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Analyzing Patents Generated by SBIR Firms

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Panel 18. Enhancing Small Business Participation in Defense Acquisition

Thursday, May 15, 2014	
1:45 p.m. – 3:15 p.m.	**Chair: Rear Admiral Seán F. Crean,** U.S. Navy, Director, Office of Small Business Programs, Department of the Navy ***Disruptive and Sustaining Technology Development Approaches in Defense Acquisition*** Gene Warner, OUSD(AT&L) Manufacturing and Industrial Base Policy ***Analyzing Patents Generated by SBIR Firms*** Toby Edison, Defense Acquisition University ***Increasing the Department of the Navy's Opportunities for Small Business and Non-Traditional Suppliers Through Simplified Acquisitions Contracting and NAICS Targeting*** Max Kidalov, Naval Postgraduate School Jennifer Lee, Naval Postgraduate School

Analyzing Patents Generated by SBIR Firms

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Abstract

The Department of Defense is the single largest funder and consumer of research and development in the United States. The main incentives the DoD gives innovators are direct funding, research contests, and, increasingly, intellectual property rights protection. Institutions protecting intellectual property provide incentives for innovation, because they give innovators the ability to commercially exploit their inventions before others can enter the market with similar technologies. To this end, the Constitution explicitly gives Congress the power to grant inventors the right to patent their inventions. Patent rights are a controversial economic incentive that grants a temporary monopoly to the inventor to exploit the technology, in exchange for public declaration of the invention. Even more controversial is the retention of patent rights by private inventors conducting publicly funded research: Proponents argue that giving private inventors title to their invention gives them incentives to commercialize their innovations, opponents argue that public research results should remain in the public domain, and not be given the temporary monopoly protection of patent. Until the 1980s, the default for the DoD in assigning patents rights was for the government to retain ownership, with private firms and individuals obtaining patent rights in exceptional circumstances. In the 1980s, the Bahy-Dole Act and Stevensen-Wilder Act, both in 1980 and the 1982, Small Business Innovation Research (SBIR) Act were part of a series of laws granting inventors and participating firms intellectual property rights, including patents rights to inventions funded by federal research money. To date there has been no systematic analysis of these laws on the propensity to patent DoD funded research. This research builds a database of patent funded by the DoD to see if the statutory changes have increased the propensity to patent of defense research performers. The analysis is specifically set up to see if participants in the SBIR program are more innovative than other research performers. To answer this question, I use non-linear regression techniques to test the following three hypotheses:

1. H0: SBIR participants have a higher patent output per R&D dollar than other research performers.
2. H0: SBIR participants receive more citations per patent than other research performers.
3. H0: SBIR participants produce more high citation patents per patent, or per R&D dollar than other research performers.

I find that SBIR contract winners are more prolific patenters per DoD R&D dollar than large defense contractors, but less prolific than Universities. The citation rate (per DoD R&D dollar and per patent) for SBIR patents is also more than other DoD Assignees but less than University assignees.

Introduction

> If science is the constellation of facts, theories and methods collected in current texts, then scientists are the men who, successfully or not, have striven to contribute one or another element to that particular constellation. Scientific development becomes the piecemeal process by which these items have been added singly and in combination, to the ever growing stockpiles that constitutes scientific technique and knowledge. (Kuhn, 1962, pp. 1–2)

> Regardless of how one thinks about science, it seems incontrovertible that the rate of technological progress depends on the way human useful knowledge is generated, processed, and disseminated. (Mokyr, 2002, p. 34)

Knowledge Production Is the Goal

Economists are unanimous in concluding that technological progress has improved the quality of human life (Solow, 1957; Romer, 1990; Mokyr, 1992). With equal unanimity, military policy makers put technological superiority as a key component of achieving and sustaining U.S. national security (QDR, 2006; JV, 2010). The creation of new knowledge and the application of existing knowledge in innovative ways are the key components of technological progress (Mokyr, 2002; Baumol, 2002). Policymakers also believe that there are “market-failures” in the private investment of knowledge production, because knowledge production is risky with uncertain payoffs, and quickly made a public good to be exploited by others (Nelson, 1959; Arrow, 1962). To overcome these market failures governments offer a range of incentives--such as contracts, prizes and intellectual property rights—to innovators to invest their time and intellectual capabilities to create new knowledge (Mennell & Scotchmer, 2005). Intellectual property rights create incentives for innovators because they give inventors certain rights to exclude other from using their ideas while the inventor tries to commercially exploit the innovation before other can. One important policy tool for protecting intellectual property is the patent, which governments use to grant exclusive monopoly rights for inventors to exploit their innovation for a period of time, provided the inventor publicly declares the innovation.

The Patent Economic Incentive

Economic incentives are increasingly aligned to reward skills, creativity and innovation, with high valued-added activities being linked with producing “ideas” rather than with producing “things.” The challenge for economists and policy analysts is to find methods to estimate the value of idea creation (Griliches, 2003). Figure 1 illustrates some of the challenges of measuring the value of ideas, because investments in knowledge production can lead direction to new marketable products, or new knowledge can indirectly influence marketable products through spill over effects. The combination of private and public returns will give policy makers the total impact of investments in knowledge production. One of the continual challenges of estimating the effects of investments in knowledge production is measuring the amount of knowledge produced. One method of estimating the amount of knowledge created is to use proxy measures such as patents.

Suzan Scotchmer and Peter Menell summarize the how intellectual property support economic growth: “The role of intellectual property in contributing to innovation, however, has been more difficult to establish. As we will see, the availability of intellectual property for innovation creates incentives for investment as well as potential impediments to diffusion and cumulative innovation. The net effects are quite complex to sort out from both theoretical and empirical perspectives.”

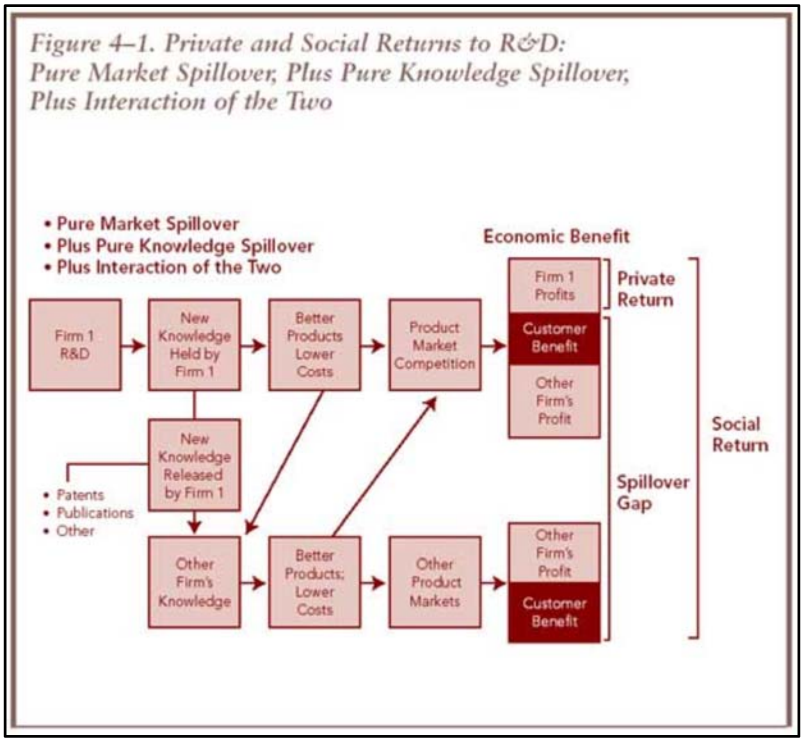

Figure 1. Knowledge Production Function
(Griliches, 2002)

Background on SBIR Patent Rights

U.S.C. 200 policy and objective:

> It is the policy and objective of the Congress to use the patent system to promote the utilization of inventions arising from federally supported research or development; to encourage maximum participation of small business firms in federally supported research and development efforts; to promote collaboration between commercial concerns and nonprofit organizations, including universities; to ensure that inventions made by nonprofit organizations and small business firms are used in a manner to promote free competition and enterprise without unduly encumbering future research and discovery; to promote the commercialization and public availability of inventions made in the United States by United States industry and labor; to ensure that the Government obtains sufficient rights in federally supported inventions to meet the needs of the Government and protect the public against nonuse or unreasonable use of inventions; and to minimize the costs of administering policies in this area. (U.S. Code 35)

Legislative Background on Federal and DoD Patent Rights

Definition of a Patent

The United States Patent and Trademark Office (USPTO) defines a patent as “A patent for an invention is a grant of property rights by the U.S. Government through the U.S. Patent and Trademark Office. The patent grant excludes others from making, using, or selling the invention in the United States. A utility or plant patent in force on June 8, 1995, is subject to either the 17 year term from grant or the 20 year term from earliest effective U.S. filing date, whichever is longer" (USPTO, 2005).

Constitutional Foundation Patents

Patents are policy instruments governments use to give inventors rights to put their inventions to practical use. Governments grant inventors temporary exclusive rights to use their inventions in exchange for the inventor disclosing the invention.

The United States Constitution explicitly grants Congress the power to enact patent laws. Specifically, Article I, section 8, states, "Congress shall have power . . . to promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries" (USPTO, 2005). Applying this power, Congress enacted the first patent laws in 1790 (Skolokoff, 2003).

The patenting of federally funded research is the subject of a consistent and long running public debate over who should control the rights to patented inventions. Since congressional debate began on the subject in the 1880s (Jaffe, 2003), some in Congress have called for government retention of rights to patented inventions, if the inventions were patented at all. Others have called for various levels of rights to be granted to the contractor for commercial technology transfer. Government rights advocates argue that since the research was funded with public money the results should become public goods. Contractor right advocates argue that without exclusive use rights to inventions no private firm has an incentive to commercialize technology that could be duplicated by other firms.

Since World War II the debate over intellectual property rights assignment has intensified, but no consensus had been reached until the 1980s when congress began a long series of legislation that grants more intellectual property rights to the inventor. I will briefly cover the highlights of legislation from the periods 1945 to 1980, and 1980 to present.

Table 1. 1945–1980 Changes in Intellectual Property Right on Government-Funded Inventions

Year	Title	Description
1945	National Patent Planning Commission	Proposed that agencies be allowed to set unique policies regarding technology
1947	US DOJ Investigation of Government Policies and Practices	Urged the adoption of uniform policy granting governement title to most federally funded technologies
1950	Executive Order 10096	Established centralized Government Patent Board to assign patent ownership
1961	Executive Order 10963	Allowed agencies to set separate patent policies and occasionally grant nonexclusive licenses.

The dramatic expansion of federal R&D activities surrounding the U.S. build-up for World War II, lead to an increase in the debate over how to assign patent rights to federal funded inventions. The continued non-consensus of the debate is highlighted by two nearly simultaneous reports commissioned by President Franklin D. Roosevelt, which offered opposing patent policy conclusions.

The first to be published in 1945, by the ad hoc National Patent Planning Commission found reasons for granting patent rights to firms:

> It often happens, particularly in new fields, that what is available for exploitation by everyone is undertaken by no one. There undoubtedly are Government-owned patents which should be made available to the public in commercial form, but which call for a substantial capital investment, private manufacturers have been unwilling to commercialized under a nonexclusive license. (U.S. House of Representatives, 1945)

The second report by the Department of Justice, completed in 1947, argued against contractor retention of patent rights:

> Innovations financed with public funds should inure to the benefit of the public, and should not become a purely private monopoly under which the public may be charged for, or even denied, the use of technology which it financed. (U.S. Department of Justice, 1947)

Over the next 30 years federal policy vacillated between granting patent rights to the government to granting patent rights to inventors. By the 1970s there was a growing consensus that government retention of patent rights was not benefiting the public in the most efficient manner. The GAO (1999) succinctly summarizes the policy debate:

> Despite the perceived success of federal efforts to support R&D, by the late 1970s there was a growing dissatisfaction with federal policies related to the patenting of the scientific knowledge resulting from research the. Many officials, for example, believed that federal laboratories harbored information that was not being disseminated to those who could make use of it. Similarly, there was a concern that the advances attributable to university-based research were not being pursued because there was little incentive to seek practical uses for inventions to which the federal government retained title. Those seeking to use government-owned technology found a maze of rules and regulations set out by the agencies in question because there was no uniform federal policy on patents for government-sponsored inventions or on the transfer of technology from the government to the private sector. (GAO, 1998b)

1980–Present: The Inventor Retention and Stronger Patent Protection

In 1980, Congress began enacting a series of legislation aimed at simplifying intellectual property rights assignment for federally funded research, transferring federally funded research to commercial use, and granting intellectual property on federally funded research to the inventor. The two milestone acts passed in 1980 were the Bayh-Dole University and Small Business Patent Procedure Act (P.L. 96-517, December 12, 1980) and the Stevensen-Wydler Technology Innovation Act (P.L. 96-480; 15 U.S.C. 3701-3714). The 1980 Acts changed the default assignment of intellectual property rights from the government to the inventor.

The Bahy-Dole Act changed U.S. patent policy related to government-sponsored research. According to the GAO (1998b), at the time the act passed, fewer than 5% of the 28,000 patents being held by federal agencies had been licensed, compared with 25% to 30% of the small number of federal patents for which the government had allowed companies to retain title to the invention. Because of this disparity, Congress decided to change how intellectual property rights were assigned on federally funded research from a preference for federal agency ownership to a preference for private ownership. To this end the act required all agencies: (1) to allow universities, not-for-profit corporations, and small businesses to patent and commercialize their federally funded inventions and (2) to allow federal agencies to grant exclusive licenses for their technology to provide more incentive to businesses (GAO, 1998b).

The major provisions of the Bayh Dole Act include the following:

- Non-profit institutions, including universities, and small businesses may elect to retain title to innovations developed under federally funded research programs;
- Universities are encouraged to collaborate with commercial enterprises to promote the utilization of inventions arising from federal funding;
- Universities are expected to file patents on inventions they elect to own;
- Universities are expected to give licensing preference to small businesses;
- The government retains a non-exclusive license to practice the patent throughout the world; and
- The government retains march-in rights.

In order to retain intellectual property rights the contractor must follow the following rules:

- The contractor or grantee must disclose to the appropriate agency any invention created with the use of federal funds within 2 months of the date the inventor discloses the invention in writing to the contractor or grantee. [1]
- If the contractor or grantee decides to retain title to the invention, it generally must notify the agency within 2 years of the date of disclosure that it has elected to do so.
- The contractor or grantee must apply for a patent on the invention within 1 year of its election to retain title or within 1 year of the publication, sale, or public use in the United States, whichever is earlier.
- In applying for a patent, the organization must add a government interest statement that discloses the government's rights to the invention.[2]

[1] Federal Acquisition Regulation (FAR) 52.227-12-c-1, Patent Rights—Retention by the Contractor. The Contractor shall disclose each subject invention to the Contracting Officer within 2 months after the inventor discloses it in writing to Contractor personnel responsible for patent matters or within 6 months after the Contractor becomes aware that a subject invention has been made, whichever is earlier. The disclosure to the Contracting Officer shall be in the form of a written report and shall identify the contract under which the invention was made and the inventor(s). It shall be sufficiently complete in technical detail to convey a clear understanding, to the extent known at the time of the disclosure, of the nature, purpose, operation, and physical, chemical, biological, or electrical characteristics of the invention. The disclosure shall also identify any publication, on sale, or public use of the invention and whether a manuscript describing the invention has been submitted for publication and, if so, whether it has been accepted for publication at the time of disclosure. In addition, after disclosure to the Contracting Officer, the Contractor shall promptly notify the Contracting Officer of the acceptance of any manuscript describing the invention for publication or of any on sale or public use planned by the Contractor.

[2] FAR 52.227-12-f-4, Patent Rights—Retention by the Contractor. (4) The Contractor agrees to include, within the specification of any United States patent application and any patent issuing thereon covering a subject invention, the following statement: "This invention was made with Government support under (identify the contract) awarded by (identify the Federal agency). The Government has certain rights in this invention."

- The contractor or grantee must attempt to develop or commercialize the invention. (GAO, 2002)

The Bayh-Dole Act offers no protection of the patent interests of large, for-profit businesses engaged in government research. In 1983, however, President Reagan issued a memorandum extending the patent policy of the Bayh-Dole Act to any invention funded by federal research and development contracts, grants, and cooperative agreements regardless of the business's size or its nonprofit status. In 1987 Executive Order 12591 required executive agencies to promote commercialization in accordance with the 1983 memorandum (GAO, 2003).

The Stevenson-Wydler Technology Innovation Act of 1980 mandates Federal Laboratories to (1) actively seek cooperative research with State and local governments, academia, nonprofit organizations or private industry (2) disseminate information (3) establish the Center for the Utilization of Federal Technology at the National Technical Information Service, (4) establish and define the basic activities of an Office of Research and Technology Applications at each federal laboratory, and (5) set aside 0.5% of each laboratory's budget to fund technology transfer activities.[3] Collectively, the provisions of the act require all Federal to agencies include technology transfer as a primary mission of their laboratories.

Nearly simultaneous to the passing of Bayh-Dole and Stevenson-Wilder, the Supreme Court changed their interpretation the antitrust implications of the monopoly rights granted by patents. Beginning in 1980, the Supreme Court reversed the prevailing interpretation by the Federal Trade Commission and the Justice Department that inventors enforcing the exclusivity of patents were anti-trust violations. Several Supreme Court decisions around 1980 stated that monopoly power was the purpose of the patent grant, therefore "efforts to enforce patents and extract the monopoly rents they generate were not, in and of themselves violations of antitrust laws" (Lerner, 1999, pp, 3–4). To support this interpretation, Congress passed the Federal Courts Improvement Act of 1982, which created the Court of Appeals for the Federal Circuit (CAFC) for exclusively applying patent laws (Hart, 1999).

The Small Business Innovation Development Act of 1982 (P.L. 97-219) requires federal agencies to set aside a small portion of their contracts and grants for small businesses. Congresses intention for the SBIR Program is to "strengthen the role of innovative small business concerns in Federally-funded research or research and development (R/R&D)." Congress has four explicit goals for the program: first, to stimulate technological innovation; second, to use small business to meet Federal research and development; third, to foster and encourage participation by socially and economically disadvantaged small businesses; and finally, to increase private sector commercialization of innovations derived from Federal R&D, thus increasing competition, productivity, and economic growth.

[3] Later amended to "sufficient funding to support technology transfer activities."

The SBID Act also allows small businesses to retain intellectual property rights including patents to their invention, provided the firm declares the invention to the government and included a government interest statement in the patent.[4]

Patenting Military Technology

The DoD's policies in determining whether to retain patent rights within the agency or grant those rights to the contractor have reflected Federal statutes and policies. The current emphasis is for the inventor to retain rights to the invention to give the inventor private incentives to commercialize public inventions.

Prior to the many laws in the 1980s favoring inventors' retention of patent rights, the default was for the DoD to retain patent rights, unless a waiver was issued. According the GAO in 1974, the DoD granted waivers to assign contractors patent rights if there was a high commercial potential, the contractor has an established nongovernmental commercial position, and the contractor is an emerging competitor in a potentially commercially successful technology. Since the 1980s, in compliance with Bahy-Dole, Stevenson-Wylder, and the SBID Acts, the Department defaults to granting patent rights to the inventor in most cases.

The DoD will retain title to patented inventions in some cases. According to responses by Army, Navy and Air Force patent attorneys to the GAO in 2002, the primary reason the DoD seeks a patent for "defensive" purposes so the agencies can protect their rights in inventions that may have a future military use.

An example of a circumstance where intellectual property rights impacted the ability of the department to sustain a critical weapon systems was detailed by the GAO in testimony given in 2002:

> In one instance, when the Army tried to procure data rights later in the system's life cycle, the manufacturer's price for the data was $100 million—almost as much as the entire program cost ($120 million) from 1996 through 2001.

Current DoD policies for assignment of patent rights are contained in the Federal Acquisition Regulation (FAR) and the Defense Federal Acquisition Regulation Supplement (DFARS). The FAR 52.227-11 and -12 states, "The Contractor may retain the entire right, title, and interest throughout the world to each subject invention." The contractor forfeits these rights if they fail to disclose and invention, or fail to make efforts to commercialize the invention. If they fail to make efforts to commercialize an invention the government can exercise its march-in rights, which are detailed in 35 U.S.C. 203.

In 2001, the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]) issued a policy guidebook detailing intellectual property rights

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[4] "Small business concerns normally may retain the principal worldwide patent rights to any invention developed with Government support. The Government receives a royalty-free license for Federal Government use, reserves the right to require the patent holder to license others in certain circumstances, and requires that anyone exclusively licensed to sell the invention in the United States must normally manufacture it domestically. To the extent authorized by 35 U.S.C. 205, the Government will not make public any information disclosing a Government-supported invention for a minimum 4-year period (that may be extended by subsequent SBIR funding agreements) to allow the awardee a reasonable time to pursue a patent."

policies for defense program managers. The manual details the core intellectual property principles for the DoD acquisition community:

1. Integrate IP considerations fully into acquisition strategies for advanced technologies in order to protect core DoD interests.
2. Respect and protect privately developed IP because it is a valuable form of intangible property that is critical to the financial strength of a business.
3. Resolve issues prior to award by clearly identifying and distinguishing the IP *deliverables* from the *license rights* in those deliverables.
4. Negotiate specialized IP provisions whenever the customary deliverables or standard license rights do not adequately balance the interests of the contractor and the Government.
5. Seek flexible and creative solutions to IP issues, focusing on acquiring only those deliverables and license rights necessary to accomplish the acquisition strategy. (USD[AT&L], 2001)

Over time, the DoD patent rights assignment has evolved from a de facto assignment of rights to the government to a de facto assignment to the private developer. The impact of these changes on patenting of federally funded research will be discussed in the next section.

Academic Literature Review of Impact of Federal Law Changes on Patenting

There have been numerous academic studies of patenting trends in American industries. Early studies focused on aggregate trends of broad industries, but as computing power increased and access to machine readable patent data improved so did the detail of academic patent analysis. The following section details some of the major patent related papers.

Jaffe (2000) reviews the broader economic theory and empirical analysis literature concerning the effects of changes in patent policy that occurred in the 1980s. He concludes that the despite the significant policy changes and rich available sets of patenting data measurable and generalizable conclusions about the effects of the institutional changes in patent policy are few.

Mowery et al. (1998) use case studies of patenting and licensing activities of Stanford University, the University of California, and Columbia University to analyze the effect of the Bahy-Dole Act on the schools' research. They find little evidence that the act affect the content of research conducted, concluding that shift in research portfolios were occurring before the act and would probably have continued without the act. They also find little support that the Bahy-Dole Act increased the universities propensity to patent, rather they find that other more import nearly simultaneous changes court rulings more permissive of biomedical patents, and the passage of other stronger patent protection laws had more effect. Finally, they raise questions about the utility of patents on the results of fundamental research or of tools whose primary purpose is to support future research, believing that there are other more efficient knowledge diffusion channels, that don't have the inefficiencies of patents.

There are two empirical analyses that specifically look at how patent law changes in the 1980s impacted the patent production of federal agencies: Jaffe, Fogarty, and Banks (2001) and Jaffe and Lerner (2001). In 2001, they studied Lawrence Livermore National Laboratory and Idaho National Engineering and Environmental Laboratory technology transfer programs, finding that the "policy changes have a substantial impact on the laboratories' patenting." Jaffe, Fogarty, and Banks (2001) analyzed patents awarded to the

U.S. government and the citations to those patents from subsequent patents to understand the role of federal labs in the commercialization of government-generated technology. They used citations to on federal patents to compare the average technological impact of NASA patents, to other federal patents, and a random sample of all patents finding that the growth in federal patenting in the 1980s did not reduce patent quality. They also compared the geographic locations of commercial (non-federal) citations to the location of the federal labs, finding that subsequent citations are more likely to be geographically near the federal labs. They concluded that there is evidence of an increased effort to commercialize federally developed technology in all federal labs and NASA specifically. Finally, through interviews and surveys of federal inventors, the researchers concluded that there is some support for using citations as proxies of technological impact and knowledge spillovers.

Government Compliance Reviews of Agency Patenting Processes, USPTO Patent Statistics, SBIR Patenting Statistics

The GAO has produced several studies on patenting of federal research and technology transfer activities of federal agencies. They found the DoD patent statistics to be difficult to obtain, incomplete, inaccurate, inconsistent, and used different data fields (GAO, 2003). Their studies in 1991 and 1999 focused on statutory compliance with Bahy-Dole, Stevenson-Wilder, SBID, and Executive Order 12591. The following two charts (Figures 2 and 3) are representative of the GAO's focus on ensuring Federal agencies are complying with statues.

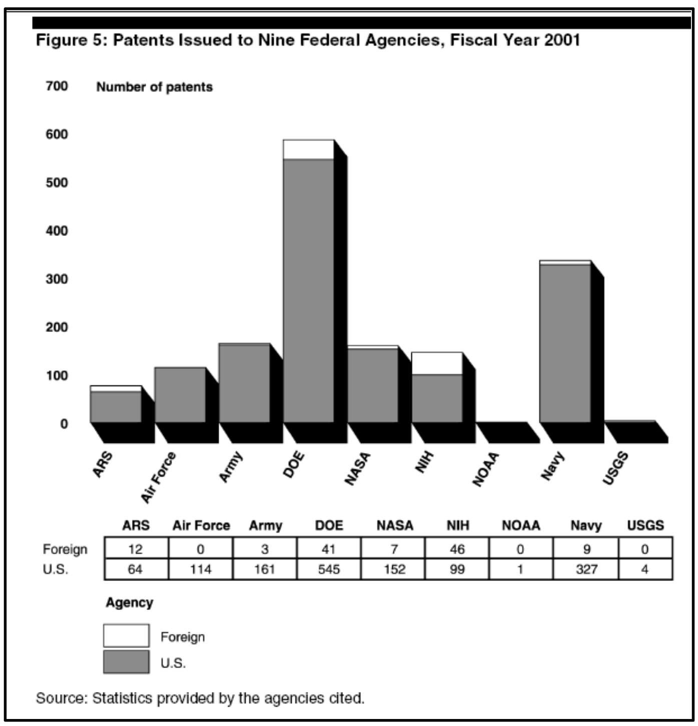

Figure 2. Patents Issued to Nine Federal Agencies, Fiscal Year 2001
(GAO, 2003)

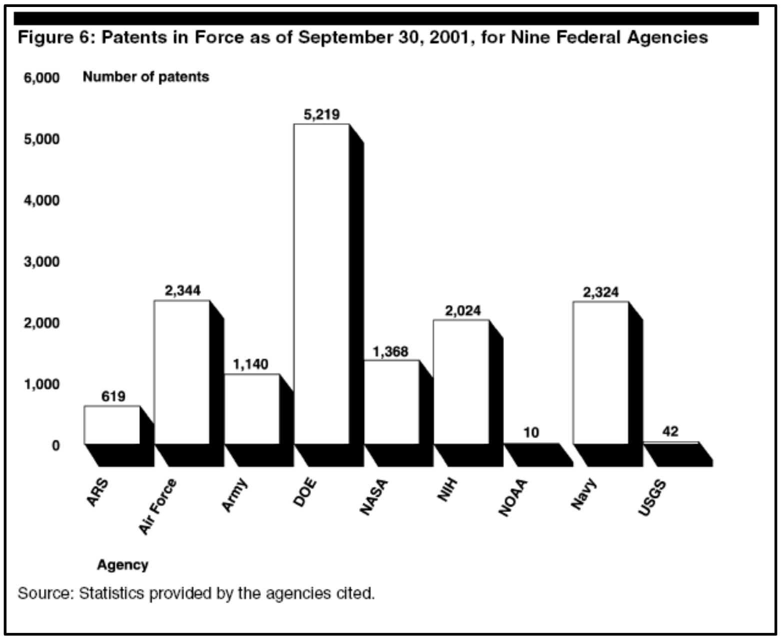

Figure 3. Patents in Force as of September 30, 2001, for Nine Federal Agencies
(GAO, 2003)

The United States Patent and Trademark Office publishes aggregate statistics for patents that have as an assignee[5] the DoD, the Air Force, Army, and Navy. They do not publish information on patents with government interest statements.[6]

SBIR and Small Business Patenting

The 1987 GAO report of the SBIR program included a survey of all firms that won a SBIR award from 1983–1985, 1131 firms of 1405 firms responded. The survey collected self-reported patents generated with SBIR funding. Collectively the respondents reported that 2427 patents had been awarded with a median of less than one per firm, and mean slightly greater than one per firm. Additionally about 35% of the respondents said that they would use patents as a means of commercializing their innovations.

Also in 1987, the GAO interviewed eight small business representatives regarding the effect the Bahy-Dole Act had on their research and innovation efforts. All eight indicated that the Act had had a "significant positive impact on small businesses." They added that other factors such as the SBIR program and changes in tax laws "have had equal or greater significance on small businesses' research and innovation efforts."

In 1992 the GAO published another report on a survey of SBIR awardees that contained questions regarding patent conducted by SBIR awardees. The survey was of all Phase II awards from 1982–1991, with respondents representing 1457 phase II awards. Among the 1,467 projects, 293 projects reported receiving 639 patents.

[5] Named owner

[6] Patent statistics by federal agencies produced by the USPTO can be found here: http://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_gov.htm

A 2006 RAND report on the DoD SBIR program, analyzed and compared the cost per DoD SBIR generated patent with patents generated by DoD research dollars, and patents generated with non-DoD SBIR dollars. The report found that the average cost per patent for DoD research was about $38.5 million, for DoD SBIR research $71.5 million, for non-DoD SBIR research $39.9 million. The study was inconclusive about the conclusions that could be drawn from the analysis because of the inconsistencies in the choice to patent and the link between patenting and innovation.

The Iknowvation Development Institute[7] has developed a database of all patenting by SBIR related firms. They have created a relational database of firms participating in the SBIR program with all of their name variations, and have linked these names to the assignee names of firms receiving patents from the USPTO. They update the database once a week. Through their analysis they have made the following finding: Awardees that are actively patenting are generally doing far better in SBIR-STTR than those which are not. They base this finding on three conclusions about SBIR awardees that patent. First patenting SBIR awardees win 60% of SBIR contracts but only constitute 29% of awardees. Second, SBIR awardees that patent receive nearly three times more SBIR awards than non-patenting participants. The number of patents per patenting SBIR firm is highly skewed with a handful of firms with a large number of patents and a long tail of thousands of firms receiving 1–4 patents.

The DoD collects self-reported data from SBIR applicants on patent generated from SBIR funded research in its non-public Contractor Commercialization Report. I did review the patent data reported and found it to be an order of magnitude higher than the USPTO database developed for this dissertation.

In conclusion, databases on all patents generated from DoD contracts do not exist, which limits the analysis that can be done. Where DoD patent data does exist, it is incomplete, biased, and difficult to obtain, which is a major reason DoD patenting has gone unexamined. The next section includes a discussion of one basic contribution to knowledge this research made: the creation of a more comprehensive database of patents funded with defense R&D dollars.

Data Sources

Creating a Database of DoD Funded Patent Data

Since there is no central database maintained by the DoD[8] on their patenting activities, and the United States Patent and Trademark Office does not maintain public databases on the patents owned by the DoD and the patents generated by DoD contractors, a new database of defense interest patents was created.

Information contained within the patent was used to create the database. Each patent grant contains a rich array of information regarding the invention:

- Inventor and Owner of Patent rights: Name of inventor and assignee firm
- Location: Of Inventor and Assignee firm

[7] Retrieved June 6, 2007, from http://www.inknowvation.com/Patents.html#1
[8] In 2002, the GAO found, "none of the services has a unified technology transfer database and, when statistics are needed, the services must query the individual commands or units for information" (GAO, 2002a).

- Time: The date the patent was applied for and the date granted
- Technology Class: One or more of 700 U.S. technology classes and sub-classes as well as international and foreign technology classes
- References Cited: Previous patents as well as scientific documents the technology this patent refers to
- Citing References: Subsequent patents granted that build related to Patent (Included in the electronic database)
- Government Interest: A mandatory statement for all patents funded by federal contracts of grants identifying government rights to this invention
- Abstract: A summary of the inventions claim of originality
- Claims: A detailed description of the claim of invention, including drawings. "The specification must conclude with a claim particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention or discovery."[9]

[9] http://www.uspto.gov/web/offices/pac/mpep/documents/0600_608_01_i.htm#sect608.01i

US006418832B1

(12) **United States Patent**
Colvin

(10) **Patent No.:** **US 6,418,832 B1**
(45) **Date of Patent:** **Jul. 16, 2002**

(54) **BODY ARMOR**

(75) Inventor: **David P. Colvin**, Cary, NC (US)

(73) Assignee: **Pyramid Technologies International, Inc.**, Cary, NC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/558,496**

(22) Filed: **Apr. 26, 2000**

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(58) **Field of Search** 89/36.05, 36.02; 2/2.5

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(57) **ABSTRACT**

A body armor system having improved impact energy absorbing characteristics includes a projectile penetrant inhibiting layer and an impact energy absorbing layer positioned in overlying relation to one side of the projectile penetrant inhibiting layer such that the impact energy absorbing layer is adapted to absorb the impact energy from an incoming projectile. The impact energy absorbing layer spreads at least a portion of the impact energy in the plane of the impact energy absorbing layer. An anti-spalling layer is positioned on the opposite side of the projectile impact inhibiting layer. In another aspect of the invention, the impact energy absorbing layer contains a foam to further enhance impact energy absorption. Additionally, a temperature stabilizing means such as a phase change material is placed within the impact energy absorbing layer and provides thermal regulation. The phase change material may be bulk, microencapsulated or macroencapsulated and may be placed directly within the impact energy absorbing layer or within the foam as desired.

19 Claims, 4 Drawing Sheets

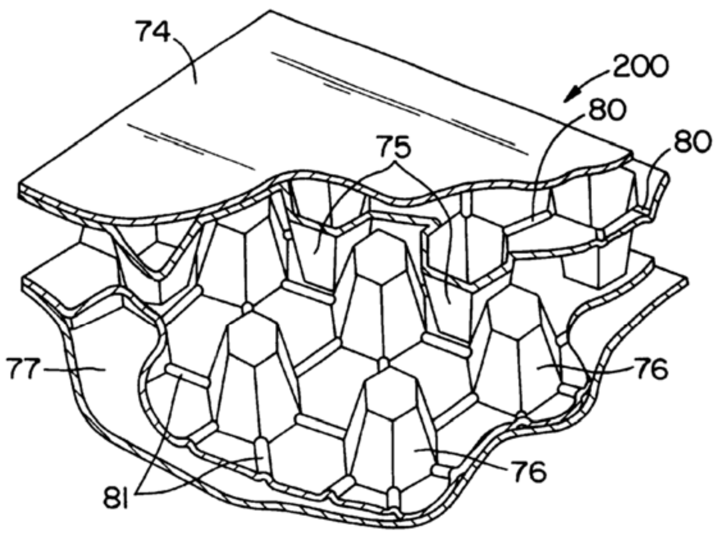

Figure 4. A Typical First Page of a Patent

Finding data on patents generated by DoD RDTE funds is a daunting task. There are three sources of data on DoD patents. The first is the USPTO database which identifies DoD agencies as Assignee's (owners) of patents and contains a government interest statement usually identifying the source of RDTE funds that generated the patent. The

USPTO database only available in its entirety via the USPTO website. The second source of information on DoD patents is the USPTO's Government Register, into which inventors are required report all patents funded with federal dollars, and thus have a limited royalty free government license. Thus the USPTO should have two separate and complete databases. The third is the individual services technology transfer offices. The next few paragraphs discuss short-comings of the later two databases, which required an innovative approach to tapping into the USPTO database.

The GAO has found the Government Register to be an inferior record of government rights to the government interest statement on the patent. In 1997 they found 2,083 unique patents listed among the two databases with either the government interest statement on the patent and/or the confirmatory license recorded in the Government Register. Of these patents only 128 or 6.1% were recorded in both databases. Of the remaining 1,955 patents, 72, or 3.5%, appeared only in the Government Register, while 1,883, or 90.4%, had only a government interest statement on the patent. In summary the government interest statement captured a total of 2011 or 96.5% of the total patents, while the Government Registry captured only 200 or 9.6% of the patents (GAO, 1999). The GAO concludes, "The patent database is a better source than the Government Register for determining the government's rights to federally sponsored inventions. It is more accessible than the Government Register in that the official patent records are available for inspection and a user can obtain from PTO's Internet Web site the full text of patents issued since 1976" (GAO, 1999).

Obtaining data directly from the DoD on their patents is not easier or more reliable. According to the Government Accountability Office, "each of the military services within DoD has its own technology transfer program and each of these is decentralized." The report further laments, "none of the services has a unified technology transfer database and, when statistics are needed, the services must query the individual commands or units for information" (GAO, 1999). Even if a researcher could identify all the organizations within the DoD with a patent and get them to agree to share the data, the GAO further finds that the data is inaccurate and inconsistent: "In comparing the statistics provided to OMB and Commerce with those provided to us, we noted that the Navy's statistics varied in all five of the categories compared, the Army varied in four, and the Air Force varied in three."

With the Government registry determined to been tremendously inaccurate, and the DoD databases difficult to obtain, and unreliable, the only remaining option is to obtain the data directly from the USPTO website. Unfortunately, the website is not designed with the researchers need for quick accurate access to massive amounts of data. The GAO is pessimistic on this route as well, "the patent database has its own problems and can be difficult to use" (GAO, 1999). While its search capability allows for a quick identification of patents with DoD agencies as the Assignee, or a DoD agency in the Government Interest field, viewing complete patent information with application data, grant data, and citations can only be accomplished one patent at a time. With nearly 30,000 patents identified with a DoD assignee or a DoD government interest, an automated method needed to be created.

Excel's Visual Basic programming permits programmers to automatically perform web downloads, and cut out of the downloaded webpage the exact information needed. An automated patent extraction program developed for this dissertation, began downloading DoD patent data in October 2004 and finished in March 2005, collecting information on each of the 29,963 patents with either a DoD agency as an assignee or a DoD related government interest statement.[10] The remainder of the dissertation will refer to this database as the “Defense Interest Patent Database.” Of DIPD. A sample of one of the programs is included in the Appendix.

To check accuracy of the download algorithm a subset of the DoD assignees from the 1990-1999 Defense Interest Patent Database is compared to the published USPTO Federal patenting statistics for DoD agencies (U.S. Patent and Trademark Office/Office of Electronic Information Products/PTMD, 2004). Over this period, the database is 1.26% larger than the USPTO database, with a minimum difference of -.01% in 1991 and a maximum difference of +5% in 1999. The DIPD may have more Patent Grants as Distributed by Year of Patent Application because it was created in 2005, versus the USPTO figures that were created in 2003 giving two more years for patents to be granted that we applied for in the later years of the 1990s.

The next step for the DIPD was to clean the data in three ways. First, names of the first listed assignee were standardized. For example, a standard name Boeing was created for all the patents with variations of the name such as “The Boeing Corporation,” “Boeing Corporation,” “Beoing,” and so on.

Table 2. Variations on Boeing

Clean Assignee:	Assignee:
Boeing	Boeing Aerospace Company (Seattle, WA)
Boeing	Boeing Commercial Airplane Company (Seattle, WA)
Boeing	Boeing North American (Seal Beach, CA)
Boeing	Boeing North American, Inc. (Seal Beach, CA)
Boeing	The Boeing Company ()
Boeing	The Boeing Company (Chicago, IL)
Boeing	The Boeing Company (Irvine, CA)
Boeing	The Boeing Company (Seal Beach, CA)
Boeing	The Boeing Company (Seattle, WA)

Second, each assignee was categorized with one of the following six categories:

- DoD: Any patent with a DoD agency as the assignee
- University: Any assignee I determined to be University, College or Institution
- Non-SBIR: Assignees that are firms that are not in the Tech-net database.
- Direct SBIR: Specific government interest statement containing variation of “SBIR” or “Small Business Innovation Research”
- SBIR Participant: A firm listed in Tech-net as a SBIR participant
- Hospital: Assignee names that looked like a hospital name
- Other: Anything else

[10] The fact that the Government Interest field in the patent is labeled as “Goverment Interests” is a clear example of how challenging the USPTO database is to work with.

Next, duplicate patents and patents that were clearly not in the population of Defense Interest patents were removed. Because several patent searches were used to identify DoD assignee patents and patents with is DoD government interest statement, the searches collected approximately 90 duplicate patents. Finally, eliminating organization with names like “Swiss Army, Inc” and “Air Force Industries” were eliminated. The following are examples of erroneous DoD-like assignee names:

- Swiss Army Brands, Ltd. (Shelton, CT)
- Rotary Air Force Inc. (CA)
- Rotary Air Force Management Inc. (Kindersley, CA)
- Rotary Air Force Management, Inc. (CA)
- Air Force 1 Blow Off Systems Inc. (Waterloo, CA)
- Ranger Joe’s Columbus Army Surplus Co. (Columbus, GA)

RDTE Spending

DD350

The DD350 is the official DoD form the contracting officers use to record individual DoD contract actions (obligations or de-obligations) in excess of $25,000. Contract offices complete DD350s according to instructions detailed in the Defense Federal Acquisition Regulations supplement. The dollar value of contracts is recorded along with information on the name and location of contractors, the location where the work will be performed, products or services purchased, contract solicitation procedures used (competitive or other than competitive), and the type of business contracted with (large, small, small disadvantaged), among other things (GAO, 1998b). The DD350 database is available for download as a compressed text file from the DoD’s Directorate for Information Operations and Reports.[11]

In its current iteration, the form has 95 separate data fields, many of which I used to construct my data for analyses. I used the fields that identify the type of goods or services contracted for, the contractor involved with the contract, the type of business performing the work, and the SBIR category of the work performed. In addition, I used information about the contract itself and the amount, dates, and procurement supply classification code purpose. The first digit of the supply classification code contains the broad category of contracts I used to identify the “color of money” the contract belonged to. The file for each year is very large uncompressed—344 megabytes (FY2003). 589,238 contract records in FY 2003. I used the files for 1999–2004.

Some of the data fields in the DD350 database are

- Contracting Office
- Contractor (name, codes, address, parent)
- Type of Business (small, minority, women owned, etc.)
- Contract Dates
- Contract Amount

[11] Accessible at http://siadapp.dmdc.osd.mil/

- Type of Contract (R&D, procurement, other services)
- SBIR Program by Phase

Some of the limitations of using DD350 data are

- Dollar values are obligations, not expenditures.
- Reporting threshold includes only obligations over $25,000.
- Classified data is masked or unreported.
- 1989 DoD/IG study found data integrity and reliability problems with DD350.
- Does not include data on subcontracts. (GAO, 1998a)

Tracking individual contractors over time is difficult, because DD350 form changes over time and contractor identification data such as identification numbers, names and addresses changed over time. It is primarily for this reason that I look a group data rather than individual contractor data.

Microsoft's Access and Excel software was used to manage DD350 data.

Identifying Groups of Policy Interest

The ideal research model would link patent data to individual firms across years to observe the changes in the propensity to patent caused by changes in federal intellectual property laws. Unfortunately tracking individual firms in DD350 across years is a difficult nearly impossible task that may not yield policy relevant insights over simple grouping of R&D spending and patents by broad organization categories. The following groups of research organizations were chosen to identify variations in the propensity to patent: SBIR participants, Non-SBIR firms, Universities, Non-profits. The details on how the groups were identified in both the patent and the DD350 data follows.

SBIR participants were identified in two ways. The first was to identify all active SBIR participants by the SBIR code in the DD350 data from 1999–2004, and remove any firms that had been bought out or erroneously coded as SBIR winners. The second method was to identify all patent assignee names, with firms' names in the Technet database. Matching names was augmented by matching the assignee city and state with the city and states listed in Technet.

Non-SBIR firms were identified by not being universities, non-profits, or SBIR participants.

Universities are perhaps the easiest research organizations to identify in both DD350, and patent data. DD350 has a specific organization code for universities which was used to aggregate defense R&D contract award dollars. Patent generated by universities were easily identified because they have distinctive assignee names.

Empirical Estimates of the Impact of SBIR Patent Rights

Utility of Patent Data Analysis

Patent analysis can offer insights into how the SBIR program affects the stock and flow of knowledge in the defense technology base. The analysis of patents and patent citations is a standard method used by economists[12] for evaluating of the effectiveness of R&D programs. Griliches (1990) supports patent analysis with three arguments: "They are available; they are by definition related to inventiveness; and they are based on what appears to be an objective and only slowly changing standard" (Griliches, 1999).

A thorough study of the SBIR program should include patent analysis because SBIR policy explicitly gives intellectual property rights derived from the contracted research to firms provided they declare the invention to the sponsor, and on the patent application.[13] Moreover, awarding SBIR contracts on secret (and therefore un-patentable) research rarely occurs, because SBIR research topic must be unclassified to be part of the public solicitation.

The DIPD is used to test the following hypothesis regarding the effect of giving SBIR participants patent rights:

1. H0: SBIR participants have a higher patent output per R&D dollar than other research performers.
2. H0: SBIR participants receive more citations per patent than other research performers.
3. H0: SBIR participants produce more high citation patents per patent, or per R&D dollar than other research performers.

Methodologies

Basic Patent Indicator Measures

There are two types of Basic Patent indicator measures. The first are those published by national Intellectual Property Offices such as the United States Patent and Trademark Office (National Science Board, 2004). The second are patent indicators published by national and international Science and Technology monitoring offices such as the National Science Foundation (NSF) and the Organization for Economic Co-operation and Development (OECD).

The national IPO measures typically issue annual reports on patenting trends by type of patent, geographic location of inventor, technology class of the invention, assignee organization and by inventor. Because the national IPO offices primary missions are for patent data storage and dissemination, such reports typically present little more than aggregated raw data, with little or no analysis. In the United States, the U.S. Patent and Trademark Office publishes numerous patent reports.[14] The USPTO offers two important insights into analyzing patent data. The first is an argument for focusing exclusively on Utility patents, commonly referred to as patent for invention rather than Design, Statutory Invention Registrations, Defensive Publications or Plant patents. Utility patents offer advantages over all others because unlike the other types of patents they are linked to technology, offer

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[12] Seminal patent analysis papers include: Schmookler (1954), Scherer (1983, 1984) and the numerous studies since 1980 by the National Bureau of Economic Researcher: Hall, Griliches, Pakes, Hausman, Jaffe, Schankerman, Trajtenberg, and Lerner.
[13] Intellectual property retention by private firms and individuals is a centerpiece of legislation in the early 1980s to stimulate the commercialization of federally funded research.
[14] For the complete patent reports published by the USPTO, see http://www.uspto.gov/web/offices/ac/ido/oeip/taf/reports.htm#misc_info

patent protection and are issued more frequently than the other types of patents. The second methodological insight is the need to assign patents to inventors and assignee firms[15] across variations in spelling and nomenclature. Many firms and inventors use different variation of names such as Boeing, Boeing Corporation, or The Boeing Corporation or J. Rappaport, John Rappaport, John W. Pappaport, which require patent officials to make judgments to match patent grants to organizations and inventors across variations in names. Sadly, the USPTO does not share a table linking variations in names to a common name.[16]

Most countries rely on science and technology policy organizations external to Intellectual Property Offices to analyze patent data and incorporate the patent indicators with other national science and technology measures. In the United States, the National Science Foundation issues an annual Science and Technology Indicators report[17] which included data and analysis on S&T indicators of inputs, outputs and capabilities of national S&T systems.[18] In the Overview section of the 2004 report, the R&D Performance, Outputs, and Capabilities section uses patent indicators for four of the eight figures reported. In Chapter 6—Industry, Technology, and the Global Market Place—six of the 30[19] figures are patent indicators.

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[15] No attempt has been made to combine data based on subsidiary relationships. However, where possible, spelling variations and variations based on name changes (e.g., ESSO to EXXON) have been merged into a single name. While every effort is made to accurately identify all organizational entities and report data by a single organizational name, achievement of a totally clean record is not expected, particularly in view of the many variations which may occur in corporate identifications.
http://www.uspto.gov/web/offices/ac/ido/oeip/taf/topo_04.htm#Desc

[16] Personal conversation in 2003

[17] To read the complete report, see http://www.nsf.gov/statistics/seind04/

[18] Input measures in the 2004 report include R&D investment by federal, state, and corporations. R&D output measures in the 2004 report include balance of trade statistics in R&D funds exchanged internationally, journal publication bibliometrics, and patent indicators. Other important section of the report are an analysis of the demographics the stock and flow of the S&T workforce and analysis of the S&T intensive industries.

[19] The six indicators are 1. U.S. patents granted, by residence of inventor: 1986–2001; 2. U.S. patents granted to foreign inventors in selected countries, by residence of inventor: 1986–2001; 3. U.S. patent applications, by residence of inventor: 1986–2001; 4. U.S. patent applications filed by selected foreign inventors, by residence of inventor: 1986–2001; 5. Patents granted to nonresident inventors in selected countries: 1985, 1990, and 2000. 6. Patents granted to residents of United States, Japan, and Germany in selected countries 2000.

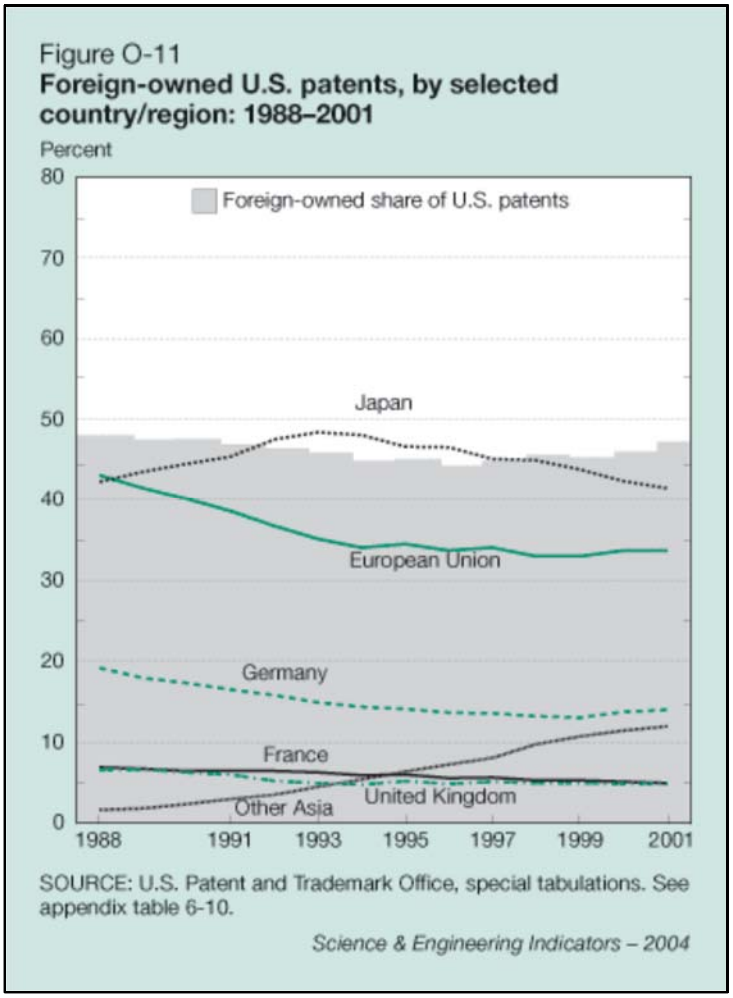

Figure 5. Example of a Patent Indicator From NSF S&T Indicators Report
(National Science Board, 2004)

Methodologically the NSF offers several useful insights. First they echo the USPTO's preference for Utility patents. Second they offer a list of limitations of using patent indicators. One limitation is that, patents indicators are incomplete-many inventions are not patented at all, in part because laws in some countries already provide for the protection of industrial trade secrets. There is inconsistency across industries and fields-the propensity to patent differs by industry and technology area. Finally they are inconsistency in importance-the importance of patented inventions can vary considerably (National Science Board, n.d.). They conclude that "despite these limitations patent data provide useful indicators of technical change and serve as a way to measure inventive output over time" (National Science Board, n.d.).

The OECD aggregates national patent indicators into international comparison reports. The OECD publishes the biannual report Main Science and Technology Indicators, which includes internationally comparable reports on R&D expenditures, S&T employment, and Patent Families, normalizing many of the measures on per capita, or percent of national GDP. In order to make cross-country comparisons, the OECD patent project has developed several standard databases and analysis methodologies. They have published a useful guide for researcher and policy analysts, *Using Patent Counts for Cross-country Comparisons of Technology Output* (OECD, 2001b). Most of the methodologies in the book focus on issues of accurately measuring patent productivity across nations and therefore are of limited us to measuring domestic innovation[20] within the defense research base. However, the OECD does offer three important standards adaptable to domestic patent analysis: geographic distribution, patent with multiple inventors from different locations, and reference date. The OECD recommends geographically linking the patent to the inventor's location rather than the assignee's location. For multiple inventors in different locations, they recommend weighting each location by the total number of locations, rather than counting all locations of the inventors equally. This prevents multiple counting. The reference date can be one of several choices: the application date, the grant date, or the date of first application internationally. The OECD recommends creating the *priority date* the first date of filing of a patent application, anywhere in the world, as the earliest and therefore closest to the invention date (OECD, 2004).

> Patent-based statistics reflect the inventive performance of countries, regions, firms, as well as other aspects of the dynamics of the innovation process (e.g., co-operation in innovation or technology paths). Patent indicators, along with other science and technology indicators, thus contribute to our understanding of the innovation system and factors that support economic growth. (OECD, 2004)

In conclusion, the review of basic methods of patent analysis recommend counting only Utility patents, developing a system to aggregate patents across variations in inventor and assignee names, linking patents geographically to inventors location, fractionally weighting multiple inventor locations, and choosing the earliest possible reference date. Additionally research need to carefully understand the limitation of using patent indicators to measure innovative processes.

Econometric Patent Analysis Methods

The discussion of econometric methods of patent analysis reviews the history of approaches beginning with Schmoolker's work in the 1950s and 1960s which relied on simple correlations of patent outputs to R&D spending inputs through modern non-linear panel data methods. The uses of patent statistics as a measure of innovation begins with Schmoolker's work and its numerous limitations to follow the evolution of econometric methods to use patents to measure R&D productivity. In the early 1950s, Schmoolker went through the paper USPTO archives by hand to build a database hundreds of time series of patent counts by technologies, industries and location. He then linked this database to known industry characteristics which he used to analyze the link between R&D spending and patent outputs, as well as other broader macro-economic trends. In his main work Invention and Economic Growth, published in 1966, Schmookler finds strong relationships between the demand for capital goods and patented inventive activity in some industries. The strongest relationship was in the railroad industry where patented inventions closely correlated with demand for rail transportation. This research supported the hypothesis that inventors responded to market forces to marshal their inventive activities when demand warranted (Griliches, 1999). Other similar relationships were found in different industries,

[20] The OECD has done tremendous work to create internationally valid patent counts that are unnecessary for entirely domestic analysis. Two such methods are: The creation of international "patent families" to relate the same protected invention across the many nations and count the invention only once; and the international concordance of patent technology classifications.

with extremely heterogeneous effects, unexplainable with the limited data Schmookler could gather. Four major problems of this early study would spawn major innovations in econometric methodology: the difficulty in linking patents to innovative activity; the heterogeneity of inventions and patents; sample selection problems and non-lineariarities in patenting propensity.

Linking Patents to Innovative Activities in Firms and Industries

The ability to explain fixed and random variations in the propensity to patent, with its relationship to the underlying randomness of the innovation process varied within industries, firms, over time and over technologies is limited by the researchers' ability to link patents to innovative activities. Schmookler calculated fixed effects in the propensity to patent in different industries by linking patents to industries through the technology classification of the patent. Though pioneering, the method was limited by judgement in technology categorization by the patent examiner, and Schmookler. Some technologies might have clear links to industries, such as patents on seed varieties to agriculture, while other may have links to several industries, such as patents on optical lenses to lasers, telescopes, eyeglasses and others. Schmookler further explained variation in propensity to patent with year fixed effects and five year patenting trends by industry. Many further attempts to link patent technology classifications to industries have been tried and been unsuccessful (Griliches, 1999).

In 1965 Scherer took a different approach in linking patents to innovative activity by matching a sample of 455 Fortune 500 companies in 1955 to their patents granted in 1959. By using only firm fixed effects, Scherer explains 43% of the variation in the propensity to patent. By adding 14 industries classification dummies for the firms, Scherer increases his explanatory power to 83%. Additionally, Scherer adds covariates to control for firm size, and industry concentration to discover non-linearity's in the effects of each. Scherer's econometric innovations enhances explanatory power, but omitted time effects, time lags in innovation, could not control for many firm characteristics and was only generalizable to 1955 Fortune 500 firms.

In the 1970s, a group of National Bureau of Economic Researchers lead by Zvi Griliches took advantage of computer readable patent databases, and the commercially available electronic firm database, COMPUSTAT made tremendous breakthroughs in using patent counts to understand economic processes. By developing a concordance between the patent assignee firm, and the COMPUSTAT data which included detailed financial data of the firm including sales, R&D expenditures and employees, the team was able to link the data on patents to fixed and variable firm observations over time (Pakes, 1980).

Pakes and Griliches (1980) chose 121 firms over 1968–1975 to model the R&D patent elasticity. The main conclusion of the analysis is that there is a statistically significant correlation between a firm's R&D spending and the number of patents the firm is granted. They find that this relationship is very strong in the cross-sectional dimension, and it is weaker in the within-firm time-series dimension. They also find that using lagged R&D spending does not improve the fit of the model, the support both a quick response of patenting to changes in R&D and a small but persistent effect of past R&D. They conclude that "patent counts do measure something systematic and hence are worthy of further study" (Pakes, 1980).

Using the initial data on 2600 firms in a 1976 cross section, Bound et al. (1984) find heterogeneous effects on firm size, with smaller firms exhibiting a larger propensity to patent. The researchers found no significant effect that only 60% of the firms reported R&D

expenditures. Econometric methods for non-linearities in count data from this paper will be addressed later.

Hall, Griliches, and Hausman (1986) using the same data as Bound et al. (1984) find changes in R&D expenditures and patent applications to be nearly contemporaneous under different model assumptions. The researchers identify the date a patent is applied for as the standard priority date for U.S. patents.

Hall, Griliches, and Hausman (1986) add a five-year lagged log(R&D), time fixed effects, time interacted with same period R&D to account for non-linear patent propensity, log of the book value of the firm to account to non-linearities in firm size, and dummies for the scientific sector of the firm. This specification's error terms are serially correlated within firms across time, and the firms do not have constant variance over time. The coefficient results do not vary substantively from Bound, but because of the added control variables, and the ability to model fixed and random variance parameters the standard errors are more efficient.

Hall, Jaffe, and Trajtenberg (2001) standardize the methods of assigning patents to firms, and technology areas by publishing the database of around 3 million U.S. patents granted from 1969–1999. Because the USPTO uses hundreds of thousands of technology classifications for patents that are inefficient for finding fixed technology classification effects, the group developed six main technological categories. The categories are: Computers and Communications, Drugs and Medical, Electrical and Electronics, Chemical, Mechanical and Others. For additional ease in creating panel data based on firm observations, the team standardized the nomenclature between the USPTO and COMPUSTAT.

In conclusion, in order to understand the variability in the propensity to patent, researchers need to associate patents at the firm and industry level as well as in time. Firm level fixed and random effects (including industry classification) have the most explanatory power for propensity to patent. There is little time lag between investment in R&D and patent output.

Since this dissertations' research questions are looking specifically at DoD funded R&D, my macro industry is defined, my micro-industries will be the specific service that funded the RDTE. This dissertation will offer a "first look" at the propensity to patent across groups of firms rather than individual firms.

Sample Selection Problems

The studies by Schmookler and Scherer have limited generalizability because their observation are censored non-random ways. Schmookler limits his patent analysis to patent technology classification that can easily be mapped to well-defined industries. There were many industries that simply could not be analyzed because they couldn't be observed to link to specific technology classes, or the linkage was too noisy.

Scherer (1965, 1982, 1984) limits his study to larger firms whose R&D expenditures can be research easily (either through public sources or through Census Bureau data). This censoring limited the type and scope of hypothesis tested to the firms sampled, with limited or no generalizability to the remainder of the firms in the industry or the industry as a whole.

Pakes (1980) chose 121 firms over 1968–1975 to model the R&D patent elasticity. To overcome the problem of observing a value of zero when taking logs they 1) selected the population to reduce the number of zeroes (only 8% of the observations chosen were zero); and 2) set zeroes equal to 1 and added a dummy value to allow the equation to chose implicitly between zero and 1.

Hall, Jaffe, and Trajtenberg (2001) NBER patent database, described earlier, greatly improves the ability to build a more representative sample of organizations based on the researcher's population of interest. Unfortunately 18.4% of the patents in this sample are still left unmatched to firms, because the inventors have not assigned their patent rights to a firm. Many of these un-assigned patents may be the result of very small research firm's innovation processes that might censor the data on firm size.

Another important issue is that many firms do not patent for a variety of reasons. This prohibits the researcher insight into the nature of non-patented innovation.

Despite the many advances in the ability to build more representative samples patent analysis ultimately devolves into "searching where the light is shining."

This dissertation improves on past studies the sample selection limitations by including all firms and organization used Defense R&D funds and creating a census of all the patented innovations resulting from these funds.

Counting Citations

Trajtenberg (2002) observes that using simple patent counts (as in the previous hypothesis test) is problematic because of the heterogeneous nature of the value of patents, some patents lead to tremendous breakthroughs in technology, and some prove to be enormously valuable economically. He proposes a method using patent citations to measure the economic and social value of a patent. He observes that patent applicants and examiners are required to cite prior patents in the application and grant processes to ensure that a granted patent represents a truly new innovation. The argument is that patents that receive more subsequent citations are more technologically important, and therefore more likely to be economically valuable. Thus by counting subsequent patent citation the researcher can measure a proxy of the technological importance of the original patent on future inventions. He suggests a simple weighting of patents by the number of citations received after the patent grant:

$$WPC_t = \sum_{i=1}^{n_t} (1 + c_i) \quad (1)$$

Harhoff et al. (1999) link a survey of inventors' estimation of the value of 962 patented inventions in the United States and Germany to the number of citations the patent received. They find support for the hypothesis that patents with more economic value are cited more frequently. They estimate the economic value of a single citation to be $1 million.

Jaffe, Trajtenberg, and Fogarty (2000), surveyed a cohort of 1993 patentees regarding two patents they had cited, and a third similar but un-cited placebo patent to better understand how citations influence the innovation process. They found that inventors report significant communication between citing and cited inventors suggesting that citation represent knowledge spillovers. However, they find that citation data is subject to a large amount of noise, that nearly one half of all citations do not correspond to any communication between inventors or technological relationship between inventions. They also find a significant correlation between the number of citations and the perception the inventor has regarding its technological and economic importance.

Hall, Jaffe, and Trajtenberg (2000) correlate citation weighted patents with the stock market value of a firm. They use a data set that links USPTO patents and citations to COMPUSTAT values of publicly traded firms, finding that citation-weighted patent stocks are more highly correlated with market value, and simple patent counts. They consider that patents receiving 20 or more citations to be both technically and economically valuable.

In conclusion citation frequency has been found by researchers to be highly correlated with economic, and technical importance through economic valuation surveys, technical communication surveys, and market value analysis. Citation frequency is therefore a valid proxy for technical and economic value.

Hypothesis Tests

This section tests the following three hypothesis:

1. H0: SBIR participants have a higher patent output per R&D dollar than other research performers.
2. H0: SBIR participants receive more citations per patent than other research performers.
3. H0: SBIR participants produce more high citation patents per patent, or per R&D dollar than other research performers.

1. IP1 H0: SBIR participants have a higher patent output per R&D dollar than other research performers.

This hypothesis is tested using a basic comparison of the number of patents produced per million dollars of defense R&D contracts. Using the techniques of identifying groups of policy interest described in the Data Sources section, the number of patents per calendar year per group[21] were divided by the dollar amount of R&D contracts per year per group.[22] The years 1999–2002 are used for comparison, because after 2002 there is a significant drop-off in patents in the USPTO database, because patents are not included in the database until they are granted, which can be a gap of two to three years. Per Hall, Griliches, and Hausman (1986) and OECD (2001), patents are counted by the priority date of application versus date of grant. Also per Hall, Griliches, and Hausman (1986), no lag between patents and R&D expenditures is included.

The lack of significant variation in patent per R&D dollar removes the necessity of using more advanced statistical or econometric techniques. A simple comparison of patent rates is sufficient to address the hypothesis.

[21] University patents were identified by using the assignees name, which were easily identified as universities, colleges, trustee, or regents. Direct SBIR patent were identified by the inclusion of "SBIR" or "Small Business" in their government interest statement. SBIR participants were identified by the matching of assignee names to the SBA's tech-net database of all SBIR awards. Non-SBIR contractors were identified by the remaining assignee names that did not fit into the University, SBIR, or SBIR participant categories. The DoD total number of patents is the entire number of patents per year in the DIPD. A very small number of patents with a government interest statement but without an assignee, and thus naming only an individual inventor could not be included in this analysis. Additionally foreign and other contractor categories were excluded from this comparison.

[22] Direct SBIR dollars were identified as DD350 contract actions coded as SBIR "B"-Phase I, "C"-Phase II, of "D" Phase III. SBIR participant dollars we identified manually by matching the names and cities of all DoD SBIR participants from the SBA Tech-net database to firm names and cities in the DD350 database. University contract dollars were identified as DD350 contract actions with organization type coded as "T" Historically Black College or University (HBCU); "U" Minority Institution (MI); or "V" Other Educational. Non-SBIR participants are all other contractors including large and small businesses. Total defense contracts is the aggregate of all DD350 contracts with a PSC Code beginning with "A". The DD350 coding can be found at http://siadapp.dmdc.osd.mil/procurement/Procurement.html

The results of the comparing the patents per R&D dollar by group show that SBIR participants produce more patents per defense R&D dollar than non-participating contractors, but fewer patents per defense R&D dollar than universities.

The Total DoD patent rate included patents assigned directly to DoD agencies with the only way to match patents to funding sources by matching the inventors' names to employment rosters of the firms, universities, and federal labs. Many of these patents most certainly would be generated by Universities, federal lab employees, SBIR participants, and non-SBIR firms. Further research is needed to see if SBIR research spills over in to more Defense assignee patents than other suppliers of defense R&D.

The analysis also reveals a significant different in rates between SBIR participants overall patent rate, and their direct SBIR patent rate. This surprising result offers further insights into the SBIR program, and the relative productivity of the program's research versus the productivity of SBIR participants.

In conclusion, the empirical analysis partially rejects the null hypothesis that SBIR participants have a higher patent output per R&D dollar than other research performers for the specific case of universities who produce more patents per R&D dollar, and accepts the null that SBIR participants produce more patents per dollar than non-participants. An additional observation can be made that research directly funded by the SBIR program is the least patent productive of any of the sources of funds analyzed.

2. IP2 H0: SBIR participants receive more citations per patent than other research performers.

This hypothesis is tested using a basic comparison of the average number of citations per defense patent. Using the techniques of identifying groups of policy interest described in the Data Sources section the number of patents per calendar year per group[23] were divided by the dollar amount of R&D contracts per year per group.[24] Modifying the techniques of Trajtenberg (2002), all citations are counted, and the sum of citations is associated with the patent by year of patent grant.

Determining the variation in citations received per patent will require using econometric techniques to control for fixed year effects, the effects of the different technology areas of the patents, the effect of the sponsoring defense agency and the effect of the type of organization performing the research.

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[23] University patents were identified by using the assignees name, which were easily identified as universities, colleges, trustee, or regents. Direct SBIR patent were identified by the inclusion of "SBIR" or "Small Business" in their government interest statement. SBIR participants were identified by the matching of assignee names to the SBA's tech-net database of all SBIR awards. Non-SBIR contractors were identified by the remaining assignee names that did not fit into the University, SBIR, or SBIR participant categories. The DoD total number of patents is the entire number of patents per year in the DIPD. A very small number of patents with a government interest statement but without an assignee, and thus naming only an individual inventor could not be included in this analysis. Additionally foreign and other contractor categories were excluded from this comparison.

[24] Direct SBIR dollars were identified as DD350 contract actions coded as SBIR "B"-Phase I, "C-Phase II", of "D" Phase III. SBIR participant dollars we identified manually by matching the names and cities of all DoD SBIR participants from the SBA Tech-net database to firm names and cities in the DD350 database. University contract dollars were identified as DD350 contract actions with organization type coded as "T" Historically Black College or University (HBCU); "U" Minority Institution (MI); or "V" Other Educational. Non-SBIR participants are all other contractors including large and small businesses.

a. Functional Form

$$TC = FE_{tech} + FE_{org} + FE_{year} + FE_{agency} + \gamma_{\#ta} + \alpha_{\#tassignees} \quad (2)$$

Total citations a function of the technology category of the patent, the organization generating the patent, the year the patent was granted,[25] and effects of variation in number of patent assignees, and number of technology areas of the patent.[26] Other models were used that included other variables, including state fixed effect but they did not affect the coefficient of interest A generalized negative binomial model with robust standard errors is used.[27] Control variables for six technology areas of the patents are used following Hall, Jaffe, and Trajtenberg (2002).

b. Results

The negative binomial regression results show that three of the six R&D organization categories have significant coefficents: DoD Assignees, Universities, and SBIR Participants. University owned patents receive nearly three more citations per patent than Direct SBIR patents. Patents with DoD agencies as assignees receive on average about 2.3 fewer citations than Direct SBIR patents, and over five fewer citations per patent than University assigned patents. SBIR participants, non-SBIR patents receive 2.3 more citations than those coded as Direct SBIR patents.

3. IP3 H0: SBIR participants produce more high citation patents per patent, or per R&D dollar, than other research performers.

a. Functional Form

$$\Pr(TC < 20) = FE_{tech} + FE_{org} + FE_{year} + \gamma_{\#ta} + \alpha_{\#tassignees} \quad (3)$$

The probability that total citations are greater than 20 is a function of the technology category of the patent, the organization generating the patent, the year the patent was granted, and effects of variation in number of patent assignees, and number of technology areas of the patent.[28] An ordinary lease squares regression is used.[29]

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[25] This analysis uses the patent grant date, breaking with the standard set by patent researchers who suggest that using the application date as the priority date for the patent analysis. Since patents are not public knowledge until they are granted and published by the USPTO, inventors and patent examiners cannot cite them prior to grant.

[26] Models including fixed effects for the state of the primary inventor were run, but no state has a significant effect on the number of citation.

[27] Non-linear regression models including poisson and negative binomial were also run, with no significant changes in coefficient signs, or significance of coefficients. OLS results are therefore used due to ease of interpretation.

[28] Models including fixed effects for the state of the primary inventor were run, but no state has a significant effect on the number of citation.

[29] Non-linear regression models including poisson and negative binomial were also run, with no significant changes in coefficient signs, or significance of coefficients. OLS results are therefore used due to ease of interpretation.

b. Results

```
. reg  tcitgreaterthan20 year_granted  ta_count no_assignees army air_force navy
dod techcat_dum* orgtype_dummy*, robust

Linear regression                                      Number of obs =   29379
                                                       F( 18, 29360) =   70.05
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.0517
                                                       Root MSE      =   .2493

------------------------------------------------------------------------------
             |               Robust
tcitgreat~20 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
year_granted |  -.0041015   .0001601   -25.62   0.000    -.0044154   -.0037877
    ta_count |   .0084065   .0006684    12.58   0.000     .0070963    .0097166
no_assignees |   .0655922   .0174481     3.76   0.000     .0313932    .0997912
        army |   .0413007   .0235213     1.76   0.079    -.0048022    .0874035
   air_force |   .0543137   .0234234     2.32   0.020     .0084027    .1002246
        navy |   .0468625   .0234123     2.00   0.045     .0009734    .0927516
         dod |   .0634359   .0251578     2.52   0.012     .0141255    .1127462
techcat_dum1 |  -.0370934   .0090636    -4.09   0.000    -.0548584   -.0193285
techcat_dum2 |   .0206178   .0094463     2.18   0.029     .0021027    .0391329
techcat_dum3 |  (dropped)
techcat_dum4 |  -.0128394   .0090531    -1.42   0.156     -.030584    .0049052
techcat_dum5 |  -.0383288   .0090879    -4.22   0.000    -.0561415   -.0205161
techcat_dum6 |  -.0262264   .0098622    -2.66   0.008    -.0455567    -.006896
orgtype_du~1 |   .0792543   .0162562     4.88   0.000     .0473915    .1111172
orgtype_du~2 |   .0141314   .0051509     2.74   0.006     .0040354    .0242275
orgtype_du~3 |   .0703728   .0056406    12.48   0.000     .0593169    .0814287
orgtype_du~4 |   .1265761   .0074711    16.94   0.000     .1119324    .1412197
orgtype_du~5 |   .1046349   .0107757     9.71   0.000      .083514    .1257558
orgtype_du~6 |   .0284484   .0233138     1.22   0.222    -.0172477    .0741445
orgtype_du~7 |  (dropped)
       _cons |   8.060687   .3212948    25.09   0.000     7.430935    8.690439
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4. Summary of Intellectual Property Hypothesis Tests

These three hypothesis tests reinforce reinforced the conclusion of the SBIR participants appear to have significantly more productive research outcomes, as measured by patents, with standard R&D contracts than they do with SBIR R&D contracts. Also reinforced is the observation that SBIR participants are second only to Universities in patent measures.

Conclusions

I find that SBIR contract winners are more prolific patenters per DoD R&D dollar than large defense contractors, but less prolific than Universities. The citation rate (per DoD R&D dollar and per patent) for SBIR patents is also more than other DoD Assignees but less than University assignees.

This research is a foundation for further studies of defense patenting. The Federal government and the DoD are significant funders of research and development, all of which are subject to complex intellectual property rules; policymakers and analysts should pay more attention to the effects of intellectual property policies on knowledge creation.

This basic analysis does not delve into the broader public costs and benefits of the differing intellectual property assignment rules for publicly funded research. More attention should be made to estimating the public benefits of the economic and technological spillovers of public research. Analyzing patent statistics and citations is one of the few methods of doing this. On the cost side, granting private monopolies on publicly funded research is controversial. It gives the intellectual property rights holder the right to exclude others from exploiting public research, which may or may not cause net harm to technological or economic progress.

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