambda) N_{y,t} \end{aligned}$$

- Therefore,

$$N_{y,t} = \frac{1}{1 + \lambda} N_t, \quad N_{o,t} = \frac{\lambda}{1 + \lambda} N_t$$

- Then use equilibrium equation for N to get

$$\begin{aligned} \frac{N_1}{N_0} &= \frac{\gamma \mathcal{P}^\sigma \left(\alpha^{\frac{\alpha}{1-\alpha}} P_1^{\sigma + \frac{\alpha}{1-\alpha}} \tilde{z}_1^{\frac{1}{1-\alpha}} \right)^{-1}}{\gamma \mathcal{P}^\sigma \left(\alpha^{\frac{\alpha}{1-\alpha}} P_0^{\sigma + \frac{\alpha}{1-\alpha}} \tilde{z}_0^{\frac{1}{1-\alpha}} \right)^{-1}} \\ &= \left(\frac{1 + \lambda}{1 + \lambda \frac{z_h}{z}} \right)^{\frac{1}{1-\alpha}} \end{aligned}$$

Derivation details for equilibrium with NO shakeouts

back

- ▶ First, we know $P_0 = P_1$. To show $P_0 < P_{-1}$, I first show that $P_1 < P_{-1}$ comes from equating the Period -1 and 1 entry values:

$$P_1 = \left(\frac{\underline{z}}{z_h} \right) P_{-1} < P_{-1} \quad (12)$$

- ▶ Next, $\tilde{z}_0 = \tilde{z}_1$ as long as the pre-breakthrough firms leave:

$$\tilde{z}_0 = \frac{N_{y0}}{N_0} z_h + \frac{N_{o0}}{N_0} \underline{z} = z_h \iff N_{o0} = 0 \iff \pi(P_0, \underline{z}) < 0$$

- ▶ Solve for $\pi(P_0, \underline{z}) < 0$ by plugging in equation 12, to get

$$z_h > \left(\frac{A}{c} \right)^{1-\alpha} P_{-1} \underline{z}^2$$

Model aligns with the five empirical facts

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- ▶ Facts 1 & 2: After a breakthrough, huge variation in shakeouts
- ▶ Fact 3: Firm labor choice \propto productivity \implies employment share \uparrow as average productivity \uparrow
- ▶ Fact 4: Mechanical, due to the assumption that firms operate for two periods
- ▶ Fact 5: Shakeouts are driven by the exit of new entrants following the breakthrough

[details](#)

The shakeout is driven by the exit of new firms

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- ▶ The relative decline of new firms is characterized by,

$$\text{Relative Decline} = 1 - \left(\frac{1 + \lambda}{\lambda} - \left(\frac{\gamma + \lambda}{\gamma + \lambda \left(\frac{z_h}{z} \right)^{\frac{1}{1-\alpha}}} \right)^{\sigma(1-\alpha)+\alpha} \right)^{-1} \left(\frac{1 + \lambda}{1 + \lambda \frac{z_h}{z}} \right)^{\frac{1}{1-\alpha}}$$