I. Effects of Government Funded R&D

- In today's class, we'll look at direct government support for R&D.
  - Government sponsored R&D
  - R&D tax credits
  - R&D prizes
- The major difference between direct funding and tax credits is that direct funding goes to a specific purpose, whereas tax credits give the R&D performers more choice over the projects on which they work.
  - Direct funding allows the government to target areas with greatest perceived social needs.
    - E.g. energy in the 70s, AIDS in the 80s.
  - Types of support
    - Research grants (e.g. NSF funding to universities)
    - Contract work awarded competitively
    - Support to research consortia (e.g. SEMATECH)

- In the United States, most federally-funded research is nonetheless performed by other sources.
  - 2011: Total federal R&D funding $125.7 billion
    - $31.5 b performed directly by govt.
    - $31.3 b performed by industry
    - $17.9 b performed by FFRDCs
    - $38.7 b performed by universities
    - $6.3 b performed by nonprofits

- Like intellectual property protection, these policies aim to stimulate R&D.
  - Whereas intellectual property rights encourage R&D by making it easier for firms to reap the rewards of their work, government subsidies directly influence the performance of R&D itself.
  - In terms of the firm's decision, intellectual property rights increase the marginal rate of return (MRR).
  - In comparison, tax credits induce R&D by lowering the marginal cost of capital (MCC).
  - As we'll see, government funding of R&D can affect both curves.
- Rationale for government intervention
  - The underinvestment rationale
    - Knowledge is a public good.
    - Positive spillovers lead to underinvestment.
    - This model was initially applied to basic research.
      - Soon found to also be relevant in applied research.
  - Increasing returns in some industries make having few producers optimal. Here, government R&D may be necessary to spur R&D among these groups.
  - Governments may promote R&D to encourage economic growth.
    - In particular, note that local governments are likely more concerned with economic development than the public goods problem.
Overcoming lock-in of existing technologies

Key question for government funded R&D: is it a substitute or a complement to private R&D?

- Recall our model of the R&D process. Firms balance the marginal costs and benefits of doing R&D.
- Government R&D as a complement to private R&D
  - Shifts of the MRR curve:
    - Spillovers from government R&D raise the expected return to R&D. This shifts the MRR return up.
      - For example, scientific knowledge from academic research may increase the productivity of private R&D.
      - Note the relation to supply-side theories of innovation.
      - Note that it may take a while for some of these shifts to occur.
    - Supplying infrastructure through government R&D may make the firm’s R&D more productive.
    - Government R&D may signal future public and private sector demand for products.
      - This lowers the risk of investing, and thus shifts the expected MRR up.
      - Note potential for spillovers here – occurs even to firms not directly funded by the government.
  - Shifts of the MCC curve:
    - Government funding may be used to pay for construction of R&D infrastructure and other fixed costs. This lowers the cost to the firm, and shifts the MCC curve down.
    - R&D funding to a small firm may act as a signal of quality, enabling it to raise capital more easily, shifting the MCC curve down.
- Government R&D as a substitute for private R&D.
  - The idea here is that government R&D crowds-out privately funded R&D.
  - Two potential sources of crowding out:
    - Limited R&D resources available
      - If there are a relatively fixed amount of R&D resources available, the employment of more resources by the government leads to less being available for private usage.
      - This raises the MCC curve.
    - Goolsbee (1998) finds that increases in funding for public R&D significantly raise the wages of scientists and engineers.
      - He suggests that scientists and engineers are the major beneficiaries of government R&D
support. By raising the cost of S&E to private laboratories, government R&D crowds out private R&D.

- The government may perform research that the private market would have done anyway. In that case, private firms do less, as government sponsored research competes with privately sponsored research.
  - The expected returns to R&D by non-funded firms may fall, as they now need to compete with a federally-funded company in the market for newly-developed innovations.
  - Govt. R&D on energy in the 1970s may be an example.
  - Here, the MRR curve shifts down, as the government is competing with the private sector.

- Empirical analysis of the effects of government R&D
  - The biggest challenge is that, since both the MRR and MCC curves are shifting simultaneously, we need to control for endogeneity.
  - Examples of endogeneity problems in R&D:
    - Selection bias in awarding grants
      - Presumably the best firms will win grants. Is their success due to the grant, or because of greater ability (e.g. what can we say about a researcher from Harvard who gets a grant?)
    - Both private and public R&D respond to the same signals
      - E.g. both private and public energy R&D spending increased in the 1970s.
  - The typical regression is of the form:
    - Private R&D = a + b*Public R&D + cX + e.
      - The sign of b tells us whether public funds are a complement or substitute to private funds.
  - Grants vs. contracts
    - Contracts most often given to for-profit firms
      - For a specific purpose
    - Grants usually competitive, and have no purchase commitment
      - Scope of research broader
      - More likely given to non-profits or universities
    - Most of the studies below apply to contract R&D
  - David et al. present results for five types of studies. I've summarized each below. Most important is the summary of all results at the end.
  - Results I: Micro cross studies at the firm or industry level
    - Here, controlling for firm characteristics is important.
    - Find public R&D is either a complement or find no significant effect (Table 1)
• Effect is small (highest is 0.336)
  ▪ Results II: Firm-level studies, often using panel data
    ▪ The use of panel data controls for time-invariant differences across firms.
    ▪ Mixed results
  ▪ Results III: Industry level studies
    ▪ Only a few done, since the data is too aggregated
    ▪ These studies tend to find complementary effects
    ▪ Includes results of some case studies
  ▪ Results IV: Aggregate studies
    ▪ Look at macro level private R&D vs. public R&D.
    ▪ Important to control for other macroeconomic influences.
    ▪ Example: Levy and Terleckyj (1983):
      ▪ Government contract R&D is a complement
      ▪ Other government R&D has little effect in the short run, but acts as a complement in the long run (lag of 3-9 years).
    ▪ Cross-country comparison:
      ▪ Levy (1990) finds government R&D is a complement in 5 countries, and a substitute in two.
      ▪ Most of these studies find positive effects
      ▪ However, recall that Goolsbee found public R&D led to higher salaries for S&E.
        ▪ These higher prices raise the price of R&D, but are included in R&D spending.
        ▪ Thus, these studies may overestimate the positive effect.
  ▪ Results V: studies of nonprofits.
    ▪ Adams (1990) surveyed 208 industrial laboratories.
      ▪ He found that publicly supported academic research does not stimulate industrial learning R&D.
    ▪ Toole (1999) found that public R&D did stimulate private R&D in the pharmaceutical industry.
      ▪ Typical lag is 6-8 years
  ▪ Summary (see table 5, p. 526)
    ▪ One-third of papers find public R&D is a substitute
      ▪ Occurs most often at firm and line-of-business level
    ▪ Most studies finding substitution (9 of the 11) are done on US data.
• Example of government supported research for industry
  ▪ Small Business Innovation Research (SBIR)
    ▪ Established in 1982 with the goal of stimulating innovation in small, high-tech firms.
    ▪ All federal agencies spending more than $100 million/yr on external research were to set aside 2.5% of these funds to award to small businesses.
Three phases to SBIR research

- In phase I, firms can get grants up to $150,000 for 6 months to investigate feasibility of proposed idea.
- In phase II, ideas with potential can receive grants up to $1,000,000 for two years.
- In phase III, the product must be brought to market with private funds.
  - SBIR does not provide funding for phase III.
  - However, some agencies may provide non-SBIR R&D funds, production contracts, or bridge funds.

In FY 2011, $1.9 b awarded to 5,396 projects

- 43% of awards come from DOD, 32% from HHS.

Motivation: Smaller firms may have a more difficult time raising research capital.

SBIR recipients must be:

- Independently owned
- For-profit firms
- Less than 500 employees
- Majority of shares must be owned by US citizens

Results:

- Question: is this because of SBIR, or does SBIR “target winners”?  
  - Lerner checks this by comparing results in low-tech and high-tech industries.
  - He argues it should be harder to pick winners in high-tech.
  - Nonetheless, the results hold in high-tech.
  - Furthermore, the first award to a firm plays a big role, and the marginal value of subsequent awards declines sharply.

II. R&D Tax Credits

- Compared to government R&D, tax credits are a more market-oriented approach than R&D subsidies, as they let firms choose the research projects they will do.
- The disadvantage of this freedom is that R&D tax credits can be taken for any project.
  - Ideally, government aid should target projects with the highest social rate of return, or the highest divergence between private and social rates.
  - Given the credit, firms will still choose to do projects with the highest private rates of return.
  - However, the credit may allow them to do more research.

Tax credits in practice

- In general, there is lots of policy variation both across countries and across time.
- This makes it difficult for firms.
- Variations include (see Table 1, pp 452-3):
  - Definitions of R&D
Most countries follow the definitions in the Frascati manual. This manual was first developed in 1963 by a team of international scientists and statisticians from over 60 OECD countries to create an international definition of R&D. The manual is continually updated.

Most recent update was in 2002. It can be seen here.

Basic definition: "Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications."

- R&D depreciation rates
- R&D capital depreciation rates
- Tax credit rates
- Base at which credit begins
  - In general, the goal is to only give credit for R&D induced by the credit, not all R&D performed.
- Special treatments for small firms
- Treatment of R&D done abroad by domestic firms
- Treatment of R&D done at home by foreign firms
- Is the credit itself taxable income?

**US policy:**
- Definition excludes contract R&D and reverse engineering.
- R&D above a base determined by the average of 84-88 R&D is eligible.
  - Adjustments are made for new firms.
- R&D depreciated at 100% (the quantity is expensed)
- The credit is taxable
- Foreign R&D is not eligible
- The credit rate is 20%.
- In addition, many states (at least 32) have their own programs
  - More than ½ of these mimic the federal program (incremental credit with fixed base)
  - A recent paper found that state tax credits do increase R&D, but that it may come at the expense of neighboring states.

**Japan's policy**
- Software is included in the definition of R&D
- 20% tax credit rate
- Base R&D is the maximum R&D since 1966
- Foreign R&D is eligible.

**Changes over time**
- Reforms tend to lower statutory rates and broaden the tax base.
- Canada has treated R&D most favorably.
- Germany has been the least generous
  - Close to neutral
- In each country in figure 1, tax treatment has become more favorable since 1980s.
Heterogeneous effects among firms
  - Historically, different firms have been treated differently by the tax credit, which can lead to perverse incentives.
  - Examples:
    - Unless the tax credit is fully refundable, firms with smaller tax burdens (such as startups) cannot take advantage of the full credit.
    - There are usually caps on the maximum credit.
    - The definition of the base affects firms differently.
      - Moving bases may affect the timing of R&D.
Effectiveness of the tax credit
  - Typically, studies compare the amount of R&D induced by the tax credit to the loss of tax revenue.
    - A ratio less than one suggests direct subsidies would be more effective.
    - A ratio greater than one suggests tax credits are more effective than subsidies.
    - Note that this doesn’t address which research projects get done, or how successful they are.
  - Issues:
    - The cost of the credit
      - Traditionally, this is measured as the total credit claimed.
        - In the US, $7.8 billion claimed in 2009, $8.3 billion in 2008
        - Claims typically represent 3-3.5% of firm R&D since 2001
      - 80% of claims generated by five industries:
        - Computer and electronic products
        - Chemicals (includes pharmaceuticals)
        - Transportation equipment
        - Information, including software
        - Professional, scientific, and technical services, including computer services and R&D services
      - Administrative costs are typically ignored.
    - Measuring the R&D induced
      - The trick is we want to know how much R&D the firm would have done without the tax credit. Since we cannot observe this, the following techniques are used:
        - Event and case studies
        - Natural experiments: what happens after policy shifts
        - Price elasticity estimation: user cost of R&D used as an explanatory variable.
Results:

- US studies
  - Early studies show little effect
  - More recent studies show price elasticities near 1.
    - For each dollar decrease in the cost of R&D (and thus each dollar of tax revenue lost, since the credit lowers costs by lowering tax bills) an additional dollar of R&D is performed.
    - Hall argues that this is because it took time for firms to adjust to its presence.
- Non-US studies
  - Canada
    - Elasticities below 1 (note that the results I gave in class were in error).
  - Australia
    - Elasticity 0.6-1.0
  - France
    - Small elasticity (0.26)
  - Cross-country study
    - Short-run effect small (0.16)
    - Long-run effect near 1.
      - Note similarity to differences in early and late US studies
      - Strong long run effects may mean that multinational firms locate R&D where tax treatment is most favorable.
- Explaining differences
  - Japan and France have a moving base: this seems to lower the effect of the tax credit.
  - An OECD study found that, in Europe, R&D tax credits were not effective at encouraging non-R&D performing firms to perform R&D.

III. Research Prizes

- Alternative funding options: research prizes
  - Most R&D funding programs provide support up front.
    - This may be important, as it helps pay for expensive equipment and staff.
  - However, paying up front does not guarantee performance.
  - An alternative that does guarantee performance is a research prize.
    - With a prize, a specific goal is set, and a monetary reward offered to the first research team to meet the goal. Examples:
      - Netflix offering a prize for a program matching movie tastes that makes predictions 10% better than its current program.
    - Longitude Prize
- Offered by British government in 1714 for developing a method to measure longitude
- NASA’s Centennial Challenges
  - Multiple challenges, in areas such as robotics and spacecraft, began in 2005
- TopCoder programming competitions
  - Online computer programming challenges
- X Prize created in 1996 offered $10 million for first private manned flight into space.
- Defense Advanced Research Projects Agency’s “Grand Challenge” awarded for the development of driverless vehicles that would reduce battlefield casualties of U.S. troops.
  - Unlike traditional R&D funding, no payments are made unless the goal is met.
    - Thus firms, rather than government, bear the risk of failure.
      - If a project is risky, a large prize will be needed to make firms willing to compete.
- Winning firm unknown ahead of time.
- Avoids potential of politics influencing who gets an award.
- Fewer bureaucratic hurdles may make it easier for smaller entities.
  - But, do they have needed money to support their effort? Particularly an issue if large up-front costs are needed.
- Example: Netflix’s $1 million prize
  - In 2006, Netflix announced a $1 million prize for the first research team for the first team that could improve its movie recommendation system
    - Competing teams needed to use Netflix’s data to predict which movies consumers would prefer
    - The winning team needed to predict a consumer’s preferences 10% better than Netflix’s existing system
  - Access to data was valuable for researchers
    - Netflix has rich consumer data, with over 100 million movie ratings, but not the researchers to work on it
      - Being able to analyze and model such data has multiple applications in business, science, and politics
    - Indeed, the team that came in second place has earned $10 million from what it learned in the research
      - Had met Netflix’s goal, but were the second team meeting the goal to submit their solution
      - They were able to develop improved statistical analysis and modeling techniques that its firm uses with other marketing clients
        - Would this work in a setting with fewer commercial applications (e.g. a new spaceship)?
Policy background
  - 2011 America COMPETES Reauthorization Act gives federal agencies authority to offer innovation prizes
    - While some agencies, such as NASA, had done so before, offered a simplified path for agencies to do so
  - Including government, private, and non-profit sector prizes, McKinsey (2009) estimates that the "prize sector" in the U.S. is between $1-$2 billion
    - However, growing rapidly
    - Most growth has come from philanthropic sector

Goals of research prizes
  - Provide incentives to create a desired technology
    - Choosing and refining prize targets
      - Often, detailed technical specifications must be met
        - Requires consultation with experts, affected parties, and potential participants
      - But, if inventors have ideas that no one has thought of, prizes with detailed specifications will not help
        - Does this make prizes less useful for basic research?
      - Thinking about price targets is also important
        - If there is one winner, they will have monopoly power
        - Setting price guidelines such as the AMC example described below, avoids abuse of market power
  - Orienting research towards designing a project capable of being used at scale by consumers
    - What event should trigger the prize: meeting technology goals or market penetration (e.g. ex post use)
    - Examples promoting market penetration:
      - Super Efficient Refrigerator Program (SERP)
        - $30 million prize offered by a group of electric utilities in 1992
        - Goal: to spur development of an energy efficient refrigerator meeting certain energy efficiency and environmental standards
          - Whirlpool won the prize in 1993
          - However, to win the full award, had to sell at least 250,000 by 1997
            - Sales were lower than expected, due to higher prices of the refrigerators
            - Thus, Whirlpool did not receive the prize
          - The market test thus ensured that the winning technology be desirable to consumers
      - Advance Market Commitment (AMC)
        - Legal contract to pay a guaranteed price for a predefined number of vaccines
        - Conditions:
          - Vaccine must meet technical specifications
Poor countries express demand, such as by contributing a small price to the purchase
- Subsidized price induces research, but long-run price will be low once initial quantity purchased at the subsidized price
  - Note how this avoids the monopoly pricing distortion of patents
    - The subsidy provides the incentive for development
    - Once developed, developing countries pay a price similar to marginal cost
- In contrast to demonstration projects
  - The Ansari X Prize is an example of a demonstration project
    - Prize offered to the first team to “build and launch a spacecraft capable of carrying three people to 100 kilometers above the earth’s surface, twice within two weeks.”
    - Goal was to show it is possible, not to develop the technology for consumers
  - Placing technology in the public domain to incentivize subsequent research
    - In 1839, France bought the patent for Daguerreotype photography and placed it in the public domain
    - Thus, it is important to consider what happens after the prize has been won
      - Some prize sponsors want to control intellectual property
      - Particularly true when businesses are the sponsor
      - Others let winners keep IP
    - If innovation is cumulative, important that the winner not be able to hinder future research on the topic
    - Patent buyouts can ensure technology remains in public domain
      - Auctions could be used to determine the commercial value of a patent
- What issues should be considered when setting the size of a prize?
  - Needs to be high enough to encourage firms to do research
  - However, government does not want to overpay
    - Analogous to patent races
      - Too many competitors may enter a race for a large prize
    - Complexity matters here
      - If the goal is difficult to reach, different teams using different methods to try to reach the goal may be useful
      - Note that the tradeoff is between duplicating research versus having enough different entrants to ensure success
  - Larger prizes may generate results more quickly
  - Looking at evidence is difficult
If a prize hasn’t been awarded, is it because the prize was too small or simply because the goal has yet to be met?

- Other markets may provide information
  - Advance market commitments for vaccines try to set a price comparable to what pharmaceutical companies could get for a product made for high income markets

**Evaluating prizes**

- Key questions:
  - Would the technology have been developed without the prize?
  - Would the technology have been developed more quickly with a different prize structure?

- Evaluation challenge: What is the appropriate baseline?
  - That is, what would firms have done if the prize had not been offered?
    - For example, the Archon X Prize for Genomics offered a $10 million price of a method of sequencing the human genome
    - However, firms were already working on this question before the prize
  - Given the small number of prizes, hard to evaluate
    - All but a few of the 200 prizes complied by McKinsey (2009) have been awarded
      - Cannot observe a world both with and without the prize
  - Because of these challenges, most existing research uses case studies
    - Suggests past prizes have been successful
  - Williams argues that field experiments would be a promising alternative
    - E.g. having groups randomly assigned to compete for a cash or not cash prize