A Model of Product Awareness and Industry Life Cycles

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Motivation I: Slow Growth and Demand

> *"[A]t the same price, a new plant will sell only 41% of the output of a plant in the same industry that is more than 15 years old... even medium plants that were 10 to 14 years old would sell only 68% as much"*
>
> *"We show that even in commodity-like product markets, these patterns do not reflect productivity gaps, but rather show differences in demand-side fundamentals."*

(Foster, Haltiwanger, and Syverson, 2016, *The Slow Growth of New Plants: Learning about Demand?*)

$\Longrightarrow$ model firm/plant/product growth through demand factors

$\Longrightarrow$ is demand growth (econometrically) isomorphic to productivity and/or quality shocks?

Motivation II: Limited Information (i.e. Awareness)

> *"[A]ssuming full information may lead to incorrect conclusions regarding the intensity of competition. Indeed, I found high estimated median markups in the PC industry in 1998, about 19%, whereas traditional full information models suggest the industry was more competitive, with estimated markups of only 5%. "*

(Goeree, 2008, *Limited Information and Advertising in the U.S. Personal Computer Industry*)

$\Longrightarrow$ market power a function of information sets

$\Longrightarrow$ demand accumulation and limited information sets connected

Motivation III: The Product Age Distribution

> *"In a typical year, 40 percent of household expenditures are on goods that were created in the last 4 years, and 20 percent of expenditures are in goods that disappear in the next 4 years."*

(Broda and Weinstein, 2010, *Product Creation and Destruction: Evidence and Price Implications*)

$\Longrightarrow$ high product entry and obsolescence rates (not necessary firms!)

$\Longrightarrow$ age distribution of products in consumption bundles is skewed

$\Longrightarrow$ distribution of limited information related to product age distribution

Broad Question

Given a model of demand as a network of information sets:

What are the implications of frictions in the expansion of consumer choice sets on the industry lifecycle and aggregate profits?

Awareness (i.e. limited choice/consideration/info sets) includes:

- Existence of the firm and product, known location to purchase the product, general quality and features of the product, match to idiosyncratic taste, etc. ▸ Empirical Evidence from Micro-Studies
- Simplification: constrain consumer to an idiosyncratic choice set
- Emphasis on implications of dynamic choice sets, not endogeneity

Secondary goal: Ensure aggregation for trade/macro/etc. applications

Some Literature

- Customer Capital and Intangible Assets in International/Macro:
  - Primarily: Arkolakis (2010, 2016), Drozd and Nosal (2012), and Gourio and Rudanko (2014a,b)
  - Also: Luttmer (2006), Ravn, Schmitt-Grohe, and Uribe (2006) and Hall (2008)

- Informative Advertising, IO, and Pricing with Market Power:
  - Klemperer (1995), Bergemann and Välimäki (2006), Bagwell (2007), Goeree (2008), Dinlersoz and Yorukoglu (2012) and many others
  - Search and price dispersion: Burdett and Judd (1983), Dinerstein, Einav, Levin, and Sundaresan (2014) and many others
  - Special case: Gabaix, Laibson, Li, Li, Resnick, and de Vries (2016)

(Note: I will not require any direct "stickiness", "habits", or "switching costs", will not concentrate on dynamic pricing strategies or price dispersion, and will not emphasize endogeneity of "advertising" intensity).

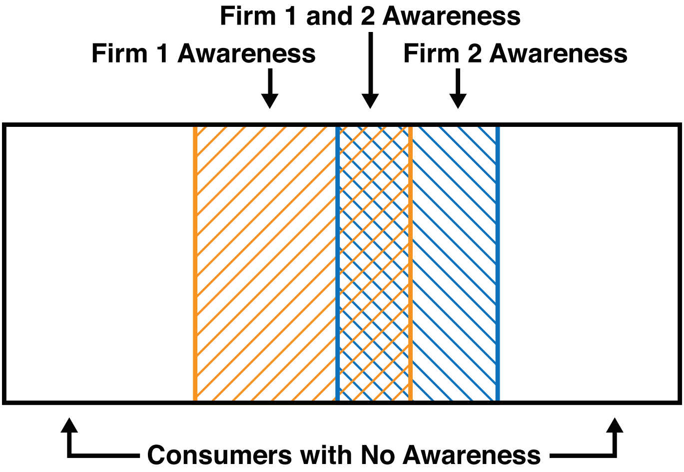
Agenda

1. Intuition for "awareness" (i.e., partial choice/consideration/info sets)
2. Model of lifecycle of a symmetric industry
3. Examples with symmetric and asymmetric industries
4. Aggregation to a neoclassical growth model (with a wedge)
5. Endogenous awareness evolution
6. Testing predictions with panel (time permitting) ▸ Industry Panel Tests

Style: Add seemingly innocuous information friction, then follow through to aggregate implications. Stylized, see paper for full asymmetric version

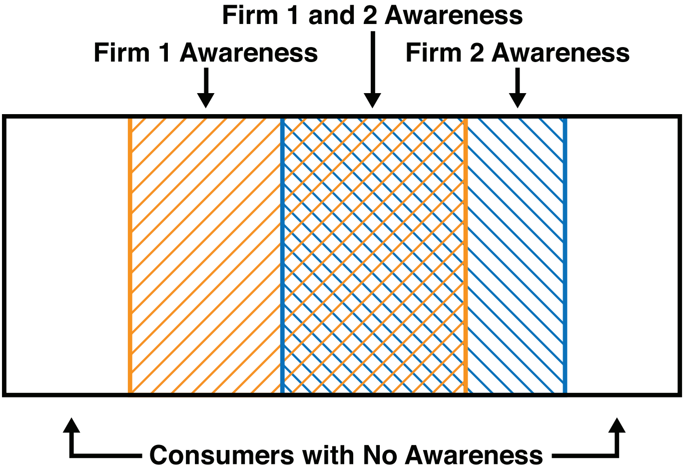
Intuition

Example Venn Diagram for Two Firms



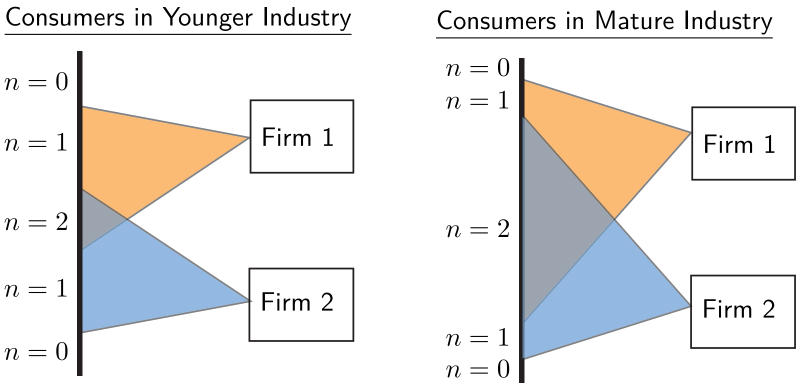
The big box is all consumers in the economy (for a given industry)

Awareness Example as Industry Matures



Includes “mechanical” growth of demand, but also a change in the overlap!

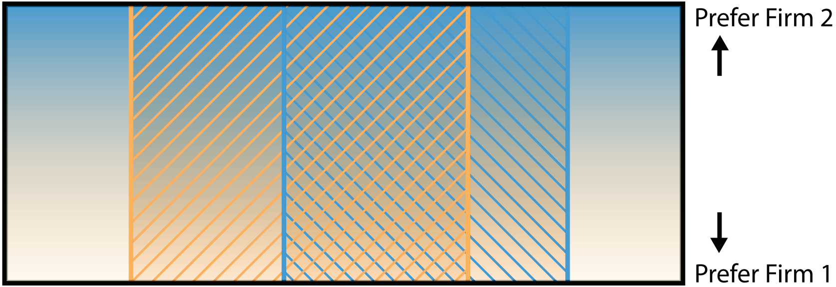
Awareness Sets as an Expanding Network (Bipartite Graph)



where n is the number of firms in the consumer's choice set

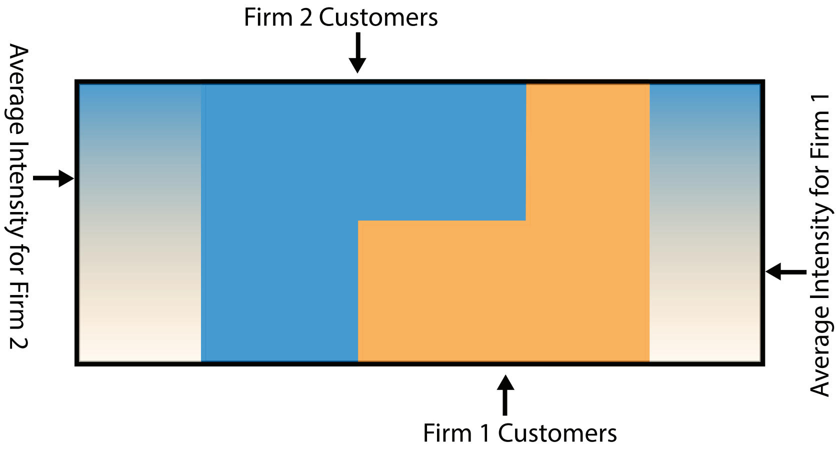
Intensity of Preferences and Sorting

What if there is an intrinsic match quality of consumer to firm?



Customer Sorting Changes Average Match Quality

If consumer only purchased from a single firm, the average match intensity depends on overlap of information sets



Preview of Key Insights from the Mechanism

1. Network $\implies$ **effective** $\neq$ **total** number of competitors
2. Expanding information sets lead to countervailing effects on profits: (1) **sorting**; and (2) **intensification of competition**
3. Sorting looks like habits or stickiness, but neither is required
4. The aggregate age distribution of products (**not firms!**) determines connectedness of the network, and hence average market power
5. Rapid **product obsolescence** or entry skews the age distribution, and hence **aggregate market power**

Stochastic Awareness

- Assume some process for how the idiosyncratic awareness sets evolve
- Assume that the evolution of the awareness sets is independent of prices, production, or demand choices—maintained throughout paper
- Derive the equilibria given generic distributions of awareness sets

Later we will,

1. Describe simple example of exogenous awareness set evolution
2. Simple example of endogenous awareness set evolution

Model

Model Summary

Nest neoclassical growth with monopolistic competition, minimal changes:

- **Consumers**: Continuum, $j \in [0, 1]$
- **Product Categories**: Continuum, $m \in [0, M(t)]$
  - $M(t)$ mass of product categories (i.e. industries) in economy
  - Products within a category are highly substitutable
- **Firms**: Finite, indexed by $i = 1, \dots N$
  - (i, m) uniquely denotes a firm. 1 product/firm
  - The set of firms producing in category m is: $\mathcal{I}_m = \{1, \dots N\}$
  - If $N = 1$ fully nests monopolistic competition
- **Time**: Continuous, t
  - Age of industry: $a \geq 0$ with $a = 0$ as birth of industry
  - For exposition: N firms enter at $a = 0$, no entry/exit thereafter.

Consumer and Product Heterogeneity

- **Idiosyncratic preferences**: $\xi_{imj} \in \mathbb{R}$
- **Idiosyncratic awareness**: $A_{mj}(t) \subseteq \mathcal{I}_m$
  - Details of $A_{mj}(t)$ evolution do not matter (yet)
- **Idiosyncratic quality/productivity**: removed for exposition

Standard CES Aggregation

- Constant elasticity of substitution (CES) **between** product categories
- Elasticity of substitution: $\kappa > 1$
- Period utility over categories is a standard CES aggregator

$$\left(\int_0^{M(t)} \bar{c}_{mj}(t)^{\frac{\kappa-1}{\kappa}} \mathrm{d}m \right)^{\frac{\kappa}{\kappa-1}}$$

- $\bar{c}_{mj}(t)$ is the quality adjusted sum of products consumed in m by j

Quality Adjusted Consumption Within a Category

Given intensive demand $c_{imj}(t)$ and awareness $A_{mj}(t)$:

$$\bar{c}_{mj}(t) \equiv \sum_{i \in A_{mj}(t)} e^{\sigma \xi_{imj}} c_{imj}(t)$$

Differences from nested CES and discrete-choice preferences:

- Perfect quality-adjusted substitution **within** a product category
- Consumers can only purchase from choice set $A_{mj}(t)$
- ξ_{imj} idiosyncratic quality for each consumer, normalized variance
- σ scales the variance of idiosyncratic tastes
  - Note: will **not** have the usual discrete choice aggregation to nested CES (with elasticity a function of σ) a function of **market shares**
  - Time-varying choice sets create time varying elasticity after aggregation

Consumer's Problem

CRRA $= \gamma$, discount rate $= \rho$. Given prices and income, maximize

$$\int_0^\infty e^{-\rho t} \frac{1}{1-\gamma} \left[\overbrace{\left(\int_0^{M(t)} \left(\sum_{i \in A_{mj}(t)} e^{\sigma \xi_{imj}} c_{imj}(t) \right)^{\frac{\kappa-1}{\kappa}} \mathrm{d}m \right)^{\frac{\kappa}{\kappa-1}}}^{\equiv C_j(t), \text{ a ``Composite Good''}} \right]^{1-\gamma} \mathrm{d}t$$

$$\text{s.t.} \int_0^{M(t)} \left[\sum_{i \in A_{mj}(t)} \hat{p}_{im}(t) c_{imj}(t) \right] \mathrm{d}m + \text{Investment} \leq P(t)\Omega(t)$$

- **Nominal prices**: $\hat{p}_{im}(t)$, and real prices $p_{im}(t) \equiv \hat{p}_{im}(t)/P(t)$
- **Nominal income** identical for each consumer: $P(t)\Omega(t)$
- **Price index**: $P(t)$—will be calculated from consumption bundle
- **Investment**: standard capital, $k(t)$, and innovation, $M(t)$, choices

Information Structure Summary

- Consumers: **incomplete** awareness: $A_{mj}(t)$
  - The only idiosyncratic state changing over time in the simple setup
- Firms: **complete** information of distribution over $A_{mj}(t)$ and ξ_{imj}
  - Incomplete information on ξ_{imj} and $A_{mj}(t)$ for any particular j
  - i.e., no price discrimination (but wouldn't matter for mechanism)
- Firms: **complete** information of other firms actions, etc.
- Prices $\hat{p}_{im}(t)$ from simple period-by-period Bertrand competition
  - With $\sigma > 0$, downward sloping demand functions and (usually) pure-strategy equilibria. Easiest to solve
  - Even if $\sigma = 0$, would not have the usual Bertrand pricing at marginal cost (as long as there are any consumers only aware of 1 firm)

Intensive Demand

Proposition (Intensive Demand)

Fix time t for exposition. Given real prices p and real income Ω,

1. *Consumer purchases product i and no others in m iff*

$$\log\left(p_{i'm}\right) - \log\left(p_{im}\right) > \sigma\left(\xi_{i'mj} - \xi_{imj}\right), \quad \forall\, i' \in A_{mj} \setminus \{i\}$$

2. *The intensive demand for product (i, m) is*

$$y_{imj}(p, \xi_{imj}) = e^{\sigma(\kappa-1)\xi_{imj}} p_{im}^{-\kappa}\Omega$$

3. *Using nominal prices of chosen products, $\hat{p}_{im}$, the price index is*

$$P_j \equiv \left(\int_{|A_{mj}|>0} e^{\sigma(\kappa-1)\xi_{imj}} \hat{p}_{im}^{1-\kappa} \mathrm{d}m\right)^{\frac{1}{1-\kappa}}$$

Total Demand and Prices

Definition (Total Demand Faced by a Firm)

Given all price in industry, p, integrate over ξ_{imj} and A_{mj},

$$y_{im}(p) \equiv \int_{[0,1]} y_{imj}(p, \xi_{imj}) \mathbb{1} \left\{ \text{Choose } i \text{ from } A_{mj} \text{ given } p \text{ and } \xi_{mj} \right\} \mathrm{d}j$$

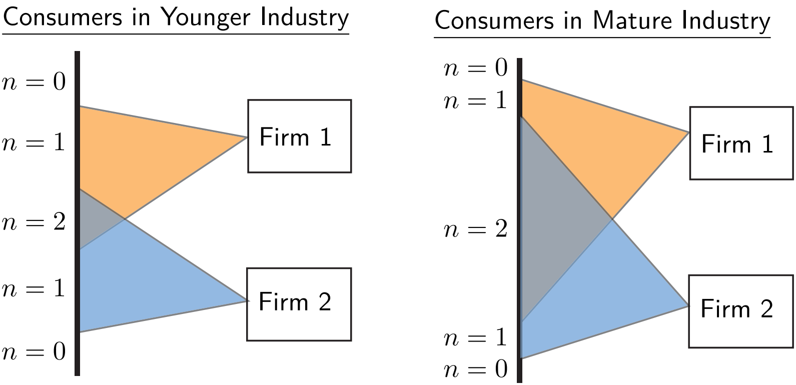
Assume all firms have a CRS production at marginal cost mc,

Definition (Bertrand Nash Equilibrium (BNE))

Consider pure-strategy equilibria, $p_m \in \mathbb{R}^N$ such that

$$p_{im} = \arg\max_{\tilde{p} \geq 0} \left\{ (\tilde{p} - mc) y_{im}(\{\tilde{p}, p_{i'm}\}_{i' \neq i}) \right\}, \; \forall i \in \mathcal{I}_m$$

Reminder: Awareness Sets as an Expanding Network



where n is the number of firms in the consumer's choice set.

- With a continuum of consumers, is the time-varying n distribution sufficient for computations?

Awareness Set Sizes are Sufficient for Industry Aggregates

For exposition, assume the following about awareness evolution:

- Independent evolution for all industries, continuum of consumers
- Independent of price/demand choices
- Independent of $\xi_{imj} \sim$ Gumbel, iid
- All N firms enter at the same time, t, where age $a = 0$.

Then, instead $A_{mj}(t)$, sufficient to track set size as a function of age a:

- Proportion aware of n firms in industry of age a: $f_n(a) \in \mathbb{R}^{N+1}$
- $f_0(a)$ is mass without any awareness, $\sum_{n=0}^{N} f_n(a) = 1$.
- Define R.V. $\hat{n} \equiv n \,|\, n > 0$, then for $g(n) : \mathbb{N}_+ \to \mathbb{R}$,

$$\mathbb{E}_a\left[g(\hat{n})\right] \equiv \sum_{n=1}^{N} \frac{f_n(a)}{1 - f_0(a)} g(n)$$

Symmetric Industry Equilibrium

Proposition

If a symmetric pure-strategy equilibrium exists for N firms, then

$$Y(a) \equiv Ny(a) = \underbrace{(1 - f_0(a))}_{\text{Limited Penetration}} \underbrace{q(a)}_{\text{Quality Growth}} \underbrace{p(a)^{-\kappa}\Omega}_{\text{Standard CES}}$$

$$p(a) \equiv \Upsilon(a) mc$$

With age-dependent average quality of matches and markup,

$$q(a) \equiv \mathbb{E}_a\left[\hat{n}^{\sigma(\kappa-1)}\right]$$

$$\Upsilon(a) \equiv 1 + \sigma\left[1 - (1 - \sigma(\kappa - 1))\frac{\mathbb{E}_a\left[\hat{n}^{\sigma(\kappa-1)-1}\right]}{\mathbb{E}_a\left[\hat{n}^{\sigma(\kappa-1)}\right]}\right]^{-1}$$

Key Properties

- $f_0(a)$ and moments of $\hat{n}$ (i.e. $\mathbb{E}_a[g(\hat{n})]$), summarize information sets
- Real income and marginal cost, Ω and mc, summarize all aggregates
  - Just as in models with monopolistic competition/CES
- N does not enter industry output or prices directly
  - Only matters by affecting $\hat{n}$ moments/asymptotics
  - Key: Effective vs. actual # of competitors
- Sorting generates quality growth, $q(a) \equiv \mathbb{E}_a\left[\hat{n}^{\sigma(\kappa-1)}\right]$
  - Magnitude of quality growth depends on differentiation, σ
- Monopolistic competition and perfect competition:
  - $N = 1$ nests monopolistic competition: $q(a) = 1$ and $p(a) = \frac{\kappa}{\kappa-1}mc$
  - $\hat{n}$ large: $p(a) = (1+\sigma)mc$, i.e. perfect competition for small σ

Industry Evolution Example

Awareness Evolution and Markov Chains

Specify $f(a) \in \mathbb{R}^{N+1}$ process directly—see paper for mapping $A_{mj} \to f$

- Discrete # states, use continuous-time Markov chain
- Then for **any intensity matrix** $\mathbb{Q}$ and $f(0) = \begin{bmatrix} 1 & 0 & \dots \end{bmatrix}$

$$\boldsymbol{\partial}_a f(a) = f(a) \cdot \mathbb{Q}(a), \quad \text{given initial condition } f(0)$$

- With solution,

$$f(a) = \begin{bmatrix} 1 & 0 & \dots & 0 \end{bmatrix} \cdot e^{a\mathbb{Q}}, \text{ for an age invariant } \mathbb{Q}$$

- From any $\mathbb{Q}$ (endogenous or exogenous)
  - Solve for $f(a)$ solution, find $f_0(a)$ and moments $\mathbb{E}_a\left[g(\hat{n})\right]$
- General theory: Poisson counting processes and queuing theory

Example: Baseline Awareness Process

- Intensity $\theta > 0$ of becoming aware per product category
  - Independent for each product category
  - Equal probability of becoming aware of any operating firm
  - Repeated meeting does not add to the count
- Forget an existing firm at rate $\mu \geq 0$ for completeness
- Rate, $\theta_d \geq 0$, of word-of-mouth diffusion
  - i.e. Mahajan, Muller, and Bass (1990)) for S-curve diffusion curves
  - Simple: diffusion from product category penetration, not specific firm

Generator for Baseline Awareness Process

In queuing theory, this is called an "M/M/1/K with customer balking":

$$\mathbb{Q} = \begin{bmatrix} -(\theta+\theta_d(1-f_0(a))) & \theta+\theta_d(1-f_0(a)) & 0 & \dots & & \dots & 0 \\ \mu & -\mu-\frac{N-1}{N}\theta & \frac{N-1}{N}\theta & 0 & \dots & \dots & 0 \\ \vdots & & & & & & \vdots \\ 0 & 0 & 0 & 0 & \dots\ \mu & -\mu-\frac{1}{N}\theta & \frac{1}{N}\theta \\ 0 & 0 & 0 & 0 & \dots\ 0 & \mu & -\mu \end{bmatrix}$$

Note, if $\mu = 0$, the S-shaped solution to "market penetration" is,

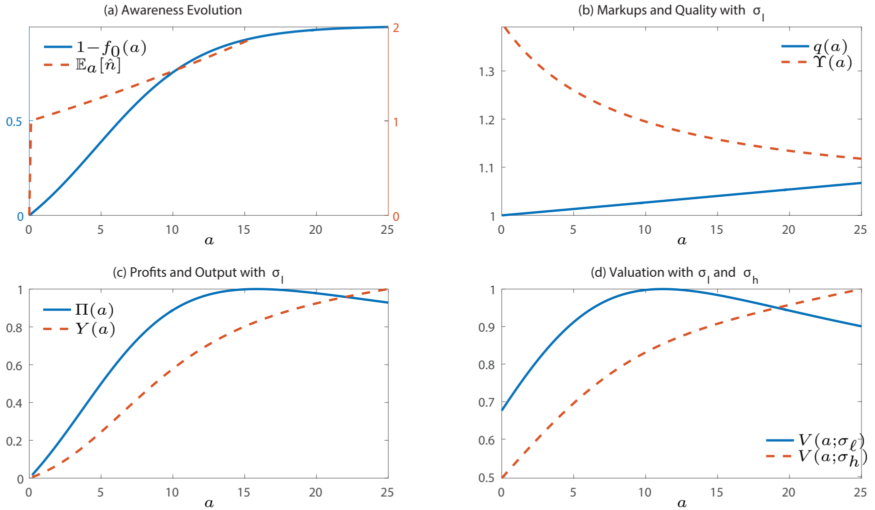
$$f_0(a) = \frac{\theta_d + \theta}{\theta_d + \theta \exp\left((\theta_d + \theta)a\right)}$$

Calibrate θ, θ_d, σ, and κ (crudely) based on industry panel data

- N **is nearly irrelevant** since θ is small. Good news for macro/trade!

Example Industry and Awareness Evolution (with $\sigma_\ell < \sigma_h$)

Profits: $\Pi(a) \equiv (p(a) - mc)Y(a)$; **Value**: $V(a) \equiv$ PDV of $\Pi(a)$



Asymmetric Entry Example

Asymmetric Entry

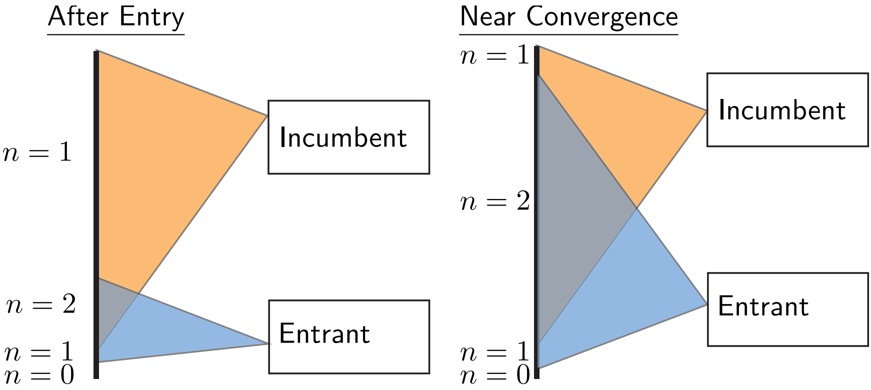
From Foster, Haltiwanger, and Syverson (2016) entrants often:

- Take over 15 years to reach 73% of an incumbent's size;
- Have small TFP advantage of entrants, disappears after five years
- Have significantly lower prices, but prices converge
- i.e. entrants small **in spite of** prices and productivity

Contradiction with this model?

- Model: if $\hat{n}$ is sub-martingale, then prices & markups decrease with a
- Doesn't imply that "younger" firms have higher prices? **No!**
- Facts are consistent with this model even with identical intrinsic productivity/quality, but different entry timing

Example: Awareness Network with Asymmetric Entry



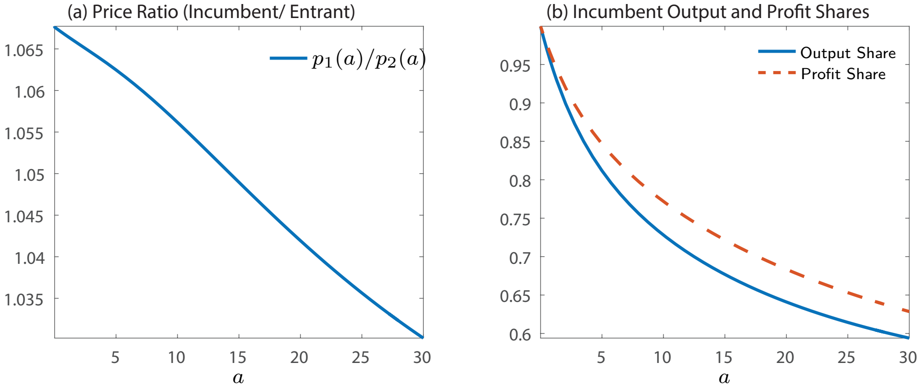
Asymmetric entry leads to **asymmetric market power** and sorting

Example: Entry into a Monopoly

- Use previous values of κ, σ, etc.
- Assume 80% of consumers aware of a monopolist
- Add entrant with same intrinsic productivity quality
- Simulate evolution
- (See paper for formal modeling with asymmetric firms)

Key: entry timing (even with the same product) affects market power

Numerical Example with Entry (with Symmetric Quality)



Also: average match quality for entrant > incumbent. Interpret as higher quality or revenue-TFP?

Aggregation to Neoclassical Growth (+ wedge)

Nesting Neoclassical Growth: Production

Keeping as standard as possible to compare against baseline

- Competitive markets for capital, K, and inelastic labor L
  - Equilibrium real rental rate of capital and wages, r and w
- Identical Cobb-Douglas, technology for all firms

$$y = zK^{\alpha}L^{1-\alpha}$$

- With output elasticity of capital $\alpha \in (0, 1)$, TFP z
  - Note: α will **not** be the factor share due to market power distortions
- Standard: derive capital-labor ratio, k and real marginal cost

$$mc \equiv \frac{1}{1-\alpha} z^{-1} k^{-\alpha} w$$

Investment and Dynamics

- Standard capital investment: $k(t)$, with depreciation rate δ_K
- Consumers can investment to create new product categories, $M(t)$
  - After invention of product category, industry of age $a = 0$ with N firms
  - Productivity of this R&D process is $z_M(t)$ vs. $z(t)$ for physical goods.
- For simplicity: **obsolescence shock** kills categories at rate δ_M
  - Ensures stationary age distribution of products exists
  - Alternatively, $\delta_M = 0$ with (semi-)endogenous growth
- If $N = 1$, perfectly nests neoclassical growth with monopolistic competition (and endogenous $\#$ varieties)
- Simplest: investment uses "composite" good
  - Denote endogenous investment rates i_K and i_M

Product Age Distribution

Key change from awareness: product age distribution matters if $N > 1$

- Let $\Phi(t, a)$ be CDF of product categories of age a at time t
- Creation rate, i_M, and "depreciation" rate, δ_M, determine $\Phi(t, a)$
  - Evolution given optimal $M(t)$ from $i_M(t)$, fulfills (normalized)

$$\partial_t \Phi(t,a) = \underbrace{-\partial_a \Phi(t,a)}_{\text{Age Increase}} + (1 - \Phi(t,a)) \left(\underbrace{\frac{\partial_t M(t)}{M(t)}}_{\text{Invention}} + \underbrace{\delta_M}_{\text{Obsolesence}} \right)$$

  - Stationary distribution is exponential: $\Phi(a) = 1 - e^{-\delta_M a}$
- Denote moments of the **product age distribution**,

$$\mathbb{E}_t\left[g(a)\right] \equiv \int_0^\infty \left(g(a)\partial_a \Phi(t,a)\right) \mathrm{d}a$$

  - e.g. $\mathbb{E}_t\left[a\right]$ is the mean product category age in the economy at t

Aggregate Distortion Terms and TFP

- Can aggregate into a problem with the following state: ▸ Aggregation
  - $k(t)$ and $M(t)$ total capital and number of product categories
  - $\Phi(t, \cdot)$ distribution of product category ages
- Denote the following functions of $\Phi(t, \cdot)$ given any awareness process,
  - **Quality distortion**: $Q(t)$; **Factor share distortion**: $B(t)$
  - Recall Markup: $\Upsilon(a)$; Market Penetration: $1 - f_0(a)$ (given **any** $\mathbb{Q}$)

$$Q(t) \equiv \left[\mathbb{E}_t\left[(1 - f_0(a))\Upsilon(a)^{1-\kappa} q(a)\right]\right]^{\frac{1}{\kappa-1}}$$

$$B(t) \equiv \frac{\mathbb{E}_t\left[(1 - f_0(a))\Upsilon(a)^{-\kappa} q(a)\right]}{\mathbb{E}_t\left[(1 - f_0(a))\Upsilon(a)^{1-\kappa} q(a)\right]}$$

- Then define "measured" TFP using with $M(t), Q(t)$, and $B(t)$

$$\underbrace{Z(t)}_{\text{"Measured" TFP}} \equiv \underbrace{z(t)}_{\text{Physical TFP}} \underbrace{M(t)^{\frac{1}{\kappa-1}}}_{\text{Varieties}} \underbrace{Q(t)}_{\text{Quality Distortion}} \underbrace{B(t)^{-1}}_{\text{Factor Share Distortion}}$$

Aggregation: Composite Good and Representative Agent

Proposition (Representative Agent)

Given initial conditions $k(0), M(0)$, and $\Phi(0,a)$, can solve representative

$$\max_{i_k(t), i_M(t), C(t)} \left\{ \int_0^\infty e^{-\rho t} \frac{1}{1-\gamma} C(t)^{1-\gamma} \right\}$$

$$\text{s.t. } \partial_t k(t) = -\delta_K k(t) + i_k(t)$$

$$\partial_t M(t) = -\delta_M M(t) + z_M(t) i_M(t)$$

$$C(t) \equiv z(t) \underbrace{Q(t)B(t)^{-1}}_{\text{Awareness Wedge}} M(t)^{\frac{1}{\kappa-1}} k(t)^\alpha - i_k(t) - i_M(t)$$

where $\Phi(t,a)$ evolves according to LOM, which determines $Q(t)B(t)^{-1}$

Stationary Solution for any $\mathbb{Q}$ (normalizing $z = 1$)

Proposition (Stationary Equilibrium)

Normalize $z = 1$. *The stationary* k *and* M *solves the system,*

$$\delta_M - \delta_k = QB^{-1}k^{\alpha}M^{\frac{1}{\kappa-1}}\left(\frac{z_M}{\kappa - 1}M^{-1} - \alpha k^{-1}\right)$$

$$\rho + \delta_k = \alpha QB^{-1}M^{\frac{1}{\kappa-1}}k^{\alpha-1}$$

Given the k *and* M, *the equilibrium* C *is*

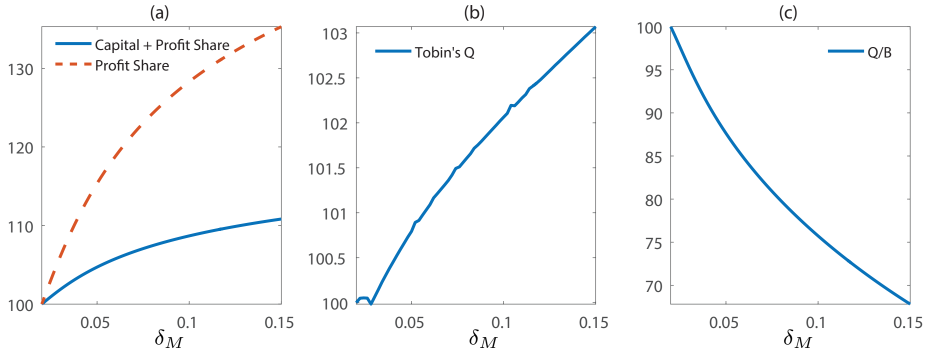
$$C = QB^{-1}M^{\frac{1}{\kappa-1}}k^{\alpha} - \delta_k k - \delta_M M/z_M$$

where $\Phi(a) = 1 - e^{-\delta_M a}$, *and* Q *and* B *are parameterized by any* $\mathbb{Q}$

Analysis of the Stationary Solution

- Given Q, B, isomorphic to model with human and physical capital
  - See Acemoglu (2009), Proposition 10.1
- The capital share, labor share, and profit share of output are $\alpha B, (1-\alpha)B$ and $(1-B)$, respectively.
  - Hence, $\mathbb{Q}$ properties determine **share distortions**
  - Variations in B deliver time varying factor shares due to awareness
- Output (and hence consumption) effected by:
  - **Quality distortion**: Q (i.e. distortions from incomplete sorting, $q(a)$, and slow penetration of product categories, $1-f_0(a)$)
  - **Factor share distortion**: B (i.e. suboptimal factor allocation due to markup dispersion)
- If $N=1$, then no B distortion, and Q only contains penetration
  - i.e. monopolistic competition given "productivity" process $1-f_0(a)$

Comparative Statics for Obsolescence Rate δ_M



Calibrated increase in obsolescence significantly changes factor shares

Data on Factor Shares and Obsolescence
Dynamics of Entry Shock

Endogenous Awareness Evolution

Endogenous Sales and Marketing Investment

- What if $\mathbb{Q}$ comes from decision of firms? Does it matter?
- Use current $\mathbb{Q}$ structure, but endogenize choice of θ arrival rate.
- Simplification: assume same parameters as $\mathbb{Q}$, and not age varying
  - Firm i builds "storefront" on entry, which delivers θ_i
  - Will look at symmetric equilibria where $\theta_i = \theta$
  - Assume N is large (i.e., no strategic considerations)
- Total cost (in composite goods) of choosing θ on firm entry
  - $\frac{\theta^\eta}{\eta\nu}$: with ν is S&M productivity and $\eta > 1$
- If all chose $\theta_i = \theta$, then nests existing $\mathbb{Q}_\theta$
  - Need to consider off-equilibrium θ_i to find FOCs

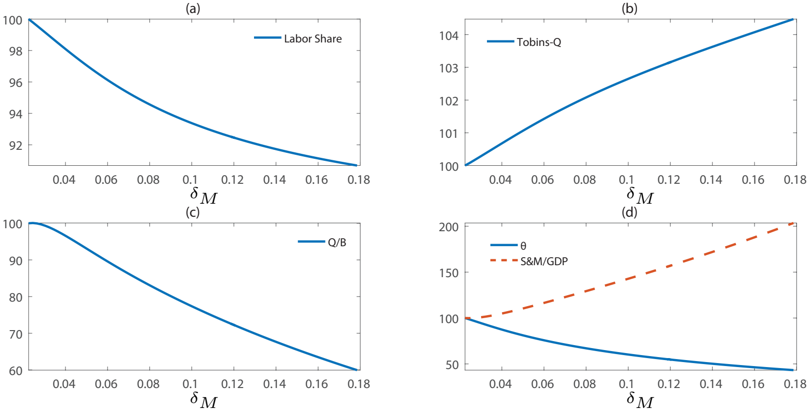
Optimal S&M Choice

- Off-equilibrium: Assume choose θ_i while others choose θ:
  - Assume likelihood of being in awareness sets gets distorted
  - Urn problem: probability to be in sets becomes Fisher's Non-central Hypergeometric instead of Hypergeometric. See paper
- Can show with large N that
  - Price choice is not distorted if $\theta \neq \theta_i$
  - Profits at any point are simply distorted by $\frac{\theta_i}{\theta}$
- Given $v(\theta)$ as the PDV of profits of firms choosing θ, optimal θ_i solves

$$\max_{\theta_i \geq 0} \left[\frac{\theta_i}{\theta} v(\theta) - \frac{\theta_i^\eta}{\eta \nu N} \right]$$

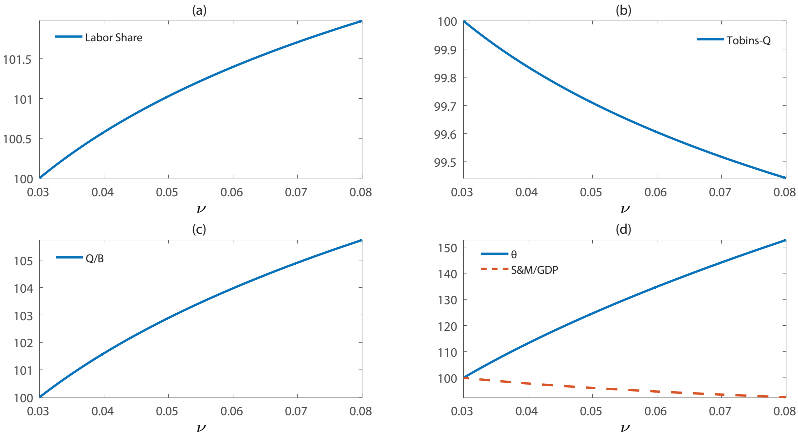
- Find FOCs and let $\theta = \theta_i$ (see paper for stationary system in k, M, θ)

Comparative Statics for Obsolescence δ_M (Endogenous θ)



Endogeneity doesn't unravel role of obsolescence. Note S&M/GDP growth

Increase in S&M productivity ν?



- Increase in ν (the Internet?) has small impact on factor shares
- Most changes are in expansion of M (product categories) and some benefit in sorting and faster market penetration (i.e. Q/B)

Conclusion

Conclusion and Key Insights

1. Network $\implies$ **effective** $\neq$ **total** number of competitors
2. Expanding information sets lead to countervailing effects on profits: (1) **sorting**; and (2) **intensification of competition**
3. Asymmetric entry leads to asymmetry market power
4. The aggregate age distribution of products (**not firms!**) determines connectedness of the network, and hence average market power
5. Rapid **product obsolescence** or entry skews the age distribution, and hence **aggregate market power**
6. Increasing efficiency in S&M expands # products, little changes in market power and corresponding factor share distortion, B

Appendix/Additional Results

Industry Panel

Industry Panel Data

Back to Question

- NBER-CES Manufacturing Industry Database (MID), the Census Concentration Ratios, and Compustat
- 189 six-digit NAICS manufacturing industries from 1961 to 2012 (or 502 manufacturing and non-manufacturing if concentration controls removed)
- Industry "birth": age at which industry reaches 5% of maximum employment level (and check robustness to measure)
- Rescale by industry lifecycle: bin based on age of industry relative to maximum employment (i.e. peak). Check vs. directly using year
- Check markup measures from Compustat (i.e. operating profit margin) and MID (price-cost margin)

Industry Panel Results (with Direct Industry Age)

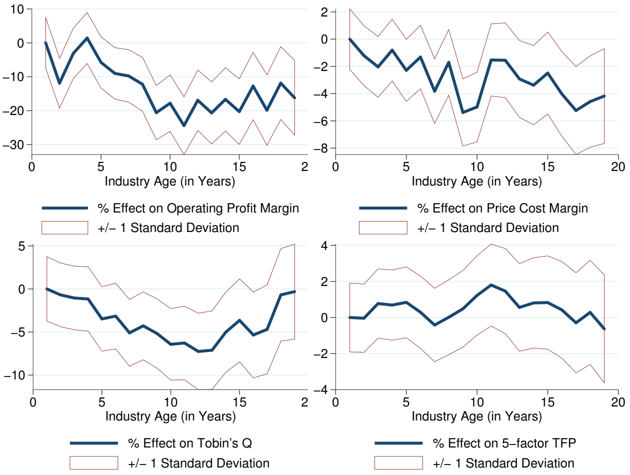


Figure: Effects of Age (Controls for # Firms & Concentration & Year Fixed Effects))

Industry Panel Results (with Normalized Lifecycles)

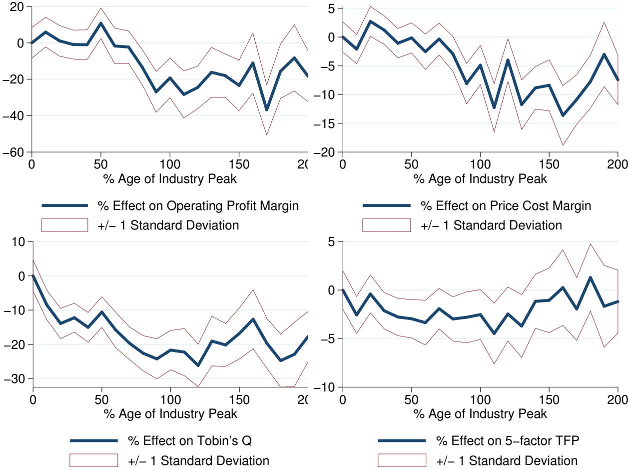


Figure: Effects of Age Relative to Peak Employment (Controls for # Firms & Concentration & Year Fixed Effects)

Histogram of Birth Year

Back

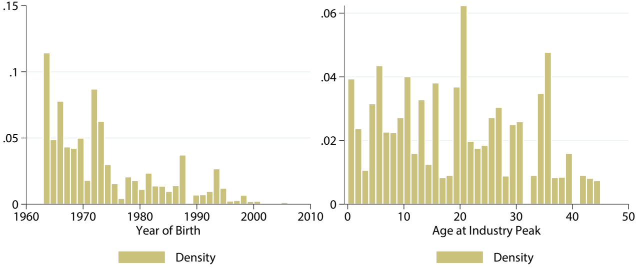


Figure: Histogram of Birth Year and Peak Employment Year

Employment and Revenue by Bin Relative to Peak

Back

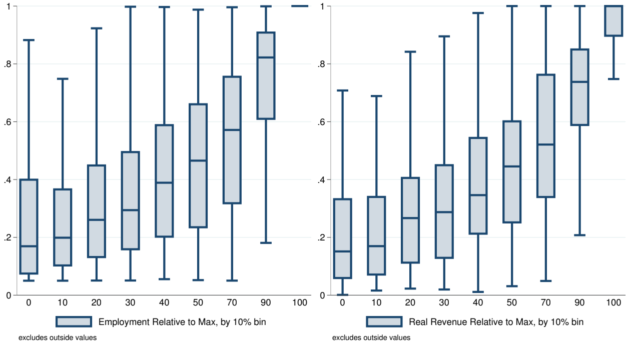


Figure: Employment and Real Revenue Relative to Peak Employment Year

Panel with No Controls for Concentration

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Figure: Effects of Age Relative to Peak Employment (Only Year Fixed Effects)

Evidence of Awareness

Limited Consumer Bookstore Awareness

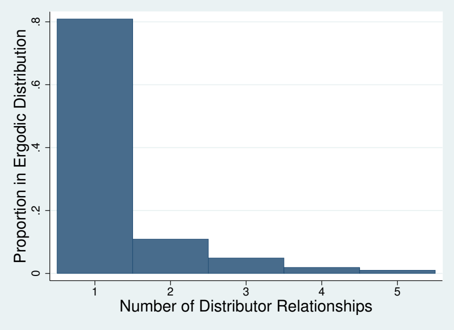
Back

- Browsing data: Online bookstores **visited** in ≈ 18 months
- "Consumer bookstore awareness": Lower bound on firm awareness

Testing Models of Consumer Search Using Data on Web Browsing and Purchasing Behavior (De Los Santos, Hortaçsu, and Wildenbeest (2012))

Limited Exporter/Distributor Awareness

- Exporters searching for distributors
- Number of relationships bounds awareness



A Search and Learning Model of Export Dynamics(Eaton, Eslava, Krizan, Kugler, and Tybout (2014))

Evidence: Advertising of an Experience Good

Back

Analysis of advertising and scanner data over **15 months** after introduction of Yoplait 150 yogurt

Households trying Yoplait 150	**13%**
Households trying other yogurts	68%
Commercial exposures/household	13.6
Advertising share of Yoplait 150	35%
Market Share of Yoplait 150	**5%**

Advertising, learning, and consumer choice in experience good markets:an empirical examination, Ackerberg (2003)

More on Aggregation

Aggregate Price Index

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Proposition (Time Varying Price Index, TFP, and Real Wages)

As functions of the aggregate state, $z(t), k(t)$, $\Phi(t,z)$, and $M(t)$,

$$P(t) \equiv \left(\underbrace{M(t)}_{\substack{\text{Variety}\\\text{Effect}}} \int_0^\infty \underbrace{q(a)\hat{p}(t,a)^{1-\kappa}}_{\text{Quality adjusted price}} \underbrace{(1-f_0(a))}_{\substack{\text{Proportion}\\\text{Aware}}} \underbrace{\mathrm{d}\Phi(t,a)}_{\substack{\text{Age}\\\text{Distribution}}} \right)^{\frac{1}{1-\kappa}}$$

$$mc(t) = M(t)^{\frac{1}{\kappa-1}} Q(t)$$

$$w(t) = (1-\alpha)Z(t)B(t)k(t)^\alpha$$

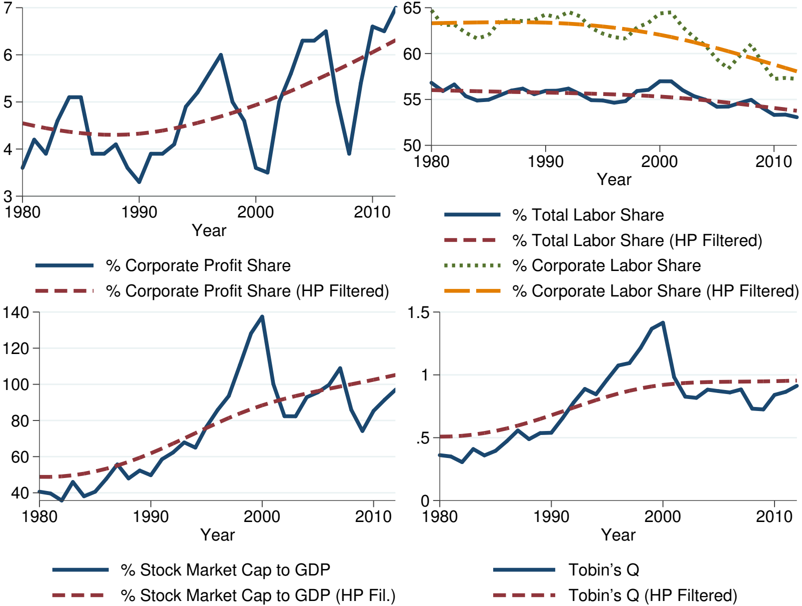
"Composite" good production aggregates to a function of TFP and is identical to the real income,

$$Y(t) = Z(t)k(t)^\alpha = \Omega(t)$$

Factor Shares and Obsolescence

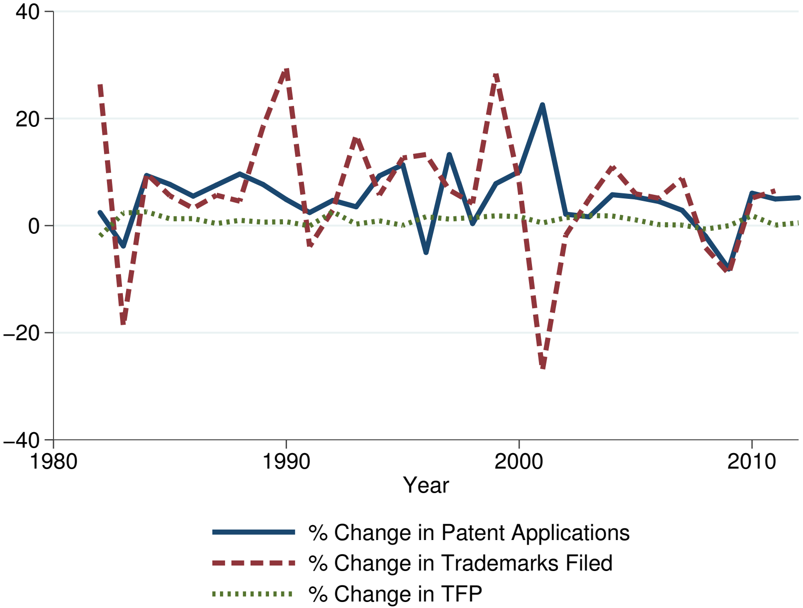
Profits and Factor Shares

Back



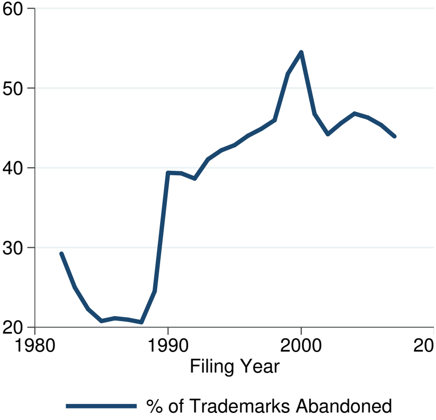
Intellectual Property and Growth Rates

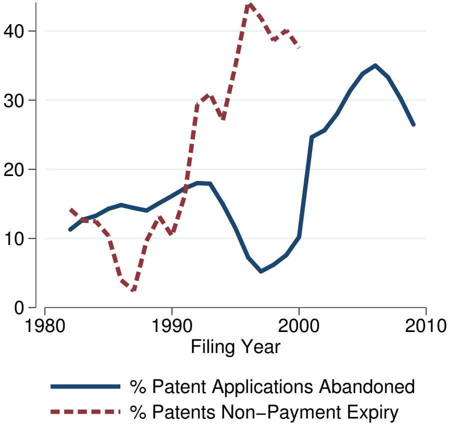
Back



Abandoned and Expired Trademarks and Patents

Back





Impulse Response of an Entry Shock on the Profit Share

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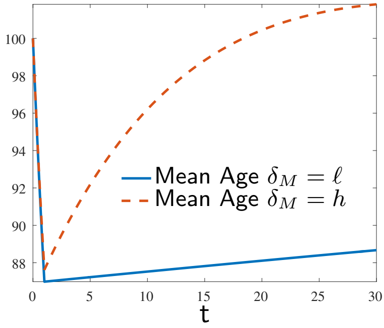

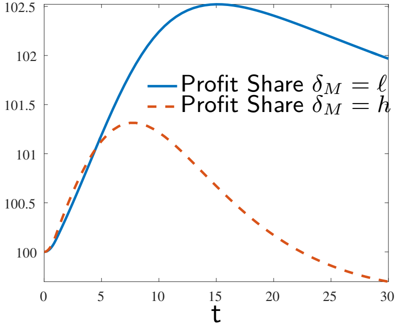

- **Shock:** ↑ product creation rate leads to a 10% in M over 1 year
- **Result:** Not much. Awareness smooths entry shocks (general point)

Calibration

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Variable	Value	Description
σ	0.15	Minimum industry markup bound from stationary solution. Calculated as the *average minimum markup* from NBER-CES MID
κ	3.5	Maximum industry bound. Calculated as the *average maximum markup* from NBER-CES MID
θ	0.06	From Nonlinear Least Squares with MID growth rates, industry panel growth rates, and theoretical bounds
θ_d	0.21	From Nonlinear Least Squares with MID growth rates, industry panel growth rates, and theoretical bounds
δ_M	$[0.0225, 0.18]$	From Broda and Weinstein (2010), trademark obsolescence rates, or Atkeson and Burstein (2015)
δ_k	0.07	Typical capital depreciation rate
α	0.28	Set from the 1980 corporate labor share in the data (using the stationary factor share distortion, B)
ρ	0.03	A typical interest rate target
γ	$[1, 5]$	Typical range of elasticity of intertemporal substitution
N	Irrelevant	With the θ and θ_d above, the N is essentially irrelevant (as long as it is above 5-10)
z, z_m, ν	N/A	Level effects, not calibrated

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