EC2212 Industrial Growth and Competition

- The role of technology in industries, and the role of both in regional/national growth
- Take course notes & seminar form from the front
- Lectures start at 3:05pm
- Study course notes before seminars
- Study other readings by exam term
- Five assignments lead to projects
- Choose project topics in next week's seminars

Weeks of the Course

1. Technology and growth.

Sources of successful technology:

2. Small firms (and regions).
3. Large firms.

Industry competition & technology:

4. Overview.
5. Market leadership change.
6. Shakeouts.
7. Sources of firm advantage.
8. Product differentiation.
9. Firm growth & technology.
10. Firm and national success.

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Lecture 1

Technology Is the Primary Source of Economic Growth

The Manufacture of Pins

- Adam Smith, *The Wealth of Nations* — example of division of labor
- Yet technology, not division of labor nor scale, has driven cost of pins
- 1770s: average worker 4,800 pins per day
- 1970s: average worker 800,000 pins per day
- 2.6% annual productivity growth

Worldwide Economic Growth

- Gross world product (GWP):
  - Measured in constant 1995 US dollars
  - $4.9 trillion in 1950
  - $26.9 trillion in 1995
  - 1.6% average annual growth
  - 0.9% average per person
- Output per worker hour has risen 0.9%+ annually

Technology and Growth

- Robert Solow won Nobel Prize largely for showing the importance of technology in economic growth
- Previous economists: capital, division, …
- Solow: 12.5% of growth in output per hour, non-farm 1909-49, from capital equipment
- Remaining 87.5% attributed to improved production and skills

National Growth & Technology

- Compare growth in output <u>per worker hour</u> among leading industrial nations
  - Differences between countries
  - Differences between time periods
  - Convergence among leading industrial nations
- Less-industrialized countries
  - Often different patterns (institutional problems)
  - Not always convergence

Growth is More than Figures Say

- New products not in "basket" of goods to measure consumer price index
  - Yet they have the most rapid price declines
  - Overestimates inflation, underestimates growth
- Quality improvements not reflected in economic growth figures

…Because of New Technology

Technology vs. Competitiveness

- Economists care about ensuring competition
- But technological change more important in medium & long term
- Suppose 10% price decrease from better competition
- Same 10% decrease in 20 years by 0.5% more productivity growth (10.6 years by 1% more), & the change keeps working

Growth Rates (% per year) of GDP per Worker Hour in Sixteen Industrial Countries, 1870-1979

	1870-80	1880-90	1890-00	1900-13	1913-29	1929-38	1938-50	1950-60	1960-70	1970-79
Australia	1.82	0.37	-0.80	1.01	1.49	0.88	2.20	2.76	2.22	2.83
Austria	1.50	1.98	1.93	1.50	0.72	0.21	1.61	5.69	5.90	4.32
Belgium	1.84	1.36	0.93	0.90	1.79	1.01	1.14	3.14	4.88	4.88
Canada	2.19	1.23	1.70	2.70	1.21	0.00	5.36	3.09	2.72	1.83
Denmark	1.47	1.95	1.90	2.21	2.57	0.43	1.23	2.97	4.90	3.06
Finland	1.29	1.14	3.36	2.42	1.95	1.89	2.10	3.96	6.37	2.60
France	2.32	0.90	2.02	1.82	2.34	2.83	0.75	4.39	5.38	4.09
Germany	1.50	2.15	2.42	1.41	1.40	2.34	-0.40	6.64	5.29	4.50
Italy	0.22	0.43	1.20	2.35	1.92	2.96	0.56	4.27	6.69	3.91
Japan	1.87	1.72	2.11	1.88	3.42	3.41	-3.20	5.57	9.96	5.03
Netherl.	1.44	1.26	0.98	1.07	2.44	-0.10	1.93	3.33	4.93	4.06
Norway	1.39	1.96	1.17	2.02	2.78	2.61	1.88	4.03	4.52	3.66
Sweden	1.76	1.95	2.70	2.62	2.40	2.66	3.43	3.43	4.79	2.55
Switzerl.	1.59	1.37	1.47	1.26	3.18	1.01	1.52	2.98	3.69	1.91
U.K.	1.63	1.20	1.24	0.90	1.44	0.87	2.21	2.19	3.56	2.77
U.S.	2.28	1.86	1.96	1.98	2.39	0.74	4.03	2.41	2.51	1.92

Source: Williamson (1991)

Joseph Schumpeter

- Pointed to productivity growth, new products, causing growth
- Large firms & monopolies as primary source of rapid growth
- Stopping anti-competitive practices thus may irreparably damage the economy!
- We will discuss more during the course

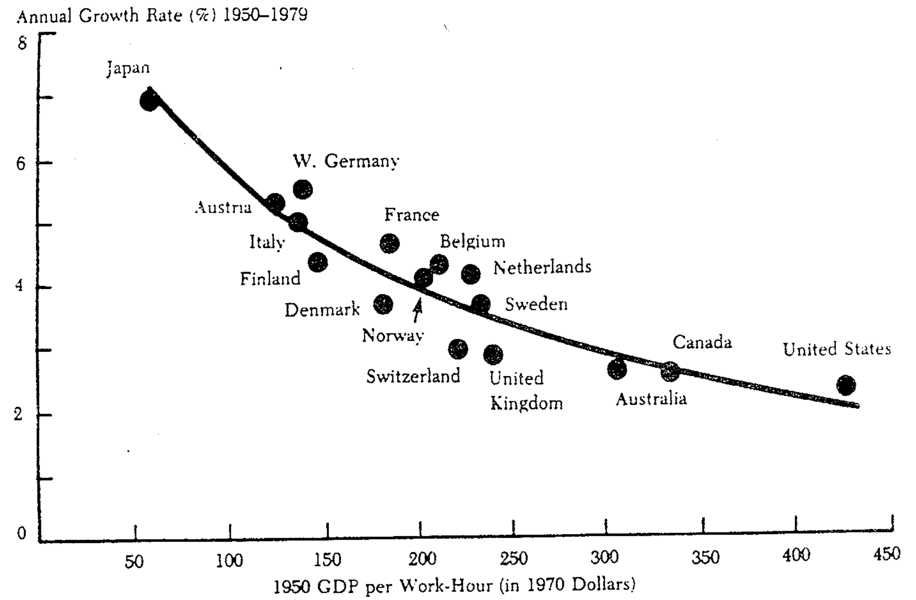


Figure 4. Postwar Productivity (GDP per work hour) Growth Rate, 16 Industrialized Countries

Country Growth Rate — Regression line

Source: BBW. Fig. 5.6. p. 103.

UK Technological Progress

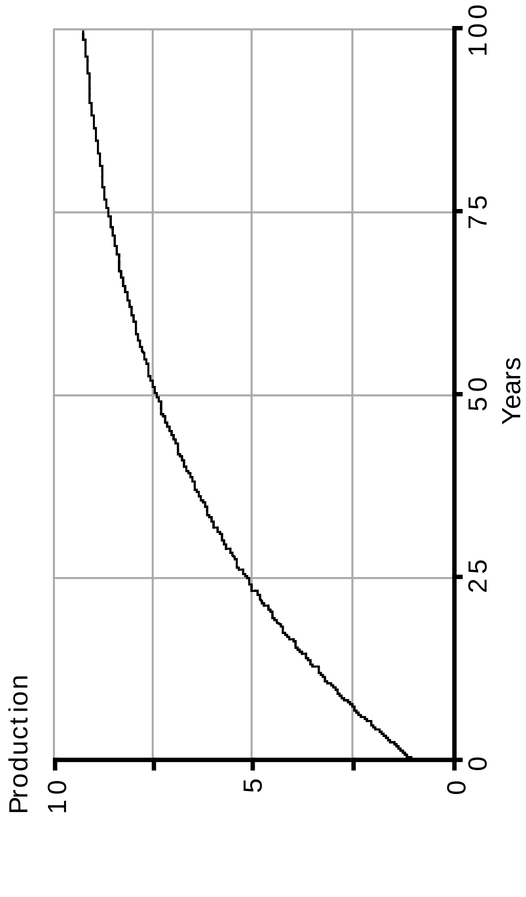
- Leadership to 1800 lost by 1900s
- Strong in services not manufacturing
- Strong in pharmaceuticals, military aerospace
- Large government budget to military
  - Benefits those industries
  - But secrecy, use of good personnel
- Little education in eng., app. science
- Culture looks down on engineers
- Oxbridge old-boy network reinforces
- Modest government R&D funding, especially non-military

Walker (1993)

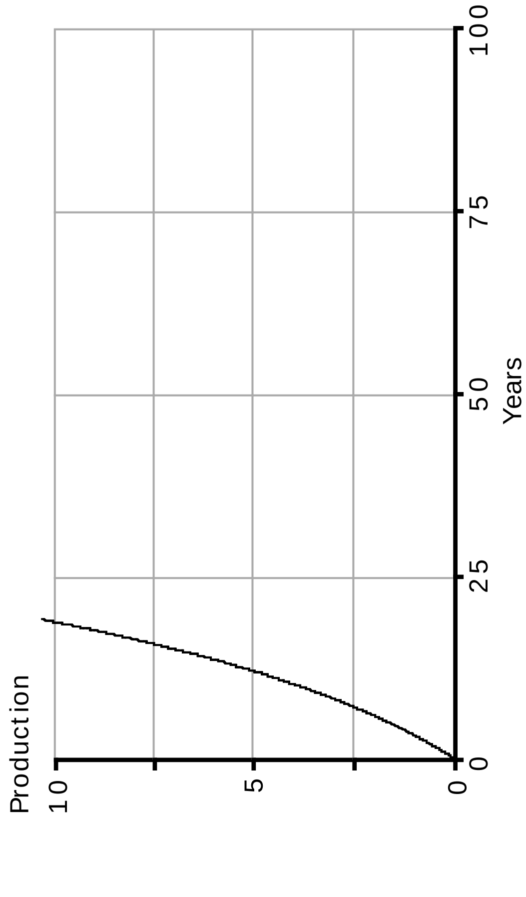
Economic Growth

- $y = A(t) \times f(k)$
  - y output per person per year
  - A(t) technology factor, changes over time t
  - f(k) production function, k capital per person
- $\frac{dk}{dt} = (1-h)y - \delta k$
  - h fraction of output consumed, (1-h) invested
  - δ depreciation rate

Production over Time in Growth Model with No Productivity Growth



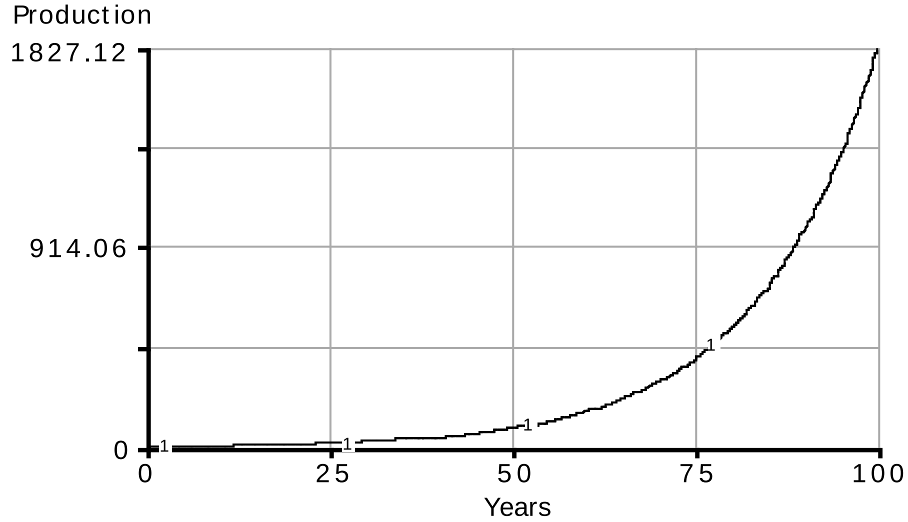
Production over Time in Growth Model with 3% Annual Productivity Growth



Is New Technology Ever from Small Firms?

- Yes:
- Jewkes, Sawers, & Stillerman (1959), *The Sources of Invention*
- Inventions often from small firms, individuals
- Small firms: cellophane tape, Terylene; individuals: self-winding watch, penicillin
- True for invention, less for innovation

Production over Time in Growth Model with 3% Annual Productivity Growth



Small Firms Are Inventive

- Above a minimum size, large and small firms have similar R&D spending per employee
- Small firms average more patents per R&D dollar spent
- Cohen (1995) reviews a large literature on the subject

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Lecture 2

Small Firms Can Be Innovative!

(and Some Ways to Help)

Helping Small Firms Innovate

- Use Heterogenous Skills
- Fit Industry-Specific Needs
- Look for Innovative Ideas Outside Firms
- Use Regional Networks of Innovators

Heterogeneous Skills

- Firms differ in employee skills, resources
- Harness the skills & resources
- E.g., radio manufacturers entering TV set production: innovated 5+ x as much, 60% lower annual exit, higher market share (Klepper & Simons, 2000 SMJ)
- E.g., automobile makers in early 1900s

Industry-Specific Needs

- Amounts & kinds of R&D needed vary by industry

% of firms conducting R&D (1000-4999 employees)

Food & kindred products	50%
Petroleum	69.2%
Aircraft & parts	89.5%

(Jewkes, Sawers, Stillerman, 1959, p. 192)

Innovative Ideas Outside Firms

- Innovative ideas often originate outside companies
- Johnston & Gibbons (1975), von Hippel (1988)
- E.g., in NMR spectrometers 79% of major innovations from users
- Other innovations from suppliers

Successful Innovation in Agglomerations

Silicon Valley successes (Saxenian, 1994):

- Interchange of ideas by managers, engineers
- Rapid job change
- Successful investors fund start-ups
- Links with university research, education
- Local government - executive cooperation
- Firms sharing resources

Sources of Innovations

Technology	User	Manuf.	Supplier	Other
Scientific instruments	77%	23%	0%	0%
Semiconductor & PCB process	67%	21%	0%	12%
Pultrusion process	90%	10%	0%	0%
Tractor-shovel related	6%	94%	0%	0%
Engineering plastics	10%	90%	0%	0%
Plastics additives	8%	92%	0%	0%
Industrial gas-using	42%	17%	32%	8%
Thermoplastics-using	43%	14%	36%	7%
Wire termination equipment	11%	33%	56%	0%

Von Hippel (1988, p. 4)

Small Firms Are Inventive (Conclusion)

- Small firms <u>are</u> inventive
  - Evidence from case studies, cross-section data
  - True for invention, less for innovation
- Tailor R&D work to firm skills, industries
- Get ideas from suppliers and customers too
- Use innovative networks;
  make innovative networks successful

Regional Networks

- Clusters of firms in an industry Marshall (1890) points out classic benefits:
  - intermediate goods supply
  - labor supply
  - knowledge spillover
- Patents (etc.) reflect clustering benefits
- E.g., tire makers: 89% in Akron (66% not) produced cord tires in 1920, yielding 3x less chance of exit (Klepper & Simons, 2000 JPE)

Organization of Lecture

1. Large firms sometimes dominate innovation

<u>A Story That Must Be Told:</u>

2. Schumpeter's view: large better
3. Investigation suggests: small better
4. Theory reinterprets: large often better
5. Large firms are better in these circumstances…

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Lecture 2 extra part

The Economy of Cities: the Role of Innovation

Large Firms Sometimes Dominate Innovation

% of Major Innovations from Largest Firms

<u>Autos</u> top 2 product 43% process 95%	<u>Tires</u> top 4 product 98% process most/all
<u>Televisions</u> top 5 product 84% process most/all	<u>Penicillin</u> top 4 product 100% process most/all

Source: Data from K. Simons (see Klepper & Simons, 1997).

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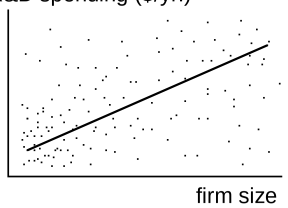
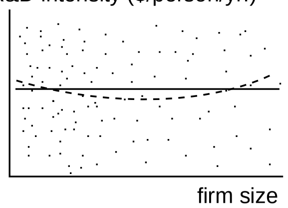
Lecture 3

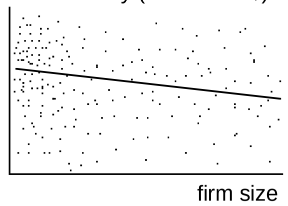
Large Firms Are Innovative (and when)

Empirical Studies of Innovation





Fake data illustrate real findings:
• R&D spending rises with firm size
• R&D intensity flat with firm size (Scherer finds slight inverted-U)
• R&D efficiency falls with firm size
• I.e., small firms spend same per employee and get more results!



Schumpeter on Innovation (1)

"[I]n capitalist reality as distinguished from its textbook picture, it is not [price] competition which counts but the competition from the new commodity, the new technology, the new source of supply, the new type of organization…—competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives. This kind of competition is as much more effective than the other as a bombardment is in comparison with forcing a door, and so much more important that it becomes a matter of comparative indifference whether competition in the ordinary sense functions more or less promptly; the powerful lever than in the long run expands output and brings down prices is in any case made of other stuff."

(*Capitalism, Socialism and* Democracy, 3rd ed., 1950, pp. 84-85)

A Theory of R&D and Firm Size

- Facts sometimes mislead, when not informed by correct theory
- I will show an economic theory (simple version of Cohen & Klepper, 1996)
- Assumptions of theory fit most industries
- The theory fits empirical facts
- The theory implies large firms better

Schumpeter on Innovation (2)

Tracking down sources of economic progress, "the trail leads… precisely to the doors of the large concerns" (1950, p. 82)

1. Monopoly prices justifiable as insurance against new technology.
2. Monopolistic or oligopolistic behavior not so bad, vs. benefit from technological change. Good (e.g. stability in recessions).
3. Technology drives down prices anyway; use hedonic prices.
4. Firms adopt new innovations despite any "loss" in capital.

5a. True monopoly is exceedingly rare; large size is not monopoly.
5b. Monopolists may be more efficient, create new products.
5c. Short-run monopoly more common than long-run monopoly.

6. Replace static perfect competition economic view; need dynamic understanding with technology. Technological change cannot happen in perfect competition, which disallows profits from innovation.

Why Two Key Assumptions

- Research results cannot be sold to other companies
  - Returns to R&D rarely can be appropriated except through a company's own sales
  - Firms can "invent around" patents, use lawsuits
- Future output Q is a fixed constant
  - E.g., $Q_{future} = Q_{now} \times k$
  - Firm growth k is limited in practice

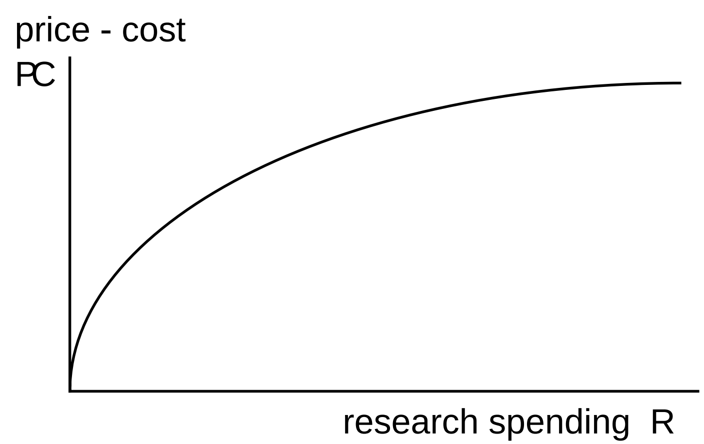
Assumptions of Theory

- Firm spends R on research & development
- R&D increases quality, lowers unit cost
  - (Or <u>expected</u> quality and unit cost)
  - I.e., R&D increases PC = price - cost: $PC'(R)>0$
  - Diminishing marginal returns to R: $PC''(R)<0$
- Firms max. profit: $\Pi = PC(R) \times Q - R$
- Future output Q is fixed; firm chooses R

Three Implications of the Theory

1. Large firms: more R&D than small firms, not (necc.) more R&D per unit of size
2. Large firms: higher PC than small firms
   - Better for society (better quality and cost)
   - Better competitors (higher profit margin)
3. Large firms: less R&D results per R&D $
   - Less wasteful duplication of easy research
   - Do more challenging (more marginal) R&D too

Price-Cost Margin versus R



Proofs Step 0: A Lemma

The firm maximizes Π by choosing R.
At the maximum, $d\Pi/dR$ must equal 0, and $d^2\Pi/dR^2$ must be negative.
So, the firm chooses R so that the marginal increase in the price-cost margin from another \$ of R&D spending equals $1/Q$; that is, $PC'(R) = 1/Q$.

$$\Pi = PC(R) \times Q - R$$

$$\frac{d\Pi}{dR} = PC'(R) \times Q - 1 = 0$$

i.e., $\boxed{PC'(R) = \frac{1}{Q}}$

$$\frac{d^2\Pi}{dR^2} = PC''(R) \times Q < 0$$

Proofs Step 1: Theorems 1a & 1b

$$PC'(R) = \frac{1}{Q}$$

$$\frac{d}{dQ}\left(PC'(R)\right) = \frac{d}{dQ}\left(\frac{1}{Q}\right)$$

$$PC''(R)\frac{dR}{dQ} = \frac{-1}{Q^2}$$

$$\boxed{\frac{dR}{dQ} = \frac{-1}{Q^2 PC''(R)} > 0}$$

Bigger firms do more R&D.

Let: $PC(R) = k \log(R)$

Then: $PC'(R) = k/R$,

so use $PC'(R) = 1/Q$,

to get $\frac{k}{R} = \frac{1}{Q}$

Then: $\boxed{\frac{d(R/Q)}{dQ} = 0}$

Bigger firms are not necessarily more R&D intensive.

Proofs Step 2: Theorems 2a & 2b

Since R increases with firm size ($dR/dQ > 0$),
and since PC increases with R,
PC must increase with firm size:

$$\boxed{\frac{dPC}{dQ} > 0}$$

Bigger firms have better quality and lower unit cost.

Compare sizes $Q_2 > Q_1$.
Optimal R&D is $R_2 > R_1$.
Suppose the larger firm spends only R_1 on R&D.

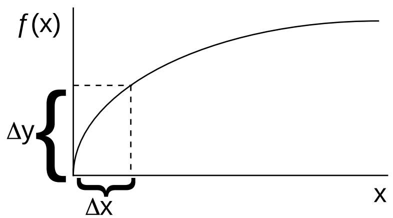
Then its profit <u>per unit</u>,
$[PC(R_1) \times Q_2 - R_1] / Q_2$
exceeds that of the smaller firm,
$[PC(R_1) \times Q_1 - R_1] / Q_1$.
Choosing optimal R&D R_2 only increases profit per unit.

Bigger firms earn more profit per unit.
They are “fitter” competitors.

Proof Step 3: Theorem 3

For any concave increasing function $f(x)$, $\Delta y/\Delta x$ is smaller for larger Δx.
Since PC(R) is a concave increasing function ($PC'(R) > 0$, $PC''(R) < 0$),

$$\boxed{\frac{d\left[\left(PC(R) - PC(0)\right)/R\right]}{dR} < 0}$$



Bigger firms accomplish less unit-cost savings per average \$ spent on R&D.
I.e., they don’t just duplicate small firms’ R&D; they do more challenging R&D too.

Conclusion

- Schumpeter's story can fit the evidence...
- When:
  - Returns to R&D are not appropriable
  - Future output is limited in practice
  - R&D is duplicated across firms
  - I.e., especially for gradual improvement, not for patentable radical inventions
- Then larger firms do more intensive R&D, are fitter competitors; society benefits more

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Lecture 4

Patterns of Industry Evolution, in part Determined by Technology

Definition of an Industry

- Different ways to define an industry
- Standard industrial classification (SIC)
  - Categories chosen by government
  - Used to analyze census data on firms
  - SIC codes are hierarchical
  - Data commonly at 2- or 4-digit levels
  - Firms in SIC class usually not competitors
  - So competitive dynamics are hidden

SIC Code Hierarchy

- Major groups:
  - 01-09 Agriculture, forestry, fishing
  - 20-39 Manufacturing
  - 60-67 Finance, insurance, real estate
- 2-digit groups:
  - 20 Food and kindred products
  - 37 Transportation equipment
- 4-digit groups:
  - 3711 Motore vehicles & passenger car bodies
  - 3724 Aircraft engines & engine parts

Patterns of Industry Evolution

- Traits that evolve: supply and demand
- Focus on supply side
- Typology of industries
  - Classify industries by evolutionary type?
  - Shakeout & concentration in some industries; some early entrants dominate
  - Non-shakeout in other industries; sometimes market leaders are replaced
  - Technology: what role does it play?

Competitive Industry Definition

- Firms compete: produce "same" product
- Product variants substitutable for most customers
- Example: automobiles
  - Sports cars, small cars, 8-seaters — fairly substitutable
  - Motorcycles, trucks, buses — serve quite different needs
- Could define as, e.g., substitutability ≥ 20%
- In practice, guesstimate given market knowledge

Supply and Demand Traits

- Supply-side
  - Firms in the industry: entry, exit
  - Technology of product and production
  - Firm growth, market share, concentration
- Demand-side
  - Number of customers & individual demand
  - Tendency to stick with a brand; switching costs
  - Spread of information and fads

Alternative Industry Definitions

- Industries defined by:
  - Substitutability (for competition analysis)
  - Price identical for all buyers (for market analysis)
  - Oligopolies if present could influence prices (for antitrust analysis)
  - Economies of scope in technology of product or production (for diversification analysis)
- This course: mainly substitutability

Shakeout in Some Industries

- Gort & Klepper (1982), Klepper & Graddy (1990)
  - 47 new products
  - First several decades or more of market
  - Initial rise in number of producers
  - Then in most products a shakeout of producers
  - Despite continued growth in output
- Greater shakeout with more technological change (Agarwal, 1998)
- Some early entrants dominate through technology (Klepper & Simons, 1997, …)

Figure 6.1. Number of Manufacturers versus Time of Various US and UK Products

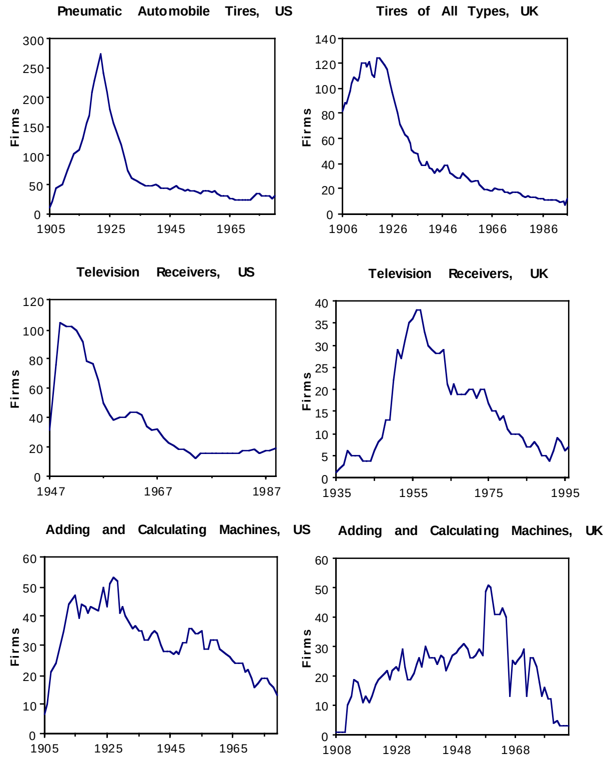
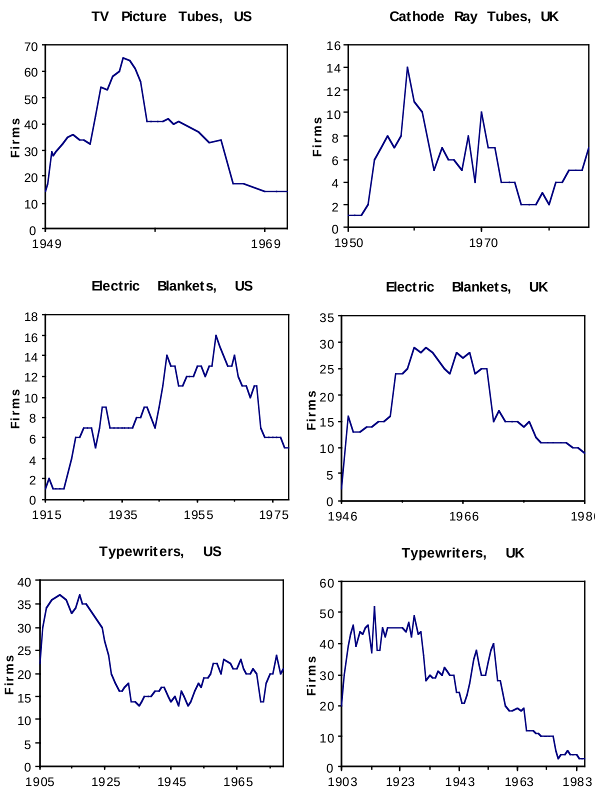


Figure 6.1 continued.



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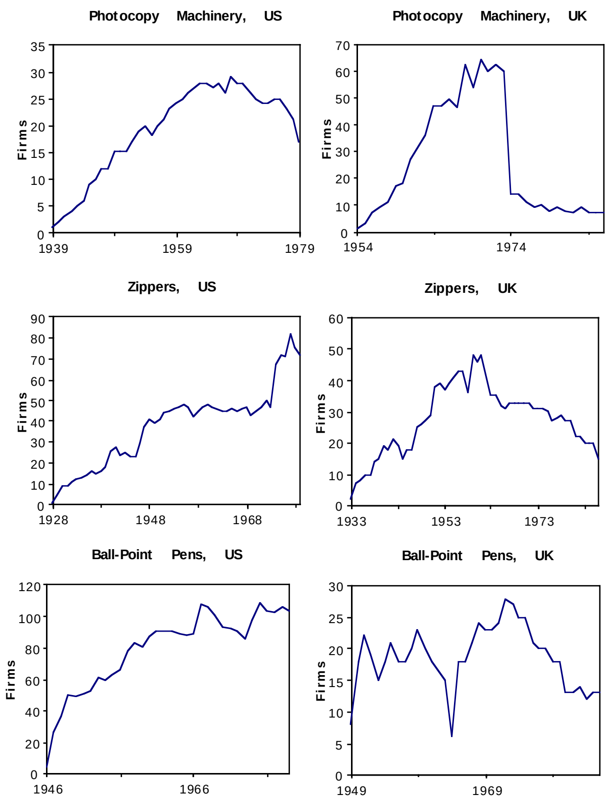

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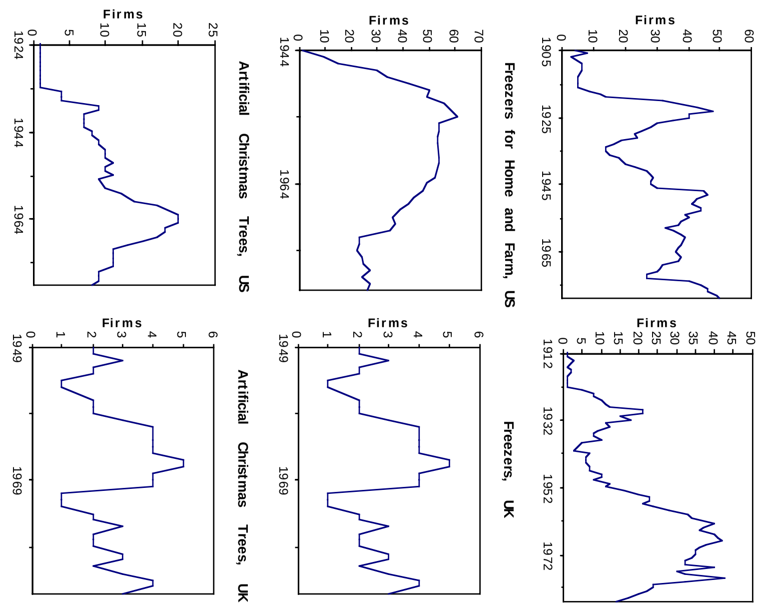

No Shakeout in Some Industries

- Number of firms may fall none or little
  - Ball-point pens in the US
  - Zippers in the US
- No early-mover advantage, unlike in shakeouts
- In other cases, late-mover advantages
  - Mechanical to electronic calculators

The Role of Technology

- Technology is a powerful competitive force
- If (1) large firms have most R&D incentive, and (2) technology fits firms' abilities, then: technology reinforces the leading firms
- If (1) R&D matters little to competition, or (2) new firms better at relevant R&D, then: leading firms have no advantage

A Validity Check

- Do technology and market traits really determine industry evolution?
- Or are outcomes just random?
- If just random, should often differ across countries
- Simons (2000) compares 18 products in US & UK
- Degree and time of shakeout very similar
- Common process at work in both nations
- Not just random

Conclusion

- Technology, other market traits, affect industry evolution
- Types of industry evolution:
  - Market leadership turnover: aided by disruptive technology
  - Continued entry & exit possible: technology leadership is unimportant
  - Shakeout: market leaders use technology to dominate, non-disruptive technology
  - Market niches protect firms

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Lecture 5

Innovators can use radical new technology to seize markets.

Turnover of Corporate Leadership

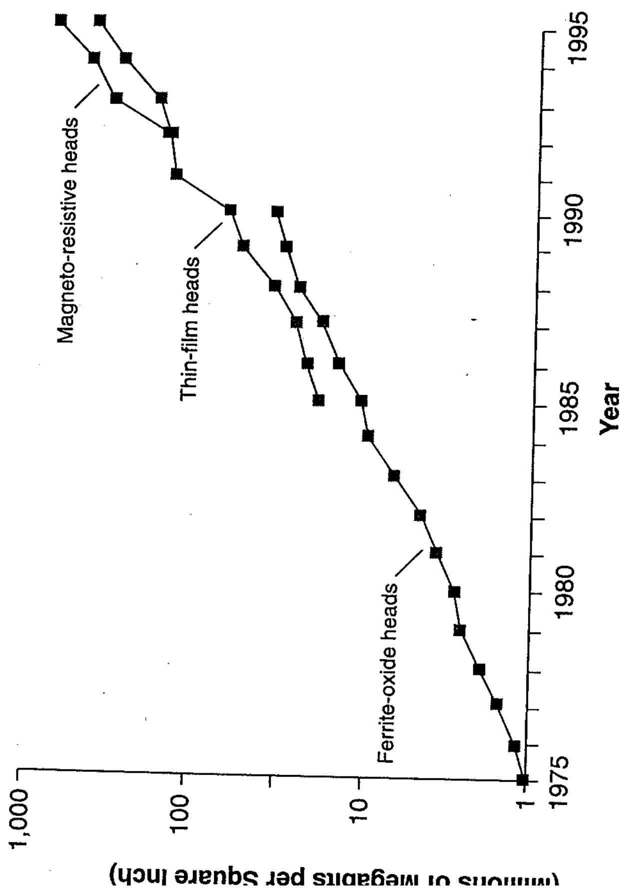
- New firms replace old as market leaders.
- Entry and exit may occur.
- Major innovations can provide the means for market turnover.

A Technology Mudslide?

Hypothesis: "Coping with the relentless onslaught of technology change was akin to trying to climb a mudslide raging down a hill. You have to scramble with everything you've got to stay on top of it, and if you ever once stop to catch your breath, you get buried." Leading firms frequently lose.

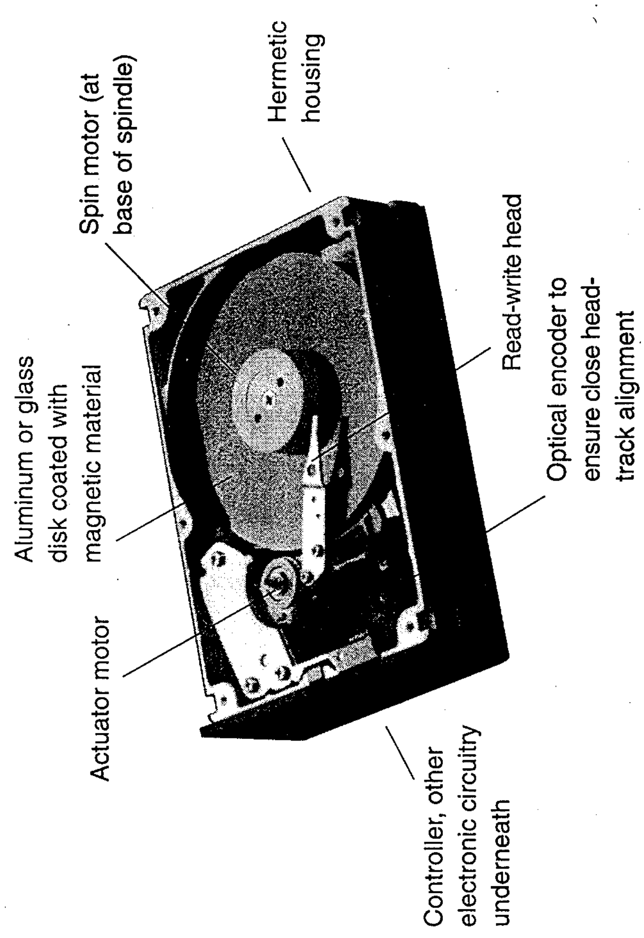
Reality: "The established firms were the leading innovators not just in developing risky, complex, and expensive component technologies…, but in *literally every… one of the sustaining innovations in the industry's history*…. [T]his pattern of technology leadership… is stunningly consistent…. [T]here have been only a few of the other sort of technological change, called disruptive technologies…, that toppled the industry's leaders."

– C. Christensen on hard disk drives



e: Data are from various issues of *Disk/Trend Report.*

Figure 1.1 Primary Components of a Typical Disk Drive



Examples

cement - rotary kiln & coal dust ~1892, suspension preheating 1972

minicomputers - solid state, ICs 1960s

container glass - semiautomation 1893, Owens machine 1903

flat glass - drawing machines 1917, continuous forming 1923, float glass 1963

aligners for semiconductor mfg. - contact / proximity / scanner /step & repeat

hard disk drives - 14", 8", 5.25", 3.5"

transistor - vs. vacuum tube

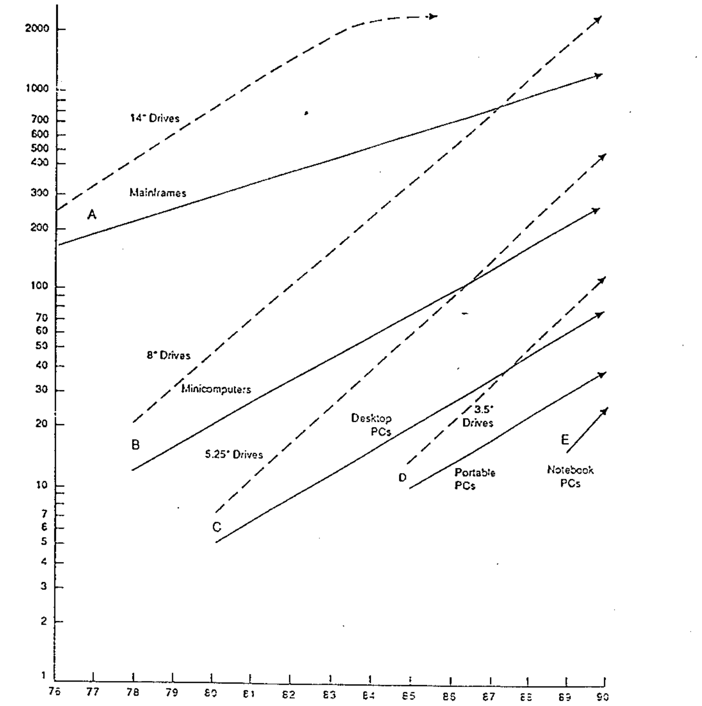
electronic calculator - vs. mechanical

Alignment Equipment

Firm	Contact	Proximity	Scanners	Step and repeat (1)	Step and repeat (2)
Cobilt	44		<1		
Kasper	17	8		7	
Canon		67	21	9	
Perkin-Elmer			78	10	<1
GCA				55	12
Nikon					70
Total	61	75	99+	81	82+

This measure is distorted by the fact that all of these products are still being sold. For second-generation step and repeat aligners this problem is particularly severe, since in 1986 this equipment was still in the early stages of its life cycle. Source: Internal firm records, Dataquest, VLSI Research Inc.

n nearly every case, the established firm invested heavily in the next generation of equipment, only to meet with very ittle success. Our analysis of the industry's history suggests that a reliance on architectural knowledge derived from experience with the previous generation blinded the incumbent firms to critical aspects of the new technology. They thus underestimated its potential or built equipment that was markedly inferior to the equipment introduced by entrants.



Comparison of the trajectories of disk capacity demanded per computer, vs. capacity provided in each architecture

Analyzing Turnover

- Innovators: new firms or old?
  E.g., powdered coal for cement
    New firms - 4 of 5 innovators
    Old firms - 1 of 5
- Era of ferment
  Product/process diversity
  Sales growth, hard to forecast
- Entry & exit, market shares
  Entry & exit rise, perhaps
    entry/exit ratio rises
  Dispersion in market shares,
    turnover
- Tushman & Anderson article.

Why Incumbents Lose
4 Explanations

- New technology makes obsolete previous core competency.
- Blinded by prior technological views & organizational filters.
- Blinded by customer base.
- Differing incentives: incumbents & entrants, existing & new markets.
- See: Tushman & Anderson, Henderson & Clark, Christensen & Rosenbloom

Non-Technological Leadership Turnover

- Non-technological reasons for turnover may also exist.
- Targeting a new market:
  UK potato crisps: Golden
    Wonder.
  US ball-point pens: Bic.
  (Both in part involved technical
    innovation, but redefinition
    of the market was key.)

Opportunities to Imitate

- Small firms pioneer new markets
  - Beat them while they're weak.
- Patents absent or can be circumvented
  - Show previous patents or usage
  - Come up with alternative design for same purpose
  - Defensive & offensive use of previous patents
- Related experience
- New market segments to create

Success with Imitation

- Anticipate unlikely threats
- Concurrent R&D
- Legal & regulatory challenges to the pioneer(s)
- Enter quickly after the market has formed, not after 1st entry
- Don't copy too closely
- Continuity for consumers, not too much change

Defense against Imitation

- Sell out
- Licensing & joint ventures
- Fight off copycats:
  - Legal measures (copyright / patent)
  - Introduce low-end generics (or focus on high-value end)
  - Perpetually innovate
  - Create a proprietary standard

You Should Know

- What kinds of technology may cause market leadership turnover? Why?
- Examples
- Predictions for the market (Tushman & Anderson)
- Why don't market leaders innovate with disruptive technologies? 4 theories
- What strategies can aid successful innovation?
- What strategies help defend market leadership?

EC2212 Industrial Growth
and Competition

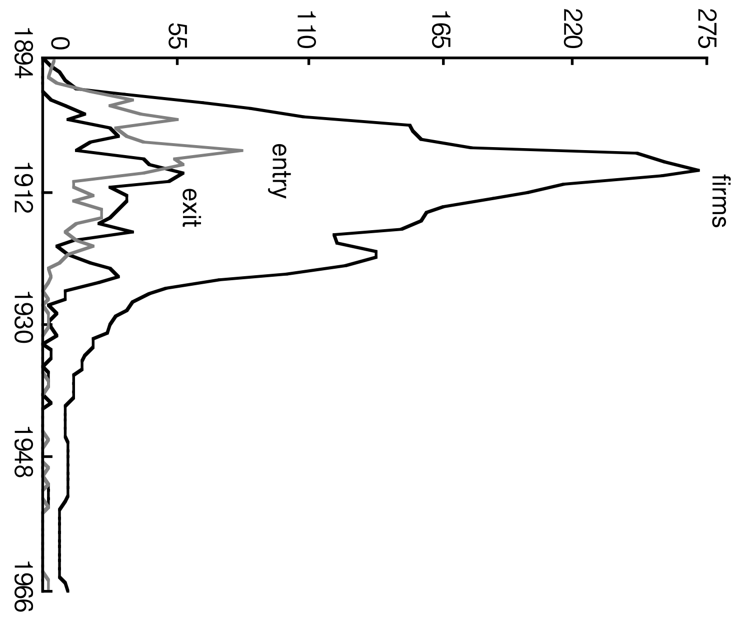
Lecture 6

Sustaining technology lets skilled early entrants destroy competitors.

Shakeouts

- New products: often rise then fall in number of producers
- Fall in number of producers often called a “shakeout”
- Most products have shakeouts, within 3+ decades of when the market forms
- Can be very dramatic: US automobiles went from 273 producers to 5
- Concentrated market shares tend to result

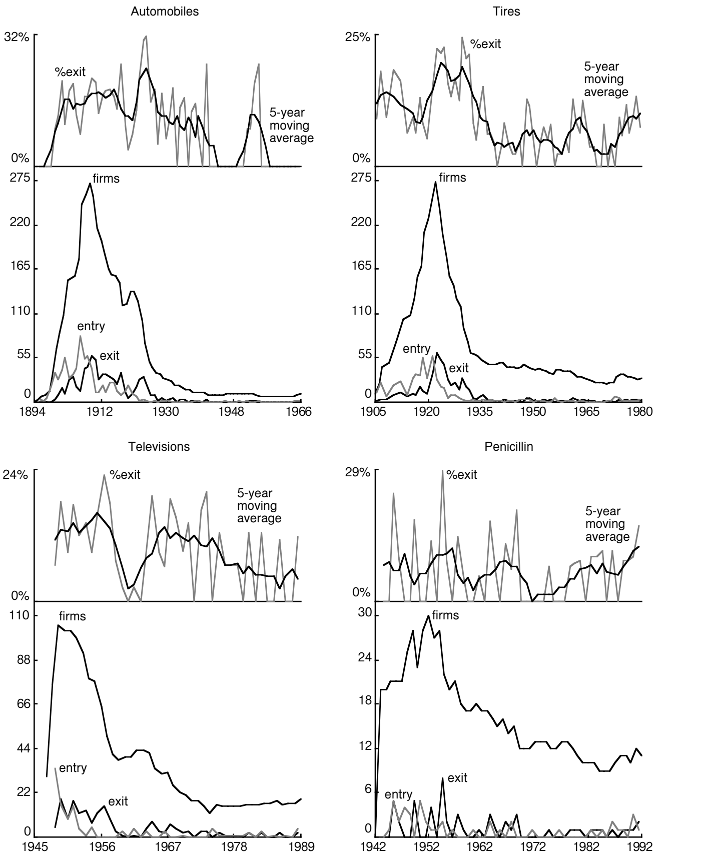
US Automobile Producers, 1896-1966



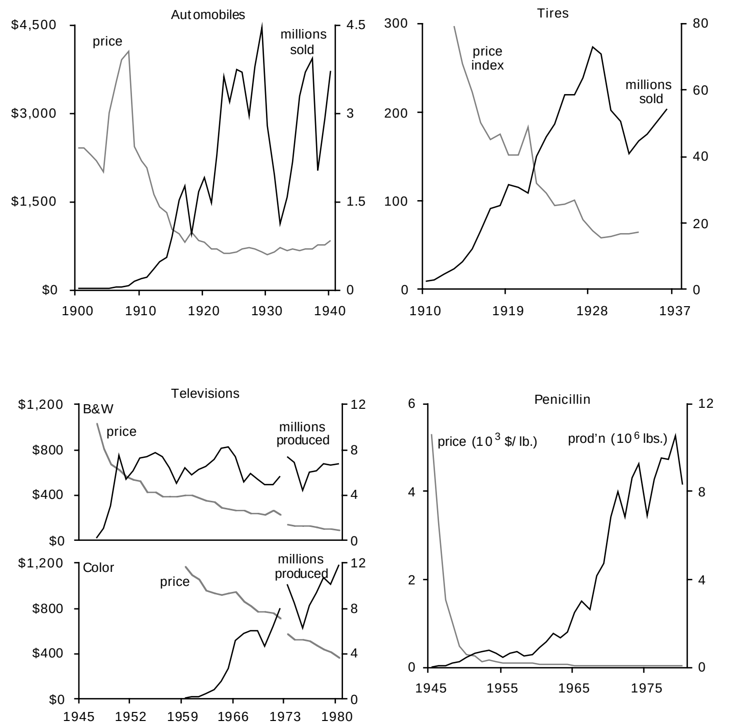
Why Do Shakeouts Happen?

- Focus on the main cause
- … in products with severe shakeouts
- You will see
  - – Evidence on entry and exit
  - – Theory that best fits the facts
    - approximately, Klepper (1996, 2001)
  - – Evidence on early-movers, technology
- Then discuss ramifications

Firms, Entry, Exit in Four Products (US)



Price and Output in the Four Products

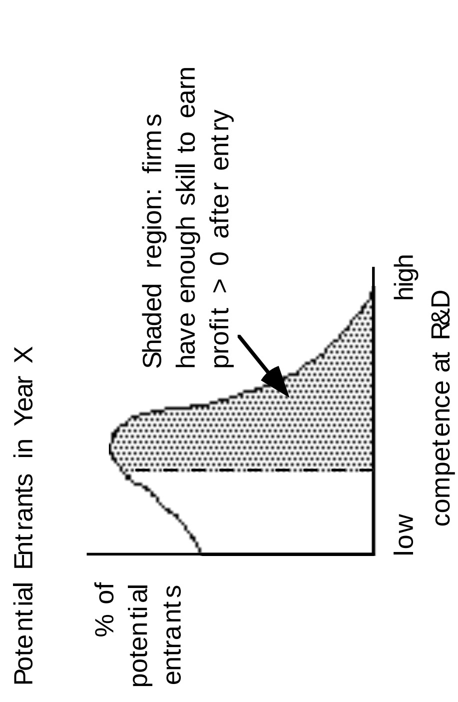


Explanation of Shakeouts

Part 1 of 3

Entrants and Their Skills

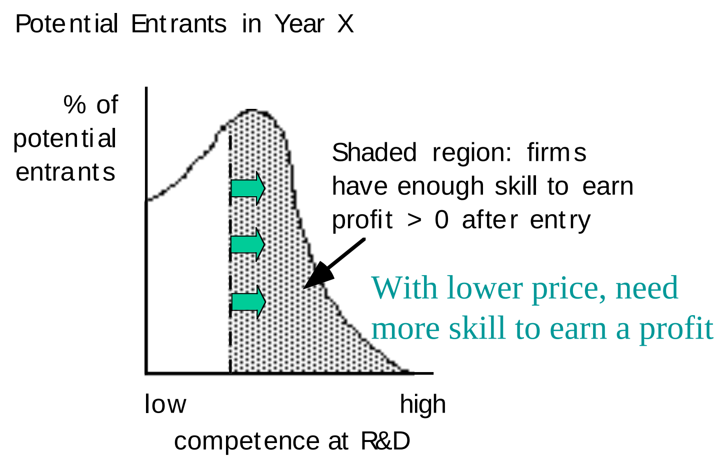
More Skilled Firms Can Earn More Profit



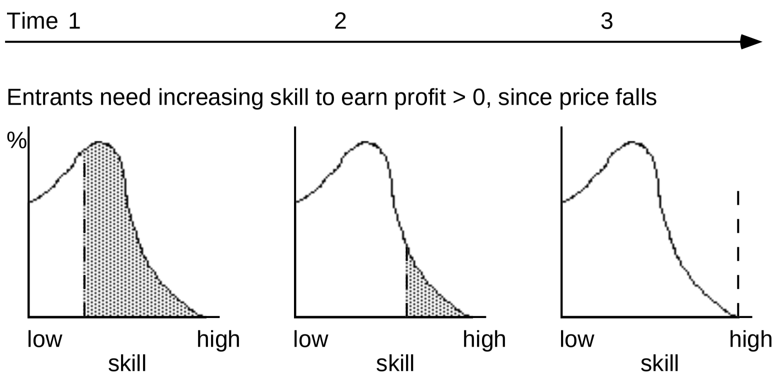
Entry & Growth Drive Down Price

- Limited number of firms have skills needed to enter, at any point in time
- Each year some number of firms can enter
- Firms enter fairly small, but then grow
- Entry and growth increase total output
- More output, lower price (demand curve)

Skill Needed to Enter Rises over Time



Entry Eventually Stops



May be more potential entrants, but eventually no entrants

EXAMPLE:

60 potential firms	300 potential firms	800 potential firms
40 enter	70 enter	0 enter

Explanation of Shakeouts
Part 2 of 3

R&D, Size, and Profit

Implications of the Profit Function

- Firms choose R_{it}, Q_{it} to maximize profit
- Larger firms spend more on R&D
  - Spread cost of R&D over more output
  - Remember lecture 3
- Growth is limited
  - Firms grow each period
  - Increasing marginal cost limits growth
- Size (Q_{it}) and skill (s_i) enhance profit

R&D with Imitation

- R&D improves quality, lowers cost
- Decreasing returns to R&D
- Cost-per-unit-of quality $c = c(R)$, $c'<0, c''>0$
- Firms benefit from R&D during 1 time period
- Firms imitate all past innovations in the next period

Explanation of Shakeouts

Part 3 of 3

Exit (given Size and Skill)

Firm i's Profit at Time t

$$\Pi_{it} = \left(p_t - \left[c_t - s_i c(R_{it})\right]\right)Q_{it} - R_{it} - g(Q_{it} - Q_{it-1})$$

- p_t price per unit of quality, $p_t = f(\sum Q_{it})$
- $[c_t - s_i c(R_{it})]$ cost per unit produced
  - c_t highest possible cost given imitation of past R&D
  - s_i firm i's skill at R&D
  - $c(R_{it})$ cost decreases with current R&D, $c'<0$, $c''>0$
- Q_{it} output produced
- R_{it} spending on R&D
- $g(Q_{it} - Q_{it-1})$ cost of growth, $g'>0$, $g''>0$

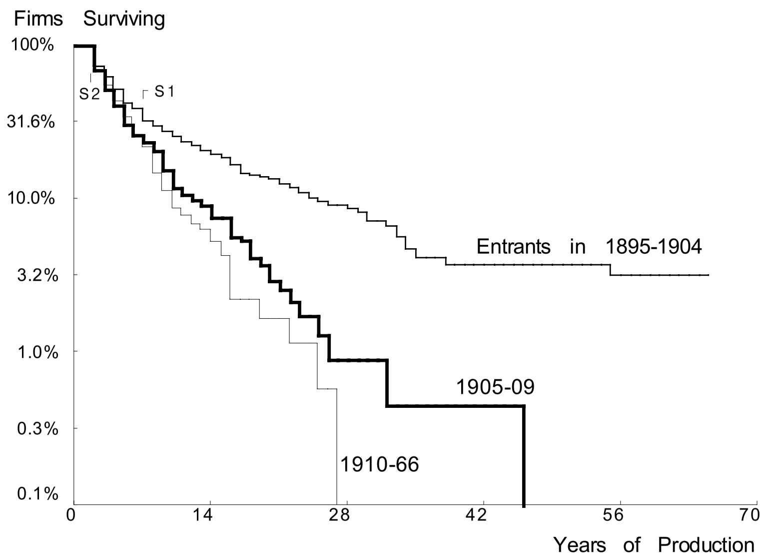
Implications of the Theory

- Shakeout
  - Entry eventually stops
  - Exit continues forever, causing shakeout
- Earlier entrants have lower chance of exit
  - Maybe not at first (depends on skill distribution)
  - But eventually even high-skilled late entrants exit
- Earlier entrants do more R&D
- Firms successful at R&D survive better

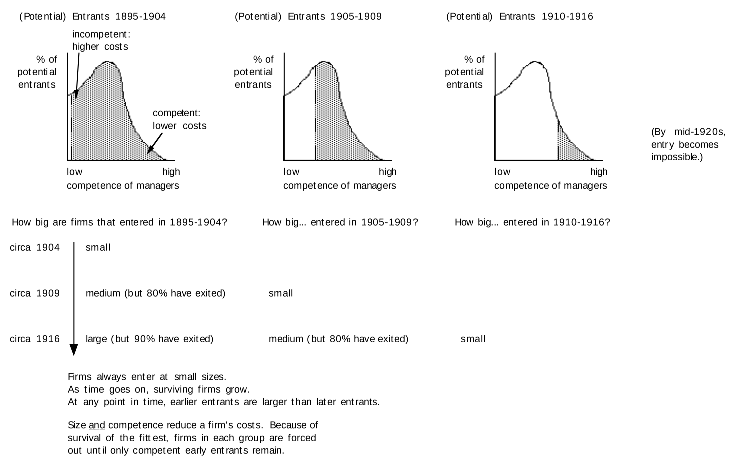
Who Exits When?

- Firms exit if $\Pi_{it} < 0$
- Growth causes exit at every t
  - Growth $\rightarrow \Sigma Q_{it} \rightarrow p_t \rightarrow$ profit
- Exiting firms are smallest, least-skilled
  - Since size and skill enhance profit
- Earlier entrants are larger, *ceteris paribus*
  - Have had more time and incentive to grow
- Skilled early entrants are long-run survivors

% Survival by Entry Date of Automobile Producers



Summary in Course Notes, p. 89

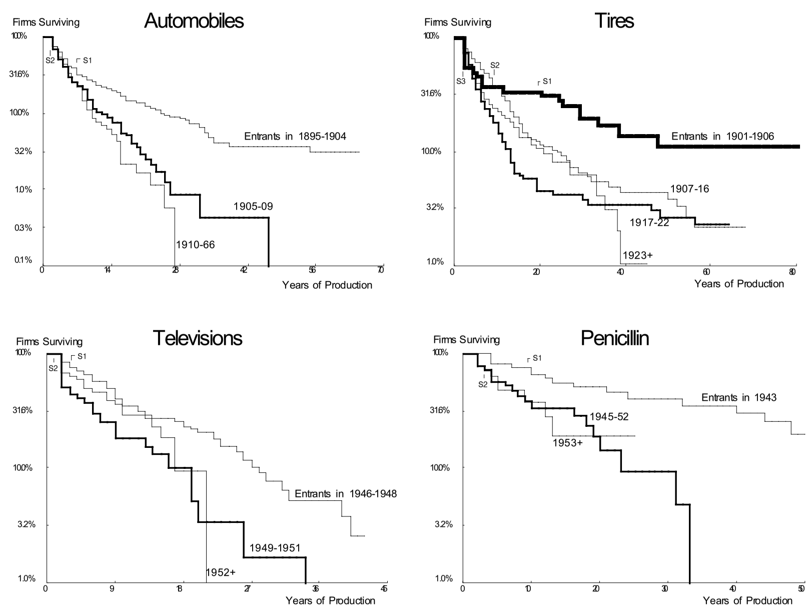


Innovation, % Adoption, by Entry Time in the Four Products

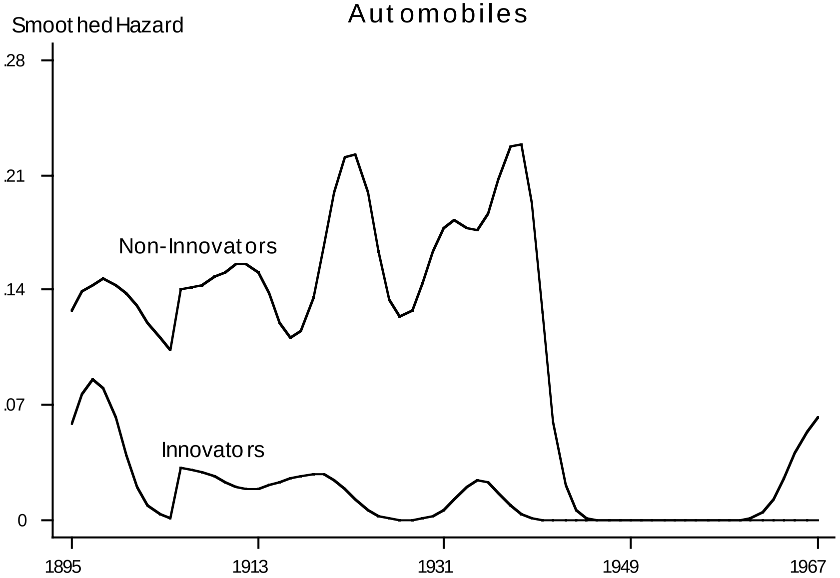
Use same entry-time cohorts as previously, but divide tires cohort 1
Relative innovation rates by product & innovation type — compare cohorts

Product	Innovation type	Cohort 1	Cohort 2	Cohort 3
Automobiles	Product	9	2	1
Automobiles	Process	3	0	0.1
Tires	Product	1	0	0
Tires	Cord 1917	36% / 8%		
Tires	Cord 1920	100% / 73%	62%	
Tires	Balloon 1923	63% / 16%	7%	
Televisions	Product	2	1	0
Televisions	Process	63	7	0
Penicillin	Process	5	0	0

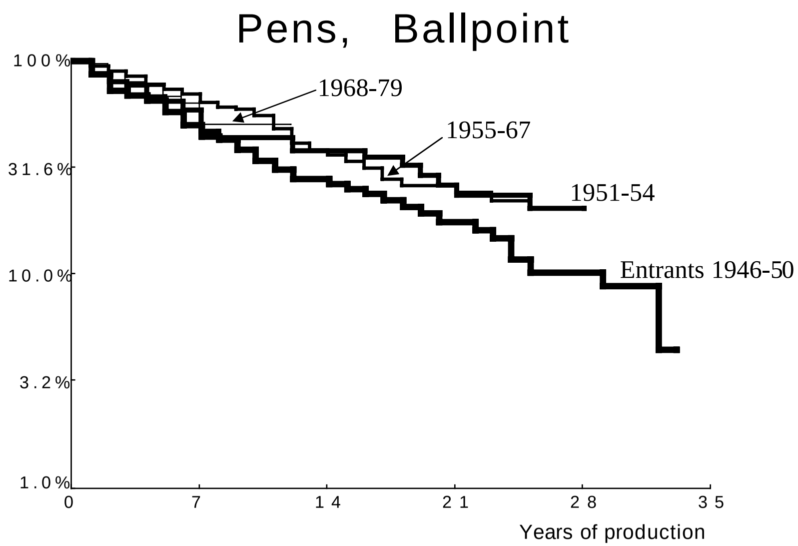
% Survival by Entry Date in the Four Products



Innovation and Exit
Automobiles



% Survival by Entry Date in a Non-Shakeout Product

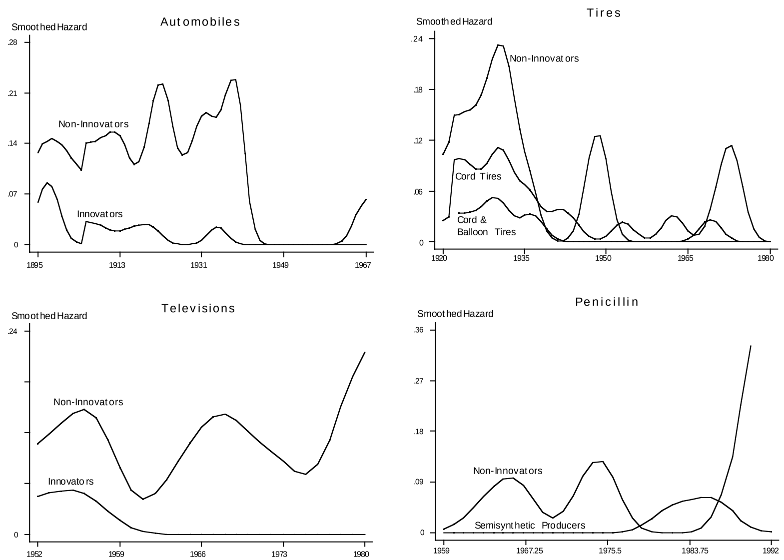


EC2212 Industrial Growth
and Competition

Lecture 7

Other factors may contribute to concentration and shakeouts.

Innovation and Exit in the Four Products



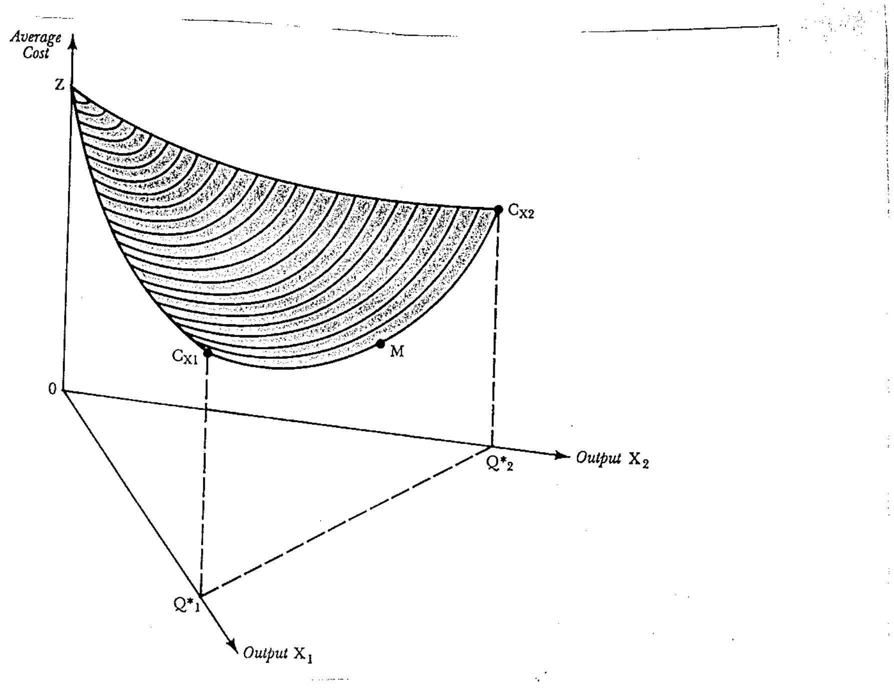
Forces Causing Concentration

- Previous lecture explained main cause of shakeouts
- Other forces may be at work simultaneously in shakeouts, or otherwise affect concentration
- Why know about these other forces?
  - Common themes; people expect you to know
  - Affect competition in certain situations
  - Understand more of how technology works
- Six forces
- Static long-run: cost-spreading & concentration

Ramifications of Shakeouts

- In industries with strong sustaining R&D
- High-skilled early entrants dominate
- Other firms may profit for a while
  - But eventually forced to exit
- Enter early, keep up with R&D, to survive
- Concentration is a natural result
  - Anti-trust authorities often investifate
  - But expect concentration with legal behavior

Figure 4.2 Costs with Two X_1 and X_2 and nomies of Scope



1. First- & Early-Mover Advantage

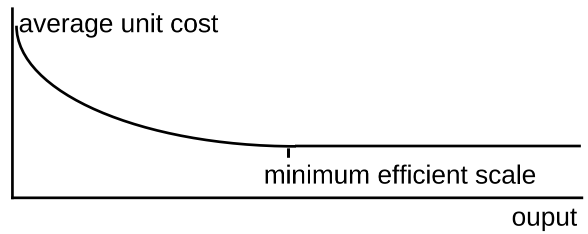
- Previous lecture: Early entrants grow larger, spread R&D cost over more units
- Other possible early-mover advantages:
  - Win race for patent(s) [But simple races are rare]
  - Reputation, customer loyalty, switching costs [But big quality/price differences undermine; limited output makes less relevant]
  - Will discuss cost-reduction, lock-in, networks shortly
  - ….

Other Scale/Scope Advantages

- R&D cost-spreading
- Advertising cost-spreading
- Distribution networks
- Managerial efficiency and inefficiency

2. Efficient Production Scale

- Lowest unit cost at a *minimum efficient scale*: output of 1 most-efficient machine
- Same cost for more output: 2+ machines
- *Increasing returns to scale* below minimum
- *Constant returns to scale* above minimum



3. Progressive Cost Reduction

- Often called *learning curves*
  - Or *experience curves*
  - Implies workers learn to be more efficient
  - But often workers become skilled quickly (2-4 weeks in TV set assembly), can move between jobs
- Studies of progressive cost reduction distinguish specific sources
- R&D a key source of progressive cost reduction

4. Technology Lock-In

- One technological standard instead of another
- Hard to change (user networks, development cost)
- May be an inferior technology
- Examples:
  - QWERTY typewriter keyboard (vs Dvorjak)
  - VHS videocassette recorders (vs Betamax)
- Arguments over whether inferior technology locked in
  - Liebowitz & Margolis contradict David re. QWERTY

5. Network Economies

- Networks of users benefit from each other
- Hard to switch standards once the network is established
- Causes one type of lock-in
- Examples
  - QWERTY, VHS
  - Microsoft Word
  - Railroad track widths

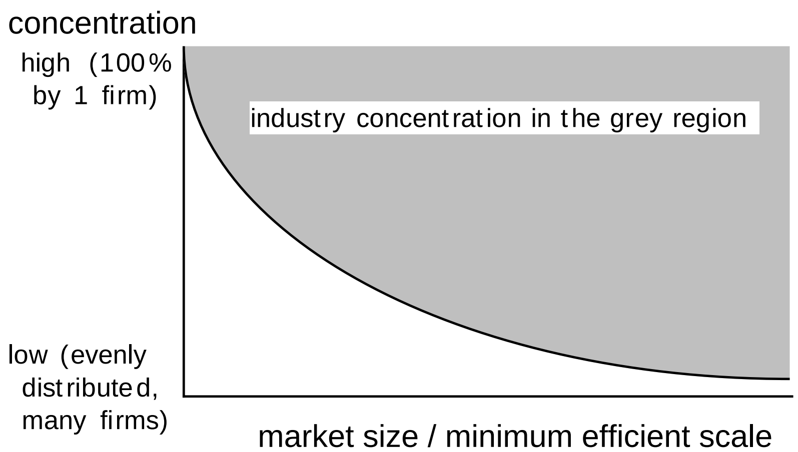
6. Sunk Costs

- Entering an industry has a cost
- May be for technology development, purchase of machines, etc.
- Few firms enter if the sunk cost is very large
- Because the cost must be spread over the number of units produced

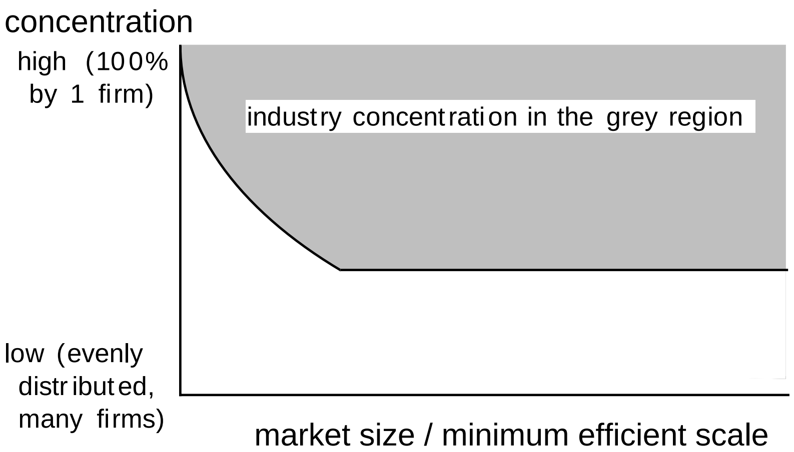
A Static Long-Run View

- Sutton (1991, 1998)
- Argues we must look across different competitive models:
  - – Bertrand vs Cournot vs monopoly
  - – Product differentiation
- Puts *bounds* on competitive outcomes, instead of predicting the outcomes

Without Cost-Spreading



With Cost-Spreading



EC2212 Industrial Growth
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Lecture 8

Product differentiation can protect against competitive destruction.

Protection by Differentiation

- Firms produce something different from rivals
- If product different enough that cross-price elasticity of demand near zero, no competition
  - Called a different product industry in this course
  - E.g., bicycles vs. automobiles or vs. apples
- Differentiation theories are for intermediate cases
  - Firms compete with each other
  - But differentiation lessens competition
- Technology: one way to achieve differentiation, tech. progress may differ across sub-markets

Economic Theories of Differentiation

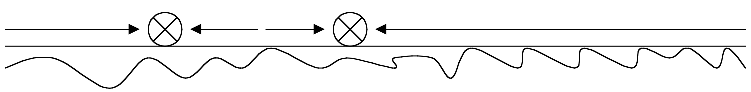
- Types of differentiation:
  - *Horizontal*: different features
  - *Vertical*: same features, different quality levels
- Abstract away from technological change
  - We just studied theories with vertical and horizontal differentiation caused by technological change
  - For now, analyze differentiation with no tech. change, or with firms' current technologies

Economic Theories Cont.

- Define "product differentiation space":
  - Line segment, e.g. sellers along a beach, car colors
  - Circle, e.g. beach around a lake, seasons of the year
  - 2-D square or circle, e.g. locations in a city, fertilizers
  - 2-D surface of a sphere, e.g. location on Earth
- Define how competition happens
  - Customers decide where to go
  - Pay a "transportation cost" to "get there"
  - Make purchasing decisions accordingly

Economic Theories Cont.

Drinks stands along a beach



Customers evenly spread out along the beach
They walk to nearest stand, if price is same
Assume price is same, for simplicitly
Where do you locate?
- how many firms?
- near each other or spread apart?
- leapfrogging?

May be distance along beach, or preference distance (e.g. car colors)

Firm Strategies and Differentiation

- Produce 1 or multiple varieties?
- Products different from competitors, or same?
- "Leapfrog" to retain best positions?
- Produce best varieties right away?
- Relation to entry and exit?

An Ecological Theory of Differentiation

- Hannan & Freeman (1989) borrow from ecology
- First, understand simple logistic growth model:
  - $\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$
  - N number of firms, t time, K carrying capacity, r growth rate
  - Number of firms grows until reaching carrying capacity
  - Think of N as population, r(K–N)/K as birth-death rate
  - Solution is: $N_t = \frac{KN_0}{N_0 + (K - N_0)e^{-rt}}$

Strategies in UK Fertilizer Manufacture

- Test ideas about product differentiation
- Using UK fertilizers as an example (Shaw, 1982)
- Square product differentiation space
  - Two sets of chemical elements to help plants grow
  - Nitrogen
  - Phosphorous & potassium (usu. in equal proportions)

Ecological Theory Cont.

- Next, allow for different market "niches":
  - $\frac{dN_i}{dt} = r_i N_i \left(\frac{K_i - N_i - \sum_{j \neq i} \alpha_{ij} N_j}{K_i}\right)$
  - Much like before, but each i (or j) refers to a different market niche (a different "species")
  - α_{ij} is competition coefficient between species i and j
  - Each species grows to its carrying capacity or is eliminated by competition
  - Solve by computer (you can use Stella II in Computer Centre)

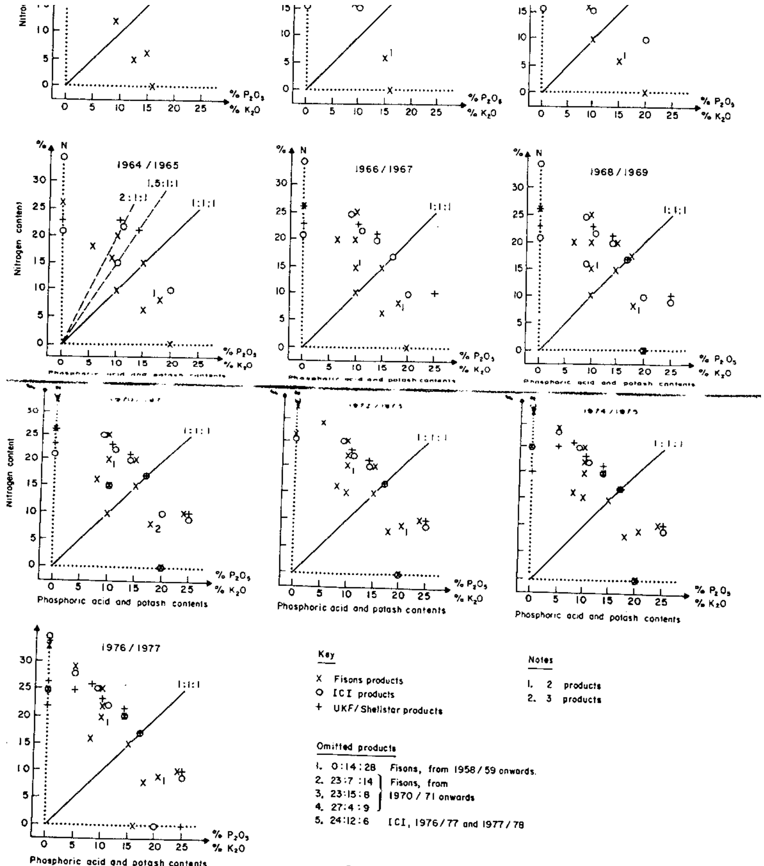


FIGURE 4
Distribution of Fertiliser Products in the Straight Nitrogen; High N; 1 : 1 : 1; Low N; and Binary PK Groups.

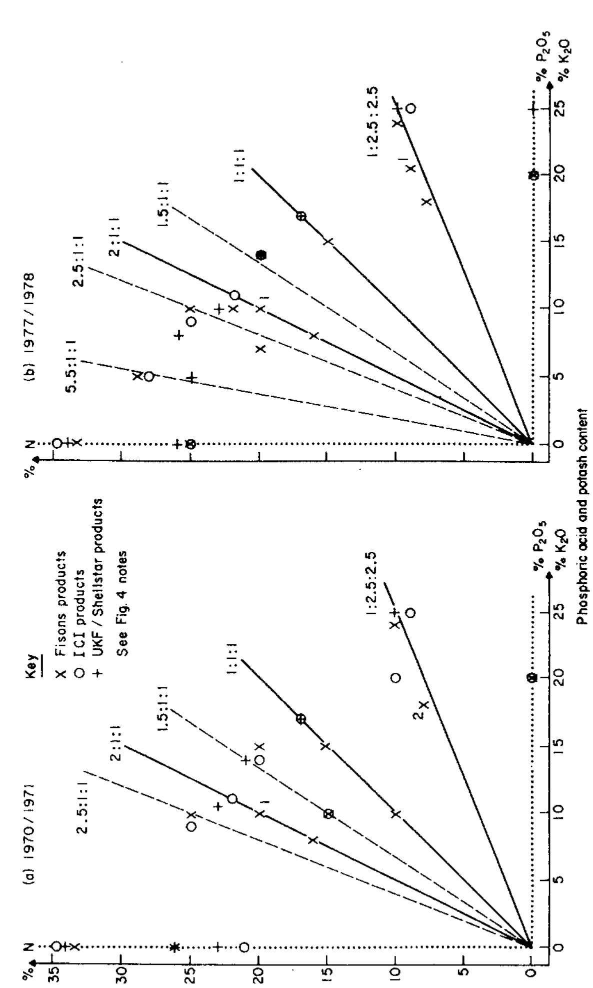


FIGURE 5
Distribution of Fertiliser Products in the Straight Nitrogen; High N; 1 : 1 : 1; Low N; and Binary PK Groups.

Technology and Differentiation

- Shakeout theory has vertical differentiation
  - Firms innovate to improve their product quality
- Market leadership turnover has horizontal and/or vertical differentiation
  - Disruptive technology yields better quality (calculators)
  - Or creates a competing market niche (hard disks)
- What if technology creates new, largely independent submarkets?
  - Protects firms from competition (penicillin)

Differentiation and Success in US Penicillin Manufacture

- Penicillin: drug, attacks bacterial disease
- Produced naturally by some mold
- Natural penicillin: types G, O, or V
  - Patents disallowed (World War II projects)
  - Produced by many firms
- Circa 1958, new techniques:
  - Extract chemical produced by mold
  - Modify it by chemical methods
  - Give to mold, get new types of penicillin
- Semi-synthetic penicillins: phenethicillin, ampicillin, …
  - Treat different diseases from natural penicillin
  - Developed by specific firms, patented
  - Legal battles limited patent rights for first 2
  - Later types patented, licensed to few firms

Table: US Penicillin Manufacturers by Type

- Also in course notes, pp. 109-110
- Drawn from Klepper and Simons (1997)
- Main source *Synthetic Organic Chemicals*
- 1948-1993
- Organized by penicillin type
  - Earliest first
  - 1988+ if made only by Beecham not all listed
- Key innovations identified by †
  - According to Achilladelis (1993)
- Innovating firm identified by *
- Table has 4 pages, numbered at bottom

Penicillin G† [Innovation dated as 1942 by Achilladelis]
Abbott 1948–1964
Baker 1948–1952
Bristol 1948–1959, 1961, 1974, 1977, 1981–1983
Commercial Solvents 1948–1959
Cutter 1948–1954
Heyden 1948–1953
Hoffman LaRoche 1948–1949
Lederle 1948–1949, 1954–1955
Lilly 1948–1969, 1972, 1976–1981
Merck 1948–1986
Pfizer 1948–1992
Schenley 1948–1953
Squibb 1948–1982
X 1948–1953, Upjohn 1954–1957
Wyeth 1948–1993
U.S. Rubber 1949
Monsanto 1954
Penick, S.B. 1954–1955

Penicillin O
X 1951–1953, Upjohn 1954–1964, 1966
Pfizer 1968–1975

Penicillin V†
*Lilly 1955–1990
Abbott 1956–1974
Wyeth 1956–1976, 1983–1985
Bristol 1958, 1970–1985, 1987, 1989–1993
Squibb 1968–1976
Pfizer 1976–1988
[*Also developed by Glaxo (UK).]

Phenethicillin†
*Bristol 1959–1975
Pfizer 1960–1965, 1967–1971
Squibb 1960–1961, 1963–1964
Wyeth 1962–1966
[*Also developed by Beecham (UK).]

Ampicillin†
Bristol 1963–1993
Wyeth 1966–1993
*Beecham 1968–1990
Squibb 1968–1976
Trade Enterprises 1971–1981
Biocraft 1972–1993
Kanasco 1986–1992

NEP penicillin
Merck 1963

Methicillin
Bristol 1961–1985
Beecham 1972–1982
Wyeth 1991

Oxacillin
Bristol 1961–1985
Beecham 1969–1992
Biocraft 1979–1992

Cloxacillin
Bristol 1964–1985
Beecham 1968–1993
Biocraft 1980–1988, 1990–1993
Kanasco 1991–1992

Nafcillin
Wyeth 1964–1990
Beecham 1975–1976, 1984–1988, 1990–1991
Bristol 1975–1977, 1979–1985, 1987

Dicloxacillin
Bristol 1966–1979, 1981–1985
Beecham 1968–1992
Wyeth 1968, 1970–1975, 1977–1989
Biocraft 1983–1993
Kanasco 1990, 1992

Hetacillin
Bristol 1966–1979, 1981–1991

Carbenicillin† [Innovation dated as 1969 by Achilladelis]
*Beecham 1970–1985, 1987, 1989+?
*Pfizer 1972–1986, 1988
Biocraft 1986

Amoxicillin
Beecham 1973–1993
Biocraft 1976–1993
Bristol 1977–1993
Trade Enterprises 1978–1979
Wyeth 1980–1985
Kanasco 1986–1992

Ticarcillin
Beecham 1976–1993

Azlocillin† [*Developed 1978 by Bayer (Germany)]

Cyclacillin
Wyeth 1978–1985
Bristol 1984–1985
Biocraft 1986, 1988
Epicillin Trade Enterprises 1978–1982
Kanasco 1986

Piperacillin
Bristol 1982–1993

Amdinocillin† [*Developed 1984 by Roche (Switzerland)]

Sulbactam† [*Developed 1986 by Pfizer]

Floxacillin
Beecham 1989+?

EC2212 Industrial Growth
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Lecture 9

Firm size and age affect growth,
and thus the firm size distribution.

Measures of Firm Size

- Different measures for different purposes
  – Financial or stock market value
  – Employees
  – Productive capacity
  – Value of production
  – Value added of production (output – inputs)
- Highly correlated
- Employees, production main focus today

No Equilibrium Firm Size

- Size changes gradually
  – No instant expansion to a desired size
  – Finance, hiring, training, purchase & set-up of equipment and operating methods take time
- Firm size apparently unlimited
  – U-shaped long run cost curves of firms are mythical
  – May be U-shaped short run curves, long run curves for a particular plant
  – Multi-product firms can keep expanding, reorganizing
  – Witness IBM, General Motors, Microsoft, etc.

Observed Growth of Firms & Plants

- Examine patterns for US plants
- Patterns are similar for firms
- Relation between % growth and age, size
- (Ignoring many other correlates of growth.)
- Dunne, Roberts, and Samuelson (1989)

Limits to Firm Growth

- Penrose (1959), *The Theory of the Growth of the Firm*
- No equilibrium amount of output
- Optimal growth rate instead
- Growth is limited
  - Managerial limits to expansion activities
  - Training of new employees by old
  - E.g., convex costs of growth, $g'>0$, $g''>0$

Average Five-Year Growth Rates among Surviving Plants

Age	Plant Size (# of employees)				
(years)	5-19	20-49	50-99	100-249	250+
1-5	61%	30%	19%	13%	7%
6-10	34%	14%	7%	1%	-1%
11-15	31%	6%	-1%	-2%	-2%

Simple Representations of Growth

- Gibrat's "law"
  - All firms have same probability distribution for % growth (at a given time)
  - E.g., firms with 10 vs. 10,000 employees have same chance to grow 50% or more in a year
- Modifications:
  - Serial correlation
  - Merger
  - Effects of firm size, age, skill, technology, ...

Observed Growth of Firms in an Industry

- Measure size within the product industry
- Growth limited by market size
- Size at time of entry
  - Entrants at different times have similar sizes?
  - Or does initial size grow/fall over time? Why?
- Which firms grows how much, which exit?
- Hence how does size distribution evolve?

Average Five-Year Exit Rates

Age (years)	Plant Size (# of employees) 5-19	20-49	50-99	100-249	250+
1-5	41%	40%	39%	33%	23%
6-10	35%	27%	28%	25%	16%
11-15	30%	21%	23%	21%	13%

Size 1 Year After Entry, US Tires

Entry Year	No. firms by Initial capitalization (US $) ?	J	K	L	M	N	Total Firms
1905-09	17	2	6	2	2	3	32
1910-14	29	20	19	20	18	4	110
1915-19	23	1	13	33	25	8	103
1920-24	69	7	15	48	33	10	182
1925-29	19	0	3	12	7	0	41
1930-80	21	0	4	11	14	23	73
Total	178	30	60	126	99	48	541

J=$2,500-9,999 K=$10,000-49,999 L=50,000-199,999 M=200,000-999,999 N=$1M+

Not adjusted for inflation. Some firms are multi-product firms. Median shaded.

Average Five-Year Growth Rates, with Exit = -100% Growth

Age (years)	Plant Size (# of employees) 5-19	20-49	50-99	100-249	250+
1-5	-6%	-22%	-28%	-24%	-18%
6-10	-13%	-17%	-23%	-24%	-17%
11-15	-9%	-16%	-24%	-22%	-15%

Skew Size Distributions Result

- Gibrat's law + entry yields skew size distribution
  - Ijiri and Simon (1977), *Skew Distributions and the Sizes of Business Firms* (with Bonini)
  - Who produces each new unit of output?
    - Probability α of production by a new firm
    - Otherwise, probability proportionate to firm size
- Skew distribution (many small firms, few large) results as # of draws $\rightarrow \infty$

Size Distribution, US Tires

	No. firms by Capitalization (US $)						Total
Year	?	J	K	L	M	N	Firms
1910	14	1	10	14	6	4	49
1920	59	9	23	53	51	35	230
1930	16	1	6	19	27	28	97
1940	6	0	3	10	10	23	52
1950	7	0	2	3	8	21	41
1960	3	0	2	4	2	28	39
1970	3	0	1	1	1	18	24
1980	7	0	0	1	3	18	29

J=$2,500-9,999 K=$10,000-49,999 L=50,000-199,999 M=200,000-999,999 N=$1M+

Not adjusted for inflation. Some firms are multi-product firms. Median shaded.

Skew Distributions: A General Phenomenon

- Ijiri & Simon point out generality:
  - Sizes of business firms (Fortune 500)
  - Populations of cities
  - How often words appear in a book
- Same principle works in each case
  - New entities appear with some probability
  - Likelihood of next appearance proportionate to number of past appearances

Firm Size Distributions

- How many firms are of each size
- Used to calculate measures of concentration
  - N-firm concentration ratio: Σs_i, N largest firms
  - Herfindahl index: Σs_i^2, all firms
- Affected by
  - Entry and exit (and sizes of entrants & exitors)
  - Growth

Comparative Advantage in International Trade

- Classical international trade models
  - Different countries' comparative advantage in different industries
  - Produce where the advantage exists, and trade
- International trade in new growth models
  - Concentrations of success build up
  - Success breeds success, and may pertain to all industries
  - Possibly yielding a poverty trap

You Have Learned

- Penrose's theory of limited firm growth
- Gibrat's "law": growth independent of size
- Growth faster for younger, smaller plants
- Within industry: entry, exit, growth
  - Entry size grew somewhat in tires
  - Surviving firms' median size grew in tires
- Evolution of skew size distributions

Comparative Advantage Example

- Utility = F*E, from Food and Entertainment
- 100 people each in countries A and B

	Country A			Country B		
	Pvity	Output	Cons.	Pvity	Output	Cons.
Food	2	200	100	1	0	100
Entert.	1	0	100	2	200	100

EC2212 Industrial Growth and Competition

Lecture 10

Firms' technological success fuels nations' economic growth.

Anam Industrial: Linear Development

- Korea's Anam Industrial, world's largest semiconductor packaging company
- Hobday (1995) characterizes linear growth phases:
  - 1968-80 Packaging chips into plastic/ceramic cases
    - machinery, engineering, product design, materials from US
  - 1980-85 Greater in-house process engineering
    - aided by US companies such as Texas Instruments
  - 1986-1990s In-house process engineering, products
    - technology diffusion & in-house engineering growth
  - By 1992, US $1.8 billion of export sales

Poverty Trap Example

- Utility = F*E, from Food and Entertainment
- 100 people each in countries A and B

	Country A			Country B		
	Pvity	Output	Cons.	Pvity	Output	Cons.
Food	2	100	100	1	50	50
Entert.	2	100	100	1	50	50

- No trade needs to occur, A better off than B
- Can B improve its productivity?

Founder: Leapfrog Development

- China's Founder, for Chinese language printing systems
- Lu (2000) describes its growth:
  - Drew on knowledge and skills from Beijing University
  - Copied & created state-of-the-art laser printing technologies
  - Introduced a product competitive internationally
  - Able to outcompete British, Japanese, US firms

Linear and Leapfrog Models of Technology Development

- Depictions of technology development for developing countries
  - Linear: Start with simplest technology, gradually build up
  - Leapfrog: Jump immediately to a complex technology, use for international competition
- These development patterns happen not just for a country in aggregate, but also for its companies
  - Companies are the bulk of the technology development process

Catching Up to the Competition

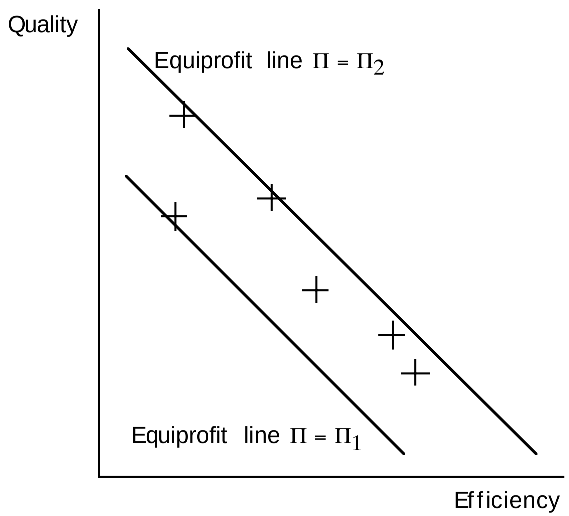
- A. Producers within a country's protected market
  - Vary in quality, efficiency
  - Quality and efficiency enhance profit
  - Minimum competitive quality, efficiency yields 0 profit
- B. International producers: higher quality, efficiency
  - How can you measure what it takes to catch up, i.e., be competitive internationally?
  - Look at quality, efficiency differences
  - Benchmarking

Leapfrogging Argument

In high-tech areas, there are big lags between our country and advanced countries. Many new ideas and methods originate abroad…. However, we should not be satisfied with merely catching up because this would not come up with competitive products. It was inevitable that we would catch up for quite a long time. However, it was possible to leap forward based on our indigenous innovative capabilities.

- Chief Designer of the Founder System

A. Within-Country Competition



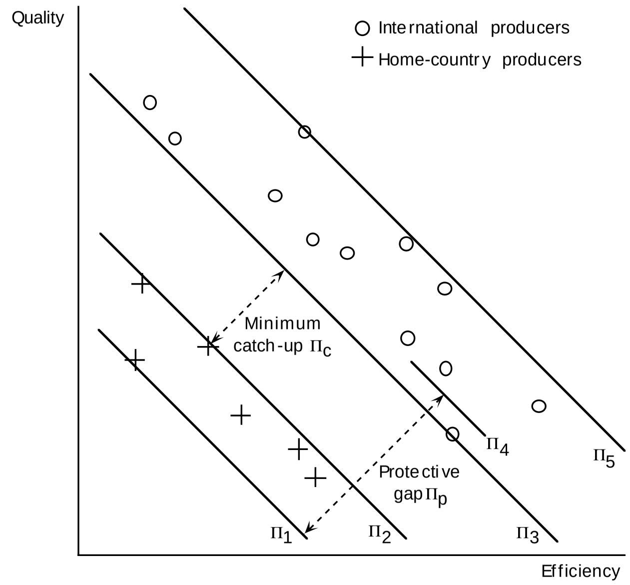
When Can Leapfrogging Work?

- Either competitors don't exist yet
  - Enter early in an industry with a shakeout
- Or new technology helps surpass the competition
  - Facilitates turnover of corporate leadership
- Or technology (etc.) not competitively crucial
  - No shakeout, no disadvantage to late entrants
- Indigenous advantages, such as initially low labor costs, also help

National Technology Policy

- What can a national government do?
- National technology programs:
  - MITI (Ministry of International Trade and Industry, now METI: Ministry of Economy,Trade, and Industry)
  - Advanced Technology Program
  - Big government-funded projects often spectacular failures, are out of favor
  - But not always failures, operate at varying scales
  - Best not to presume inter-firm cooperation

B. Between-Country Competition



National Technology Policy cont.

- Other policies:
  - Location incentives (including for multinationals)
  - Tax & funding incentives targeted by technology
  - University R&D funding
  - Education
  - Change cultures that hinder innovation
  - Shift emphasis off military R&D, or encourage transfer of military technology

C. Catching Up

- Benchmark to determine differences now
- Estimate technology growth rates for competitors
- How much technology is needed in future to be competitive?
- How can you catch up?
  - What improvements to make, strategies, how to get technology?
  - Cost? Worth the investment?
  - What are the odds?