Lecture # 11 – Science vs. Profit

I. What Motivates Scientists

- What motivates scientists? What is the reward structure?
  - Priority of discovery
    - Being first to communicate new information
    - Forms of recognition
      - Naming (e.g. Halley's comet)
      - Prizes
      - Publication
        - Essential for establishing priority
    - Implications of priority
      - Need to publish quickly
        - Time to publish is much shorter in natural sciences than social sciences
      - Is science a "winner take all" contest?
        - For some high profile goals (e.g. discovering Higgs Boson particle), perhaps
        - However, many problems have multiple components
          - For example, there is no one cure for cancer
          - Thus, Stephan argues science best fits a "tournament model"
            - There are rewards for coming in second or third as well
  - Financial rewards
    - Compensation depends, in part, on success
      - Base salaries relatively flat
        - Senior faculty may not earn much more than junior faculty
      - However, prestige opens up new opportunities
        - Speaking fees, consulting, awards, royalties
      - Can earn money by spinning off start-up companies
  - Satisfaction of solving a puzzle
  - What about scientists in industry?
    - Slightly over 1/3 of PhDs work in industry
    - Most in R&D, but not all
    - Firms may allow some basic research as a recruitment tool
      - Note that those in the private sector will want to publish if they hope to move between sectors
- What are the inputs of science?
  - Time
  - Cognitive ability
    - Scientists need to keep up with changes in their discipline or become obsolete
    - Collaboration allows combinations of different abilities

        - Collaborations have been increasing
            - Number of authors per paper increased from 2.8 to 4.2 from 1981-1999
            - Why has collaboration increased?
                - Importance of interdisciplinary research
                    - No one person has all of the needed skills
                    - Individual researchers becoming more specialized over time
                        - As knowledge becomes deeper, it is difficult to keep up with multiple fields
                - Internet makes collaboration easier
                    - Not only communication, but also sharing of resources
                - Increased complexity
    - Research resources
        - Lab equipment
            - May be large, such as a particle accelerator or telescope
            - Even laboratory mice are costly
                - Many bred for specific purposes
        - Computers
            - Over time, capital has been replacing labor in research
            - Falling costs of sequencing base pairs of the human genome documented on p. 228 is an example
        - Higher fixed costs also provides incentives for collaboration
            - Sharing access to needed materials in exchange for co-authorship
        - If needed equipment is off-campus, researchers need funding to support time off for research
    - Over time, grants have become a more important source of resources for universities
        - In the 1950s, overhead at NIH was just 8%, 20-25% at NSF
            - Faculty salaries initially not supported
            - By late 1960s, almost ½ medical school faculty received salary support from grants
            - Today, medical school faculty routinely cover nearly all of their salary on grants
            - Makes receiving external funding more important for faculty
        - Because of research funding from NIH and NSF, universities increased research capacity in the 1950s and 1960s
            - Number of PhDs increased by 40%
            - Government grants didn't support PhD students until after WWII
        - Competition for grants increased in 1970s, as funding cut
            - During 1980s, federal support grew again, but industry support for university research grew more quickly
    - Serendipity

            - Not necessarily an accident, but “finding answers to questions not yet posed” (p. 232)

- Choice of contests
    - Because of importance of priority, scientists must choose research areas carefully
        - Want to signal worthiness, yet be successful
            - For example, young scientists want to show independence from mentors while still being close enough to their research area to show the value of their training
        - Monopolizing an area of research reduces the risks of being scooped
            - Could develop a methodology and collaborate with others to apply the methodology
            - Control a needed resource (e.g. a genetic strain)
    - Because of uncertainty, choose a portfolio of projects
        - Choose projects with varying degrees of risk
    - Also need to choose where to work.
        - Work within academics, or also in private sector?
- How do the economics of science affect efficiency?
    - Advantages of priority as reward
        - Solves the problem of monitoring scientific effort
            - Scientists are rewarded for outcome, not effort
        - Encourages early dissemination of results
            - Can’t get credit without letting others know of your work
        - Peer review discourages plagiarism and fraud
        - Offers non-market rewards for the production of a public good
    - Funding regimes
        - Some countries fund research centers (institutes)
            - E.g. CNRS (National Scientific Research Center) in France
            - Less common in the US, but there are examples, such as FFRDCs, NIST, and NIH
            - Pros
                - Allows scientists to follow a research agenda for a period of time
                - Don’t need to spend time chasing grants
            - Cons
                - Agenda set by institute director
                - Scientists not getting research appointments at the institute locked out of key resources
        - In the US, most funding is competitive
            - Apply to government agencies, such as NSF, NIH, DOD, DOE
            - Most applications are peer reviewed
                - Exceptions are awards earmarked by Congress
                - Reputation plays a role in peer review
            - Pros

                - Encourages scientists to remain productive throughout their life cycle, so as to remain competitive for grants
                - Peer review promotes quality and sharing of information
                - Encourages “entrepreneurial” science
            - Cons
                - Seeking grants takes time away from research
                    - 2006 survey: 42% of research time filling out forms or in meetings
                - May choose less risky projects with short-run payoffs to increase chances of funding
                    - Not uncommon to apply for support for research that is almost finished
            - Private foundations and industry also support research
                - About 6% of university funding comes from industry
                - Such funding raises questions about blurring lines between science and profit

II. The Role of Government: Science vs. Profit

- Traditional views of science and technology treated them as separate:
    - Science was seen as understanding nature, whereas technology was seen as controlling nature.
    - These boundaries are more likely to be blurred today.
- This distinction can also be seen in attitudes toward the output of research:
    - Science views knowledge as a public consumption good.
    - Technology views knowledge as a private capital good.
- These attitudes affect the scientific process
    - Scientists are rewarded for achievements. For achievements to be rewarded, they must be disclosed. Thus, disclosure (e.g. through publication) becomes important.
    - In technology, the rewards are the economic rents captured by innovators.
    - As more and more “technological” fields depend on scientific knowledge, these boundaries become blurred.
- The Quadrant model of organization of scientific research and technology development
    - Curiosity-Inspired Basic Research:
        - Bohr’s Quadrant (after Danish physicist who searched for a model of atomic structure).
        - Results may later lead to technological improvement, but the motivation is simply scientific curiosity.
        - Who supports:
            - Private foundations
            - Universities
            - Government

- Applied Research & Industry-Sponsored Technology Development
  - Edison's Quadrant
    - Research at Menlo Park was focused on development of commercial technology.
    - Needed to be economically viable.
  - Who supports:
    - Private sector, both by using profits from previous successes and by the expectation of future profits.
- Use-inspired basic research/dual purpose knowledge
  - Research with both practical value and fundamental insights
  - Pasteur's Quadrant
    - Pasteur's early research on fermentation was trying to solve problems in using beets to produce alcohol.
    - His research on vaccines was aimed at problems of great economic and social significance.
    - A contemporary example would be the mapping of the human genome.
    - Note that both private and public organizations may support.
  - Dual-purpose knowledge can both advance scientific understanding and technological knowhow
- Government-sponsored applied research and technology development
  - Here, government support is needed, as market institutions are too weak to induce private investment.
  - Mission research fits here
    - Agricultural research has historically been a good example.
    - Does biotechnology change this?

- When the lines between pure science and pure applied research are not clear, scientists must choose how they will disseminate their research
  - Publish or patent (or both)?
    - Dual purpose research could be patented or published
    - If patent, must patent before publish
      - Cannot get a patent if the idea is already in the public domain
  - Publications
    - Most publications come from academics
      - See Table 1, p. 236
        - Of 211,200 articles from US institutions in 2003, 156,600 from academia
        - Private non-profits next at just 16,300
  - Patents
    - Number of patents from academia increasing
    - Growing faster than patents overall
  - Do patents affect scientific research?
    - Examples:
      - In 1983, both US and French research teams published the discovery of a blood test for HIV in Science

                - The USPTO gave a patent to the US researchers, but not the French researchers
                - French team challenged the US patent
                    - Took two years to resolve, slowing HIV research
                - Ended with a royalty sharing agreement
            - Oncomouse
                - Genetically engineered for cancer research
                - Patented by Harvard, licensed to DuPont
                    - Set high prices
                    - Restricted breeding
                    - Retained oversight of publication
                    - DuPont retained a share of any commercial breakthroughs
                        - Thus, all research using the Oncomouse became dual nature.
        - Evidence
            - Murray and Stern (2007) examine patent/paper pairs: research outcomes that were both patented and published
                - Because it takes 2-3 years to examine a patent application, publications appear after the patent application, but before the patent is granted
                - Murray & Stern ask whether citations to articles fall after the related patent is granted
                    - Must control for article quality and for changing citation patterns over time
                        - Consider 340 peer reviewed articles from *Nature Biotechnology*
                        - For roughly ½, a patent was granted for knowledge related to the article
                - Key findings
                    - Articles with associated patents initially cited more frequently than other articles
                        - Much explained by observable characteristics such as author location and number of authors
                    - Citation rates fall 10-20% after patent grant
                        - Anti-commons effect strongest for articles with public sector coauthors
- *The Economist* articles deal with blurring boundaries between science and profit, raising the question about whether both can co-exist.
    - Note, for example, how Celera's activity moved genome mapping from the 2nd to 3rd type of knowledge.
        - They plan to profit by selling packaged descriptions of parts of the genome to drug companies. Thus, the commercial opportunities offered by commercial research make their research possible.

        - However, as we also noted, their results may have come faster than results from a public group would have been.
        - Thus, while it is easy to argue against patents *once a new treatment exists*, the more difficult question is to ask whether the treatment would exist at all without the patent protection.

- Another tradeoff with private versus public funding is control. The second article raises the concern of corporate sponsorship of university research.
    - Note that the % university funding from industry has been growing
        - 1970: 2.7%
        - 1980: 4%
        - 1990: 6.9%
        - 1997: 7.1%
        - 2009: 6.0%
            - Industry financing fell 2001-2004, and is now recovering
    - The key question is whether support buys control, in either direct or subtle ways.
    - Examples:
        - Will hiring and firing decisions be based on sponsor's interests?
            - The article gives an example from the University of Toronto, which receives funding for a research center from Eli Lily, the maker of Prozac. The university rescinded an offer to a doctor that argues Prozac increases suicides among depressed patients.
        - A 1998 review by the *New England Journal of Medicine* found that authors supporting a certain kind of drug for treating heart ailments were significantly more likely to have a financial relationship with the manufacturer.
        - A 1998 study by the *Journal of American Medical Association* (*JAMA*) found that whether or not the authors of articles on smoking had financial affiliations with tobacco predicted the results of the study.
        - In 2008, *The New York Times* reported a study finding that 94% of positive studies on drugs were published, but just 14% of studies with disappointing results
            - Note that publication bias, as well as the influence of funding, may be an issue here.
        - Defense:
            - Research studies are traditionally "double-blind" to avoid bias.
    - Possible remedies:
        - Many journals require disclosure of financial interests.

            - *JAMA* requires authors to sign a statement certifying that they have control of the design, analysis, and presentation of data.
        - However, such agreements can be hard to enforce, as the example in the reading shows
- What about mission R&D? Should the government support applied research? (we'll discuss on Wednesday)
    - Mission R&D is publicly funded research programs with specific goals
    - Examples:
        - Manhattan project
        - Apollo project
        - More recently, calls for mission R&D programs for climate change and medical research
    - Examples of public funded R&D with mission components:
        - Defense R&D
            - In US, largest government funded R&D program
                - Most funding goes to development of weapons
            - Government itself is the consumer
            - May support technology with both civilian and defense applications
                - However, the spinoffs are not an explicit goal of US defense R&D policy
            - Because of government's role, creates strong political constituencies
        - Agricultural R&D
            - Most funding decisions made at state level
            - Principal beneficiaries are consumers, via lower food prices
            - International agencies funded research to improve agriculture in developing countries
        - National Institutes of Health
            - Does some of its own research, but most funding goes to universities
            - Conflict: should NIH funding target specific diseases or basic research
                - Industry favors basic research, as they benefit from the results
    - Another important role of mission R&D is demonstration projects
        - Serve as a bridge between R&D and commercialization
        - Examples:
            - Field trials for new crops
            - Clinical trials for medicine
            - Prototypes for defense equipment
    - When is government support for mission R&D justified?
        - High social returns, but low private returns, so that private sector unwilling to invest

        - Because of high social returns, policy should encourage disclosure of research results
            - Mapping of human genome is an example
            - USDA did this for hybrid agriculture, keeping knowledge of hybrids in the public domain
    - What characterizes problems where activists call for mission R&D
        - Broad challenges requiring long run research efforts
            - Climate change is an example
            - Require the work of many parties
                - Unlike Manhattan or Apollo projects, new technologies will need to compete with existing ones
    - Guidelines for policy design
        - Future mission-oriented R&D programs will need to support development of many technologies
        - Long-term support crucial
        - Public policy also affects demand
            - Climate policy as an example
            - Government as user of technology
        - Foster competition
            - Don't allow one industrial partner to monopolize
            - Will need to shift to private funding once ready for commercialization
        - Maintain communication with users of technology, so as to understand their needs
        - Seems particularly relevant for demonstration projects

III. US Science and Technology Policy

- In the United States, science and technology policies originate from the desire to mobilize science and technology resources in support of the war effort during WWII, and later during the cold war.
    - Vannevar Bush, then president of the Carnegie Institution in Washington, and a former dean of engineering at MIT, convinced FDR that university science departments should play a role in the war effort.
    - Unlike countries such as France, the US does not have a central science agency.
        - In France, research has traditionally been organized and funded through the National Scientific Research Center (CNRS).
            - The focus was on large projects for both civilian and military use.
            - One example is research aimed at developing nuclear power.
            - State-owned industries were called upon to support research operations.
                - Universities were less involved than elsewhere.

        - During the 1990s, these large, state-sponsored research programs have become less important.

- Much federally funded research ends up being done by universities and by private contractors.
    - The National Science Foundation was founded in 1950 to support basic research.
        - Most NSF money goes to basic research.
        - Also, NSF is a major supporter of university research (along w/NIH)
    - Other agencies, such as Depts. of Agriculture, Interior, Labor, and Commerce, also had research budgets. They were reluctant to give up control to NSF.
        - As a result, science policy in the US is decentralized
    - Current distribution of funds:
        - Total federal R&D: $125.7 billion
            - Basic: $40.9 billion (33%)
            - Applied: $30.3 billion (24%)
            - Development: $54.5 billion (43%)
                - Note that much of the development R&D is from DOD.