Week 9: Introduction to Markets for Ideas

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Econ 220C: Topics in Industrial Organization

Upcoming deadlines and logistics

- Problem set 2 due on Friday 4/14 (posted today)
- Research proposal due Friday 5/12
  - There will be an intermediate meeting with Ben and me, details forthcoming
- Paper comments due 24 hours before class
- Office hours on Wednesdays 1-2pm in Haas F-690 (please sign up in advance)

Roadmap

1. Introduction to markets for ideas
2. Intellectual property rights
3. Demand and innovation
4. Innovation and competition
5. The economics of basic science
6. The funding of science and innovative activity

Key Themes

Throughout these six lectures, I plan to highlight three key themes:

1. The potential for market failures and the importance of policy in markets for ideas
2. The interplay and complementarity between theory and empirics
3. The importance of understanding institutions and settings

Second half overview

Why study markets for ideas and innovation?
- Markets for ideas are important
- Markets for ideas are unusual

Are ideas getting harder to find?
- Idea production
- Bloom et al. (2020)

Optimal patent length
- Nordhaus (1969) and Budish et al. (2016)

What is innovation?

- Innovation is the discovery, development, and diffusion of new goods, services, or production processes
- It is how society expands the production possibilities frontier
- Economists also understand that innovation is a process that involves agents responding to incentives. It can be a policy choice!

Innovation is synonymous with economic growth

Recall the Solow model:

$$Y_t = A_t K_t^{\alpha} (L_t)^{(1-\alpha)}$$

$$y_t = A_t k_t^{\alpha}$$

$$\dot{y}_t / y_t = g_y = g_A + \alpha g_k$$

Takeaway: growth in A is *critical* for economic growth. But A is often treated as a black box ("Solow residual"). Big goal of this class is to open that black box

Innovation and growth I: GDP per capita

Explosion in prosperity in the late 18th century:

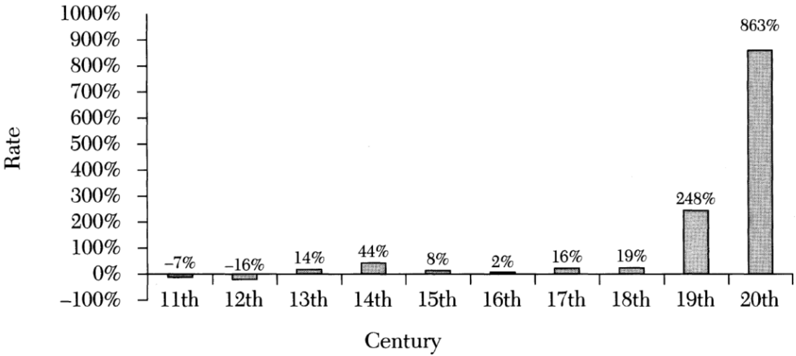
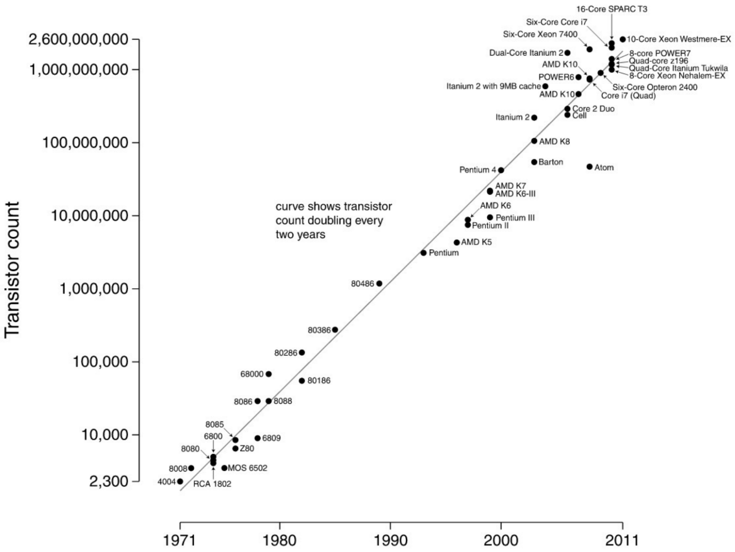


Figure 1. Growth in Real World Per-Capita GDP by Century.
Source: J. Bradford DeLong 2000.

Innovation and growth II: Microchips

Moore's Law:



Innovation and growth III: Agriculture

Innovation has saved us from a Malthusian fate:

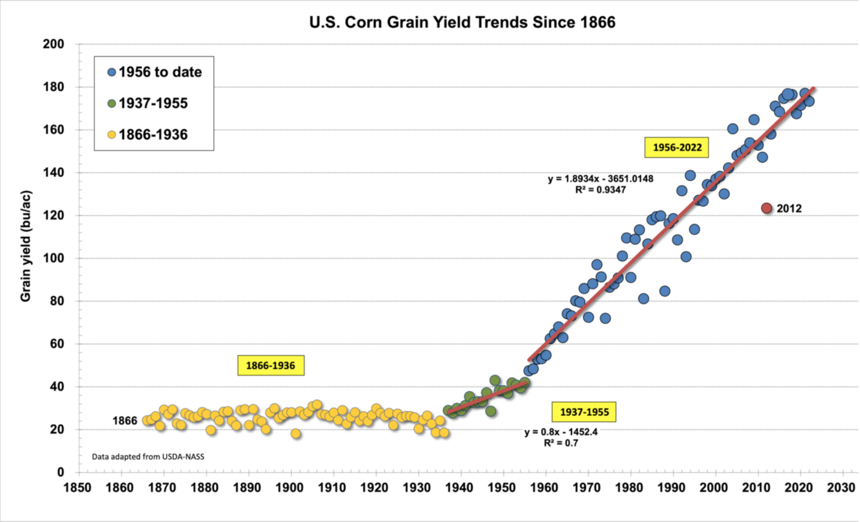


Fig. 1. Annual U.S. Corn Grain Yields and Historical Trends Since 1866. Data derived from annual USDA-NASS Crop Production Reports.

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What makes ideas unique?

Several features, but here are two important ones:

1. Ideas are non-rival
2. Ideas are non-excludable

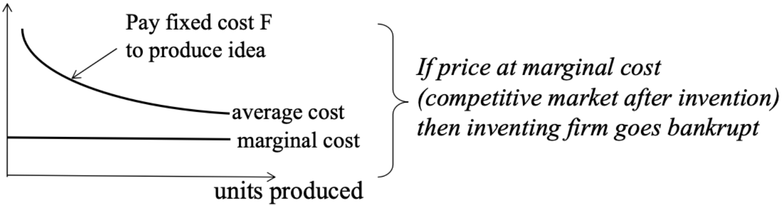
We will come back to these features throughout the course. They suggest that markets alone will not function well for the production of ideas

Ideas are non-rival

- Use of an idea by one person does not preclude or reduce the value to another person
- Examples:
  - Invention of calculus
  - Assembly line manufacturing
  - Newest way of adjusting standard errors for TWFE
- New ideas lead to positive spillovers. Innovator does not capture full benefit $\rightarrow$ underinvestment in new ideas

Non-rivalry leads to increasing returns to scale

- Ideas are expensive to produce but free to copy / re-use
- This is great for growth! Recall that A in the Solow model has increasing returns to scale (why?)
- However, non-rivalry means we will produce inefficiently few ideas



Ideas are non-excludable

- Generally, ideas are non-excludable $\rightarrow$ you can't stop someone else from using them once they are out there
- There are important exceptions:
  - Institutions like the patent system give innovators the right to exclude
  - Other ways to exclude: trade secrets, etc.

Ideas are public goods

Non-rivalry and non-excludability make ideas public goods:

	non-rival	rival
non-excludable	public goods (lighthouse, mathematical formulas)	common resources (fish in the ocean)
excludable	club goods (patented ideas, Spotify subscription)	private goods (sandwich)

Public goods lead to the free-rider problem and under-investment. Institutions and interventions are therefore critical:

- Patent system allows for ex-post excludability (trade monopoly for underinvestment)
- Government funding of basic research allows for ex-ante funding

Other special features of ideas

- Developing ideas is an uncertain process and effort is not always observable
- Ideas are cumulative (relates again to positive spillovers)

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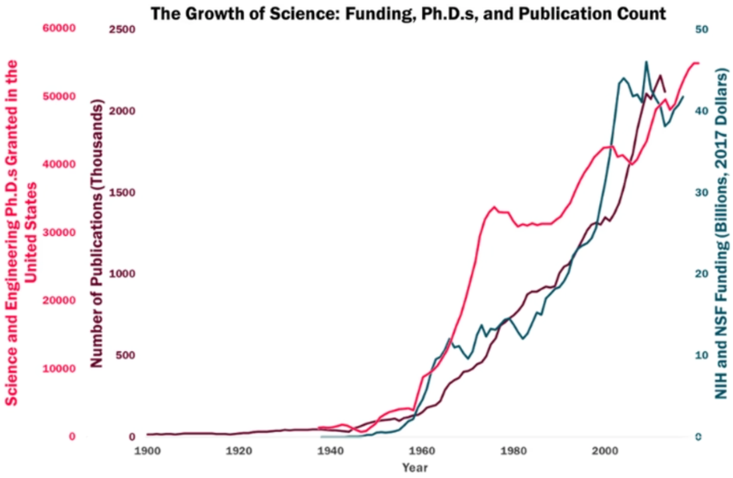
Production function of ideas

- Hopefully I have convinced you that ideas are key for growth
- But where do ideas themselves come from?
- Some competing theories:
  - Past ideas make current researchers more productive (Newton's "standing on the shoulders of giants")
  - Past ideas make current research harder ("fishing out")
    "It's hard to believe, for me, anyway, that anything as comprehensive as Darwin's view of the evolution of life or Mendel's understanding of the nature of heredity will be easy to come by again. After all, these have been discovered!" – Bentley Glass

Evidence of diminishing returns

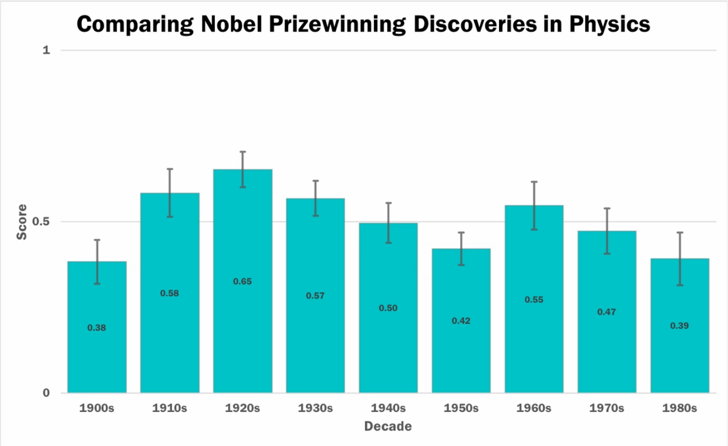
We spend more than ever on science...



Data from Patrick Collison and Michael Nielsen

Evidence of diminishing returns

But not clear that we are discovering more important ideas. Evidence from Collison and Nielsen survey of academics (pairwise discovery comparisons)



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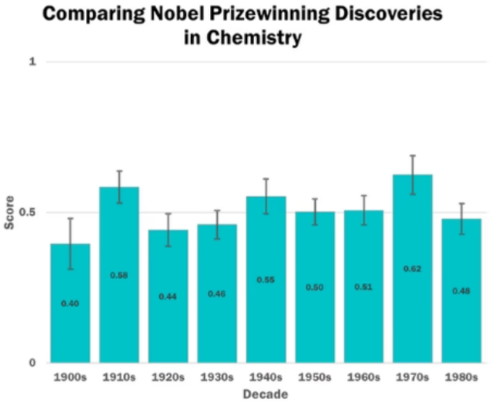

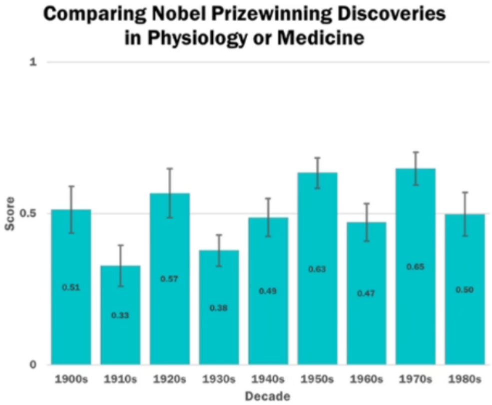

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Bloom, Jones, Van Reenan, and Webb (2020)

- Bloom et al. (2020) formalize this idea
- Let S_t be some measure of research input (scientists). Then growth in A can be written as:

  $$\frac{\dot{A}_t}{A_t} = g_A = \alpha S_t$$

  where α is research productivity
- Then, research productivity is:

  $$\alpha = \frac{\dot{A}_t / A_t}{S_t} = \frac{\#\text{ of new ideas}_t}{\#\text{ of researchers}_t}$$

- Note: what are we assuming about the "unit size" of a new idea? Raises output by a constant percentage. Why?

Key question: how is α trending over time?

- We think $\dot{A}_t/A_t$ is pretty stable over time
- But that does not mean that α is constant!
- Indeed, macro evidence suggests not:

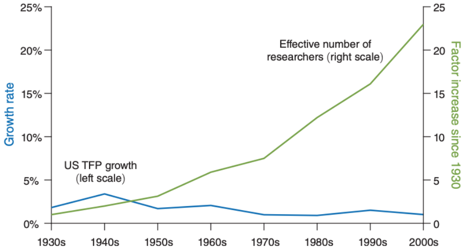

FIGURE 1. AGGREGATE DATA ON GROWTH AND RESEARCH EFFORT

Notes: The idea output measure is TFP growth, by decade (and for 2000–2014 for the latest observation). For the years since 1950, this measure is the Bureau of Labor Statistics (2017) Private Business Sector multifactor productivity growth series, adding back in the contributions from R&D and IPP. For the 1930s and 1940s, we use the measure from Gordon (2016). The idea input measure, *Effective number of researchers*, is gross domestic investment in intellectual property products from the National Income and Product Accounts (Bureau of Economic Analysis 2017), deflated by a measure of the nominal wage for high-skilled workers.

Three case studies

Macro evidence could be misleading. Paper presents three carefully done case studies that all tell a similar story:

1. Semiconductors
2. Crop yields
3. Drug development

For each industry, the authors want to compute the time series of:

- Technological growth ($\dot{A}_t/A_t$)
- "Effective scientists" or "research effort" (S_t)

Evidence from semiconductors

- Moore's Law implies $\dot{A}_t/A_t = 0.35$ (doubling every 2 years)
- S_t = R&D expenditure by major seminconductor firms deflated by nominal wage of high-skilled workers

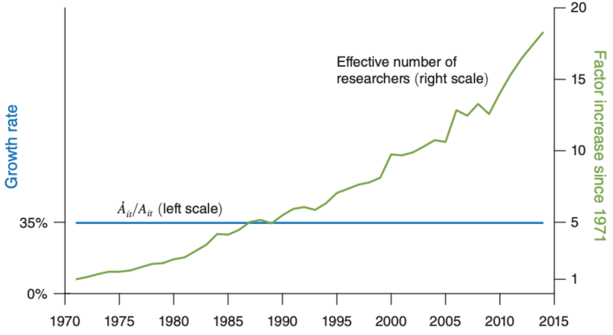

FIGURE 4. DATA ON MOORE'S LAW

Notes: The effective number of researchers is measured by deflating the nominal semiconductor R&D expenditures of key firms by the average wage of high-skilled workers and is normalized to 1 in 1970. The R&D data include research by Intel, Fairchild, National Semiconductor, Texas Instruments, Motorola, and more than two dozen other semiconductor firms and equipment manufacturers; see Table 1 for more details.

Evidence from agriculture

- $\dot{A}_t / A_t$ = yield per acre growth rate
- S_t = public + private agricultural R&D expenditure deflated by nominal wage of high-skilled workers
  - R&D on biological efficiency (genetic modification of seeds) AND
  - R&D on biological efficiency + pesticides, etc.

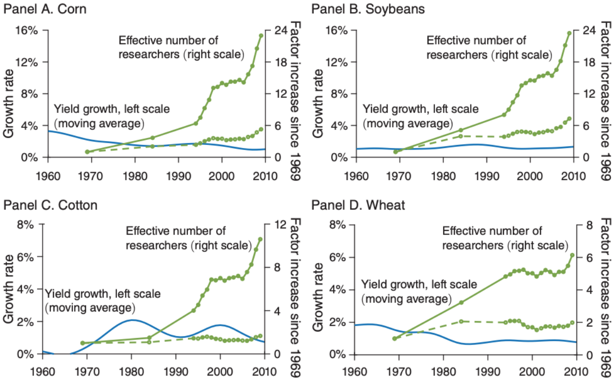

FIGURE 6. YIELD GROWTH AND RESEARCH EFFORT BY CROP

Notes: The blue line is the annual growth rate of the smoothed crop yields over the following 5 years; national realized yields for each crop are taken from the US Department of Agriculture National Agricultural Statistics Service (2016). The two green lines report *effective research*: the solid line is based on R&D targeting seed efficiency only; the dashed lower line additionally includes research on crop protection. Both are normalized to 1 in 1969. R&D expenditures are deflated by a measure of the nominal wage for high-skilled workers. See the online Appendix for more details.

Evidence from biomedical sciences

- $\dot{A}_t / A_t$ = years of life saved
- S_t = number of publications OR number of clinical trials
- $\alpha = \dfrac{\text{years of life saved}}{\text{number of publications}}$ OR $\dfrac{\text{years of life saved}}{\text{number of clinical trials}}$

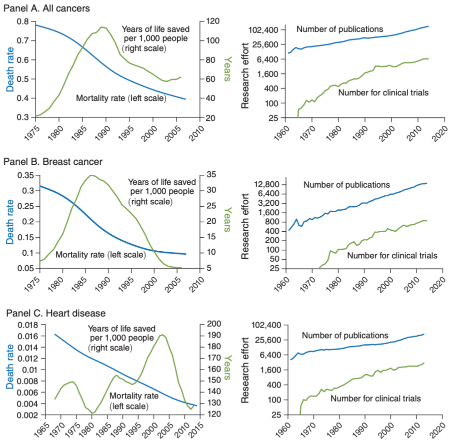

Figure 8. Mortality, Years of Life Saved, and Research Effort

Notes: For the two cancer panels, the mortality rate is computed as negative the log of the (smoothed) five-year survival rate for cancer for people ages 50 and higher, from the National Cancer Institute's Surveillance, Epidemiology, and End Results program at http://seer.cancer.gov/. For heart disease, we report the crude death rate in each year for people aged 55–64. *Years of life saved per 1,000 people* is computed using equation (16), as described in the text. Research effort is measured by the number of related publications and clinical trials, taken from the PubMed publications database. For *publications*, the research input is based on all publications in PubMed with "Neoplasms" or "Breast Neoplasms" or "Heart Diseases" as a MeSH keyword. The lines for "clinical trials" restrict further to publications involving clinical trials.

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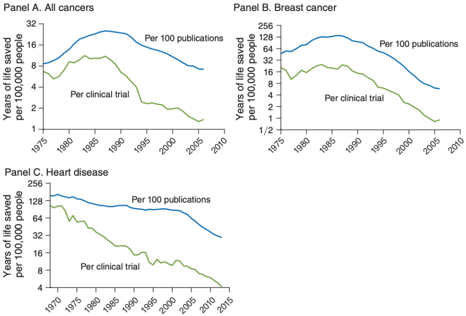

FIGURE 9. RESEARCH PRODUCTIVITY FOR MEDICAL RESEARCH

Note: Research productivity is computed as the ratio of years of life saved to the number of publications.

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Nordhaus (1969) versus Budish et al.(2016)

- Nordhaus (1969) is the classic model of optimal patent length
  - Firm chooses level of R&D investment
  - R&D investment creates private and social benefits by lower production costs
- Budish et al. (2016) modify this setup slightly:
  - Firm chooses level of R&D investment
  - R&D investment creates private and social benefits by bringing to market innovations that would not otherwise have existed.

Setup

- There is a unit mass of potential innovations $i \in I$
- If a firm decides to develop i, it will incur cost c_i and succeed with probability p_i
- If successful, the innovation has a useful life of T_i
- Patents allow the firm to sell the innovation as a monopolist for t_{patent}

Private and social payoffs

- Successful innovations generate annual monopoly profits of π_i
- Successful innovations generate social value:
  - v_i^m of annual social value when priced by a monopolist
  - v_i^c of annual social value when priced competitively
- Key idea / tradeoff:
  - Firms will be more willing to incur c_i if t_{patent} is long
  - But $v_i^m < v_i^c$ so there is more social value if t_{patent} is short

Which innovations will firms develop?

- Firms are risk neutral
- Ignore discounting
- To develop an innovation, expected monopoly profits need to exceed costs:

$$p_i \cdot \min(t_{patent}, T_i) \cdot \pi_i > c_i$$

- If we look across all $i \in I$, this implicitly defines a set of I^* innovations that will be developed
- Raising t_{patent} increases the right hand side $\rightarrow$ increases the number of innovations that are developed
- Can define ξ as the elasticity of R&D wrt to t_{patent} $\rightarrow$ key parameter of interest

Marginal benefits and marginal costs

- Effective monopoly life (EML): $p_i \cdot \min(t_{patent}, T_i)$
- Effective total life (ETL): $p_i \cdot T_i$
- What happens if we increase t_{patent} a bit...?
- Marginal benefit: social value of innovations elicited on the margin

$$\underbrace{\xi}_{\text{elasticity of R\&D}} \times \underbrace{\mathbb{E}_{EML_i \cdot \pi_i = c_i}}_{\text{average over marginal innovations}} \underbrace{[ETL_i \cdot v_i^c - EML_i(v_i^c - v_i^m) - c_i]}_{\text{value of marginal innovations}}$$

- Marginal cost: additional time under monopoly for inframarginal innovations

$$\int_I \underbrace{\mathbb{I}_{\{EML_i \cdot \pi_i \geq c_i\}} \mathbb{I}_{\{T_i > t_{patent}\}}}_{\text{affected inframarginal patents}} \times \underbrace{(v_i^c - v_i^m)}_{\text{DWL}} \, di$$

- Optimal patent term equates marginal benefits and marginal costs

Empirical challenges

- Measuring ξ is hard empirically – why?
- Requires us to measure "missing innovations"
  - Innovations that were scientifically feasible
  - But not brought to market because the patent term was too short to justify the costs
  - How to measure?

What else do patents do?

- Is knowing ξ sufficient to set optimal patent term policy?
- What else do patents do? What other parameters might we want to know?

1. Patents can improve disclosure
   - To receive a patent, firms must publicly disclose their innovations
   - Makes it easier to build upon innovation
   - Firms may choose not to patent all innovations (trade secrets)
2. Patents can affect follow-on innovation
   - There may be valuable follow-on work to an innovation, and the innovating firm may not be the best positioned to do it
   - If the innovation is patented, the follow-on firm will need a license
   - Will patents increase or decrease follow-on research?

Further reading

- The special nature and importance of ideas
  - Arrow, Kenneth (1962). "Economic Welfare and the Allocation of Resources for Invention" in *The Rate and Direction of Inventive Activity: Economic and Social Factors*
  - Jones, Ben and Lawrence Summers (2022). "A Calculation of the Social Returns to Innovation" *Innovation and Public Policy*
- Ideas and growth
  - Jones, Charles (2015) "Growth and Ideas" lecture slides (available here)
- Are ideas getting harder to find?
  - Collison, Patrick and Michael Nielsen (2018). "Science is Getting Less Bang for Its Buck." *The Atlantic*
  - Kortum, Samuel (1993). "Equilibrium R&D and the Patent-R&D Ratio: U.S. Evidence." *American Economic Review*