Lecture 3
Supply and Demand for Innovation

E5104 – Economics of Innovation

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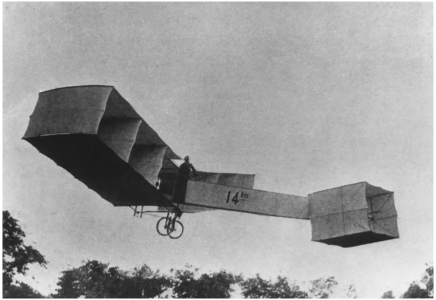
The Quest for Human Flight

- Montgolfier brothers in 1783
- “First to fly a heavier than air machine” in early 1900s
  - Wright Brothers
  - Alberto Santos-Dumont
- Why not earlier?
- Advances in other mechanical forms of propulsion, such as bicycles and gas-powered internal combustion engines? Complementary inventions?
- Desire to be first? Supply of basic components? Money to be made (Wright Brothers)?



“Operation Warp Speed”

- September 2020: Pfizer-BioNTech received Eur 375 million from the German government for vaccine development
- May 2020: U.S. federal government initiated Operation Warp Speed to accelerate the development, manufacturing, and distribution of COVID-19 vaccines, therapeutics and diagnostic tests
  - multiple companies simultaneously pursue the development of vaccines
  - eight companies were (partially) funded in August 2020, three produced successful vaccines by the end of 2020 (J&J, Astra-Zeneca, and Moderna)
- Pfizer-BioNTech and OWS widely viewed as successful: vaccine development in less than a year between initiation and vaccine deployment (usual timeline: 10–15 years)
- *Key feature:* clearly identified need sending a strong demand signal that an innovation would have a market

Supply and Demand

- Examples illustrate two key determinants of innovative activity and outcomes: supply and demand
- Quest for human flight:
  - driving force seems to be long-felt human desire for flight
  - availability of relevant technologies (engines, steering mechanisms, or lightweight construction)
  - $\rightarrow$ supply of relevant inputs to the innovation, including the innovators
- OWS:
  - driving force behind COVID-19 vaccine was demand!
  - although: development rested heavily on supply of information from biomedical science (e.g., mRNA technology)

Supply Factors and Motivators

- innovators (and the lack thereof)
- scientific and technical knowledge (*technological opportunity*)
- expected profits (e.g., costs of production, appropriability)
- absorptive capacity
- availability of financing

Supply: Innovators

- Many factors determine the availability of innovators: life expectancy, nutrition, willingness to bear risk, geography, religion (negative relationship between religiosity and patenting), values
- Some have become less important over time (e.g., life expectancy and nutrition) in developed economies
- Today, key requirement for modern innovation is **educated population** (particularly in STEM fields)
  - Griliches (2000): robust cross-country evidence for strong relationship of education/human capital and economic growth
  - Furman et al. (2002): number of scientists/engineers and share of GDP spent on higher education associated with country's level of patenting

What Motivates *Scientists?* – Importance of Priority

- Merton (1957, . . .):
  - goal of scientist is to establish priority of discovery, by being first to communicate an advance in knowledge
  - rewards to priority: recognition by the scientific community of being first
- This quest of being first induces incentives.
- Various forms:
  - Eponymy
  - Prizes
  - Publication

- **Eponymy:** attaching the name to the discovery
  - Haley's comet, Higgs' boson, Planck's constant;
  - Arrow's theorem; Bertrand Paradox, Diamond Paradox, ...
- **Prizes:**
  - Nobel prize ($1.3m); Fields medal ($13k); Abel Prize ($920k); ...
  - Zuckerman (1992): 3,000 prices in the sciences available in North America in the 1990s
  - *No systematic study (2007)*
- **Publication:**
  - Lesser form of recognition
  - Within reach of most scientists
  - Publication, or more importantly, the number of citations (has become easier to find)

Being First is Key

- Recognition in science depends on being first. Need to publish quickly.
- In extreme, no rewards for being second or third.
  - *Pro:* Quickening of the publication process (*Science:* 7 day referee deadlines; economics is becoming faster; sciences faster than social sciences)
  - *Con:* Excessive energy devoted to establishing priority over rivals (“rent”-seeking; publication races) - LATER
- Why is there such a winner-take-all society in science?
  - Difficult/lack of monitoring (effort not observed; reward based on outcomes; standard P-A/hidden action problem)
  - Little social value produced by runner-up:
    - But: replication and verification have social value; and has been object of a debate even in finance and economics

Financial Remuneration

- Winner-take-all nature of the race places risk on shoulder of scientists. Not surprising, compensation is in two parts:
  - one part paid regardless of output
  - one part is priority-based and reflects the value of winner's contribution to science.
- This compensation structure can be in place within company or university (publication and citations matter for tenure and hiring)
- Also found with a broader view (especially in academe): academic salary and outside compensation (more of which is earned with higher scientific output).
- Other monetary awards (priority based):
  - Prize money, speaking, consulting fees
  - Royalty payments from patents
  - Start-up companies (founders or members of scientific advisory boards; IPOs!)

Satisfaction from Solving a Puzzle

- Richard Feynman (1999):
  “the prize is the pleasure of finding the thing out, the kick in the discovery”

- Time spent on a discovery an argument in the utility function for a scientist? For scientists and scientific discovery, is the proper utility function one that has features of procedural utility?

- Handbook chapter by Stephan (2010 – see Ilias) cites some recent work by Sauermann and Cohen (2007) that tackles this question

Supply: Where are the Missing Einsteins and Marie Curies?

- Invention, innovation, and entrepreneurship is unequally distributed across the population w.r.t. gender, race, and family background
- $\Rightarrow$ missing inventors who might contribute to innovation and society if they had the same opportunities
- Bell et al. (2019) find (for U.S. data):
  - Children with parents in top 1% of income distribution are 10 times more likely to become inventors than children with below-median income parents
  - White children are three times more likely to become inventors than black children
  - Only 18% of inventors are female!
- During-childhood exposure is a critical factor. Innovation and economic growth would benefit from more attention paid to mentoring and other programs.

Supply: Where are the Missing Einsteins and Marie Curies?

- Hoisl et al. (2021) find (for Danish data, exploring choices by about 1 million individuals born 1966–1985):
  - Parental background in the form of STEM education and inventorship predict entry into inventing
  - Effects are larger for males than for females
  - Having a STEM degree improves the odds for women becoming inventors (not so for men), but women are less likely to complete a STEM degree in the first place

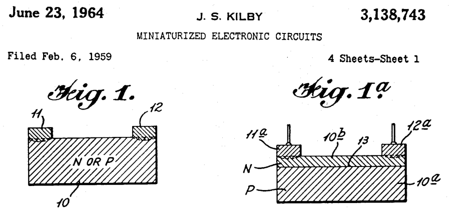
Supply: Technological Opportunity

- State of scientific and technological knowledge as another important supply factor
- Most innovations rely heavily on scientific discoveries. For example: CRISPR technology for editing genes
  1. scientific discovery of DNA by Crick, Watson, and Franklin
  2. Cohen-Boyer work on splicing DNA
  3. UC Berkeley/MIT developed CRISPR technology
- **Technological opportunity**: the potential for new inventions created by earlier science and technological development

Supply: Expected Profits . . .

- Function of projected demand as well as costs
- Jack Kilby's (of TI) concern with production costs at TI when trying to come up with an integrated circuit caused him to settle on semiconductors as a material

  "Probably the only thing they [TI] could make cost effectively were semi-conductor products. This triggered the thought that maybe you could make everything from semiconductors.' (Kilby 2000, p. 110)



Supply: . . . and Ability to Capture Them

- **Appropriability** is the ability of inventors to capture the profits of an innovation
- Patents provide for appropriability, and we expect innovation to increase when inventors can patent their ideas, or: some innovators at some times have been encouraged by the availability of patents
- Other appropriability mechanisms:
  - keeping the invention secret (initially the Wright Brothers)
  - being (among the) first to market
  - lowering costs by moving down the learning curve fast
  - producing complementary output (e.g., sales, marketing, and service activities)
- Firms use all these in addition to patenting (Levin et al. 1987; Cohen et al. 2000)

Supply: Absorptive Capacity

- **Absorptive capacity** is the firm's ability to monitor technological knowledge in their domain and reduce the cost of future innovation
- Cohen and Levinthal (1989): important driver of R&D is firms' desire to build this capability
- Firms will invest in basic research in order to increase their absorptive capacity, despite the broader spillovers from basic research
  - Early/classical work (Nelson 1959, Arrow 1962) argue that spillovers reduce incentives to invest (e.g., by rendering costs of imitation lower than that of invention)

Supply: Availability of Financing

- Acquiring funding for innovative activities can be an obstacle
- Some projects (that should be undertaken) may not be undertaken
- **Asymmetric information**
  - Inventor has more information about the likelihood of success than potential investor
  - Creates market-for-lemons problems (Akerlof 1970)
  - Mitigate by increasing amount of details shared; but counters problem of appropriability (solution: NDAs, early patent applications)
- **Moral hazard**
  - Conflict between financier and entrepreneur, or investors and management
  - Startups: venture capital firms undertake substantial monitoring, or supply funds in installments (“tranches”)
  - Venture capitalists also pool risk by funding a number of startups at the same time

Where Does Demand for Innovation Come From?

- From consumers and other firms (size of the market, capita income in the relevant market, . . .)
- Schmookler (1966): supply of science and technology was important, but with a larger potential or actual market, more of inventive activity would be directed to that market
  - Patent data: 1936–1950
  - Shows: the greater the capital investment in an industry, the higher the patenting rate for capital goods used in that industry
  - Scherer (1982) replicates the results with U.S. FTC line of business data
- Government Requests for Proposal (RFPs)
- Regulation. Examples:
  - Fuel efficiency targets
  - California’s 2010 adoption of the lighting chapter of the Long Term Energy Efficient Strategic Plan resulted in wave of innovation in LED bulb technology **(→ Assignment 2)**

Direction of Innovation

Different paths in multiple ways:

- broad science/technology field
- product vs. process innovation
- incremental vs. radical innovation

Product vs. Process Innovation and Firm Maturity

- Product life-cycle model of innovation (Abernathy and Utterback 1978) **(→ Assignment 2)**: more mature firms (larger? older? both?) invest more in process than product R&D
- Reasoning:
  - Early years, emphasis on product innovation: numerous small firms compete to establish a market position
  - New product ideas are tested, and eventually a "dominant design" emerges
  - With the dominant design comes product standardization and a new emphasis on process innovation
  - Efforts on realizing the benefits of large-scale production, mechanization, improving production yields
  - Returns to process innovation are greater when the production volume across which the savings can be spread is greater
- Cohen and Klepper (1996) partially confirm this (and others do not)

Simultaneous Invention

- Innovation is often nearly simultaneous; same idea almost at the same time
- Historical examples:
  - calculus (Newton, Leibniz)
  - theory and natural selection (Darwin, Wallace)
  - principle of least squares (Legendre, Gauss)
  - telephone (Bell, Gray)
  - flying machines (Wright, Langley, . . .)
  - photography (Daguerre-Niepe, Talbot)
  - telegraph (Henry, Morse, Cooke Wheatstone, Steinheil)
- Both supply and demand factors can be made responsible for this.

CRISPR

- CRISPR technology: two patents filed within 6 months
  - Jennifer Doudna (UC Berkeley) and Emmanuelle Charpentier of the Max Planck Institute for Infection Biology (Nobel Prize in Chemistry 2020) – first described in *Science* paper published online 28 June 2012
  - Feng Zhang et al. of the Broad Institute at MIT and Harvard – reported in a 3 January 2013 *Science* paper
- Patent disputes in U.S. and Europe

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New CRISPR patent hearing continues high-stakes legal battle

Lawyers trade pointed exchanges over invention of genome editor

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UC Berkeley loses CRISPR patent case, invalidating patent rights it granted gene-editing companies developing human therapies

By Megan Molteni Feb. 28, 2022

Reprints

Jennifer Doudna of the University of California, Berkeley

BRIAN ACH/GETTY IMAGES FOR WIRED

Ending the latest chapter in a years-long legal battle over who invented CRISPR, the U.S. Patent and Trademark Office ruled on Monday that the revolutionary genome editing technology belongs to the Broad Institute of Harvard and MIT.