Lecture 5
Innovation and Market Structure

E5104 – Economics of Innovation

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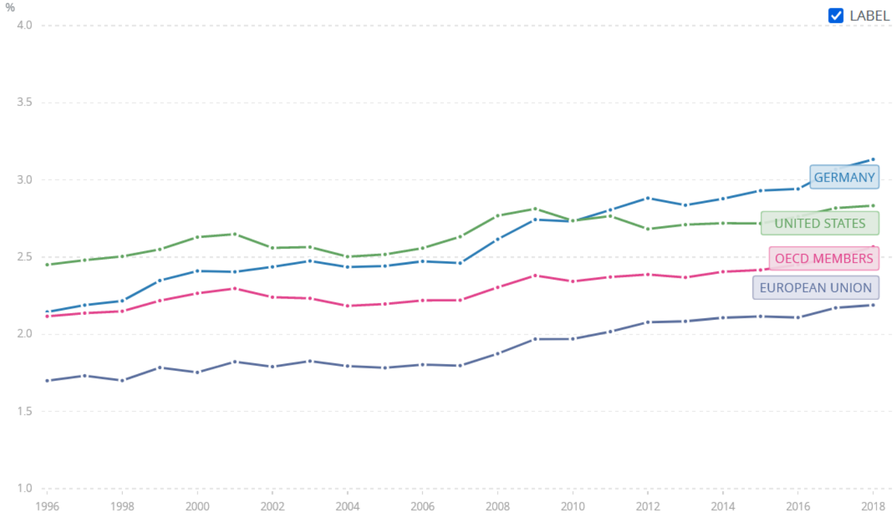
Today's Questions

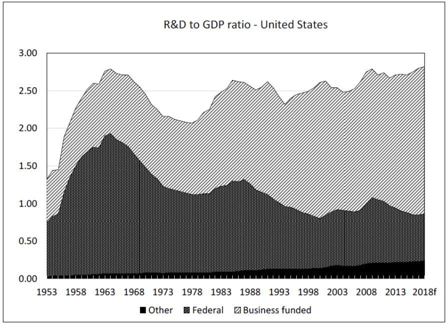
- How does the market environment affect firms' innovative activities?
  - Industry
  - Market concentration
  - Competition
- Innovative activity = R&D spending
  - What's wrong with patent counts?
  - What's wrong with innovation survey measures?

R&D Expenditure (in % GDP)



Source: https://data.worldbank.org

R&D Expenditure (in % GDP)



Source: NSF STI Indicators, Appendix Table 4-1

- Substantial increase in spending funded by industry
- …coupled with decline in federal spending (end of cold war arms race?)
- Business funded R&D in U.S. increased from 0.5% to 1.8% of GDP i the past 50 years
  - technological opportunity
  - market demand for new products
- Bloom et al. (2020): not associated with increased productivity and economic growth

Industrial R&D Varies by Industry!!!

	R&D/Sales	Share R&D
Pharma and medicines	10.46%	16.35%
Semiconductor	8.94%	8.41%
Software publishers	12.22%	7.35%
Other information	10.17&	7.35%
Motor vehicles	3.00%	5.93%
Other computer	5.31%	5.37%
…		

- Six sectors could for half of all U.S. R&D spending
- Some (not all) very R&D intensive
- Half of six highly R&D intensive industries are not in manufacturing
- One of most important predictor of innovation is **industry**

Are R&D Intensities Related to Firm Size?

Table 2: Worldwide R&D to sales ratio for US-based firms in 2018 by firm size

Size (number employees)	*R&D (M$)*	*R&D to sales*	*Share R&D*
10–19	4,518	21.42%	0.8%
20–49	11,821	16.04%	2.2%
50–99	13,013	9.51%	2.4%
100–249	20,420	5.78%	3.8%
250–499	21,824	6.70%	4.0%
500–999	20,214	3.96%	3.7%
1,000–4,999	83,761	4.26%	15.5%
5,000–9,999	60,875	4.43%	11.2%
10,000–24,999	106,777	3.25%	19.7%
25,000 or more	198,190	3.09%	36.6%
All	**541,413**	**3.74%**	

Worldwide R&D performed by US company and paid for by company & others
Source: Authors' computations from NSF S&E Indicators for 2018

Are R&D Intensities Related to Firm Size?

- Majority of R&D (83%) is performed by large firms with more than 1000 employees
- When small and medium-size firms perform R&D, their intensity is much higher (few do R&D, though)
- Why?
  - *Selection:* For smaller firms, failure means they disappear from the market; the same is not true for larger firms
  - Larger firms are broader in their activities. Small firms, if they do R&D, are often specialized in R&D
- Example: pharma where large firms also manufacture drugs, market, and distribute them (cf. Cohen & Klepper 1996)

Competition and Innovation

Which Market Structure is Favorable to Innovation?

- Advantages of monopoly and large firms partly come from economies of scale and scope
  - R&D is a fixed cost, spreading it over more units is efficient
  - Multi-product firms can more efficiently internalize spillovers
  - In some circumstances, monopolists face greater incentives to innovate (because they lose market power if they fail to innovate)
    - Gilbert and Newbery (1982): incentive to remain a monopolist is greater than an entrant's incentive to become a monopolist.
  - Large firms may find it easier to finance
  - *Welfare angle:* Pure monopolist reduces redundant R&D spending

- Advantages for competition
  - "Creative destruction" can spur innovation (Schumpeter 1942)
  - Under competition, pressure to innovate comes from fear of entrants innovating
  - *Welfare angle:* Innovation is uncertain, and with more than one firm in the market it is easer to achieve a diversity of approaches

In a Static World

- First best solution: cover fixed cost of an invention with a lump-sum tax and let competition bring the price down to marginal cost
- Property-rights solution:
  - *Patent protection* for an inventor, grants inventor a short-term monopoly
    - All projects whose costs are covered by profits are realized
    - But: deadweight loss from monopoly pricing
  - What if patent protection is not available? *First-mover advantage*
    - Imitation; consumer surplus grows and profits and deadweight loss shrink as more entrants arrive and imitate
    - No entry past the point where profits cover R&D costs

In a Static World: Recap

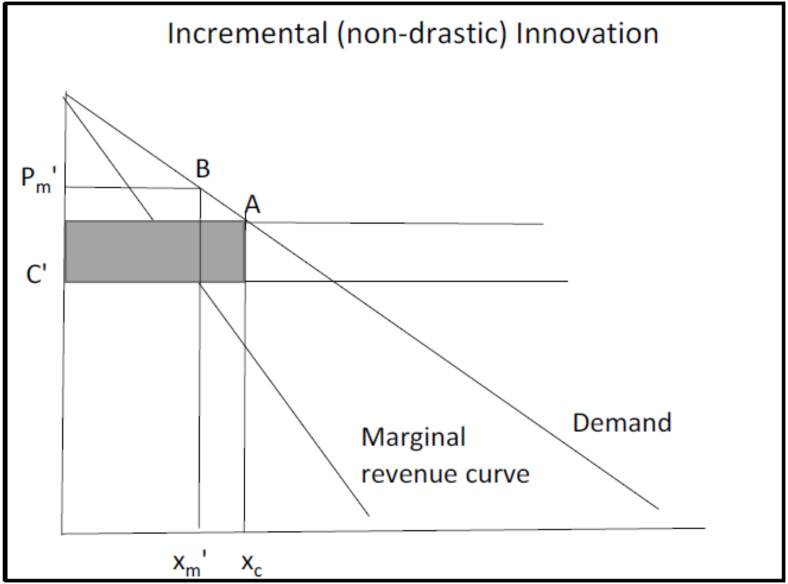
1. *Cautious*: More innovation with patents, as their are higher profits to cover the costs (at cost of DWL)
2. Without patents, number of firms in the market depends on relative cost of imitation. High imitation costs? Few firms will find it profitable to enter
3. If there is no first-mover advantage, in equilibrium, no firm will enter if innovation cost is greater than imitation cost

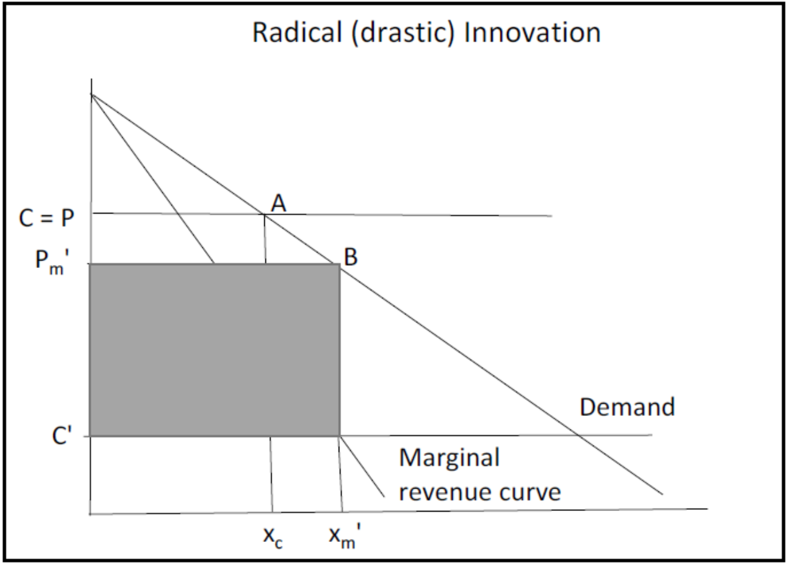
Monopoly or Competition: Schumpeter (1942)

- Expectation of some transient ex post market power gives the incentive to invest in R&D *(post-innovation market power)*
- Possession of ex ante market power (linked to an ex ante imperfect competition market structure) also favors innovation
  1. oligopolistic market structure is more stable, reduces uncertainty of excess rivalry undermining incentives to invent
  2. with imperfect financial markets, the profits from ex ante market power help with the financing of innovation
- So: more market power, more R&D investment

Monopoly or Competition? Arrow (1962)

- Cost-saving innovation; perfectly appropriable (no imitation). Can lower unit cost from c to c'
- *Key distinction:* Drastic vs. non-drastic innovation
- Non-drastic/incremental:
  - $p'_M > c$
  - Potential post-innovation monopoly price is above the pre-innovation unit cost; limits the market power of the innovator.
- Drastic/radical:
  - $p'_M < c$
  - Post-innovation monopoly price is below the pre-innovation unit cost; innovator drives everyone out of the market.


Incremental (non-drastic) Innovation
B
A
P_m'
C'
Marginal
revenue curve
Demand
x_m'
x_c


Radical (drastic) Innovation
A
C = P
B
Pm'
Demand
C'
Marginal
revenue curve
xc
xm'

Monopoly or Competition? Arrow (1962)

- Pre-innovation market structure: Competition
  - Profit prior to innovation: 0
  - Radical innovation: firm becomes monopolist; p'_M and q'_M; profits are Π'_M
  - Incremental innovation: firm cannot price higher than c (competition from the old technology); quantity is x_C; costs have fallen to c'; profits are $x_c(c - c')$.
- Pre-innovation market structure: Monopoly
  - Either innovation: pre-innovation profits are Π_M; post-innovation profits are Π'_M

Benefits from Innovation: Arrow's "Replacement Effect"

	Competition	Monopoly	Compare
Non-drastic innovation	$x_C(c - c') - 0$	$\Pi'_M - \Pi_M$	$M < C$
Drastic innovation	$\Pi'_M - 0$	$\Pi'_M - \Pi_M$	$M < C \iff \Pi_M > 0$

- In this static model, monopolist has less incentive to innovate because she already has some profit, and cost reduction is spread over smaller output then in competition
- Monopolist has relatively stronger incentive for minor than major innovations

An Entry Threat Can Reverse This Result

- Gilbert and Newbery (1982): allow for entry
- Monopolist has greater incentive to introduce new patented technology than an entrant
- Because profits from pre-empting a potential entrant are greater than the profits he would earn if they were to compete (or collude)
- Competition or monopoly? Depends on what we assume about potential entry threats.

Gilbert and Newbery (1982): Setup

- Suppose one firm has monopoly on a product, and a new innovation may infringe on this monopoly power.
  - i.e., asymmetric firms
- Example: successive versions of computers, software, . . .
- *Questions:*
  - Who has the highest incentive to do research?
  - Monopolist to protect profits?
  - Or entrants to start making profits?

Gilbert and Newbery (1982): Setup

- Entry into the monopolized market only through the invention and patenting of a single patentable substitute for the monopolist's product.
- There are two products:
  1. Current product on which firm 1 has monopoly; sells at price P_1^m
  2. New product sold (either by monopolist or entrant) at a price P_2
- Before patenting of second product, monopolist has profit $\Pi(P_1^m)$.

Gilbert and Newbery (1982): Setup

- After patenting of the second product:
  1. If product is patented by monopolist: $\Pi(P_1^m, P_2^m)$ for the monopolist and 0 for the entrant.
  2. If product is patented by entrant: $\Pi^m(P_1^m, P_2^e)$ for the monopolist and $\Pi^e(P_1^m, P_2^e)$ for the entrant
- Monopolist has option of patenting the substitute technology or allowing entry to occur.
- Discovery time is deterministic (as in Dasgupta-Stiglitz-1980).
- Let $C(T)$ be the cost of research allowing to obtain discovery at T.

The Simple Model

- There is free entry into patent competition.
- Suppose that potential entrants spend money to enter the market.
- With free entry into patent competition, discovery time T^* will be the earliest date at which zero profit is made:

$$C(T^*) = \int_{T^*}^{\infty} \Pi^e(P_1^m, P_2^e)e^{-rt}dt$$

- With entry, the monopolist has an expected gain of

$$\int_0^{T^*} \Pi(P_1^m)e^{-rt}dt + \int_{T^*}^{\infty} \Pi^m(P_1^m, P_2^e)e^{-rt}dt$$

The Simple Model

- If, instead, the monopolist decides to patent, she must invent at a date $T^* - \epsilon$ at a cost $C(T) + \delta(\epsilon)$. It is safe to assume ϵ and $\delta(\epsilon)$ are arbitrarily small. In other words: by investing $C(T^*)$, the monopolist is the first one to invent (a limit argument!). Monopolist's profits are then:

$$\int_0^{T^*} \Pi(P_1^m)e^{-rt}dt + \int_{T^*}^{\infty} \Pi^m(P_1^m, P_2^m)e^{-rt}dt - C(T^*)$$

- Hence, monopolist prefers to invest if

$$\int_{T^*}^{\infty} \Pi^m(P_1^m, P_2^m)e^{-rt}dt - C(T^*) \geq \int_{T^*}^{\infty} \Pi^m(P_1^m, P_2^e)e^{-rt}dt$$

or

$$\int_{T^*}^{\infty} \{\Pi^m(P_1^m, P_2^m) - [\Pi^m(P_1^m, P_2^e) + \Pi^e(P_1^m, P_2^e)]\}\, e^{-rt}dt \geq 0$$

The Simple Model

- The monopolist invests more (and hence persists!) if

$$\Pi^m(P_1^m, P_2^m) \geq \Pi^m(P_1^m, P_2^e) + \Pi^e(P_1^m, P_2^e)$$

Proposition (Preemptive Patenting)

1. *The monopolist preemptively patents if the loss in profit due to entry is higher than the profit of the entrant.*
2. *The monopolist preemptively patents if the maximal monopoly profits from both products are higher than the total industry profit earned when an entrant patents.*

Discussion

- Paper also contains a more general model.
- Allowing for the possibility of entry has a marked effect on monopoly incentives (unlike Arrow-1962 who argues that [with the threat of entry], the monopolist has weaker R&D incentives than a firm under competitive conditions).
- Monopolist will achieve this through “sleeping patents” (patents that are not used) when even after patenting the second product, it holds that

$$\Pi^m(P_1^m, P_2^m) < \Pi(P_1^m).$$

More Competition $\rightarrow$ More Innovation

- Scherer (1980)
  - insulation from competition or competitive pressure may breed bureaucratic inertia
  - discourages innovation
- Porter (1990)
  - Porter argues from a behavioral perspective (study on national competitive advantage)
  - active pressure from rivals stimulates innovation as much from fear of falling behind as the inducement of getting ahead
  - in his view, more intense rivalry in national markets contributes to the emergence of more capable, innovative firms

Aghion et al. (2005): A Dynamic Perspective

- Show an inverted U-shape between competition (firm's markup) and innovation (citation-weighted patents)
- Model:
  - Firms innovate to climb a quality ladder, moving one step at a time
  - Firms succeed with probability determined by level of R&D
  - Firms are either *neck-in-neck* (at the same point) or *leader-follower* (one step behind on the quality ladder)
  - Follower is assumed to imitate the leader and move up with small probability
  - When neck-in-neck: Bertrand competition or some degree of quantity competition
- Model nests Arrow (1962) when on different steps:
  - Zero profits for the follower
  - Profit for the leader determined by the size of the step

Aghion et al. (2005): Conclusions

1. Research intensity of neck-in-neck increases with less collusion (*escape-competition effect*); research intensity of laggard firm declines with less collusion (the *Schumpeterian effect*)
   - Competition is good for innovation if firms are on the same level; but discourages innovation of firms behind

2. Low imitation probability of success: aggregate innovation rate follows inverted U-shape relationship

3. Technological gap between leader and follower increases as product market competition increases

Empirical Evidence: What do we know?

Positive Relationship (Geroski 1990)

- Market structure and innovation (the output of innovative activity) rather than R&D (an input)
- Innovation measure: counts of commercially significant innovations from the Science Policy Research Unit (SPRU) database; 1378 innovations btw. 1945 and 1983
- Different measures: market structure, but also entry, exit, import penetration, number of small firms
- Findings: positive relationship between competition and innovation; reversal he attributes to inclusion of a control for technological opportunity
- Further: industry-level factors are important; dropping the industry FE ("technological opportunity") reversed basic finding of positive relationship

Mixed Results (Blundell et al. 1999)

- Relationship between ex ante market power (market share) and innovation (commercially significant innovations from the SPRU database)
- Panel of 340 firms; 1972–1982
- Findings:
  - market share has positive effect on innovation
  - overall market concentration has negative effect on innovation
- Summary: market share/market power stimulates innovation; concentrated industries, however, innovate less

Inverted U-Shape (Aghion et al. 2005)

- 21-year panel, 1973–1994, 17 two-digit industries
- Inverted U-shape relationship between market power (average Lerner index) and industry innovation (average number of citation-weighted patents)
- Also U-shaped relationship in Aghion et al. (2009), but with entry

Concentration Dampens Innovation (Koeller 1995)

- Finds a negative effect of concentration on small firms' innovative output
- The results hint at differential effects of structure on small vs. large firms
- The literature on life cycles goes at it (e.g., Cohen and Klepper 1996)

Competition is Good for Innovation

- Aghion et al. (2018): provide results on a causal relationship between competition and innovation from laboratory experiments (positive effect)
- Igami and Uetake (2020): exploit the consolidation of the hard disk drive industry to establish a causal link (positive effect)
- Bloom et al. (2016):
  - Chinese imports as a proxy for competition faced by European firms
  - They show that firms facing higher levels of Chinese import competition apply for more patents, raise their IT intensity, and increase their overall level of productivity.
- Autor et al. (2020): taking the same approach as Bloom et al. (2016), show that for publicly listed companies in the U.S., increased competitive pressure reduced investment in R&D and decreased output of innovation (measured by patent grants).