NBER Innovation Research Boot Camp: Introduction

Ben Jones & Heidi Williams
July 2022

Boot Camp Outline

Session Title	Time	Faculty
Introduction	Friday 9am-12pm	Ben Jones & Heidi Williams
Innovation in a Historical Perspective	Friday 1:30-4:30pm	Naomi Lamoreaux
Economics of Science and Science Funding	Saturday 9am-12pm	Pierre Azoulay
Innovation Policies 1: Patents	Saturday 1:30-4:30pm	Heidi Williams
Idea-Based Models of Economic Growth	Monday 9am-12pm	Chad Jones
Human Capital and Innovation	Monday 1:30-4:30pm	Ben Jones
Dinner Keynote: Clusters, Agglomeration, and Geography	Monday 6:30pm	Scott Stern
NBER Innovation Meeting (Tuesday-Wednesday)		
Innovation Policies II: Taxes, Competition, and Labor Markets	Thursday 9am-12m	John Van Reenen
Diffusion & Wrap up	Thursday 1:30-4:30pm	Kevin Bryan & Team
Dinner Keynote: Organizations and Innovation	Thursday 6:30pm	Rebecca Henderson

Introduction

- Boot Camp Outline
- **Why Study Innovation?**
- The Nature of Ideas
- Policies and Institutions: An Introduction
- Data & methods

For most of human history, the average person has not been much more prosperous than their ancestors….all this changed beginning in the late 18th century

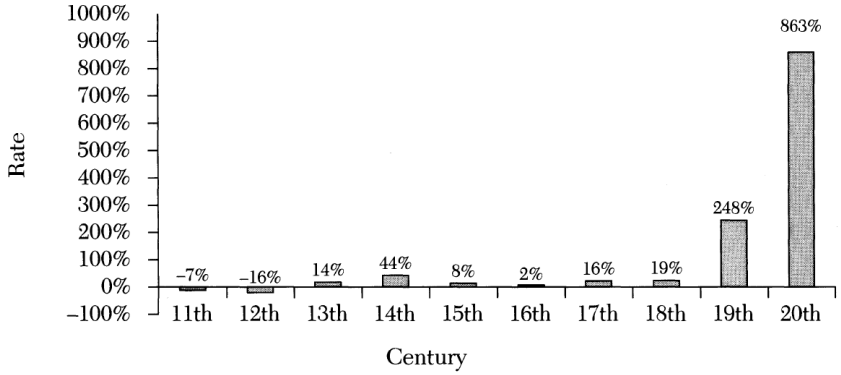
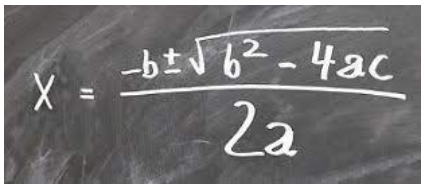


Figure 1. Growth in Real World Per-Capita GDP by Century.
Source: J. Bradford DeLong 2000.

- It seems almost self evident that the advance of "ideas" is key. See, e.g., Mokyr (1990) "Lever of Riches" for a history of ideas and their impact.


NASA


X = -b±√b² - 4ac
2a

Why Study Innovation?

- The advance of ideas informs central phenomena
  - The path of economic prosperity
    (income, health; inequality)
  - The dynamics of markets, industries, trade
  - The role of institutions and policy

- Ideas are a special form of good. Idea production can be understood through distinctive economic, institutional, and sociological features.

- Idea production interfaces with many forms of market failure, pointing to key roles for public policy

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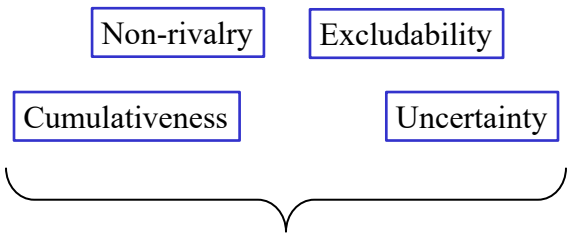
Ideas are Special Goods: An Introduction



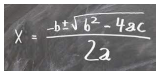
All underpinning market failures.

- The boot camp will repeatedly emphasize these features to understand major phenomena and several special institutions (e.g., intellectual property, universities, R&D tax credits…)

Ideas are Special Goods: Non-Rivalry

❖ Ideas are *non-rival* goods
- Unlike most goods, the use of an idea by one party does not preclude its use by another party

Rival good



Non-rival good

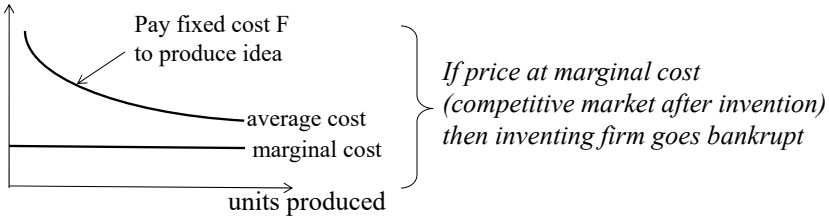
Non-rivalry:
- Algebra
- Germ theory of disease
- Assembly line
- Chemical process
- Regression
- CRISPR

❖ This property quickly leads to *market failures*

Ideas are Special Goods: Non-Rivalry

❖ *Non-rivalry* suggests that markets underinvest in new ideas

- *Increasing returns to scale:* hard to produce idea (fixed cost, possibly very large) but easy to copy (non-rival)



- *Spillovers:* Hard for innovator to capture full benefit of ideas

Ideas are Special Goods: Excludability

- Ideas may (or may not) be *excludable*
  - Excludability: can you stop others from using something?
  - Excludability is a source of *market power* (and thus private return on investment)

- Excludability depends on institutions and technology
  - *Institutions.* The patent system provides patent holder the right to exclude others from using an idea for a fixed period of time in exchange for disclosure of that idea to the public domain. Other intellectual property forms includes copyright, trademarks, non-competes.
  - *Technology*. Ideas may be excludable without IP (secrets, cryptography, control of complementary inputs)

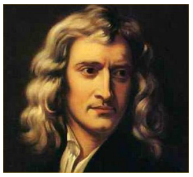
Ideas vs Other Goods: Examples

	Non-Excludable	**Excludable**
Non-Rivalrous	Basic Research, Calculus, National Defense	Satellite Radio, Patented Ideas
Rivalrous	Fish in Ocean	Lawyer services, Airplane seat

- Need special institutions to support idea creation. Consider:
  - Intellectual property provides ex-post excludability
  - Public agencies (e.g., NIH) provide ex-ante funding

Ideas are Special Goods: Cumulativeness

❖ The production of ideas is associated with spillovers -- across time, location, industries, technologies, etc



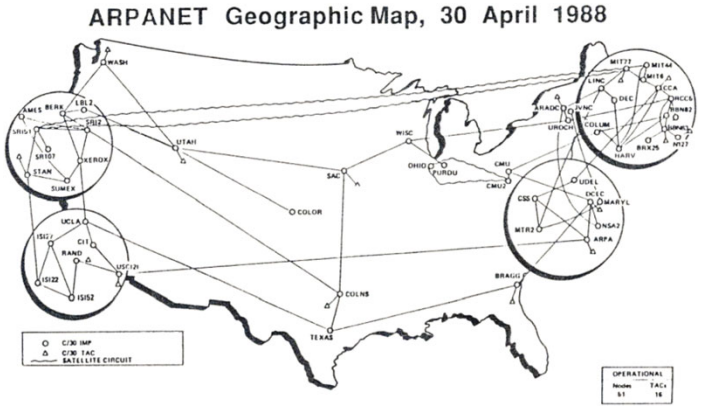
❖ Ideas are *cumulative* -- spillovers across time
- *"If I have seen further, it is by standing on ye shoulders of giants" (Newton)*

❖ This cumulative process seems largely unpriced
- Do we pay Newton for the use of calculus?
- How do we pay Tim Berners-Lee for the WWW?

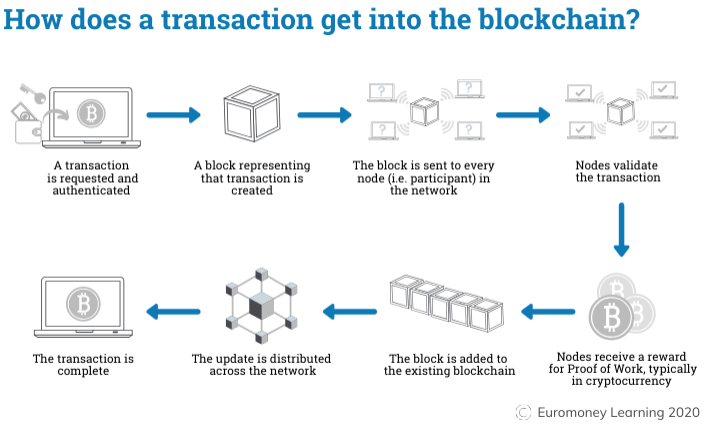
❖ Implications for
- Social welfare / policy
- Strategic interaction
- The nature of creativity itself

Ideas are Special Goods: Uncertainty

Could you have foreseen the value of ARPANET when it was first developed?



How about this one:
How much value do you think there is in blockchain technology?



Uncertainty is fundamental to the production of ideas and innovation…

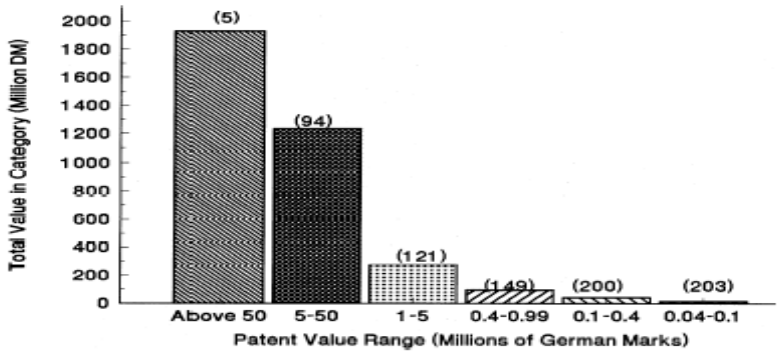
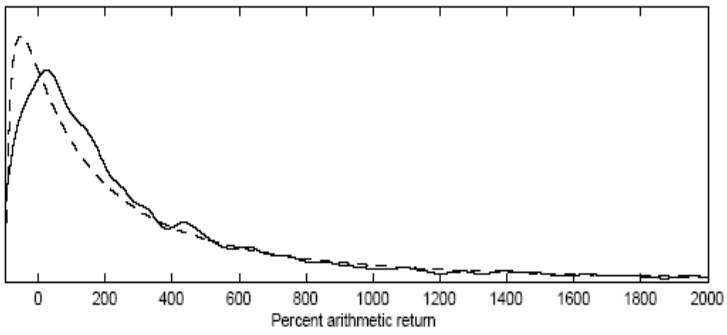


Fig. 1. Distribution of German patent values.

Among more than 750 *patented* inventions, 5 were collectively worth more than 1 billion DM, more than 50% of the total value of the entire sample!

Scherer and Harhoff, *Research Policy*, 2000

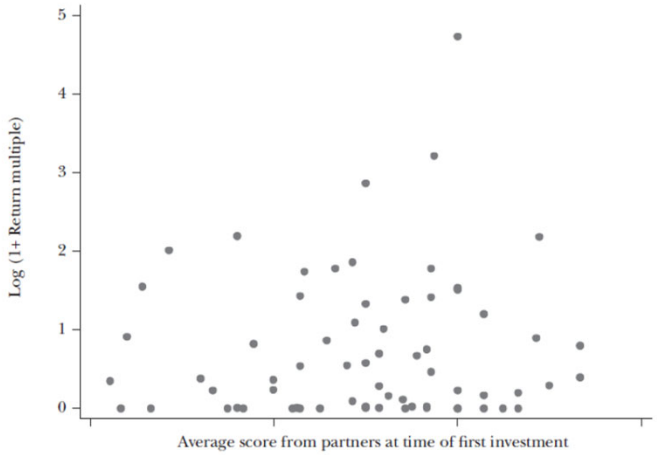
Conditional on being *funded* by VCs, a very small proportion of the total returns to VC are realized by a small number of investments.



Cochrane, *JFE*, 2005

Even close, incentivized observers (i.e., the VCs) don't know what will happen…

B: Correlation between Scores and Outcomes



Note: The labels on the horizontal axis have been suppressed to maintain the confidentiality of the investor's rating scale, but lower predictions were on the left and higher predictions were on the right.

Kerr et al., JEP 2014

Not simply a matter of traditional risk, the inability to forecast innovation seems to be fundamental (Rosenberg)

	Bell Labs Development of the Maser & Laser: "Bell's patent department at first refused to patent our amplifier…for optical frequencies because…optical waves had never been of any importance to communications and hence the invention had little bearing on Bell System interests" (Charles Townes, Nobel Laureate)
	Bell - Western Union Patent Agreement of 1878: Western Union will agree to stay out of the telephone business if Bell agrees to stay out of the telegraph business

Nate Rosenberg's Dimensions of Uncertainty

Can think of as a lack of foresight (not just risk)

- Initial technology is developed for a narrow application
- Little understanding of potential applications or uses
- Dependence on the emergence of complementary innovations and/or the emergence of entirely new technological systems
- Inability to imagine how to satisfy human needs in a novel way

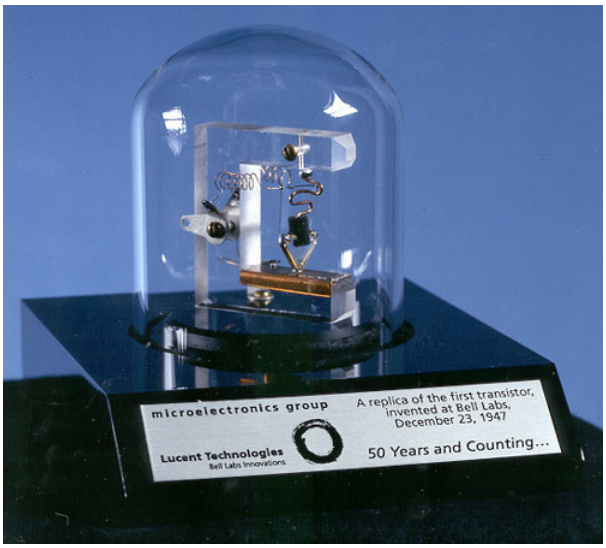
Related Note on Research Methods: Sampling

- Highly convex payoffs suggests somewhat peculiar focus. In studying invention/ innovation/ basic research, there is substantial interest in upper tail "outliers"
  - Highest-value patents
  - Home-run papers, "star" scientists, and prizes (e.g., Nobel)
  - Tech entrepreneurship
- Conversely, studying median inventors, entrepreneurs, or researchers may not be representative for outcomes of interest
- In empirical research on ideas/innovation, it can be good therefore to either examine the census (or a random sample thereof), but also good to emphasize the upper tail

Uncertainty and the Market for Ideas

- What should the "price" of a given idea be?
  - The main determinant of "willingness to pay" for a traditional economic commodity is buyer's *ex-ante* information about the characteristics of that good. The correct willingness-to-pay for an idea therefore depends on *knowing* the idea
  - At which point one does not need to pay for it!
- Figuring out the "price" for an idea requires information that intrinsically reduces its value
  - N.B.: Not simply "information asymmetry" of the traditional kind, but a more fundamental consequence of inappropriabilty that limits transactions in the market for ideas

Uncertainty meets Organizational Design



Example: Organizations for Basic Research

- Important link between *cumulativeness* and *uncertainty* about downstream applications for understanding org design.

- What is the appropriate organizational form to encourage basic research? An introductory view:

  - The Industrial Lab (e.g., Bell Labs, Google X)
    - Nelson's "finger in many pies" (Nelson 1959). Integration downstream essential to monetize uncertain outcomes from basic research (industrial lab model). Scope is key.

  - The University (e.g., outputs like ML, CRISPR)
    - Public funding, embracing public goods model. Different set of organizational rules, norms, personal motivations.

Uncertainty Meets Cumulativeness

- Suzanne Scotchmer has emphasized a core incentive problem in *cumulativeness* (sequential innovation) that is challenging to solve

- Let it cost r to produce an innovation. Consider two innovations, A and B, that have complementary value. Innovation A has value V(A), but also triggers the possibility of making innovation B, with marginal value V(A,B). The investment decision is based on

  A: $V(\mathrm{A}) - \mathrm{r} + \omega V(A,B)$ B: $(1\text{-}\omega)V(A,B) - r$

  where $\omega \in [0,1]$ is the share of downstream innovation value A inventor receives (i.e., due to a patent on A) if B is created.

- Scotchmer: greater ω encourages investment in A, but discourages investment in B from another firm. Patents thus can't solve this problem. Hence publically supported R&D in A with $\omega = 0$?

The Nature of Ideas: Private vs. Social Returns

- The nature of ideas suggests many market failures
  - Put another way, the social returns to innovation may differ substantially from the private (market) return.
  - Put another way, idea creation and diffusion may engage spillovers/externalities that defeat the general welfare theorems
  - If so, room for institutions and policy interventions

- But how big are the social returns to innovation? Are markets a little off or way off? Do we really underinvest?

What Are the Social Returns to Innovation?

- To answer this question we must (a) measure the social benefits from innovation investment, and (b) compare these benefits to the investment costs.
- But assessing the social benefits of specific advances is super difficult.

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Social Returns and the Spillover Challenge

- The root measurement challenge is that society-wide gains seem to differ considerably from the private returns to the innovator and are fundamentally hard to trace.
- Numerous "spillover" margins; e.g.,
  - Imitative spillovers (+)
  - Intertemporal spillovers (+/-)
  - Business stealing (-)
  - Duplication (-)

- How can we estimate the social returns in light of these complex spillovers?
- And how can we avoid "picking winners" for these assessments, since innovation investments often fail?

Literature: Methods

- Many approaches to calculating the social returns to R&D

1) Case studies (e.g., Griliches 1958, Mansfield et al. 1977, …)
2) Firm & industry studies (e.g., Hall et al. 2010, Bloom et al. 2013,…)
   - Regression models
   - R&D spillovers to other firms/industries
3) Country studies
   - Regressions (e.g., Coe and Helpman 1995, Kao et al. 1999)
   - Growth models (e.g., Jones and Williams 1998, 2000)

- Typical finding: social returns appear very large

Literature: Challenges

- Regression methods
  - Spillover boundaries?
  - Intertemporal spillovers? Lags?
  - Causative interpretation?

- Case studies
  - Successes only? What about failures?
  - What about advances with diffuse applications?

- Innovation investments that may be especially important seem especially hard to assess
  - Basic research
  - General purpose technologies

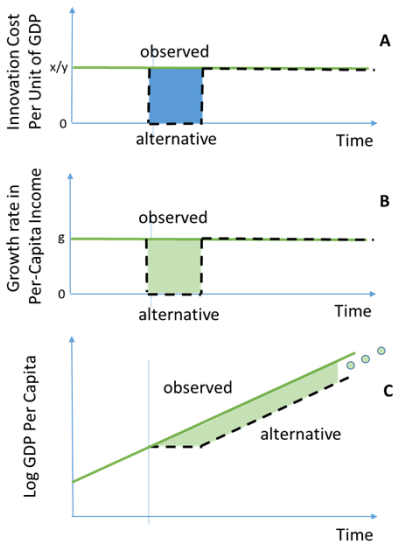
Jones and Summers (2021): Overview

1) Consider the *average* social returns to innovation
   - Examine path of GDP per capita to net out spillovers
   - Examine total innovation investment to capture success and failure
   - Produce baseline calculation, based on transparent and easily editable assumptions

2) Generalize the baseline
   - Reasons baseline may be too low
   - Reasons baseline may be too high

3) Consider distinction between marginal and average returns
   - Micro-founded arguments
   - Macro growth models

Baseline Calculation: Conceptual Model



Investment cost is x/y for one year

Benefit is g% higher income forever

Present value of benefit is g/r

Baseline Calculation: Conceptual Model

The *average* social returns are then

$$\rho = \frac{g/r}{x/y}$$

Present value of the benefits

Investment cost

Implications:
If x is R&D costs only, then average social returns appear enormous.
If x is incorporates all sorts of other investment costs, then the average social returns are still very large.

The "R&D Only" Baseline: Candidate Social Returns

Take $g = 1.8\%$ and $x/y = 2.7\%$ (U.S.)
Then the average social returns are:

Table 1: The Average Social Returns, by Social Discount Rate

Social discount rate (r)	Average Social Benefit-Cost Ratio (ρ)
1%	66.7
2%	33.3
3.5%	19.0
5%	13.3
7%	9.5
10%	6.7
67%	1

Extending the Baseline

The baseline calculation may be too high or too low. Introduce the corrective factor, β.

$$\rho = \beta \frac{g/r}{x/y}$$

Baseline too high? ($\beta < 1$)

- Lags
- Capital investment
- Other sources of innovation

Baseline too low? ($\beta > 1$)

- Inflation bias
- Health gains
- International spillovers

Conclusions: Jones and Summers (2020)

- A new approach, complementary to prior literature
  - Focus on the *average* return to innovation investments
  - Allows extensions to many potentially first-order issues
- Findings
  - Even under conservative assumptions, it is difficult to find an average return below \$4 per \$1 spent.
  - Middle-of-the-road estimate suggests at least \$10 per \$1 spent, and perhaps multiples higher
  - Marginal returns look somewhat lower, but not much lower

The Bigger Picture: Policy

❖ If the social returns are, on average, very large, what are the main market failures? What institutional structures and policies can overcome specific market failures? For example, how important is science and how can we can support science effectively?

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END