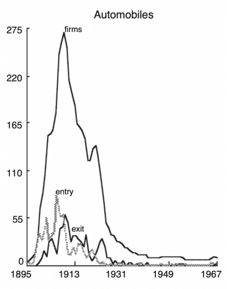
The Life-cycle of Concentrated Industries

Martin Beraja (MIT) Francisco Buera (WashU)

Motivation

- Many disruptive industries have had a **life-cycle**: Entry → Shakeout → Concentration

  Gort and Klepper, 1982; Klepper-Graddy, 1990; Klepper-Simons, 2005



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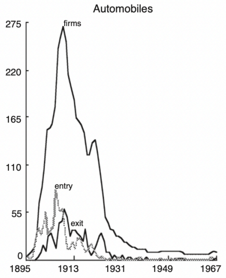

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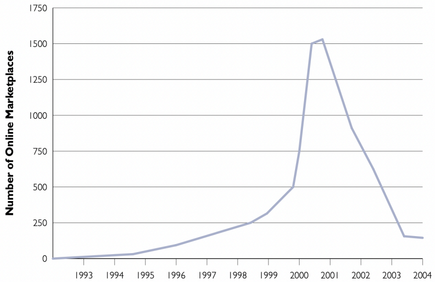

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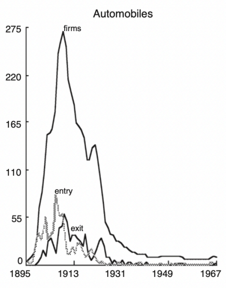

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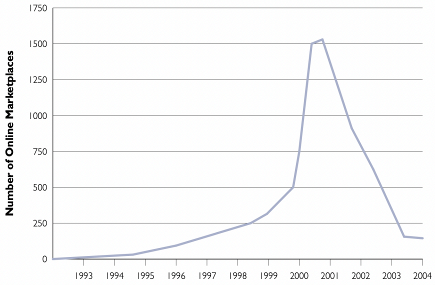

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- Also, OS or search engine industries. Windows or Google far ahead in a decade...

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Ex-post interventions

Come into play only after an industry has sufficiently concentrated

- Essential infrastructure or IP access (AT&T, Intel)
- Data-sharing (EU Digital Markets Act)?

This paper

1. When should governments **promote competition** in a nascent industry?
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2. **Application:** Digital and AI industries in the US (dataset from VentureScanner)

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Assumption 1: Flow profit function is:

(i) decreasing in $\underline{N}$ and $\bar{N}$,

(ii) increasing in z,

(iii) converges to fixed cost $-f$ as $z \rightarrow 0$ and $\bar{N} \rightarrow \infty$, and

(iv) such that at least one firm enters $\pi\left(1, 0; \underline{z}\right) + \lambda\pi\left(0, 1; \bar{z}\right)/r > 0$.

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Special case:

- Cost function: $\Gamma(q; z) = \frac{1}{z} q + f$
- Inverse demand function:

$$p_i = \frac{\sigma - 1}{\sigma} \left[\sum_{j=1}^{\underline{N}_t + \bar{N}_t} (q_j)^{\frac{\epsilon - 1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon - 1} \frac{\sigma - 1}{\sigma} - 1} (q_i)^{-\frac{1}{\epsilon}}$$

- Cournot competition in q

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Households

$$V\left(\underline{N}_t, \bar{N}_t\right) = \mathbb{E}_t\left[\int_t^\infty e^{-r(s-t)} U\left(\underline{N}_s, \bar{N}_s\right) ds\right]$$

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Special case:

$U = Q_t + X_t$, with quantity Q_t and outside good X_t,

and $Q_t = \left[\sum_{i=1}^{\underline{N}_t+\bar{N}_t} \left(q_{it}\right)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}\frac{\sigma-1}{\sigma}}$

Solve backward (recursively) for value functions and exit/entry policies

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- A **long-run** concentrated industry **equilibrium** $(0, \bar{N}^{LF}_{\infty})$ is given by $\bar{N}^{LF}_{\infty}$:

  1. Large firms don't **exit** in the long-run $\iff J\left(0, \bar{N}^{\mathrm{LF}}_{\infty}; \bar{z}\right) = \frac{\pi\left(0, \bar{N}^{\mathrm{LF}}_{\infty}; \bar{z}\right)}{r} \geq 0,$
  2. Small firms don't **enter** in the long-run $\iff J\left(1, \bar{N}^{\mathrm{LF}}_{\infty}; \underline{z}\right) = \frac{\pi\left(1, \bar{N}^{\mathrm{LF}}_{\infty}; \underline{z}\right) + \lambda \times J\left(0, \bar{N}^{\mathrm{LF}}_{\infty} + 1; \bar{z}\right)}{r+\lambda} < 0,$
  3. Small firms **enter** before $\iff J\left(1, \bar{N}^{\mathrm{LF}}_{\infty} - 1; \underline{z}\right) = \frac{\pi\left(1, \bar{N}^{\mathrm{LF}}_{\infty} - 1; \underline{z}\right) + \lambda \times J\left(0, \bar{N}^{\mathrm{LF}}_{\infty}; \bar{z}\right)}{r+\lambda} \geq 0.$

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Lemma 1. The equilibrium number of large firms $\bar{N}_{\infty}^{\mathrm{LF}}$ in a concentrated industry state $(0, \bar{N}_{\infty}^{\mathrm{LF}})$ is uniquely determined by (1)-(3).

Intuition: profit functions decreasing in $\bar{N}$, and hence so is value function $J(1, \bar{N}; \underline{z})$

Let $\underline{N}^{\mathrm{LF}}(\bar{N})$ be the max # of small firms that industry with $\bar{N}$ large firms can sustain

$$J\left(\underline{N}^{\mathrm{LF}}(\bar{N}),\bar{N};\underline{z}\right)\leq 0<J\left(\underline{N}^{\mathrm{LF}}(\bar{N})-1,\bar{N};\underline{z}\right) \tag{1}$$

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1. If industry has **too few** firms $\underline{N} < \underline{N}^{\text{LF}}(\bar{N})$, then $\underline{N}^{\text{LF}}(\bar{N}) - \underline{N}$ firms **enter** immediately

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   - Remaining $\underline{N}^{\mathrm{LF}}(\bar{N})$ **exit** at rate $\eta^{\mathrm{LF}}(\bar{N})$. Exit rate such that firms are **indifferent**:

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Lemma 2. Equilibrium $\underline{N}^{LF}(\bar{N})$ and $\eta^{LF}(\bar{N})$ are uniquely pinned down by (1)-(2).

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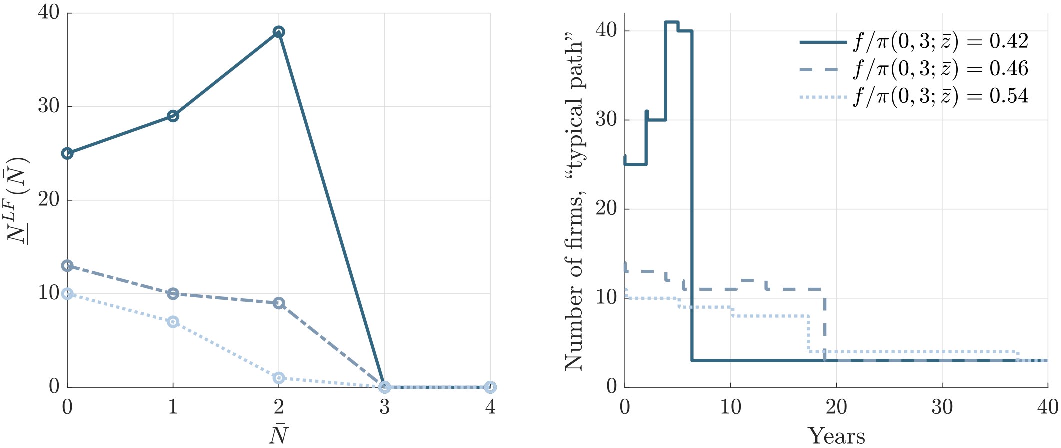
Entry, Shakeout, and Concentration: A Numerical Illustration



- In a competitive industry, the life-cycle is monotonic. **Why the non-monotonicity?**
  - Cost of delaying entry: more large firms present; e.g., $\pi(\underline{N}, 1; \underline{z}) - \pi(\underline{N}, 0; \underline{z}) < 0$
  - Benefit: Large gains right before the shakeout; e.g., $\pi(0, 3; \bar{z}) - \pi(\underline{N}, 3; \bar{z}) > 0$ ▸ Intuition

Equilibrium industry life-cycle: Scale differences

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- Particularly important in **AI/digital** industries (Goldfarb-Tucker)

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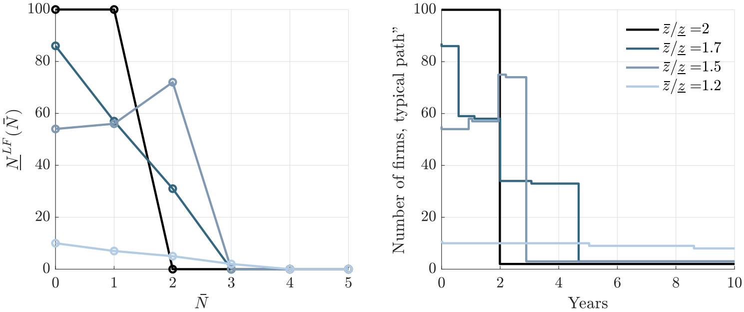

Optimal policy

- **Primal approach**: choose # of firms that enter/exit. Second best policy. ▸ SB v. LF
  - First best: production subsidies to large firms to correct markup distortions
  - Infeasible/unrealistic. No widespread use. Information? Politics?

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  - Mimic observe/proposed policies to promote competition over an industry's life-cycle
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- Goal: characterize the **timing** of optimal policy over the life-cycle
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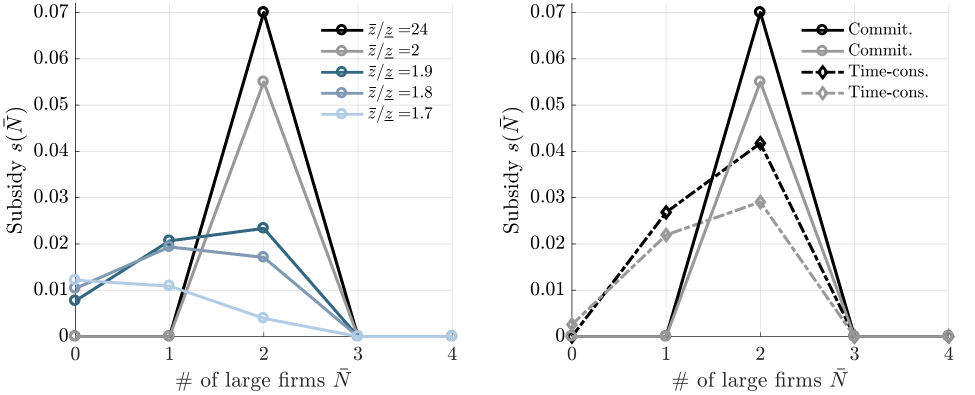
2. $\bar{z}/\underline{z} = 1$. Small scale differences, competition in the market
   - The government finds it optimal to intervene at all times.
   - Uniform **ex-ante** and **ex-post** interventions are needed.

Scale and optimal policy



- Firm entry/exit mostly driven by **option value** of taking over the market
  $\Longrightarrow$ Governments can wait to intervene later in the life-cycle
- If the government cannot commit, the **time-consistent** policy must subsidize **earlier**

1. Collusion and antitrust

$$\pi\left(\underline{N}, \bar{N}; \bar{z}\right) = \frac{1}{\bar{N}} \pi^{\text{Cartel}}\left(\underline{N}, \bar{N}; \bar{z}\right)$$

2. Endogenous Rate of Innovation λ at cost $c(\lambda)$

$$J\left(\underline{N}^{LF}\left(\bar{N}+1\right), \bar{N}+1; \bar{z}\right) - J\left(\underline{N}, \bar{N}; \underline{z}\right) = c'\left(\lambda\left(\underline{N}, \bar{N}\right)\right)$$

3. Innovation spillovers from large firms $\lambda(\bar{N})$

Application: Digital & AI Industries in the US

The **question** of how to regulate an industry **in practice** can be understood as:

Are firm choices mostly driven by competition for the market?
Or, is competition in the market important too?

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Analyze **Digital and AI industries** in the US using dataset from Venture Scanner

- 17 categories of technologies/services: "AI," "Financial," "Real Estate," "Security," etc.
- Subcategories: "Deep and Machine Learning," "Consumer Payments," "Short Term Rentals and Vacation Search," "Threat Detection and Compliance," etc.
- **Define** a product industry as a Subcategory. Total of 155 industries.

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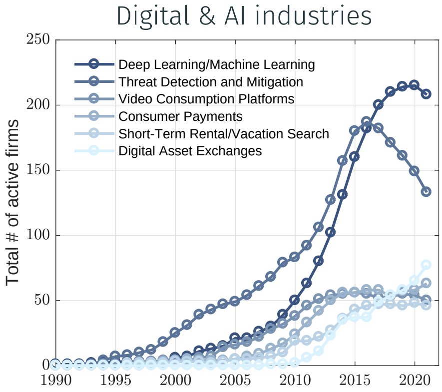
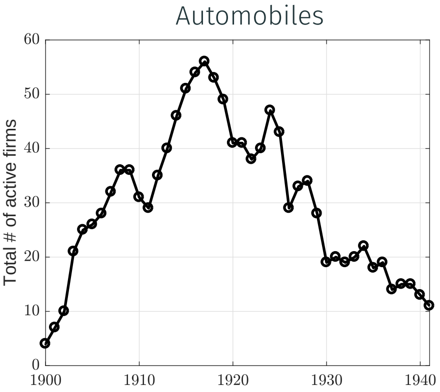
Analyze **Digital and AI industries** in the US using dataset from <u>Venture Scanner</u>

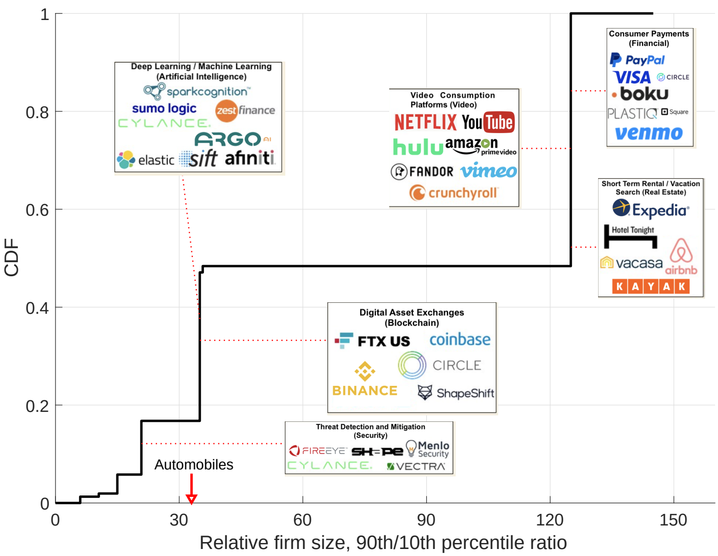
- 17 categories of technologies/services: "AI," "Financial," "Real Estate," "Security," etc.
- Subcategories: "Deep and Machine Learning," "Consumer Payments," "Short Term Rentals and Vacation Search," "Threat Detection and Compliance," etc.
- **Define** a product industry as a Subcategory. Total of 155 industries.

As a comparison, look at **Automobile** industry using <u>*The 100 Year Almanac*</u>


Digital & AI industries
Total # of active firms
Deep Learning/Machine Learning
Threat Detection and Mitigation
Video Consumption Platforms
Consumer Payments
Short-Term Rental/Vacation Search
Digital Asset Exchanges
0
50
100
150
200
250
1990
1995
2000
2005
2010
2015
2020


Automobiles
Total # of active firms
0
10
20
30
40
50
60
1900
1910
1920
1930
1940

Relative scale across industries



Intuition for non-monotonic life-cycle

- In a **competitive** industry (Jovanovic-MacDonald), the life-cycle is **always monotonic**

  No firms exit when quantities are low (price is high). A mass of firms exit once they are high (price is low)

- In an **oligopolistic** industry (our model), the life-cycle may be **non-monotonic**
- Incentives to **delay entry**, from $\bar{N} = 1 \to 2$, given $\underline{N}$:

$$J(\underline{N}, 2; \underline{z}) - J(\underline{N}, 1; \underline{z}) = \overbrace{\pi(\underline{N}, 2; \underline{z}) - \pi(\underline{N}, 1; \underline{z}) + \frac{\lambda}{r + \delta + \lambda \underline{N}} \left[\pi(\underline{N}, 3; \bar{z}) - \pi(\underline{N}, 2; \bar{z})\right]}^{\text{cost of competing with an additional large firm } < 0}$$

$$+ \underbrace{\frac{\lambda}{r + \delta + \lambda \underline{N}} \left[\pi(0, 3; \bar{z}) - \pi(\underline{N}, 3; \bar{z})\right]}_{\text{benefits of entering closer to the shakeout} > 0}.$$

- "Business stealing" gains at shakeout occur closer to the time of entry

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Sources of Inefficiency

Constrained Planner's value of an additional firm (SB) v. **Equilibrium** value of staying (LF)

$$\text{SB:}\quad U\left(\underline{N},\overline{N}\right)-U\left(\underline{N}-1,\overline{N}\right)\qquad+\lambda\left(V\left(\underline{N}\left(\overline{N}+1\right),\overline{N}+1\right)-V\left(\underline{N},\overline{N}\right)\right)$$

$$\text{LF:}\quad \pi\left(\underline{N},\overline{N};\underline{z}\right)\qquad+\lambda J\left(\underline{N}\left(\overline{N}+1\right),\overline{N}+1;\bar{z}\right)+\eta\left(\overline{N}\right)\left(\underline{N}-1\right)J\left(\underline{N}-1,\bar{N};\underline{z}\right)$$

1. Source of inefficiency I: Firms care about profits, not surplus $\Rightarrow\uparrow$ # firms
2. Source of inefficiency II: Firms do not internalize surplus destruction $\Rightarrow\downarrow$ # firms
3. Source of inefficiency III: War of attrition $\Rightarrow\downarrow$ # firms

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