Knowledge Transfers from Federally Supported R&D

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Abstract:

The purpose of this paper is to identify covariates with publication activity, a form of knowledge transfer, from SBIR publicly funded research. The paper offers an argument about the policy relevance of studying knowledge transfers from publicly funded research that occurs in private sector firms. Relevant explanatory variables are the length of the funded research project, university involvement in the project, the firm's history of SBIR funding, and the academic background of firms' founders.

Keywords: technology transfer | public sector R&D | entrepreneurship | program evaluation | SBIR program

Article:

Introduction

On November 17, 1944, U.S. President Franklin D. Roosevelt wrote to Dr. Vannevar Bush, the Director of the Office of Scientific Research and Development in Washington, DC (Bush 1945, pp. 3–4):

> [Your Office] represents a unique experiment of team-work and cooperation in coordinating scientific research and in applying existing scientific knowledge to the solution of the technical problems paramount in war. … There is, however, no reason *why the lessons to be found in this experiment cannot be profitably employed in times of peace* [emphasis added] … for the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national standard of living. … New frontiers of the mind are before us, and if they are pioneered with the same vision, boldness, and drive with which we have waged this war we can create a fuller and more fruitful employment and a fuller and more fruitful life.

Bush accepted this invitation, and he submitted to President Harry S. Truman on July 5, 1945, a report entitled *Science—the Endless Frontier*.[1] Bush wrote in his report: (Bush 1945, p. 12):

[1] President Roosevelt passed away on April 12, 1945.

> The publicly and privately supported colleges, universities, and research institutes are the centers of basic research. They are the wellsprings of knowledge and understanding. As long as they are vigorous and healthy and their scientists are free to pursue the truth wherever it may lead, there will be a *flow of new scientific knowledge to those who can apply it* [emphasis added] to practical problems in Government, in industry, or elsewhere.

Not only was *The Endless Frontier* a blueprint for what would eventually become the National Science Foundation (UNESCO 1968), but also it reflected both President Roosevelt's and Bush's awareness about the importance of publicly supported scientific and technical knowledge flowing to society for the commonweal. Herein, I refer to such a knowledge flow by the general term: *knowledge transfer*.

After summarizing the U.S. government's efforts to encourage the transfer of public sector funded scientific and technical knowledge in the next section, I document a renewed U.S. policy emphasis on publicly funded research. Noteworthy is that this policy emphasis is on research that occurs in federal laboratories. However, what has been ignored in the policy debate, as well as in the economics literature, is consideration of the knowledge transfers emanating from publicly funded research that occurs in private sector firms.[2]

This paper focuses on the research-based knowledge transfers from private sector firms that received research funding though the U.S. Small Business Innovation Research (SBIR) program. The mechanisms through which the research-based knowledge from such SBIR funded projects enters society are two: through the commercialization of innovations resulting from new technology developed in the funded project, and through scientific publications authored by those researchers in the funded firms. Much has been written about the commercialization of SBIR-funded technology because commercialization is a stated objective of the program (see below).[3] In this paper I focus on the latter measure of research-based scientific and technical knowledge, namely knowledge transfers through scientific publications. My goal in this paper is to identify covariates with publication activity from SBIR funded firms.

In the third section, I describe the data on SBIR-supported scientific publications used in this study, and then I present and discuss my empirical findings about SBIR-based scientific publications over time as well as across project variation in publication activity. The paper concludes in Section V with brief summary remarks and suggestions for future research on this topic.

Public sector efforts to promote technology transfer

A recent Congressional Research Service (CRS) report (Schacht 2012) made the case for the public sector's interest in transferring technology from federal laboratories to the private sector:

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[2] There is a relevant literature on the impact of the Bayh-Dole Act on publicly funded university-based research. See, Grimaldi et al. (2011) and Link and van Hasselt (2019).

[3] Link and Scott (2010) have previously focused on the commercialization of innovation from SBIR research projects. See also, Link (2013).

> Technology transfer is a mechanism to get federally generated technology and technical know-how to the business community where it can be developed, commercialized, and made available for use by the public sector. … Economic benefits of a technology or technique accrue when a product, process, or service is brought to the marketplace where it can be sold or used to increase productivity. When technology transfer is successful, new and different products or processes become available to meet or induce market demand.

While this CRS argument focuses on the transfer of federal laboratory-based scientific and technical knowledge embodied in "product, process, or service" (quoted from above), I contend that the CRS argument is equally relevant for the transfer of federally funded scientific and technical knowledge through scientific publications. That is, the transfer of scientific and technical knowledge through scientific publications from publicly funded research also has the potential to "get federally generated technology and technical know-how to the business community where it can be developed, commercialized, and made available for use by the public sector" (quoted from above). And, the transfer of scientific and technical knowledge is important whether that publicly funded knowledge is developed in federal laboratories *or* [my emphasis] in private sector firms.

As background, the hallmark legislation related to technology transfer from federal laboratories is the Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96–480) and its amendments.[4] The Act states in Section 2:

> No comprehensive national policy exists to enhance technological innovation for commercial and public purposes. There is a need for such a policy, including a strong national policy supporting domestic technology transfer and utilization of the science and technology resources of the Federal Government.

And, the Act states in Section 11:

> It is the continuing responsibility of the Federal Government to ensure the full use of the results of the Nation's Federal investment in research and development. To this end the Federal Government shall strive where appropriate to transfer federally owned or originated technology to State and local governments and to the private sector.

The federal laboratory technology transfer mechanism emphasized in the Stevenson-Wydler Act is patents.[5] The Technology Partnerships Office (TPO) at the National Institute of Standards and Technology (NIST) within the Department of Commerce has a legislated mandate to collect information from federal agencies on a number of technology transfer mechanisms, and the TPO publishes, by agency and by fiscal year, metrics on those mechanisms in its annual report

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[4] The relevant amendments are, as documented and discussed in Schacht (2012), the Federal Technology Transfer Act of 1986 (Public Law 99–502), the 1988 Omnibus Trade and Competitiveness Act (Public Law 100–418), the 1990 Department of Defense Authorization Act (Public Law 101–189), the National Defense Authorization Act for FY1991 (Public Law 101–510), the 1996 Technology Transfer Improvements and Advancement Act (Public Law 104–113), and the Technology Transfer Commercialization Act of 2000 (Public Law 106–404).
[5] To the best of my knowledge, the only empirical study of the impact of the Stevenson-Wydler Act on federal laboratory patenting is by Link et al. (2011).

entitled *Federal Laboratory Technology Transfer [Fiscal Year]: Summary Report to the President and the Congress*.[6] The technology transfer mechanisms in each report include not only patent applications, patents received, and licensing revenues but also the report includes CRADAs (Cooperative Research And Development Agreements), new invention disclosures, invention licenses, and related examples of transfer success.[7]

One important technology transfer mechanism from federal laboratories that has infrequently been studied is scientific publications.[8] As noted in the TPO's recent annual report (Federal Laboratory Technology Transfer Fiscal Year 2016*: Summary Report to the President and the Congress*, p. 14)[9]:

> Although intellectual property has traditionally been tracked in terms of the number of patents, licenses, and collaborative efforts [CRADAs], most federal research results are transferred through publication of S&E [Science and Engineering] articles.

While the Stevenson-Wydler Act and its amendments emphasized technology transfers from federal laboratories,[10] the results from publicly funded research entering society, regardless of the venue in which it occurs, merit study.

The National Science Board (2020, p. 7), as did Bush in *The Endless Frontier*, takes a broad perspective about the elements of our nation's innovation system:

> Three distinct but interrelated components of [the innovation system] environment are invention, *knowledge transfer* [emphasis added], and innovation.

Thus, in the next section, I describe the "knowledge transfer" (quoted from above) that occurs through scientific publications that resulted directly from publicly funded research that occurred in private sector firms.[11]

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[6] Prefacing each fiscal year report is the statement: "This report fulfills the requirement of Title 15 of the United States Code, Section 3710(g)(2), for an annual report summarizing the use of technology transfer authorities by federal agencies."

[7] These mechanisms are discussed in each annual report by the TPO, and descriptive analyses of the associated metrics are in Link and Oliver (2020).

[8] See Link and Scott (2019a, 2019b) for studies of scientific publications from NIST, See Link and Oliver (2020) for a descriptive analysis of scientific publications from federal laboratories.

[9] Metrics related to scientific publications are conspicuously absent from the TPO's Federal Lab Technology Transfer Database v.2015; see, https://www.nist.gov/tpo/reports-and-publications.

[10] *U.S. Technology Policy* (Executive Office of the President 1990), arguably our nation's first formal technology policy statement, also emphasized technology transfer from federal laboratories.

[11] The Patent and Trademark Law Amendments Act (Public Law 96–517), informally known as the Bayh-Dole Act, was passed in 1981 as companion legislation to the Stevenson-Wydler Act. The motivation for the Act is stated as: "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." Thus, universities, just like federal laboratories, were given ownership to patentable public-sector funded technologies. Obviously, the venue for the research is at the university, and patents have been the mechanism of choice to evaluate the effectiveness of the Act. Link and van Hasselt (2019) question the appropriateness of using patents over time to test the effectiveness of the Act, but neither Link and van Hasselt nor other researchers, to the best of my knowledge, have studied university publications stemming from public-sector funded research.

Publications from SBIR-funded research

The SBIR program was initiated through the Small Business Innovation Development Act of 1982 (Public Law 97–219).[12] The mission of the program as currently stated is[13]:

> … to support scientific excellence and technological innovation through the investment of Federal research funds in critical American priorities to build a strong national economy. The program's goals are four-fold:
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> - Stimulate technological innovation.
> - Meet Federal research and development needs.
> - Foster and encourage participation in innovation and entrepreneurship by women and socially or economically disadvantaged persons.
> - Increase private-sector *commercialization* [my emphasis] of innovations derived from Federal research and development funding.

To be eligible to apply for an SBIR award, the firm must have fewer than 500 employees, it must be operated for profit in the United States, and it must be more than 50% owned and controlled by one or more individuals who are citizens or permanent resident aliens of the United States.[14]

The data examined in this paper relate to Phase II projects funded through four agencies that participate in the SBIR program.[15] A Phase II project is defined by the SBIR program in the following way[16]:

> The objective of Phase II is to continue the R/R&D [Research and (Applied) Research and Development] efforts initiated in Phase I. Funding is based on the results achieved in Phase I and the scientific and technical merit and commercial potential of the project proposed in Phase II. Only Phase I awardees are eligible for a Phase II award. SBIR Phase II awards normally do not exceed $1,000,000 total costs for 2 years.

The U.S. Congress authorized the National Research Council (NRC) of the National Academies[17] to conduct a survey of Phase II SBIR-funded projects. In 2005, 2011, and 2014, the

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[12] Detailed histories of the SBIR program are in Schacht (2010), Link and Scott (2012), and Leyden and Link (2015).
[13] See, https://www.sbir.gov/about/about-sbir. See Link and Scott (2012) for a discussion of the rewording of this mission statement.
[14] This is an overly simplified eligibility statement. More details about eligibility are at, https://www.sbir.gov.
[15] Eleven departments and agencies participate in the SBIR program. See, https://www.sbir.gov/about/about-sbir.
[16] See, https://www.sbir.gov/about/about-sbir. At this same site, a Phase I program is defined as: "The objective of Phase I is to establish the technical merit, feasibility, and commercial potential of the proposed R/R&D efforts and to determine the quality of performance of the small business awardee organization prior to providing further Federal support in Phase II. SBIR Phase I awards normally do not exceed $150,000 total costs for 6 months." A Phase III is often discussed with regard to the SBIR program, but it is not a research phase that is supported by the SBIR program. "The objective of Phase III, where appropriate, is for the small business to pursue commercialization objectives resulting from the Phase I/II R/R&D activities. The SBIR program does not fund Phase III. In some Federal agencies, Phase III may involve follow-on non-SBIR funded R&D or production contracts for products, processes or services intended for use by the U.S. Government."
[17] See, https://www.nationalacademies.org/.

NRC conducted surveys of random samples of Phase II projects funded by the Department of Defense (DOD), the National Institutes of Health (NIH), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the National Science Foundation (NSF). In this paper, I use publication data for Phase II projects funded by the DOD, NIH, NASA, and DOE.[18]

The empirical analysis

The SBIR data on small entrepreneurial firms

A sampling population of 2024 Phase II projects from the NRC surveys are studied in this paper. The construction of this sample and the distribution of Phase II projects across the four agencies considered are in Table 1.

Table 1. Data Reduction Process

	DOD	**NIH**	**NASA**	**DOE**
Random sample of Ph II projects from NRC surveys	2075	1068	470	401
Deletion of not completed and failed projects	1466	822	336	294
Deletion of projects with missing data	967	593	219	245
Final Sample ($n = 2024$)	967	593	219	245

Note: The 2005 survey was relevant to all four agencies, and the years of the funded Phase II awards was 1992–2001. The 2011 survey was relevant to DOD and NASA, and the years of the funded Phase II awards was 1998–2007. The 2014 survey was relevant to NIH and DOE, and the years of the funded Phase II awards was 2001–2010

Definitions of the variables used in the empirical analyses below are in Table 2, and descriptive statistics on these variables are in Table 3.

Table 2. Definition of Variables

Variable	**Definition**
Publications	Number of scientific articles published for the technology developed as a result of the current Phase II research project
Project Characteristics	
ProjectYears	Number of years between the year of the NRC survey and the year when the Phase II project was funded
University	Binary variable equal to 1 if university resources were involved in the Phase II project (including university faculty, graduate students, and/or university developed technologies); 0 otherwise
PreviousPhIIs	Number of previous Phase II funded projects that are related to the project or technology supported by the surveyed Phase II award
PhaseIIAward	Amount of the Phase II award ($2005) – only available on the 2005 survey
DOD	Binary variable equal to 1 for Phase II projects funded by the Department of Defense; 0 otherwise
NIH	Binary variable equal to 1 for Phase II projects funded by the National Institutes of Health; 0 otherwise
NASA	Binary variable equal to 1 for Phase II projects funded by the National Aeronautics and Space Administration; 0 otherwise

[18] Publication data from the 2011 and 2014 NSF surveys were not made available from the NRC for this study.

Variable	Definition
DOE	Binary variable equal to 1 for Phase II projects funded by the Department of Energy; 0 otherwise
Firm Characteristics	
Employees	Number of employees at the time the current Phase II project proposal was submitted (as phrased on the 2005 survey); number of employees at the time the current Phase II project was awarded (as phrased on the 2011 and 2014 surveys)
AcademicFounders	Binary variable equal to 1 if a founder of the firm had an academic background; 0 otherwise

Table 3. Descriptive Statistics on the Variables (n = 2024)

Variable	DOD (*n* = 967)	NIH (*n* = 593)	NASA (*n* = 219)	DOE (*n* = 245)	All Agencies (n = 2024)
Publications	2.177	4.506	2.708	2.722	2.983
	(4.380)	(14.347)	(4.296)	(7.075)	(8.856)
	[0–60]	[0–165]	[0–30]	[0–100]	[0–165]
ProjectYears	6.674	7.447	7.557	7.122	7.050
	(2.461)	(2.746)	(2.830)	(2.604)	2.631
	[4–13]	[4–13]	[4–13]	[4–13]	[4–13]
University	0.333	0.578	0.297	0.437	0.414
	(0.472)	(0.494)	(0.458)	(0.497)	(0.493)
	[0/1]	[0/1]	[0/1]	[0/1]	[0/1]
PreviousPhIIs	1.239	1.376	1.183	1.118	1.258
	(1.737)	(2.986)	(1.592)	(1.588)	(2.15)
	[0–28]	[0–28]	[0–10]	[0–12]	[0–28]
Employees	37.567	22.444	37.918	32.196	32.524
	(63.658)	(44.687)	(64.774)	(46.909)	(72.414)
	[1–476]	[1–422]	[1–401]	[1–300]	[1–476]
AcademicFounders	0.593	0.845	0.603	0.616	0.670
	(0.492)	(0.362)	(0.490)	(0.487)	(0.470)
	[0/1]	[0/1]	[0 /1]	[0/1]	[0/1]

Mean, (Standard Deviation), [Range]

The purpose of this study is to describe SBIR-based scientific publications as well as across Phase II project variations in publication activity. Toward this end, Table 3 shows that the mean number of publications varies by funding agency from a low of 2.18 to a high of 4.51. Across all Phase II projects, the mean number of publications is 3 with a range from 0 to 165.[19]

The empirical model

To investigate Phase II project variation in publication activity, I considered two reduced-form models:

1. *Publications* = f (**Project Characteristics**, **Firm Characteristics**)
2. *Publications per Employee* = f (**Project Characteristics**, **Firm Characteristics**)

where the variables in the vector **Project Characteristics** and the vector **Firm Characteristics** are defined in Table 2.

[19] The date of each publication is not available in the NRC database.

Referring to Table 2, the first project characteristic in the models is *ProjectYears*. I do not offer a hypothesis about the direction of the estimated coefficient on this variable. On the one hand, the estimated coefficient on this variable might be positive. Firms with Phase II projects that were funded the largest number of years prior to the survey have had more time to publish their findings. In addition, completed Phase II projects are unlike research projects in federal laboratories because of the hurdle clearing that preceded them. To receive a Phase II award, the firm had to have been successful in receiving a Phase I award and completing the Phase I project successfully. Then, the firm had to compete for the Phase II award.[20] Recall from Table 1 that only successfully completed Phase II projects are in the sampling population studied in this paper. On the other hand, the estimated coefficient might be negative. Bloom et al. (2020, p. 1138) make the point through examples—examples primarily from the private sector—that good ideas are becoming harder to find. These authors conclude that: "[o]ur robust finding is that research productivity is falling sharply everywhere we look."[21]

I hypothesize the estimated coefficient on *University* to be positive. The objective function of university personnel, who are either directly or indirectly involved in the Phase II project, is to be involved in research with results that are possibly publishable. It might have been the case, or so I hypothesize, that a university would only be willing to devote its resources to the Phase II project if the resulting scientific and technical knowledge enters the public domain.

I also hypothesized that a firm with more previous Phase II projects in the technology area related to the Phase II project surveyed will have a greater scientific base and basis on which to be able to publish. Also, as Goel and Rich (2005) point out, there is an important research policy ➔ conduct ➔ performance paradigm to be acknowledged. Within that framework, previous Phase II projects are an element of conduct and should positively affect performance as measured here in terms of publications. Thus, the estimated coefficient on *PreviousPhIIs* is hypothesized to be positive.

Referring again to Table 2, the first firm characteristic is *Employees*, which measures the number of firm employees at the time the Phase II project was proposed/awarded and is generally viewed as a proxy for firm size in SBIR studies (Link 2013). To the extent to which this variable approximates the human capital resource base of the firm, one would expect its estimated coefficient to be positive.[22]

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[20] Based on SBIR award data over the years 1992 through 2010, 16.1% of applications for Phase I projects received an award. Of those projects, 81.9% submitted a Phase II proposal but only 51.4% received an award. See, www.sbir.gov.

[21] Complementing the Bloom et al. examples, Link and Scott (2019a, 2019b, p.7) report, using data specific to the National Institute of Standards and Technology (NIST, a federal laboratory within the Department of Commerce) that there has been over time a "negative rate of change in the shift factor that captures technological change in the knowledge production function [of scholarly publications] is consistent with the prediction of de Solla Price (1963) there would be a breakdown in the overall process of creating new science as science inevitably ceases its exponential growth."

[22] Conspicuously absent from the list of project and firm characteristics are two variables. The first variable is the amount of the Phase II award. Information on the Phase II award is only available in the 2005 survey. Separate models were estimated only using the Phase II projects from the 2005 survey. The estimated coefficient on the award amount variable was not statistically significant, and the estimated coefficients on the other variables mirror

Finally, the estimated coefficient on *AcademicFounders* is hypothesized to be positive.[23] A firm with academic founders might be predisposed to publications based on the objective function that dominated him/her in a previous setting.

Because the variable *Publications* is censored at 0, a Tobit model was considered for both models: 759 of the 2024 Phase II projects had 0 publications. The Tobit results from eqs. (1) and (2), with funding agency fixed effects, are presented in Table 4.

Table 4. Tobit Regression Coefficients for Eqs. (1) and (2) (standard errors in parentheses) (n = 2024)

	Dependent Variable	
Variable	***Publications***	***Publications Per Employee***
ProjectYears	0.401***	0.042***
	(0.107)	(0.012)
University	4.283***	0.442***
	(0.579)	(0.066)
PreviousPhIIs	0.463***	0.020
	(0.130)	(0.015)
Employees	0.021***	–
	(0.0049)	
AcademicFounders	1.328**	0.139**
	(0.616)	(0.070)
DOD	−1.073	−0.214**
	(0.935)	(0.107)
NIH	0.711	−0.173
	(1.004)	(0.114)
DOE	−0.478	−0.292**
	(1.158)	(0.132)
Intercept	−7.083***	−0.457***
	(1.266)	(0.143)
Log likelihood	−5380	−2647
Sigma	11.522***	1.321***
	(0.237)	(0.027)

Notes: *NASA* is subsumed in the intercept term
*** significant .01-level, ** significant at .05-level, *** significant at .10-level

Overall, the data fit the model reasonably well. The results from either eq. (1) or (2) do not support the Bloom et al. (2020) finding that good ideas (or publishable ideas in the case of this paper) are getting harder to find. The estimated coefficient on *ProjectYears* is positive and significant. The other hypotheses are also supported empirically from the model in eq. (1). More publications result from a Phase II project if a university is involved, if the firm has received more Phase II awards related to the technology developed by the current Phase II project, and if the firm has an academic founder. Also, larger firms, as measured by the number of employees at the time of submission/awarding of the Phase II project, publish more. From the specification in

those reported below. These results are available from the author on request. The second variable is a measure of the educational background of the principal investigator. Unfortunately, that variables is not in the NRC database.

[23] The initial study of publications and the academic background of SBIR-funded firms with academic founders is by Link and Rhum (2011).

eq. (2), the hypothesis about previous Phase II awards does not hold empirically but the other hypotheses do.

Concluding remarks

This study considered publications from publicly funded research projects as an example of a knowledge transfer.[24] Although descriptive in its approach and its findings, it does emphasize that publications are indeed a relevant output from Phase II SBIR-funded projects; the mean number of publications is 3.

This study has neglected to consider several relevant issues due to limited data. The first issue to consider, and this issue might be what some consider the elephant in the paper, is the answer to the question: Why would the small entrepreneurial firms that receive an SBIR award publish any information about their developed technology? Hayter and Link (2018, p. 143) conceptualized about this question, and they conclude:

Based on our review, we categorize the extant literature by two motivational logics: competitive and accretive. Competitive logic assumes that firms publish to achieve a strategic advantage over market competitors [and competitive publishing logic is also known as defensive publishing]. Accretive logic assumes that firms use publications as a signal to potential partners to attract financial resources, enhance the reputation of in-house scientists, and obtain new technologies critical to the development of new products.

To the best of my knowledge, these roles for small, entrepreneurial firms publishing about their newly developed technology vis-à-vis patenting their newly developed technology has not been systematically empirically studied, and from my vantage it should be so studied.

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