Capturing knowledge: Private gains and public gains from university research partnerships

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Abstract:

In this monograph I ask: Does university involvement in the research of private firms enhance the firm's private gains as well as society's public gains? To address this question I analyzed, in an exploratory manner, data relevant to firm-based research projects funded by the U.S. Small Business Innovation (SBIR) program. The data suggest that when a university is involved in a Phase II SBIR project it does realize private gains in the form of greater patenting activity and greater employment growth. However, university involvement is not related to such public gains descriptors as the likelihood that the technology from the SBIR project will be commercialized, the likelihood that the developed technology will be licensed to other U.S. entities, or the likelihood that the firm will enter into a research and development agreement with other U.S. entities. I conclude from my study that firms that receive SBIR research awards are very strategic about involving a university as a research partner. Perhaps such firms only involve universities in activities through which they can appropriate most, if not all, of the related benefits.

Keywords: technology transfer | small business | public-private partnerships | knowledge spillover

Article:

1 Introduction

The main title of this monograph is *Capturing Knowledge*. To academic scholars this title could appear to be misleading because it could represent a contradiction in terms. Economists, for example, view knowledge, say new knowledge, as a pure public good, something that cannot be permanently, or at least for a sufficiently long period of time, captured or appropriated absent trade secrets or institutional arrangements such as the patent system. But what about the subtitle: *Private Gains and Public Gains from University Research Partnerships*? Note the conjunction that is in the subtitle: "and" rather than "or." The subtitle is intended to clarify any misconception associated with the main title. The notion is that a firm — my broadly defined unit of observation in this monograph — can possibly capture new knowledge gained through a university research partnership in the short run and thus realize private gains, but in the long run there should eventually be public gains to society associated with the transfer of knowledge that is embodied in marketable products, processes, services, and attendant activities — hence my use of "and" rather than "or." Stated differently, the public good characteristics of knowledge should eventually (i.e., in the long run) spill over to society in the form of public gains. But does it? More formally, the question asked in this monograph is: Does university involvement in the research of private firms enhance a firm's private gains as well as society's public gains?[1]

1.1 Setting the stage

For many, the general topic of knowledge spillovers or knowledge externalities might raise the question: From where does knowledge originate? An important role of a university is clearly to create as well as distribute knowledge, both of which have public good characteristics. Of course, through class instruction faculty draw upon the wellspring of existing knowledge to educate students and to form the foundation for their future scholarly inquiries and endeavors. But, faculty also create new knowledge that is distributed openly through publications, lectures, and seminars; hence, knowledge per se has public good characteristics. But, if universities create and distribute knowledge, which is a public good or at least has public good characteristics, then it is fair to ask: How permanent are the private gains to a firm from involving a university as a partner in its research?

Joseph Stiglitz, who received the Nobel Prize in 2001, pointed out one presumed origin of the concept of knowledge as a public good [1999, p. 308]:

> Thomas Jefferson, the third President of the United States, described knowledge in the following way: "He who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine, receives light without darkening me." In doing so, Jefferson anticipated the modern concept of a public good.

But, Stiglitz also acknowledged that the more modern concept of knowledge as a public good came from the 1972 Nobel Laureate Kenneth Arrow [1962]. Drawing from Arrow, Stiglitz offered the following statement about a public good [1962, p. 308]:

> A public good has two critical properties, non-rivalrous consumption — the consumption of one individual does not detract from that of another — and non-excludability — it is difficult if not impossible to exclude an individual from enjoying the good.

From a firm's perspective, a university represents a fountainhead of knowledge, both new knowledge as well as existing knowledge. And, with effort and with resources, a firm can tap into that body of knowledge for what I refer to as a short-term private gain. In other words, a research partnership with a university should leverage the firm's ability to use its resources more

[1] The genesis of my interest in universities as research partners stemmed in part from my friend and virtual mentor, Ed Mansfield. It was Ed who first encouraged me to think about the social returns to university research and that challenge led me to think about the firm characteristics that affected those returns. See Link and Scherer [2005] and the special issue of the *Journal of Technology Transfer* (30(1–2), 2004) prepared in his honor.

effectively or even to substitute for missing critical resources so that the firm appropriates the economic benefits of university-based knowledge. What should follow from short-term private gains is what I refer to as long-term public gains or positive externalities to society.

Long-term public gains need not be at the expense of long-term private gains. A university research partnership might increase producer surplus in the short run, but it also might increase consumer and producer surplus in the long run. The fact that a firm can appropriate private gains over time does not negate the importance of asking whether university involvement in a firm's research eventually generates external benefits to society.

The short-term private gains and the long-term public gains associated with the knowledge transferred to a firm through a university research partnership relationship have been recognized by others. Their recognition might have come about because much of the knowledge created in a university is generally publicly funded. Johnson [1972, pp. 15–16], for example, wrote, when commenting on science per se or more accurately on scientific knowledge as a public good:

> Public goods pose two basic problems. The amount of them to be provided cannot be left to private decision but must be decided collectively, because private decision could result in under-supply since the private gain is less than the social; and people should not be charged for the enjoyment of them — as distinct from the cost of provision, which must of course be met somehow — because charging would deter use of something the use of which is costless.
>
> Science, as a specific type of public good, poses both these problems. In the nature of the case, it cannot be charged for until embodied in specific economic applications; when it is so embodied and charged for, however, it involves an artificial monopoly which creates problems of an obvious sort. From the social point of view, the main question under this head is whether the monopoly privileges that attach to embodied applications of science are efficiently designed to encourage socially useful applications of science; and the conclusion one is driven to, at least at the theoretical level, is that they are not. And this conclusion assumes that the user of scientific knowledge embodied in a product has full knowledge of the consequences of using the product and pays the full cost of so doing — whereas the use of many science-based products gives rise to what economists term "externalities", i.e., costs imposed on or benefits conferred on other people with no recompense, or at no cost to themselves. In an earlier age, society tended to be more conscious of the positive than of the negative externalities — for example the social benefits of personal cleanliness and hygiene. Recently, society has become conscious of and alarmed about the negative externalities, described generally as the pollution of the environment.

The remainder of this monograph reflects an exploratory effort into the proposition that knowledge transferred from a university to a firm or group of firms (hereafter simply from a university to a firm) through a research partnership, be it a formal or an informal partnership, results in short-term private gains to a firm as well as to long-term public gains to society. The data analyzed in this monograph to explore this proposition relate to the U.S. Small Business Innovation Research (SBIR) program, a publicly funded set aside program. Thus, more specifically, the purpose of this monograph is to explore the extent to which research-based knowledge from a university to a firm conducting publicly funded research generates short-term private gains to the firm as well as long-term public gains to society.

1.2 The SBIR program and related data

To probe into the validity of this proposition, I rely on descriptive empirical evidence from analyses of firm-based research projects funded by the SBIR program that was created through the Small Business Innovation Act of 1982. In the following paragraphs I attempt to place that act in a broader economic and policy context.

The Small Business Innovation Act of 1982 is directly relevant to the recent history of U.S. technology and innovation policy. Figure 1.1 shows the trend in a total factor productivity (TFP) index for the private non-farm U.S. business sector over the years 1948 through 2013 (2005 = 100).[2] A TFP index, or multifactor productivity index as it is referred to by the U.S. Bureau of Labor Statistics, is an index that arguably measures over time the technological advancement of an economy, the U.S. in this case. Many date this interpretation of a TFP index to the early work of the 1987 Nobel Laureate Robert Solow [1957].[3]

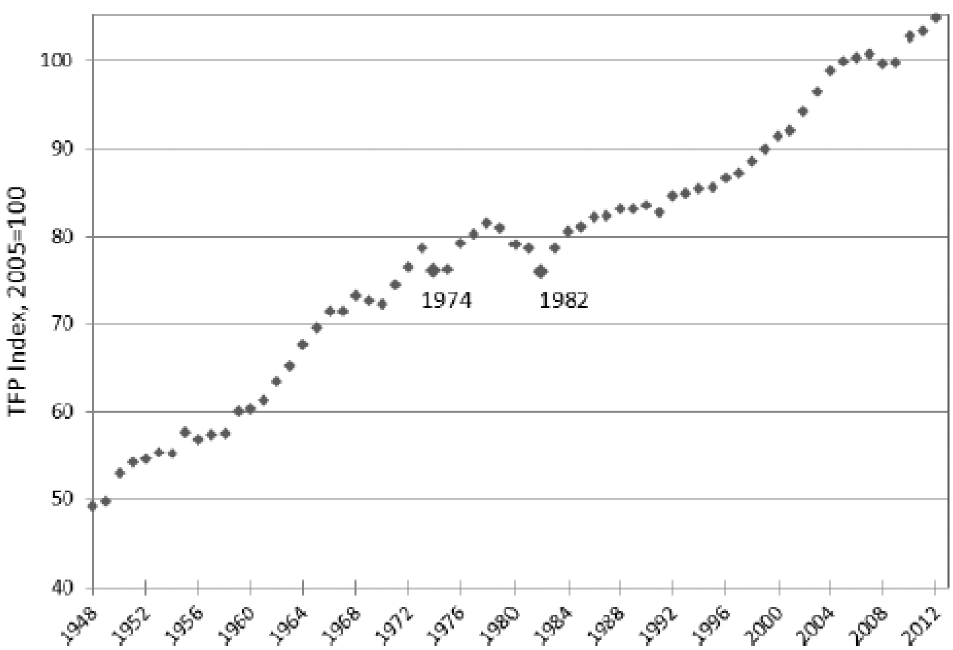

Figure 1.1. Total factor productivity index for the private non-farm U.S. Business Sector, 1948–2013 (2005 = 100).
Source: Compiled by the author.

[2] Following the derivation by the U.S. Bureau of Labor Statistics — <http://www.bls.gov/mfp/> — the private non-farm business sector is defined as follows. Gross Domestic Product (GDP) less general government equals the total private economy. The total private economy less output of household workers, nonprofit institutions, gross housing product of owner-occupied dwellings, and the rental value of nonprofit institutional real estate equals the business sector. The business sector less government enterprises equals the private business sector. And, the private business sector less the farm sector equals the private non-farm business sector.
[3] See in particular Link and Siegel [2003].

Clearly, with reference to Figure 1.1, TFP declined slightly in the early-1970s and then again the late 1970s and early 1980s. This so-called productivity decline or period of technological retrogression, was observed not only in the U.S. but also in many other industrialized nations.[4]

Link and Siegel [2003] document many of the ex post explanations that economists and policy makers offered at that time for the U.S. productivity decline.[5] These explanations range from the decline being a typical cyclical swing in the economy to the decline being a consequence of the energy crisis of the early 1970s. Explanations aside, the decline in the late 1970s and early 1980s precipitated the passage of a number of technology and innovation policies in the U.S. Leyden and Link [2015] refer to these legislative initiatives as examples of public sector entrepreneurship[6]; and Link and Link [2009] refer to the agencies, offices, and infrastructures that grew out of these initiatives as examples of government as entrepreneur.[7] These policy initiatives include the University and Small Business Patent Protection Act of 1980 (known simply as the Bayh-Dole Act of 1980); the Stevenson-Wydler Technology Innovation Act of 1980 (known simply as the Stevenson-Wydler Act of 1980); the Economic Recovery Tax Act (ERTA) of 1980 (of which the relevant section is known simply as the R&E Tax Credit of 1981); the Small Business Innovation Act of 1982, which is the focus of this monograph; and the National Cooperative Research Act of 1984.[8]

The empirical analyses in this monograph focuses specifically on the Small Business Innovation Act of 1982. The empirical content of the analytical sections that follow might seem to some scholars, regardless of their disciplines, to be cryptic in its nature. That is by intent. This monograph is descriptive in nature; it is not written exclusively for academic researchers. My goal is that the ideas herein might also reach students interested in this subject matter as well as the broader population of learned individuals.

I rely on simple partial correlations from a number of parsimonious regression models to illustrate, in an exploratory manner, the role of universities as research partners on a variety of performance-related activities. Treating university involvement as an independent and exogenous variable is not problematic because the university was likely involved in an SBIR project from its inception. In many of the regressions in subsequent sections the size of the SBIR research project is also held constant as an independent and exogenous variable. The size variable controls for economies of scale and scope within the firm that received the SBIR award. My point from this explanation is that although the models estimated in the following sections are parsimonious in structure, they rely on available information (and thus they are replicable), and

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[4] Again, see Link and Siegel [2003].
[5] I have written about the productivity decline for other purposes. See, for example, Bozeman and Link [forthcoming] and Leyden and Link [2015].
[6] "Public sector entrepreneurship refers to innovative public policy initiatives that generate greater economic prosperity by transforming a status-quo economic environment into one that is more conducive to economic units engaging in creative activities in the face of uncertainty" [Leyden and Link, 2015, p. 14].
[7] "Government acts as entrepreneur in the provision of technology infrastructure when its involvement is both innovation and characterized by entrepreneurial risk (i.e., uncertainty)" [Link and Link, 2009, p. 17].
[8] Bozeman and Link [forthcoming] argue as well as demonstrate empirically that these policies collectively shaped the post-productivity slowdown level of R&D investments, which had a measurable impact on the recovery in TFP.

endogeneity of the independent variables is, in my view, not an issue of econometric concern for the analyses herein.

Table 1.1. Firms collaborating on innovation with higher education or public research institutions by firm size, 2008–2010.

	Percent of product/process innovative firms in each category	
Country	**SMEs**	**Large firms**
Finland	29.2	70.0
Slovenia	19.8	58.7
Austria	20.5	56.5
Hungary	18.6	50.3
Sweden	12.9	48.2
Belgium	18.2	44.5
German	13.9	43.2
Norway	15.1	42.2
Denmark	12.4	40.8
Korea (2005-2007)	18.3	39.8
Portugal	8.20	39.2
Japan (2009-2010)	18.7	37.3
South Africa (2005-2007)	16.2	37.0
France	13.7	34.9
Luxembourg (2006-2008)	13.6	34.2
Czech Republic	13.8	33.8
Switzerland (2009-2011)	9.90	32.3
Spain	10.8	31.3
U.K.	16.8	31.3
Slovak Republic	11.9	30.4
Netherlands	9.40	29.1
Estonia	8.50	28.9
Israel (2006-2008)	15.6	28.6
Poland	10.1	28.4
Ireland (2006-2008)	9.30	27.5
Italy	4.90	26.1
Turkey	7.50	24.0
Russian Federation (2009-2011)	16.2	23.3
New Zealand (2009-2010)	5.10	22.5
Brazil (2006-2008)	4.60	18.0
Chile (2009-2010)	2.70	13.6
Mexico (2008-2009)	12.5	3.90
Australia (2011)	4.10	3.50

Source: OECD [2013] data taken from http://dx.doi.org/10.1787/888932891359 and compiled by the author.
Note: Small and medium-sized enterprises (SMEs) is a descriptor used in the European Union (EU) and other countries and not in the U.S. Generally a small enterprise has up to 50 employees and a medium-sized enterprise has less than 250 employees.

It is important to emphasize that I implicitly assume in much of what follows that the flow of knowledge is from the university to the firm. There is much evidence, some of which has come from my own research, that there are also important knowledge flows from the firm back to the university. Most data on universities as research partners are of an aggregate nature, and all that one might obtain from an examination of aggregate data are static performance implications of the partnership as opposed to individual gains from the flows of knowledge.[9]

The importance of knowledge transferred from any particular university to a firm through a research partnership is more than of regional or local interest. Knowledge transferred from a university to a firm has global relevance and global implications. As shown in Table 1.1, which is based on data collected by the Organization for Economic Co-operation and Development (OECD), there are noticeable cross-country differences in firm collaborations with universities and public research institutions. The percentages in the table refer to small and medium-sized enterprises (SMEs) and to large firms. The data related to SMEs are perhaps closer to the data related to SBIR-funded firms because SMEs are defined as having less than 250 employees and small firms (in the case of SBIR) are defined as having 500 or fewer employees.

It remains an open question as to how the aggregate data in Table 1.1 correlate with performance metrics that characterize each national innovation system. The simple fact that OECD collects such partnership information might in itself be a testament to the importance of such relationships. Accepting the conclusion that I have just drawn from the fact that OECD collects such data, attention should be drawn to the fact that there are no data in Table 1.1 that describe the U.S. experience. That observation might possibly make the analyses in this monograph and the conclusions in the final section more important.

Knowledge transferred from a university to a firm is also relevant to domestic policies. For example, the President's Council of Advisors on Science and Technology (PCAST) issued a report in 2008 titled, *University-Private Sector Research Partnerships in the Innovation Ecosystem*.[10] Therein it is stated (PCAST, 2008, p. 19):

> Private sector engagement with researchers in academic . . . laboratories is increasingly vital to the health of U.S. R&D, and ultimately to the technology-based economy.

Among the justification for this statement, PCAST appropriately noted that (p. 19)[11]:

> This is because . . . industrial basic research laboratories have been reduced in both number and size and therefore industry has come to rely further on academic as well as government laboratories for basic research output . . . and the escalating pace of

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[9] Having offered this caveat, which of course will temper my conclusions in this monograph and any recommendations that follow, I also offer, as an aside, a charge to academic researchers to pursue case studies to understand better the two-way flows of knowledge and the potentially different implications from those flows.

[10] President George W. Bush established PCAST by Executive Order 13226 in September 2001 for the purpose of advising the President on matters involving and related to science and technology policy.

[11] The report found (PCAST, 2008, p. 27): "Universities continue to serve as a primary engine for discovery research that can lead to innovation and the Federal government remains the primary source to support basic research." And in response to this finding PCAST recommended that: "While exploring new partnership models and assessing the evolving innovation ecosystem, the essential role for the Federal government in supporting basic research must be recognized and maintained." Another important finding in the report (p. 33) was: "The connection points between partners in the innovation ecosystem need to be strengthened to reduce barriers to collaborations." Accordingly, PCAST recommended to (p. 34): "Formalize and enhance opportunities and incentives for researchers to have flexibility in moving between academia, industry, and government."

technology development calls for enhanced and novel technology transfer processes to capture these developments.

1.3 An overview of the monograph

The remainder of this work is outlined as follows. In Section 2, I offer a skeleton review of the extant academic literature, written mostly by economists, on universities as research partners. I begin with this review in an effort to motivate the remaining section topics in the monograph.[12]

I briefly summarize in Section 3 aspects of the Small Business Innovation Act of 1982, which created the SBIR program.

Descriptive information about universities as research partners in SBIR projects is presented in Section 4. That section segments the SBIR data in several ways not only to illustrate the different roles that universities play as a partner in an SBIR-funded project, but also to motivate the roles of a university in the research process.

The roles of a university in the research process described in Section 4 are delimited by the availability of data related to SBIR-funded projects. Clearly, and appropriately, another researcher might describe and quantify the roles of a university in the research process differently from both a conceptual point of view as well as from an empirical point of view depending on the data that he/she has in hand.

The descriptive empirical analyses presented in Section 5 focus on the impact of university research partnerships on the performance of SBIR-funded projects and firms. They are intended to emphasize the private gains to the firm from its research involvement with a university and to explore the presence of public gains. The findings in this section allow me to offer, in Section 6, a tentative answer to the question that underlies this work: Does university involvement in the research of private firms enhance the firm's private gains as well as society's public gains?

Concluding remarks are offered in Section 6. To anticipate those remarks, my analyses in Section 5 suggest that there are indeed measurable private gains from university involvement in SBIR projects, but contrary to expectations, or some might say contrary to economic theory, there does not appear to be evidence of public gains.[13] Caveats about the quality and extensiveness of the data in hand aside, a possible explanation for the empirical finding that university involvement as a research partner afford the partnering firm private gains but does not benefit society through public gains is that firms involved in SBIR projects are being very strategic about involving a university as a research partner. Perhaps firms only involve universities in activities through which they, the firms, can appropriate most if not all of the related benefits.[14]

2 University Research Partnerships: The Academic Literature

[12] Much of the empirical literature summarized in Section 2 was co-authored with long-time collaborators.
[13] See Audretsch et al. [2012].
[14] See Audretsch and Link [2015].

This section summarizes aspects of the academic literature that relate to universities as research partners. That body of literature, much of which has been developed by economists, can be partitioned in a number of ways. The taxonomy that I have chosen, and have written about elsewhere, follows from the early work of Mason [1939] and Bain [1949].[1] For decades their so-called structure-conduct-performance paradigm dominated the pedagogical approach to research within the broadly defined field of industrial organization.

The relationship of this taxonomy to the study of universities as research partners is as follows. The structure of the university or of its faculty and/or the structure of the potential partner research firm is what determines if a research partnership will develop. The formation of a research partnership is the conduct that follows from the structure characterizing each partner. Given that a partnership has been formed, the performance of the partnership becomes the relevant and final descriptor.

I have grouped the extant literature into these two broad areas: the body of research related to what I call the structure → conduct paradigm and the body of literature related to the conduct → performance paradigm. The former body of literature is summarized in Table 2.1 and the latter is summarized in Table 2.2.

Before discussing the content of these two tables, several qualifying remarks are needed. First, I probably have overlooked some, or even many, relevant and surely important writings about universities as research partners. If so, this error of omission was entirely unintentional. Second, my summary of the cited works is brief and some author(s) might think that I have missed subtleties and nuances of his/her/their research. If so, I acknowledge as well the need for an apology for this shortcoming.

The purpose of these tables is not to supplement a detailed literature review of universities as research partners — although such a detailed review would be an important contribution to the academic and policy literatures—but rather the purpose is to illustrate the scope of antecedents and consequences associated with university research partnerships. That is, the purpose of the tables is to acknowledge for descriptive purposes the characteristics of universities and firms that affect the probability of a research partnership occurring, and having occurred the probability that the partnership will have performance-based outputs (i.e., private gains) and possibly outcomes (i.e., public gains or social externalities).

Also, there is some overlap between the research included in Table 2.1 and Table 2.2. This is not by accident. Some of the cited literature is, in my opinion, not clearly within one paradigmatic category or another.

As an aside, and I mention this here for the reader to anticipate my concluding remarks about the public gains associated with universities as research partners in Section 6, none of the conduct → performance literature referenced in Table 2.1 deals with spillover benefits associated with university research partnerships.

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[1] The framework for presenting the extant literature in this section is patterned after Link and Wessner [2011] and Leyden and Link [2015].

Table 2.1. Selected academic literature related to the structure → conduct paradigm of university research partners.

Author(s)	Summary
Link and Zmud [1987]	Link and Zmud demonstrate descriptively that universities are not one of the most common sources of external knowledge on which R&D firms rely. They also show statistically that larger firms, measured in terms of firm sales, tend to rely on external sources of knowledge per se to a greater degree.
Baldwin and Link [1998]	Baldwin and Link argue that larger research joint ventures, measured in terms of number of members, are more likely to invite a university to be a research partner than small research joint ventures. Their logic is that with more members the ability for any one firm to appropriate the intellectual knowledge from the venture's research decreases and thus the addition of a university will not have much of an appropriability loss impact.
Hall et al. [2001]	Hall et al. identify barriers that inhibit firms from partnering with universities. Intellectual property issues are a significant problem, and the problem is greater the shorter the time period of the research relationship and greater if the firm has had previous partnering experience with a university.
Siegel et al. [2003b]	Siegel et al. conclude on the basis of structured interviews with university technology transfer officers that faculty involvement in the process of transfer university-based technology for the private sector can be enhanced through improved reward structure for faculty.
Hall [2004]	Hall's literature review focused on the extent and scope of industry-university research relationships as affected by the presence of intellectual property mechanisms.
Siegel et al. [2004]	Siegel et al., building on Siegel et al. [2003a], argue on the basis of structured interviews with university and corporate technology transfer officers that the reward systems for university technology transfer and staffing competences are critical for the transfer to firms to occur.
Link and Scott [2005]	Link and Scott estimate econometrically the probability that a university will be a member of a U.S. research joint venture. Their results show that the larger the joint venture the greater the likelihood that a university will be involved in the research.
Link and Siegel [2005]	Link and Siegel identify from their empirical analysis the organizational structures of university technology transfer offices that are most conducive to the transfer of technology from the university to private sector firms.
Fontana et al. [2006]	Fontana et al. show that from the firm's perspective, the likelihood of collaboration with a university is greater in large rather than small firms.
Allen et al. [2007]	Allen et al. examine empirically the relationship between the demographic characteristics of university faculty and their tendency to collaborate with private sector firms. They find that tenured male faculty are more likely to collaborate with firms especially if the resulting research is patentable.
Bercovitz and Feldman [2007]	Bercovitz and Feldman show empirically that firms are more likely to establish university research relationships (i.e., partner with a university) when their R&D is exploratory in nature.
Link et al. [2007]	Link et al. document methods of information technology transfer out of universities to private firms. Those so engaged tend to be male faculty who are tenured.
Stuart et al. [2007]	Stuart et al. argue that upstream alliances with universities increase over the age distribution (i.e., the maturity) of firms.
Boardman and Corley [2008]	Boardman and Corley show that when university faculty are associated with a university research center they are more likely to collaborate with industry.
Bozeman et al. [2008]	Bozeman et al. provide survey information on barriers associated with the adoption of nanotechnologies by firms in North Carolina. Their analysis highlights that lack of access to university equipment is a barrier that could be overcome through research partnerships and/or related public policies.
Kodama [2008]	Kodama's study of Japanese research firms concludes that firm size and firm profitability are not correlated with the likelihood of university collaboration.

Author(s)	Summary
Leyden et al. [2008]	Leyden et al. model the firm's decision to locate on a university research park, and they test their model empirically. They find that U.S. firms that locate research facilities on university research parks are more research active and more diversified than the typical public firm reporting R&D activity.
Link and Siegel [2009]	Link and Siegel outline how the traditional evaluation model that builds on consumer and producer surplus is applicable to evaluating the social benefits of technology transferred from a university to a firm.
Link and Wessner [2011]	Link and Wessner present a limited literature review. Their review, which is done from a policy perspective, segments the literature into those papers that emphasize structure, conduct, and performance. That is, a portion of the policy literature emphasizes firm and university characteristics (i.e., structure) that bring about a research partnership (i.e., conduct). Another portion of the literature emphasizes the output and outcomes associated with the partnership (i.e., performance).
Leyden and Link [2015]	Leyden and Link extend the Link and Wessner taxonomy to include a broader body of literature.

Source: Compiled by the author.

Table 2.2. Selected academic literature related to the conduct → performance paradigm of university research partners.

Author(s)	Summary
Link and Rees [1990]	Link and Rees show statistically that large firms are more active in university-based research per se but small firms are able to utilize their university-based associations (i.e., gained knowledge) to leverage their internal R&D to a greater degree than large firms.
Baldwin and Link [1998]	Baldwin and Link argue that larger research joint ventures, measured in terms of number of members, are more likely to invite a university to be a research partner than small research joint ventures. Their logic is that with more members the ability for any one firm to appropriate the intellectual knowledge from the venture's research decreases and thus the addition of a university will not have much of an appropriability loss impact.
Link [1999]	Link offers policy-oriented arguments about the importance of quantifying the impact of university technology transfer on private sector economic growth.
Cohen et al. [2002]	Cohen et al. address indirect industry/university partnerships. They contend that publications, conferences, and informal relationships are the indirect mechanisms through which university research impacts industrial R&D.
Hall et al. [2003]	Hall et al., based on Hall et al. [2000], conclude from their analysis of universities as research partners in research joint ventures funded by the U.S. Advanced Technology Program that universities create research awareness among the research partners.
Hall [2004]	Hall's literature review focused on the extent and scope of industry–university research relationships as affected by the presence of intellectual property mechanisms.
Siegel et al. [2004]	Siegel et al., building on Siegel et al. [2003a], argue on the basis of structured interviews with university and corporate technology transfer officers that the reward systems for university technology transfer and staffing competences are critical for the transfer to firms to occur.
Link and Scott [2005]	Link and Scott estimate econometrically the probability that a university will be a member of a U.S. research joint venture. Their results show that the larger the joint venture the greater the likelihood that a university will be involved in the research.
Link and Siegel [2005]	Link and Siegel identify from their empirical analysis the organizational structures of university technology transfer offices that are most conducive to the transfer of technology from the university to private sector firms.
Hertzfeld et al. [2006]	Hertzfeld et al. show descriptively that negotiations about intellectual property rights among members of a research joint venture are more difficult when a university is involved in the venture.
Allen et al. [2007]	Allen et al. examine empirically the relationship between the demographic characteristics of university faculty and their tendency to collaborate with private sector firms. They find that

Author(s)	Summary
	tenured male faculty are more likely to collaborate with firms especially if the resulting research is patentable.
Link and Scott [2007]	Link and Scott review the academic literature related to university research parks including those parks that identify performance differences between on-park and off-park firms.
Link et al. [2007]	Link et al. document methods of information technology transfer out of universities to private firms. Those so engaged tend to be tenured male faculty
Bozeman et al. [2008]	Bozeman et al. provide survey information on barriers associated with the adoption of nanotechnologies by firms in North Carolina. Their analysis highlights that lack of access to university equipment is a barrier that could be overcome through research partnerships and/or related public policies.
Leyden et al. [2008]	Leyden et al. model the firm's decision to locate on a university research park, and they test their model empirically. They find that U.S. firms that locate research facilities on university research parks are more research active and more diversified than the typical public firm reporting R&D activity.
Link and Ruhm [2009]	Link and Ruhm show that the probability of a SBIR project reaching the commercialization stage is greater if a university is involved in the funded project.
Link and Siegel [2009]	Link and Siegel outline how the traditional evaluation model that builds on consumer and producer surplus is applicable to evaluating the social benefits of technology transferred from a university to a firm.
Link and Wessner [2011]	Link and Wessner present a limited literature review. Their review, which is done from a policy perspective, segments the literature into those papers that emphasize structure, conduct, and performance. That is, a portion of the policy literature emphasizes firm and university characteristics (i.e., structure) that bring about a research partnership (i.e., conduct). Another portion of the literature emphasizes the output and outcomes associated with the partnership (i.e., performance).
Leyden and Link [2013]	Leyden and Link present a model of the role that universities play in facilitating the transmission of knowledge to private-sector business enterprises so as to generate economic growth. Their model demonstrates mathematically that the precondition for a university to complement the firm's R&D must structure its program so that the firm's revenues increase more that their cost of collaborative R&D.
Perkmann et al. [2013]	Perkmann et al. review the literature on academic engagement (e.g., inter-organizational collaboration or technology transfer) and firm commercialization and find weak evidence of a causal relationship.
Leyden and Link [2015]	Leyden and Link extend the Link and Wessner taxonomy to include a broader body of literature.

Source: Compiled by the author.

2.1 Why form a research partnership?

Having identified in Table 2.1 the antecedents of a university research partnership with a firm, one sees that the literature is thin on the economic motivations that initiate the search for a research partner, whether or not the search begins on the university side or on the firm side. The obvious point of the question that titles this part of the section is that either the university or the firm, or both, seek additional research resources.

I offer the thought that one might turn to the writings of the 1991 Nobel Laureate Ronald Coase for insight both about a firm searching for a university research partner and/or a university searching for a firm to be a research partner. In his paper, "The Nature of the Firm," Coase wrote [1937, p. 393] about a firm, but I suggest the notion that his argument could also apply to a university, or to other organizations, that rationally allocates its scarce resources:

A firm . . . consists of the system of relationships which comes into existence when the direction of resources is dependent on an entrepreneur. The approach which has just been sketched would appear to offer an advantage in that it is possible to give a scientific meaning to what is meant by saying that a firm gets larger or smaller. A firm becomes larger as additional transactions (which could be exchange transactions co-ordinated through the price mechanism) are organised by the entrepreneur and becomes smaller as he abandons the organisation of such transactions.

In other words, the boundaries of a firm are determined by those aspects of allocation that can be most efficiently done internally rather than done through the external market.[2] Likewise, so are the boundaries of a university. That is, when the marginal cost to a firm (university) for acquiring relevant external research resources from a university (firm) is less than the marginal cost of developing and using those research resources internally, a research partnership — formal or informal — will likely follow.

2.2 The structure → conduct paradigm

As limited as well as heterogeneous in scope as the information in Table 2.1 is, some generalizations are perhaps still possible.[3] I present these generalizations from the literature below in equation form not only to anticipate that some who read this monograph might be motivated to enter into the research discussion, but also because equations are a natural part of the written dialogue of economists.

From the perspective of the university, *univ*, the probability that it will initiate a research partnership with a firm increases: (1) if there are university incentives to encourage faculty/firm interactions or even to encourage the transfer of a faculty's research to a firm, *incentives*; (2) if the faculty member establishing or participating in the partnership is a male, *male*; and (3) if the faculty member establishing or participating in the partnership is tenured, *tenure*. Thus:

$$\text{Probability of a partnership}_{univ} = \mathrm{f}(incentives,\ male,\ tenure) \quad (2.1)$$

Were a regression version of equation (2.1) considered, the estimated regression coefficients on each of the independent variables would be expected to be positive.

From the perspective of a firm, *firm*, the probability that it will initiate a research partnership with a university increases: (1) if intellectual property ownership by either party is not an issue, *IP* and (2) if the research being conducted collaboratively is basic or exploratory in nature, *explore*. Thus:

$$\text{Probability of a partnership}_{firm} = \mathrm{f}(IP,\ explore) \quad (2.2)$$

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[2] Coase continued [1937, p. 395], assuming that exchange transactions are homogeneous: "The point has been made . . . that a firm will tend to expand until the costs of organising an extra transaction within the firm become equal to the costs of carrying out the same transaction by means of an exchange on the open market or the costs of organising in another firm."

[3] One should realize that these generalities follow from the data available to the researchers cited in Table 2.1.

Were a regression version of equation (2.2) considered, it follows from the literature that the estimated regression coefficients on each of the independent variables would also be expected to be positive.

2.3 The conduct → performance paradigm

As with Table 2.1, some generalizations are perhaps possible. These generalizations are not as easily represented as an equation as those from the structure → conduct literature, but that pedagogical fact does not diminish their importance, and hopefully it does not diminish my related arguments. The literature in Table 2.2 suggests that there are a number of performance attributes that characterize having a university as a research partner. Many of these attributes are related to the research nature of the firm with which the university is partnering. These performance attributes include: enhanced research awareness, an increase in R&D efficiency, and a more effective transfer of university-based technologies.

To emphasize that university research partnerships enhance the firm's R&D and technology development process, thus increasing the firm's private gains, consider an early-on observation by Rosenberg and Nelson [1994, p. 340]:

> What university research most often does today is to stimulate and enhance the power of R&D done in industry, as contrasted with providing a substitute for it.

Similarly, Hall et al. [2003, p. 491] concluded[4]:

> Universities are included (invited by industry) in those research projects that involve what we have called "new" science. Industrial research participants perceive that the university could provide research insight that is anticipatory of future research problems and that it could be an ombudsman anticipating and communicating to all parties the complexity of the research being undertaken. Thus, one finds universities purposively involved in projects that are characterized as problematic with regard to the use of basic knowledge. Because of the type of project into which a university is likely to be invited as a research partner, the research will not move faster than expected toward a commercial application of the resulting technology. Universities are more likely to partner in new technological fields where R&D is closer to science, and such fields can be more uncertain and difficult.

2.4 Summary

[4] One possible way to formalize the Hall et al. [2003] observation is in terms of a firm's production function where Q represents output, K represents the input of capital, L represents the input of labor, and T represents the input of technical knowledge. It is assumed that R&D activity in the firm is functionally related to T. If there are constant returns to scale in K and L, meaning the sum of the relative shares of $K(\alpha)$ and $L(\beta)$ equal one, $[(\alpha + \beta) = 1]$, and if there are increasing returns to scale in all inputs meaning that the relative share of $T(\gamma)$ is positive and $[(\alpha + \beta + \gamma) > 1]$, then output can be expressed as $Q = A_0 K^{\alpha} L^{\beta} T^{\gamma}$ for A0 being a constant shift factor. In this specification, γ would be a function of university's research involvement in the production of knowledge. See Link and Rees [1990] for exploratory estimates of such a specified production function. See also, Hall et al. [2000].

It might be fair to say that there is a growing academic interest about university partnerships as evidenced by the number of published articles cited in Table 2.1 and in Table 2.2, and through an inspection of the dates of publication of that literature. And using the same criterion, it might be fair to say that such interest in the antecedents that bring about the partnership and the performance consequences of it is increasing as well. But, there has yet to be a broad based systematic study of either the structure → conduct or the conduct → performance paradigms. This monograph takes, I believe, a small step forward in that direction.

In a very general way, the following sections reflect the structure → conduct and the conduct → performance paradigms with respect to universities as research partners in SBIR projects and in RJVs. That is, one might think of Section 4 as framing the structure through which universities as research partners come about. One might also think of Section 5 for identifying the conduct that results from this structure.

3 Small Business Innovation Act of 1982

The U.S. Small Business Administration (SBA) was established in 1953 through the Small Business Act of the same year, Public Law 85-536.[1] During the post-World War period Congress came to realize the importance of small firms in stimulating economic growth. Congress's response to the productivity slowdown reflected, in some measure, this realization.[2] Prefacing the Small Business Innovation Act of 1982 (hereafter, the Act), Public Law 97-219, is the following:

> The Congress finds that–
>
> (1) technological innovation creates jobs, increases productivity, competition, and economic growth, and is a valuable counterforce to inflation and the U.S. balance-of-payments deficit;
> (2) while small business is the principal source of significant innovations in the Nation, the vast majority of federally funded research and development is conducted by large businesses, universities, and government laboratories; and
> (3) small businesses are among the most cost-effective performers of research and development and are particularly capable of developing research and development results into new products.

Therefore, the purposes of the Act are–

> (1) to stimulate technological innovation;
> (2) to use small business to meet Federal research and development needs;
> (3) to foster and encourage participation by minority and disadvantaged persons in technological innovation; and

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[1] I have written extensively about the institutional history of the SBIR program. Even though this historical trace and data description in Section 4 were written anew, similarity to my other writings is inevitable and unavoidable. See Link [2013].

[2] Link and Scott [2012, 2013] provide a brief history of U.S. policy emphasis on small, entrepreneurial firms.

(4) to increase private sector commercialization innovations derived from Federal research and development.

In this public law is a statement about the SBIR program that it created and the processes associated with the program.

> The term ‘Small Business Innovation Research Program’ or ‘SBIR’ means a program under which a portion of a Federal agency’s research or research and development effort is reserved for award to small business concerns through a uniform process having–
>
> (A) a first phase [Phase I] for determining, insofar as possible, the scientific and technical merit and feasibility of ideas submitted pursuant to SBIR program solicitations;
> (B) a second phase [Phase II] to further develop the proposed ideas to meet the particular program needs, the awarding of which shall take into consideration the scientific and technical merit and feasibility evidenced by the first phase and, where two or more proposals are evaluated as being of approximately equal scientific and technical merit and feasibility, special consideration shall be given to those proposals that have demonstrated third phase, non-Federal capital commitments; and
> (C) where appropriate, a third phase [Phase III] in which non-Federal capital pursues commercial applications of the research or research and development and which may also involve follow-on non-SBIR funded production contracts with a Federal agency for products or processes intended for use by the U.S. government.

Note that the empirical analyses in the following sections relate to Phase II projects as defined above. To fund the SBIR program, the Act mandated a set aside amount:

> Each Federal agency which has an extramural budget for and research or research and development in excess of $100,000,000 for fiscal year 1982, or any fiscal year thereafter, shall expend not less than 0.2 per centum of its extramural budget in fiscal year 1983 or in such subsequent fiscal year as the agency has such budget, not less than 0.6 per centum of such budget in the second fiscal year thereafter; not less than 1per centum of such budget in the third fiscal year thereafter, and not less than 1.25 per centum of such budget in all subsequent fiscal years with small business concerns especially in connection with a small business innovation research program which meets the requirements of the Small Business Innovation Development Act of 1982 and regulations issued thereunder: That any Federal agency which has an extramural budget for research or research and Development in excess of $10,000,000,000 for fiscal year 1982 shall expend not less than 0.1 per centum of its extramural budget in fiscal year 1983, not less than 0.3 per centum of such budget in the second fiscal year thereafter, not less than 0.5 per centum of such budget in the third fiscal year thereafter, not less than 1 per centum of such budget in the fourth fiscal year thereafter, and not less than 1.25 per centum of such budget in all subsequent fiscal years with small business concerns specifically in connection with a small business innovation research program which meets the requirements of the Small Business Innovation Development Act of 1982 and regulations issued thereunder:

The implementation of the Act required that to participate in the program the firm must be small with 500 or fewer employees, it must be independently owned and operated, and it must not be the dominant firm in its industry.

The SBIR program, as created through the Act, was not to be a permanent part of our nation's innovation infrastructure. The program was reauthorized in 1986 through Public Law 99-443. In 1992 the SBIR program was reauthorized again through Public Law 102-564. That reauthorizing public law stated that:

> The small business innovation research program has been an effective catalyst for the development of technological innovations by small business concerns.

The Small Business Research and Development Reauthorization Act of 1992 went on to amend the purposes of the original act to:

> Improve the Federal Government's dissemination of information concerning the small business innovation research program, particularly with regard to program participation by women-owned small business concerns and by socially and economically disadvantaged small business concerns.

Over time, the set aside to fund the SBIR program has increased from the original 0.2 percent to the 2.5 percent through 2008. The National Defense Authorization Act of 2012, Public Law 112-81, or more specifically in Section 5001 known as The SBR/STTR Reauthorization Act,[3] stated that the set aside amount should increase to be not less than 2.6 percent in fiscal 2012 and then to increase systematically year-by-year to be not less than 3.2 percent in fiscal year 2017.

Also over time the amount of funding has increased for Phase I and Phase II awards. Originally, Phase I awards were to be less than $50,000 for a six-month research project, and Phase II awards were capped at $500,000 for a two-year research project. The 1992 reauthorization of the program increased Phase I awards to $100,000 and Phase II awards to $750,000. In 2010, the SBA authorized that Phase I awards be increased to $150,000 and Phase II awards to $1,000,000.

The SBIR program is, in my opinion, an important institution in the U.S. as well as a critical part of our nation's technology and innovation infrastructure. As such, from an academic perspective, it is important to study it not only as an example of public sector entrepreneurship, as Leyden and Link [2015] have done, but also as a vehicle to generate economic growth through the development of new technology and through the commercialization of the new technology as an innovation.[4]

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[3] STTR refers to the Small Business Technology Transfer program which often involves university faculty participation.

[4] Link and Scott [2012] have assessed a dimension of the economic importance of the SBIR program on employment growth. While employment growth has never been a stated purpose of the program, during the Great Recession in the U.S. (December 2007 to June 2009), many programs were evaluated in terms of their potential and actual impact on employment growth. They showed that the mean employment gains from Phase II projects were, across funding agencies, between 24 and 65 persons per million dollars of public moneys.

4 Universities as SBIR Project Partners

4.1 The NRC database

As part of Congress' reauthorization of the SBIR program in 2000, it mandated that the National Research Council (NRC) undertake a comprehensive evaluation of the economic benefits associated with the program. As stated in The Small Business Reauthorization Act of 2000, Public Law 106-554, Congress shall:

> Cooperatively enter into an agreement with the National Academy of Sciences for the National Research Council to:
>
> (1) conduct a comprehensive study of how the SBIR program has stimulated technological innovation and used small businesses to meet Federal research and development needs, including–
>
> > (A) a review of the value to the Federal research agencies of the research projects being conducted under the SBIR program, and of the quality of research being conducted by small businesses participating under the program.

As part of its evaluation, the NRC developed and administered a comprehensive survey of completed Phase II projects in 2005 (Phase I projects were defined in Section 3 above). The Phase II projects that were funded between 1992 and 2001 (inclusive) related to the largest five agencies participating in the SBIR program: 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). A total of 11,214 Phase II projects were funded over this time period.[1] These five agencies accounted for nearly 98 percent of the Phase II SBIR awards over that time period.

Of these 11,214 funded projects, the NRC created a 57 percent sampling population of 6,408. Table 4.1 shows, by agency, the population of funded Phase II projects (11,214 total), the sampling population (6,408 total), the number of survey responses (1,916 total), and the number of projects in the final random sample (1,878 total).[2] The final random sample is 29.3 percent of the sampling population.

To elaborate on the reduction from the 1,916 survey responses to the final random sample of 1,878 projects, it is important to note that not all of the projects surveyed were randomly selected by the NRC Steering Committee. An additional criterion was added by the Committee for selection from the population to the sampling population of projects (i.e., from 11,214 to 6,408 projects). That criterion was that the project had to have had by 2005 commercialization revenues in such an amount that it could be characterized in the NRC's final report to Congress as an extremely successful project.

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[1] Phase II projects generally last two years. Projects funded in 2001 were implicitly given four years to complete the Phase II research and enter into or even complete Phase III. Thus, projects funded in 2001 were the last considered for the 2005 survey.
[2] A more detailed discussion of the data reduction process is in Link and Scott [2012].

Table 4.1. Sampling information from the population of funded Phase II projects, 1992–2001, by Agency.

Agency	Population of projects	Sampling population	Survey responses	Random sample of responses
DoD	5,650	3,055	920	891
NIH	2,497	1,678	496	495
NASA	1,488	779	181	177
DOE	808	439	157	154
NSF	771	457	162	161
All Agencies	11,214	6,408	1,916	1,878

Source: Compiled by the author and based on Link and Scott [2012].

The non-randomly selected projects are clearly an important part of the NRC's final report and should not be dismissed, but I deleted them from the analyses that follow in this section and in Section 5 in an effort to be able to make generalizations about the SBIR program as a whole.

Table 4.2 shows the survey responses for the random sample of 1,878 projects, by year of funding. The sampling population was evenly distributed across the funding years, but, not unexpectedly, the random sample of respondents was not. Clearly, there is firm attrition over time especially among small firms, technology-based or otherwise. See Table 4.3 as support of this statement. For example, in Table 4.3 only 24.6 percent of small firms (establishments) that were started in 1994 survived through 2010. Thus, a portion of those firms that were funded in the earlier years were likely not in business in 2005 when the NRC undertook its survey, and thus there was no contact individual to whom the survey could be addressed or directed.

Table 4.2. Random sample of Phase II project, by year of funding.

Year of funding	Random sample of responses
1992	93
1993	124
1994	121
1995	149
1996	153
1997	164
1998	215
1999	256
2000	260
2001	343
All Years	1,878

Source: Compiled by the author.

Table 4.3 available at the end of section 4.

4.2 Universities as research partners

The relevant survey questions (labeled here for reference purposes as Q1 and Q2) on the NRC project survey related to a firm's perspective about university involvement in its funded project are as follows:

Q1. In executing this award, was there any involvement by university faculty, graduate students, and/or university developed technologies? Yes or No

Q2. If Yes to the preceding question, select all relationships between your firm's efforts on this Phase II project and any university(ies) or college(s) that apply.

a. The Principal Investigator (PI) for this Phase II project was at the time of the project a faculty member.
b. The Principal Investigator (PI) for this Phase II project was at the time of the project an adjunct faculty member.
c. Faculty member(s) or adjunct faculty member(s) work on this Phase II project in a role other than PI (e.g., consultant).
d. Graduate students worked on this Phase II project.
e. University/college facilities and/or equipment were used on this Phase II project.
f. The technology for this project was licensed from a university or college.
g. The technology for this project was originally developed at a university or college by one of the participants in this Phase II project.
h. A university or college was a subcontractor on this Phase II project.

Of the 1,878 random Phase II projects described in the NRC database, 626 had a university involvement (based on Q1 above).[3] Stated differently for the purposes of this monograph, of the firms that were involved with the 1,878 Phase II projects between 1992 through 2001 (inclusive), 626 or 33.3 percent of those projects included a university as a research partner.[4]

Table 4.4 shows the percentage of the 626 Phase II projects that partnered with a university, by year. It is clear from the data in this table that the number of projects as well as the percentage of those projects involving a university in one role or another has increased over time. This increase is not due to the increase in the attrition rates of small firms over time (see Table 4.3) because that phenomenon has already been captured by the decrease in the number of responding firms to the project survey over time.[5]

There are a number of ways to categorize the form of university involvement in a Phase II research project. I have reduced the eight categories in Q2 above to six: PI was a faculty or adjunct faculty member (category a or b), faculty member but not as PI (category c), graduate

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[3] The NRC database is arguably the most complete database related to university-with-firm partnerships in the U.S. That said, and as an aside, there are data on the extent of university research partnerships with firms, or more accurately university-with-firm collaborative research relationships, for a number of European countries. Surprisingly, with the exception of Cunningham and Link [2014], these European Commission data have not been systematically analyzed much less compared, where possible, to the U.S. university-with-firm experience.
[4] The 1,878 projects are not in 1,878 different firms. A few firms received more than one Phase II award over the 1992 to 2001 time period, but multiple firm projects are deleted in the analyses in Section 5 once the dataset is conditioned on the project not having been discontinued at the time of the survey.
[5] I hypothesize that this increase in the percentage of projects involving a university as a research partner over time is related to an ever growing realization among small firms that their likelihood of technical success increases when a university is involved in the research project. The evidence from the SBIR data to support this hypothesis is weak, as I discuss in Section 5. But, this is a topic that should be on the research agenda of scholars in future years.

student researcher (category d), university equipment (category e), university-based technology (category f or g), and university was a contractor (category h).

Table 4.4. University involvement in a Phase II project (from Q1), by Year.

Year of funding	Number of projects involving a university	Percent of the sample involving a university (*n* = 626)
1992	23	3.6
1993	47	7.5
1994	40	6.4
1995	38	6.1
1996	49	7.8
1997	52	8.3
1998	74	11.8
1999	91	14.5
2000	91	14.5
2001	121	19.3
All Years	626	

Source: Compiled by the author.
Note: The sum of the percentages is less than 100% due to rounding.

Table 4.5 shows the percentage of the 626 projects with university involvement, by type of involvement (based on Q2 above). Forty-five percent of the reported involvement is through a contractual agreement; 21.2 percent appears to clearly be through a private consulting agreement with a faculty member whose role is other than PI.

Table 4.5. University involvement in a Phase II project, by category of university involvement.

Category of university involvement	Number of projects	Percent of projects involving a university (*n* = 626)
PI was a faculty or adjunct faculty member	19	3.0
Faculty member but not as PI	133	21.2
Graduate student researcher	71	11.3
University equipment	61	9.7
University-based technology	60	9.6
University was a contractor	282	45.0
Total	626	

Source: Compiled by the author.

These six categories, developed by the NRC Steering Committee for the NRC survey, might not be as defining as they could be. For example, a faculty member could be involved in an SBIR Phase II project as an independent consultant, or he/she could be involved through a university contractual consulting agreement. In either case, the faculty member has the same role and so the firm completing the survey could respond correctly in one of two ways. This duality might also apply to graduate students and university equipment. Thus, an understanding of the role of university involvement among the 282 projects shown in Table 4.5 as being involved in a contractual relationship with a university might actually represent a role described by one of the other five categories.[6]

[6] I thus question the probative value of this NRC survey question except possibly a second-best way to understand the frequency with which firms drew upon university-based technology to pursue their Phase II SBIR project.

In an effort to make a general observation about the probability of a university being involved in a SBIR Phase II project by technology area, I first calculated the percentage of projects with a university by funding agency. See Table 4.6. My initial thought was that the technologies being funded are similar within a funding agency but possibly different across funding agencies. A noticeably larger percent of projects involving a university are DoD and NIH funded.[7]

Table 4.6. University involvement in a Phase II project, by agency.

Agency	Number of projects involving a university	Percent of a projects involving a university (*n* = 626)
DoD	209	33.4
NIH	238	38.0
NASA	47	7.5
DOE	55	8.8
NSF	77	12.3
All Agencies	626	

Source: Compiled by the author.

The NRC survey also asked, for each project, the following question (labeled here for reference as Q3):

Q3. How did you (or do you expect to) commercialize your SBIR award?

a. No commercial product, process, or service was/is planned.
b. As software
c. As hardware (final product, component, or intermediate hardware product)
d. As process technology
e. As new or improved service capability
f. As a drug
g. As a biologic
h. As a research tool
i. As educational materials
j. Other

Table 4.7 shows the number of Phase II projects with a university as a research partner by technology area as defined in Q3. For these calculations some deletions to the NRC database were needed. First, not all firms responded to this question. But also, other deletions were made because of how the survey instrument directions are phrased. For those projects that were discontinued because of, for example, the market demand for their being-researched technology being too low, respondents were not directed to answer Q3.[8] Note that the number of project responses to Q3 was 416 out of a possible 626.

[7] The fact that DoD and NIH had more projects involving a university reflects in part that those agencies funded more projects per se; their budgets were larger.
[8] These deletions were not made for the calculations in any of the previous tables. Respondents to discontinued projects were still asked if a university was involved.

From Table 4.7, it appears that most SBIR Phase II projects resulted in or are expected to result in a technology that takes the form of hardware or a research tool.

Table 4.7. University involvement in a Phase II project, by commercialized technology (n = 416).

Technology area	Number of projects
Software	46
Hardware	115
Process Technology	41
Service Capability	33
Drug	3
Biologic	5
Research Tool	83
Educational Material	36
Other	42
	416

Source: Compiled by the author.
Note: Not all projects had a response to the relevant survey question.

4.3 The probability of having a university research partner

In this section, I explore more systematically covariates with the probability that a firm that received a Phase II SBIR award will have a university research partner. The relevant regression model is simply:

$$\text{Probability}(univ) = \text{f}(\mathbf{X}) \tag{4.1}$$

The variable *univ* equals 1 if there was a university involved with the Phase II project in any role (see Table 4.5), and 0 otherwise. **X** is a vector of project characteristics and firm characteristics. The extant firm-perspective literature that was summarized in Section 2 and represented by equation (2.2) suggests that the lesser the extent to which intellectual property issues are relevant to the project the greater the likelihood that a university will be involved in the project, other factors held constant. And, the closer the research being conducted is toward the basic or exploratory end of the R&D spectrum of investments, the greater the likelihood that a university will be involved, other factors held constant.

There is perhaps a tradeoff at play. On the one hand, a firm — be it small and technology-based or not — will seek to appropriate the knowledge gained from its research. On the other hand, including a university as a research partner in a project, especially if the involvement of the university includes faculty or graduate students, might suggest that the university member of the research team would have a tendency to publish some of the cooperatively determined research results.[9] If so, this tendency would decrease any one firm's ability to appropriate fully the

[9] Audretsch and Link [2015] are investigating covariates with the probability that a technology-based entrepreneur will publish about his/her research.

knowledge gained.[10] Unfortunately, there are no variables in the NRC database that approximates the basic or exploratory nature of the Phase II research activity.

Toward an approximation of equation (4.1), I estimated the probability that a Phase II project will include a university as a research partner as a function of two independent variables. The dependent variable *univ* = 1 if a university is involved in the Phase II research project in any of the roles in Table 4.5, and 0 otherwise. The first independent variable measures the general background of at least one of the firm's founders. The variable *acad* = 1 if at least one of the firm's founders has an academic background, and 0 otherwise. My argument is that a founder with an academic background will understand better the nature of the public good characteristics of the knowledge generated from the research project and will thus seek university involvement if and only if his/her firm is able to still appropriate a sufficient amount of the knowledge gained. Thus, the estimated coefficient on *acad* in an estimable version of equation (4.1) is hypothesized to be positive. As a control for economies of scale and scope, I included as the second independent variable the number of employees in the firm at the time the Phase II proposal was submitted as a measure of firm size, *size*.[11] I hypothesize that the larger the firm the less likely it will need to expand its research boundaries by including a university as a research partner.

Descriptive statistics on these variables are in Table 4.8, a correlation matrix of the variables is in Table 4.9, and the probit results from the estimation of an equation (4.1) are in Table 4.10.[12] All relevant data are available for 1,614 projects of the 1,878 random projects.

Table 4.8. Descriptive statistics on the variables used to estimate the likelihood that a Phase II project will have a university as a research partner (*n* = 1, 614).

Variable	Mean	Standard deviation	Range
univ	0.369	0.483	0/1
acad	0.634	0.482	0/1
size	31.08	59.88	1–460

Source: Compiled by the author.

Table 4.9. Correlation matrix for the variables used to estimate the likelihood that a Phase II project will have a university as a research partner (*n* = 1,614).

	univ	***acad***	***size***
univ	1		
acad	0.088*	1	
size	–0.068*	0.050*	1

Source: Compiled by the author.
*significant at the 0.01-level or higher

Note in Table 4.8 that over 60 percent of the 1,614 Phase II projects were conducted in a firm where at least one of the founders had an academic background. Also note that the mean size of firms in the sample was about 31 employees at the time that the Phase II proposal was submitted,

[10] Leyden and Link [2015] have shown that firms have a greater incentive to enter into a cooperative research relationship the closer the research is to the basic end of the R&D spectrum of investments.
[11] I emphasize "at the time the Phase II proposal was submitted" to justify that *size* is an exogenous variable.
[12] The number of projects for which data were available on all three of the relevant variables is 1,614 as noted in the title of Tables 4.8–4.10.

although the range went up to a firm with 460 employees. The size of the standard deviation and range on the variable *size* suggests the merit of testing whether that variable enters equation (4.1) in a non-linear manner. To anticipate the probit regression results in Table 4.10, there was no statistical evidence of a non-linear size effect and thus a specification that included $size^2$ is not reported.

Table 4.10. Probit regression results for the likelihood that a Phase II project will have a university as a research partner (n = 1,614).

Variable	Estimate	Standard error	*t*-Value
acad	0.244*	0.067	3.64
size	–0.0016*	0.00055	–2.87
Intercept	–0.445*	0.056	–7.97
Log Likelihood	–1052		

Source: Compiled by the author.
*significant at 0.01-level or higher

Note in Table 4.9 that the Pearson correlation coefficient between *univ* and *acad* is positive and significant at the 0.01-level or higher. This finding anticipates a positive and possibly significant probit coefficient. The estimated probit results in Table 4.10 confirm my hypothesis regarding the academic background of the founder. The estimated coefficient on *acad* is positive and significant at the 0.01-level or higher. Also, the larger the firm, as measured in terms of number of employees when the Phase II proposal was submitted, the less likely that the project will involve a university in its Phase II SBIR project as hypothesized.[13] The estimated probit coefficient on *size* is negative and significant at the 0.01-level or higher.

4.4 Summary

The pattern of behavior revealed from the NRC database suggests that university involvement in Phase II SBIR projects has been increasing over time (see Table 4.4). These relationships take on a number of different forms ranging from the direct involvement of a university faculty member as PIs in a firm's Phase II project to the use of university equipment to facilitate the funded research project (see Table 4.5). And, a variety of technology areas, measured in terms of the characteristics of the being-researched technologies, are represented by the Phase II research (see Table 4.7). Finally, the likelihood of university involvement as a research partner in a Phase II project is not independent of the academic background of the recipient firm's founder(s) or on the size of the firm as measured in terms of the number of employees at the time the Phase II proposal was submitted (see Table 4.10).

In the following section, I investigate whether or not university involvement is correlated with any of several performance variables that characterize the outputs and outcomes of SBIR projects, and I attempt to draw implications from my findings about the extent that universities as research partners are associated with private gains as well as public gains.

[13] Care should be taken in generalizing from this finding because it is opposite from what Link and Zmud [1987] and Fontana et al. [2006] found; but, they were analyzing non-comparable data.

Table 4.3. Survival Rates of establishments, by number of years since starting, 1994–2010 (in percent).

	Year																
Years Since Starting	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2	79.8	79.2	79.0	78.8	80.6	79.6	78.9	75.5	78.4	79.2	79.1	80.0	78.3	77.2	74.4	76.3	—
3	68.5	68.5	67.6	68.7	69.1	67.6	66.3	64.5	67.5	68.4	69.1	68.7	66.2	63.4	62.4	—	—
4	61.2	60.5	60.4	60.6	60.2	59.0	58.5	57.5	60.2	61.4	61.3	60.1	56.1	54.9	—	—	—
5	54.9	54.7	54.1	53.5	53.6	53.2	53.1	52.4	55.0	55.3	54.7	52.2	49.3	—	—	—	—
6	50.2	49.5	48.8	48.1	48.7	48.7	48.6	48.2	50.4	50.1	48.2	46.5	—	—	—	—	—
7	45.8	45.0	44.5	44.2	45.0	45.0	45.1	44.5	46.3	44.7	43.7	—	—	—	—	—	—
8	42.1	41.4	41.2	41.0	41.9	42.1	42.1	41.2	42.0	40.9	—	—	—	—	—	—	—
9	38.9	38.6	38.5	38.2	39.4	39.3	39.1	37.6	38.7	—	—	—	—	—	—	—	—
10	36.4	36.3	36.0	36.2	37.0	36.8	36.0	34.7	—	—	—	—	—	—	—	—	—
11	34.2	34.1	34.0	34.0	34.8	33.9	33.4	—	—	—	—	—	—	—	—	—	—
12	32.4	32.2	32.1	32.1	32.2	31.7	—	—	—	—	—	—	—	—	—	—	—
13	31.0	30.5	30.4	29.8	30.3	—	—	—	—	—	—	—	—	—	—	—	—
14	29.3	29.0	28.6	28.1	—	—	—	—	—	—	—	—	—	—	—	—	—
15	27.8	27.1	26.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	26.0	25.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17	24.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Source: Bureau of Labor Statistics, <http://www.bls.gov/bdm/entrepreneurship/bdm_chart3.htm>

5 Universities and SBIR Project Performance

I discuss a number of performance variables that characterize Phase II SBIR projects in this section, and I examine each of them independently in terms of whether the funded project involved a university or not. These analyses are conditioned on the Phase II project not being discontinued; that is, these analyses are conditioned on the funded research project being completed. My examination is statistical, but much like the analysis in Section 4 it is, as previously explained, parsimonious in nature.

The first set of performance variables that I consider are related to private gains. See Table 5.1.

- *Discontinue:* If a project was discontinued prior to completion, *discontinue*.
- If a project resulted in a patent or a patent application, *patents received* or *patents applied for*
- If employees were hired as a result of the technology developed, *emphired*
- If additional developmental funding was received, *addlfund*
- If the additional development funding came from a U.S. venture capitalist, *vcfund*
- If a project that was not discontinued resulted in the sale of a product, process, service, or some other sale (e.g., licensing of the resulting technology), *commerc*

Table 5.1. Private and public gains performance variables.

Variable	Survey question	Definition
discontinue	What is the current status of the project funded by the SBIR award?	= 1 if the following survey response was selected: Efforts at this firm have been discontinued and no sales or additional funding resulted from this project; 0 otherwise
patents received/ applied for	Please give the number of patents that were developed as a result of this project.	= 1 if the firm received and/or applied for at least one patent; 0 otherwise.
emphired	Please give the number of current employees who were hired as a result of the technology developed during this Phase II project. Please include both part time and full time employees and consultants in this calculation.	= number of employees hired
addlfund	Have you received or invested in any additional developmental funding for this project?	= 1 if YES; = 0 if NO
vcfund	Have you received any additional developmental funding from U.S. venture capitalists for this project?	= 1 if YES; = 0 if NO
commerc	If your firm has not discontinued the project, did it or a licensee have any actual sales of products, processes, services, or other sales incorporating the technology developed during this project?	= 1 if YES; = 0 if NO
saletech	A finalized sale of technology rights to a U.S. firm or investor.	= 1 if the firm sold the technology rights to the technology developed during the Phase II SBIR project to a U.S. firm or investor; 0 otherwise
rdagg	A finalized R&D agreement with a U.S. firm or investor.	= 1 if the firm engaged in a R&D agreement with a U.S. firm or investor that was based on the Phase II SBIR project; 0 otherwise

Source: Compiles by the author.

One might be inclined to think about these seven performance variables in terms of an underlying linear or even branching model of events. That is, given that a project was not discontinued, did the firm patent? Did it hire additional employees? Was it able to acquire additional developmental funding? And finally, did it commercialize the technology developed through the Phase II SBIR award (keeping in mind that the goal of the SBIR project is to increase private sector commercialization as discussed in Section 3 in terms of the enabling legislation)? However, the SBIR database is not sufficiently rich to definitely sketch such a model of related events. The information needed to do so is missing because the dates of these activities is not known: when did the firm patent or publish, when additional employees were hired, when additional developmental funds were obtained, and when a firm first commercialized. As a result, in the descriptive statistical analysis that follows, I treat each performance variable as a discrete event conditional only on the project not being discontinued.

The second set of performance variables that I consider are dichotomous and are related to public gains. They come from the NRC survey question: As a result of the technology developed during this project, which of the following describe your firm's activities with other firms or investors? See also Table 5.1.

- If a project that was not discontinued resulted in the sale of a product, process, service, or some other sale (e.g., licensing of the resulting technology), *commerc*
- A finalized sale of technology rights to a U.S. firm or investor, *saletech*
- A finalized research and development (R&D) agreement with a U.S. firm or investor, *rdagg*

Note that commercialization, *commerc*, is also included here as a variable related to public gains. Each of these three variables are associated with private gains to the extent that the Phase II firms receive some financial benefit from engaging in such activity. In the case of commercialization, the firm will benefit in terms of an increase in producer surplus since the firm will have, at least temporarily, some degree of monopoly power when its new technology enters the market as an innovation. However, each of these three variables is also associated with public gains to the extent that the knowledge generated through public support of Phase II projects spills over to other firms who adopt the technology and thus gain in producer surplus and to customers in the form of consumer surplus as the new technology engenders other firms to innovation and competition ensues. Thus, a question of interest is if these spillovers or public gains are correlated with a university having been a research partner in the Phase II project.

5.1 Phase II projects that were discontinued

Of the 1,878 random projects in the SBIR database, 427 projects or 22.7 percent were discontinued before their Phase II projects were completed. The NRC 2005 survey asked: "What is the current status of the project funded by the SBIR award?" One possible response was: "Efforts at this firm have been discontinued. No sales or additional funding resulted from this project."

The NRC survey also asked for information about why a project was discontinued. Survey explanations — and more than one explanation could be selected by the survey respondent — included dimensions of technical failure and market failure. As shown in Table 5.2, the mean response for the survey explanations suggests that insufficient market demand and insufficient funding were the main reasons for discontinuing a project — 77.8 percent of the discontinued projects were done so because of insufficient market demand and 66.8 percent because of insufficient funding. Only 43.1 percent of the projects that were discontinued reported technical failure as a reason.

Table 5.2. Explanations for why a Phase II project was discontinued.

Explanation	Mean	Standard deviation
Technical failure or difficulties	0.431	0.726
Market demand too small	0.778	0.811
Level of technical risk too high	0.222	0.468
Not enough funding	0.668	0.725
Firm shifted priorities	0.458	0.660
Principle investigator left	0.168	0.454
Licensed to another firm	0.127	0.447
Product, process, or service not competitive	0.288	0.530
Inadequate sales capability	0.227	0.478

Source: Compiled by the author.

There is at best suggestive evidence of a relationship between the likelihood of a project being discontinued and the involvement of a university in the project. Separately, I calculated the Pearson correlation coefficient between projects being discontinued, *discontinue*, and the presence of a university as a research partner, *univ*; the coefficient is −0.037 and it is significant at only the 0.15-level. Link and Wright (forthcoming) reached a similar conclusion using a more complete model of the probability of failure.[1] Link and Wright's explanation, keeping in mind that commercialization is a stated goal of the SBIR program, was:

> Universities may be less likely to possess the commercial expertize to develop R&D projects, and projects in universities may be more likely to be generic and distant from markets.

However, given the responses summarized in Table 5.2, their explanation is intuitive because university involvement could not have overcome insufficient market demand or, in general, insufficient funding issues.

5.2 Private gains performance variables and university involvement

[1] The findings reported by Link and Wright [forthcoming] should perhaps be placed in the context of a current National Research Council report on team science (NRC, 2015, p. Sum-1): "Conducting research collaboratively can introduce challenges; for example, while the increasing size of team-based research projects brings greater scientific expertise and more advanced instrumentation to a research question, it also increases the time required for communication and coordination of work. If these challenges are not recognized and addressed, projects may fail to achieve their scientific goals."

Conditional on a project not being discontinued, I analyze below the partial correlations between university involvement, *univ*, and the first six of the performance variables in Table 5.1. Held constant in these analyses are selected other variables, one of which is firm size, *size*, as previously discussed. For each performance variable similar analyses are conducted. For each performance variable descriptive statistics on the variable relevant to the analysis are presented, a correlation matrix of the variables is presented, and a regression model is estimated of the general form:

$$\text{Performance} = f(\mathbf{X}) \tag{5.1}$$

where **X** is a vector of the project and firm characteristics being considered. In my discussion about the regression results I emphasize the direction of estimated influence of *univ* and its statistical significance.

Again, emphasizing the descriptive nature of the regression models similar to equation (5.1) that frame this monograph, there is another econometric issue to address, namely selection bias. The sample size for most of the analyses in this section differs slightly depending on the dependent and independent variables under study. The one variable that is constant throughout is a binary variable indicating if the SBIR-funded project involved a university or not; *univ*. Regardless of the size of the sample, the mean values of the binary measure of university involvement are not statistically different from each other (assuming unequal variance), thus suggesting that each regression model can be interpreted as representative of SBIR project performance in general.

5.2.1 Patenting

The likelihood of university involvement in the Phase II project influencing the two dimensions of patenting defined in Table 5.1 was investigated. Along with *univ*, the business background of at least one of the founders of the firm was held constant. The variable *buss*; *buss* = 1 if at least one of the firm's founders has a general business background, and 0 otherwise. As an alternative to the variable *buss, bussemp* = 1 if the most recent employment of a founder of the firm was in another private firm, and 0 otherwise. My argument to explain the probability of patenting regarding either of these two control variables is that a founder with either a general business background or recent business experience will understand the nature of as well as the importance of protecting any intellectual property associated with the being-developed technology. Thus, the firm is more likely to receive a patent or to file for a patent for the being-developed technology when at least one of the firm's founders has such business acumen.

Descriptive statistics on these variables are in Table 5.3, the correlation matrix for the variables is in Table 5.4, and the probit results from the estimation of the probability of patenting are in Table 5.5.

The first thing to notice in Table 5.3 is that there are 1,256 projects that have not been discontinued and for which data are available for all of the relevant variables. Among the non-discontinued projects, 30.7 or 39.6 percent have received or applied for a patent. Also, founders of the firm that received Phase II awards tend to have had recent business experience in other firms more often than a general business background; 70.2 percent compared to 45.0 percent.

Table 5.3. Descriptive statistics on the variables used to estimate the likelihood of patenting from a Phase II project (n = 1,256).

Variable	Mean	Standard deviation	Range
patents received	0.307	0.385	0/1
patents applied for	0.396	0.497	0/1
univ	0.376	0.485	0/1
buss	0.450	0.498	0/1
bussemp	0.702	0.457	0/1

Source: Compiled by the author.
Note: The variables are conditional on the Phase II project not having been discontinued.

Table 5.4. Correlations matrix for the variables used to estimate the likelihood of patenting from a Phase II project (n = 1,256).

	patents received	***patents applied for***	***univ***	***buss***	***bussemp***
patents received	1				
patents applied for	0.818*	1			
univ	0.058**	0.055**	1		
buss	0.020	0.018	0.009	1	
bussemp	0.063**	0.046**	0.127*	0.288/	1

Source: Compiled by the author.
* significant at the 0.01-level or higher.
** significant at the 0.05-level.
*** significant at the 0.10-level.

Table 5.5. Probit Regression results for the likelihood of patenting from a Phase II project (n = 1,256) (standard error) [t-value].

Variable	***patents received***	***patents received***	***patents applied for***	***patents applied for***
univ	0.170* (0.077) [2.34]	0.156** (0.076) [2.04]	0.160** (0.074) [2.15	0.142** (0.074) [1.94]
buss	—	0.051 (0.074) [0.68]	—	0.044 (0.072) [0.61]
bussemp	0.207** (0.083) [2.50]	—	0.155*** (0.079) [1.89]	—
Intercept	–0.722* (0.079) [–9.14]	–0.589* (0.058) [–10.14]	–0.431* (0.075) [–5.74]	–0.338* (0.056) [–6.06]
Log Likelihood	–768.8	–771.7	–839.4	–841.0

Source: Compiled by the author.
* significant at 0.01-level or higher.
** significant at 0.05 level.
*** significant at 0.10-level.

The correlations matrix in Table 5.4 suggests that Phase II projects in which a university is a research partner are more involved in the process of patenting compared to projects that do not involve a university partner. The correlation coefficients among these variables are significant at the 0.05-level. Also, prior business experience is statistically more important than general business background.

The estimated probit regression results are in Table 5.5. They also show that university involvement in a Phase II project is positively and significantly related to the probability of patenting. The estimate probit coefficients on *univ* are always significant at least at the 0.05-level.

5.2.2 Employment

The likelihood of university involvement in a Phase II project influencing the number of new employees hired as a result of the technology developed during the Phase II project, *emphired*, is assumed to be related to *univ* and firm size, *size*.

Descriptive statistics on the relevant variables are in Table 5.6, the correlation matrix for the variables is in Table 5.7, and the negative binomial results from the estimation of an equation related to the number of employees hired are in Table 5.8.

Table 5.6. Descriptive statistics on the variables used to estimate the number of new employees hired as a result of the technology developed from a Phase II project (n = 1,219).

Variable	Mean	Standard Deviation	Range
emphired	2.69	8.85	1 – 150
univ	0.379	0.485	0/1
size	28.33	54.06	1 – 423

Source: Compiled by the author.
Note: The variables are conditioned on the Phase II project not having been discontinued.

Table 5.7. Correlations matrix for the variables used to estimate the number of new employees hired as a result of the technology developed from a Phase II project (n = 1,219).

	emphired	***univ***	***size***
emphired	1		
univ	0.057**	1	
size	–0.041	–0.069**	1

Source: Compiled by the author.
** significant at the 0.05-level.

Table 5.8. Negative binomial regression results for the number of new employees hired as a result of the technology developed from a Phase II project (n = 1,219).

Variable	Estimate	Standard error	Wald χ^2
univ	0.350*	0.094	13.08
size	–0.003*	0.0009	8.93
Intercept	0.907	0.065	194.22
Pearson χ^2	4801.8		
Log Likelihood	2901.8		

Source: Compiled by the author.
* significant at the 0.01-level or higher.

From Table 5.6, note that there are 1,219 non-discontinued projects for which project data are available for all of these three variables. The mean number of employees hired as a result of the technology developed during a Phase II project is almost 3, and the range is 1 to 150. As a reminder, employment growth is not an explicit criterion for a SBIR Phase II award; commercialization is.

Firms that received a Phase II award and that partnered with a university to develop a new technology are more likely to hire more new employees than firms that did not partner with a university. The Pearson correlation coefficient between *emphired* and *univ* is positive and significant at the 0.05-level. The negative binomial results in Table 5.6 confirm this relationship, holding constant the size of the firm, *size*. And, larger firms tend to hire fewer new employees. The estimated negative binomial coefficient on *size* is negative and significant at the 0.01-level or higher. Perhaps larger firms enjoy sufficient economies of scale and scope so that employees can move internally between research projects more easily than in smaller firms with fewer economies of scope.

5.2.3 Additional developmental investments

As shown in Table 5.9, data are available for both of the additional funding variables for 1,218 projects. Of those projects that were not discontinued, 68.1 percent received some form of additional developmental funding for their Phase II project, *addlfund*. Only 3.6 percent of the projects received additional development funding from U.S. venture capitalists, *vcfund*. The correlation matrix in Table 5.10 suggests, although weakly, that Phase II projects that involved a university as a research partner are more likely to receive U.S. venture capital support.

Table 5.9. Descriptive statistics on the variables used to estimate the likelihood that a Phase II project will receive additional developmental funding (n = 1,218).

Variable	Mean	Standard deviation	Range
addlfund	0.681	0.466	0/1
vcfund	0.036	0.187	0/1
univ	0.379	0.485	0/1
size	28.35	54.07	1 – 423

Source: Compiled by the author.
Note: The variables are conditioned on the Phase II project not having been discontinued.

Table 5.10. Correlations matrix for the variables used to estimate the likelihood that a Phase II project will receive additional developmental funding (n = 1,218)

	addlfund	*vcfund*	*univ*	*size*
addlfund	1			
vcfund	0.132*	1		
univ	0.044	0.048***	1	
size	–0.038	–0.044	–0.069**	1

Source: Compiled by the author.
* significant at the 0.01-level or higher.
** significant at the 0.05-level.
*** significant at the 0.10-level.

The likelihood of a firm receiving additional developmental funding for its Phase II project is assumed to be a function of *univ* and *size*. Holding constant the size of the firm, the probit results in Table 5.11 suggest that if university involvement increases the likelihood of receiving additional developmental funding from any source, or additional development funding from U.S. venture capitalists, that influence is minimal. The estimated probit coefficients on *univ* in both specifications are positive but only marginally significant (at the 0.15-level).

Table 5.11. Probit regression results for the likelihood that a Phase II project will receive additional developmental funding (n = 1,218) (standard error) [t-value].

Variable	***addlfund***	***vcfund***
univ	0.113	0.212
	(0.078)	(0.137)
	[1.45]	[1.55]
size	–0.0008	–0.003
	(0.0007)	(0.002)
	[–1.21]	[–1.48]
Intercept	0.453*	–1.826*
	(0.052)	(0.102)
	[8.73]	[–17.75]
Log likelihood	–760.3	–186.3

Source: Compiled by the author.
* significant at the 0.01-level or higher.

Table 5.12. Descriptive statistics on the variables used to estimate the likelihood that the technology from a Phase II project will be commercialized. (n = 1,218).

Variable	Mean	Standard deviation	Range
commerc	0.643	0.479	0/1
addlfund	0.681	0.466	0/1
vcfund	0.036	0.187	0/1
univ	0.379	0.485	0/1
size	28.35	54.07	1 – 423

Source: Compiled by the author.
Note: The variables are conditioned on the Phase II project not having been discontinued.

Table 5.13. Correlations matrix for the variables used to estimate the likelihood that the technology from a Phase II project will be commercialized (n = 1,218).

	commerc	***addlfund***	***vcfund***	***univ***	***size***
commerc	1				
addlfund	0.174*	1			
vcfund	0.043	0.132*	1		
univ	–0.004	0.044	0.048***	1	
size	0.027	–0.038	–0.044	–0.069**	1

Source: Compiled by the author.
* significant at the 0.01-level or higher.
** significant at the 0.05-level.
** significant at the 0.10-level.

5.2.4 Commercialization

The likelihood that a Phase II project will be commercialized, *commerc*, is estimated to be dependent on *univ* and separately on *addlfund* and by *vcfund*.

Descriptive statistics for the variables used to estimate equation (8) are in Table 5.12, the relevant correlation matrix is in Table 5.13. And the probit regression results are in Table 5.14.

Table 5.14. Probit regression results for the likelihood that the technology from a Phase II project will be commercialized (n = 1,218) (standard error) [t-value].

Variable		
addlfund	0.181*	—
	(0.029)	
	[6.23]	
vcfund	—	0.115***
		(0.064)
		[1.80]
univ	–0.009	–0.004
	(0.028)	(0.028)
	[0.32]	[–0.13]
size	0.0003	0.0003
	(0.0003)	(0.0003)
	[1.16]	[0.99]
Intercept	0.515*	0.633*
	(0.0270)	(0.019)
	[18.92]	[32.81]
Log likelihood	–812.6	–830.5

Source: Compiled by the author.
* significant at the 0.01-level or higher.
*** significant at the 0.10-level.

The NRC database reports data for all of these variables for 1,218 projects. From both the correlation matrix and the estimated probit coefficients, having a university as a research partner is not statistically related to the probability that the firm will commercialize a technology from its Phase II research.[2] What is statistically significant in the probit regression equations is the presence of developmental funding from any source, *addlfund*, and specifically from U.S. venture capitalists, *vcfund*. The estimated probit coefficient on both of these variables is statistically significant, the former at the 0.01-level or higher and the latter at the 0.10-level. Holding constant the presence of additional funding, projects involving a university as a research partner, *univ*, are not more likely to commercialize compared to those that do not partner with a university.

5.3 Public gains performance variables and university involvement

One public gains variable is *commerc*, as analyzed above. The other two public gains variables are *saletech* and *rdagg*. Each is examined as a function of university involvement, *univ*, holding firm size, *size*, constant.

[2] The parsimonious nature of the analysis may be problematic in this case. Link and Ruhm [2009] showed that the probability of a SBIR project reaching the commercialization stage is greater if a university is involved in the funded project. Their analysis was specific to NIH Phase II SBIR awards and it controlled for institute effects.

Descriptive statistics on all of these variables are in Table 5.15. These data suggest that there are indeed public gains associated with SBIR projects. Firms sell their technology rights 4.7 percent of the time, and they enter into R&D agreements 14.0 percent of the time. Thus, other firms and consumers are benefitting from spillovers associated with SBIR projects; firms are increasing their producer surplus and consumers are realizing an increase in their consumer surplus through the sale of the new technology. But, as the associated correlation matrix in Table 5.16 shows and as the probit regression results in Table 5.17 show for the 1,218 projects for which data are available, these public gains are unexpectedly the same whether a university is involved as a research partner or not.

Table 5.15. Descriptive statistics on the variables used to estimate the likelihood of public gains from a Phase II project (n = 1,218).

Variable	**Mean**	**Standard deviation**	**Range**
saletech	0.047	0.211	0/1
rdagg	0.140	0.348	0/1
univ	0.379	0.485	0/1
size	28.31	54.07	1 – 423

Source: Compiled by the author.
Note: The variables are conditional on the Phase II project not having been discontinued.

Table 5.16. Correlation matrix for the variables used to estimate the likelihood of public gains from a Phase II project (n = 1,218).

	saletech	***rdagg***	***univ***	***size***
saletech	1			
rdagg	0.213*	1		
univ	0.011	0.025	1	
size	–0.057**	0.019	–0.069**	1

Source: Compiled by the author.
* significant at the 0.01-level or higher.
** significant at the 0.05-level.
*** significant at the 0.10-level.

Table 5.17. Probit regression results for the likelihood of public gains from a Phase II project (n = 1,218) (standard error) [t-value].

Variable	***saletech***	***rdagg***
univ	0.003	0.019
	(0.012)	(0.021)
	[0.25]	[0.92]
size	–0.0002**	0.000
	(0.0001)	(0.000)
	[–1.98]	[0.69]
Intercept	0.052*	0.130*
	(0.0080)	(0.014)
	[6.16]	[9.34]
Log likelihood	167.65	–439.86

Source: Compiled by the author.
* significant at the 0.01-level or higher.
** significant at the 0.05-level.
*** significant at the 0.10-level.

Important from the correlation matrix in Table 5.16 is that university involvement as a research partner is not correlated in a significant way with any of these two knowledge spillover variables. (I showed in Table 5.14 that university involvement as a research partner was not correlated in a significant way with commercialization). And in the probit regression results in Table 5.17, holding firm size, *size*, constant, confirms this conclusion.

The bottom line is that university involvement as a research partner is not associated with greater knowledge spillovers, including the likelihood of commercialization.

6 Concluding Remarks

Does university involvement in the publicly funded research of private firms enhance the firm's private gains as well as society's public gains? The descriptive evidence that I present in this monograph suggests that the answer to this question is both "yes" and "no." Yes, firms conducting Phase II research projects do appropriate private gains from universities being involved in their SBIR-funded research, but that involvement does not appear to induce any knowledge spillovers (i.e., public gains) to others either through a greater likelihood of commercialization, a greater likelihood of being able to sell their technology rights, or a greater likelihood of bringing about R&D agreements compared to firms with which there is no university involvement.

With the caveat that the analysis herein is exploratory, my findings suggest when a firm engages in a Phase II project along with a university research partner, it is able to appropriate the knowledge flows from university in terms of a greater likelihood of patenting and in terms of greater employee growth. These university-associated advantages for the firm are definitely positive. My findings indicate that firms are purposefully expanding their boundaries to capture the knowledge embodied in university resources.

However, as I have argued throughout this monograph, one might have expected there to be some public gains as well as private gains because of the public good characteristics associated with knowledge *per se*, and with university-based knowledge in particular. Surprisingly, my findings do not show this. In fact, they show uniformly that there are public gains from SBIR projects — measured in terms of the likelihood of commercializing, the likelihood of selling technology rights, or the likelihood of entering into R&D agreements — but those gains are not enhanced through university research involvement.

More research is clearly needed on the economic role of universities as research partners. As I have emphasized throughout, my analysis herein is descriptive. The research role of universities might also be driven by industry, business cycles, organizational structures Dornbusch and Neuhäusler [2015], and the nature of technology itself — disruptive technology in particular.

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