DRAFT – NOT FOR CIRCULATION OR QUOTATION

Bringing Science to Market:

Commercializing from NIH SBIR Awards

Albert N. Link
Department of Economics
University of North Carolina at Greensboro
Greensboro, NC 27402
anlink@uncg.edu

and

Christopher J. Ruhm
Department of Economics
University of North Carolina at Greensboro
Greensboro, NC 27402
chrisruhm@uncg.edu
and
National Bureau of Economic Research

We are pleased to acknowledge the helpful comments and suggestions of David Ribar, and the able research assistance of Rebecca Klimowicz.

Abstract

We offer descriptive information relevant to an assessment of commercialization activity from research projects funded through the U.S. National Institutes of Health's (NIH's) Small Business Innovation Research (SBIR) award program. Specifically, we estimate a model of the probability of commercialization as a function of the project's ability to attract additional developmental funding, along with other control variables. We find that additional developmental funding from non-SBIR federal sources and from own internal sources are important predictors of commercialization success, relatively more so than additional developmental funding from venture capitalists. We also find, among other things, that university involvement in the underlying research increases the probability of commercialization.

Bringing Science to Market:
Commercializing from NIH SBIR Awards

I. Introduction

In light of the productivity slowdown in the United States in the late-1970s and early-1980s, a number of public policy responses were initiated to enhance the rate of U.S. innovation through increases in research and development (R&D) and related activities.[1] The Bayh-Dole Act was passed in 1980, the R&E Tax Credit was enacted in 1981, the Small Business Innovation Research program was created in 1982, and the National Cooperative Research Act was legislated in 1984. The broad purpose of these policy responses was to renew technological growth throughout the nation.[2]

This paper focuses specifically on the Small Business Innovation Research (SBIR) program, and it offers descriptive information primarily relevant to an assessment of the program's objective of stimulating the private sector's commercialization of the innovations resulting from the use of public resources. We certainly do not claim that the SBIR program was the most significant of the post-productivity slowdown policy initiatives. However, our focus on it is particularly fruitful because of the availability of unique and rich data—recently collected by the National Research Council (NRC) within the National Academies as part of an overall evaluation of the SBIR program—related to SBIR projects funded by the National Institutes of Health (NIH).

Statistical analysis of commercialization is important at two levels. Broadly, it is a dimension of public accountability (Link and Scott 1998); as stated in a recent NRC report: "Commercializing SBIR-supported innovation is necessary if the nation is to capitalize on its SBIR investments" (National Research Council 2007, p. 5). And, at a narrower level,

[1] Real R&D performed in U.S. industry had been decreasing since 1970 and not until 1977 did it return to its 1969 pre-decline level. A number of culprits have been identified as related to the U.S. productivity slowdown. For a review of this literature, see Link and Siegel (2003).

[2] Public support for enhancing innovation in small firms can be traced to the 1960s (Turner and Brown 1999).

an assessment offers the potential for policy recommendations to improve the SBIR program.

Commercialization of SBIR projects funded by the NIH is of particular interest for several reasons. First, as detailed below, the Department of Health and Human Services is the largest funder of non-defense related SBIR projects and most of these are through the NIH. Second, commercialized technologies that result in improvements in health are particularly likely to have high rates of return (social and private). For instance, recent research (e.g., Murphy and Topel 2006; Hall and Jones 2007) documents both the large net benefit of previous health spending, as well as the desirability of even higher expenditure shares in the future.

This paper is outlined as follows. In Section II, we overview the history of the SBIR program with an emphasis on current funding activities. Section III describes the NIH SBIR dataset analyzed, and therein we posit the empirical framework used for estimating the probability that an SBIR-funded project will be commercialized. Section IV presents and discusses our econometric findings. Section V concludes with summary remarks and policy recommendations.

II. Overview of the SBIR Program

The SBIR program is a public/private partnership that provides grants to fund private R&D projects. It aims to help fulfill the government's mission to enhance private-sector R&D and to complement the results of federal research.[3] A prototype of the SBIR program began at the National Science Foundation (NSF) in 1977 (Tibbetts 1999). At that time, the goal of the program was to encourage small businesses—increasingly recognized to be a source of innovation and employment in the U.S. economy—to participate in NSF-sponsored research, especially research with commercial potential. Because of the early

---

[3] This section draws on Link and Scott (2000); Audretsch, Link, and Scott (2002); National Research Council (2004); and Wessner (2000, 2007). For a taxonomy of public/private partnerships, see Link (1999, 2006).

success of the program at NSF, Congress passed the Small Business Innovation Development Act of 1982 (P.L. 97-219; hereafter, the 1982 Act).

The 1982 Act required all government departments and agencies with external research programs of greater than $100 billion to establish their own SBIR program and to set aside funds equal to 0.20 percent of the external research budget.[4] In 1983, this amount totaled $45 million.

The 1982 Act stated that the objectives of the program 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
(4) to increase private sector commercialization of innovations derived from federal research and development.

As part of the 1982 Act, SBIR program awards were structured as defined by three phases (National Research Council 2004; Wessner 2007).[5] Phase I awards are small, generally less than $100,000 for the six month award period. The purpose of Phase I awards is to assist businesses as they assess the feasibility of an idea's scientific and commercial potential in response to the funding agency's objectives.[6] Phase II awards typically range

[4]Since SBIR is a set aside program, it redirects existing R&D funds for competitive awards to small businesses rather than appropriating new monies for R&D. The 1982 Act allowed for this percentage to increase over time.

[5] As stated in the 1982 Act, to be eligible for an SBIR award, the small business must be: independently owned and operated; other than the dominant firms in the field in which they are proposing to carry out SBIR projects; organized and operated for profit; the employer of 500 or fewer employees, including employees of subsidiaries and affiliates; the primary source of employment for the project's principal investigator at the time of award and during the period when the research is conducted; and at least 51 percent owned by U.S. citizens or lawfully admitted permanent resident aliens. Our database does not cover projects funded under the related Small Business Technology Transfer (STTR) program, which has similar aims but different eligibility requirements.

[6] "The objective of Phase I is to determine the scientific or technical feasibility and commercial merit of the proposed research or R&D efforts and the quality of performance of the small business concern, prior to providing further Federal support in Phase II." See, http://grants.nih.gov/grants/funding/SBIRContract/PHS2008-1.pdf, page 1.

up to $750,000 over two years.[7] These awards are for the business to develop further its proposed research, ideally leading to a commercializable product, process, or service.[8,9] The Phase II awards of public funds for development are sometimes augmented by outside private funding (Wessner 2000). Further work on the projects launched through the SBIR program occurs in what is called Phase III, which does not involve SBIR funds.[10] At this stage businesses needing additional financing—to ensure that the product, process, or service can move into the marketplace—are expected to obtain it from sources other than the SBIR program.

In 1992, the SBIR program was reauthorized until 2000 through the Small Business Research and Development Enactment Act (P.L. 102-564). Under the 1982 Act, the set aside had increased to 1.25 percent; the 1992 reauthorization raised that amount over time to 2.50 percent and re-emphasized the commercialization intent of SBIR-funded technologies (see point (4) of the 1982 Act above).[11] The 1992 reauthorization broadened objective (3) above to also focus on women: "to provide for enhanced outreach efforts to increase the participation of … small businesses that are 51 percent owned and controlled by women." The Small Business Reauthorization Act of 2000 (P.L. 106-554) extended the SBIR program until 2008 and kept the 2.50 percent set aside.

Eleven agencies currently participate in the SBIR program: the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and the Departments of Agriculture (USDA), Commerce (DoC), Defense (DoD), Education (ED), Energy (DoE), Health and Human Services

---

[7] It is not uncommon, however, for NIH Phase II awards to exceed the $750,000 threshold. While NIH offers no research assessment-based justification, the NRC, as part of its evaluation of SBIR programs (discussed below) has recommended that NIH formalize criteria for larger awards.

[8] "The objective of Phase II is to continue the research or R&D efforts initiated in Phase I. Funding shall be based on the results of Phase I and the scientific and technical merit and commercial potential of the Phase II proposal." See, http://grants.nih.gov/grants/funding/SBIRContract/PHS2008-1.pdf, page 1.

[9] According to Wessner (forthcoming), in 2004 about 6 percent of Phase I applications were approved. Of those, just over one-third of those that requested Phase II funding were approved.

[10] "The objective of Phase III, where appropriate, is for the small business concern to pursue with non-SBIR funds the commercialization objectives resulting from the outcomes of the research or R&D funded in Phases I and II." See, http://grants.nih.gov/grants/funding/SBIRContract/PHS2008-1.pdf, page 1.

[11] The percentage increased to 1.5 in 1993 and 1994, 2.0 in 1995, and 2.5 in 1997.

(HHS, particularly the NIH), Transportation (DoT), and, most recently, Homeland Security (DHS). In 2005, DoD maintained the largest program, awarding about 51 percent of total dollars and funding about 57 percent of total awards in that year. Five agencies—DoD, HHS, NASA, DoE, and NSF—account for nearly 97 percent of the program's expenditures. See Table 1.

III. The NRC Dataset and the Statistical Framework

The National Research Council dataset on NIH SBIR awards was constructed for the broader purpose of conducting a cross-agency evaluation of the SBIR program, as requested by Congress as part of the Small Business Reauthorization Act of 2000.[12] This is the dataset analyzed herein.[13]

Between 1992 and 2001—the time period over which the data were collected—2,497 Phase II SBIR project awards were made by NIH. Of these, 1,672 were randomly selected to receive an in-depth survey related to outputs associated with the project, representing a random sampling proportion of 66.96 percent. The NCR's random sample was chosen to ensure balanced coverage by year and by number of Phase II awards received each year between 1992 and 2001. From the 1,672 random projects, 488 completed or partially completed surveys were returned to the NRC. Phase II research was not yet finished in 34 of the projects with completed surveys, 5 projects were excluded because they were funded by Institutes with fewer than 5 completed surveys, and another 44 did not provide all of the information needed for our analysis (discussed below).[14] The final sample of projects analyzed is 405 (see Table 2).

---

[12] This National Research Council initiative was mandated by the Small Business Reauthorization Act of 2000 (H.R. 5667). For background information on the Council's efforts, see National Research Council (2007) and Wessner (2007). The NRC, which graciously made these data available for this study, is also in the process of assessing the SBIR program in the Department of Defense, Department of Energy, NASA, and the National Science Foundation. See National Research Council (2004, 2007) for an overview of these agencies.

[13] The dataset and survey questionnaires are described completely in Cahill (2006).

[14] The National Institute of Dental and Craniofacial Research had only four funded projects with surveys returned, there was only a single project funded by the National Library of Medicine and no projects funded by the National Center for Complementary and Alternative Medicine. We tested robustness of the econometric results (below) to including observations with missing values for one or more covariates by placing a value of zero on these regressors and also controlling for a set of missing value dummy variables.

The output focused on in this study is a dichotomous variable taking the value of one (zero) for completed Phase II projects that had (had not) resulted in a commercialized product(s), process(es), service(s), or other sale(s) such as rights to technology or licensing revenue(s)) by 2005, the year that the NRC survey was administered. As shown in Table 3, the mean value of this dichotomous variable *Commercial* is .5111. In other words, the chance of a Phase II NIH SBIR award being successful, as measured in terms of it resulting in a technology that is commercialized, is, on average, just over 50 percent or just better than the odds associated with the flip of a fair coin.[15]

There is a conspicuous void of systematic information in the academic literature on factors associated with the success of small entrepreneurial firms (Åstebro 1998). The data that do exist are limited in scope, and they relate in general to the longevity and commercial success of R&D-based technologies in larger, well-established organizations.[16] Thus, our hypotheses below follow from both a selected theoretical literature and related and generalizable empirical studies.

We posit a positive correlation between commercialization and the presence of additional development funding for the award project. We believe that small entrepreneurial businesses face what Zeira (1997) calls "structural uncertainty" (p. 204). Specifically, such businesses do not know *a priori* if their SBIR technology is commercializable, and if it is, what its commercial potential might be. Zeira argued that under structural uncertainty

---

The findings were not materially different than those presented below; these results are available from the authors on request

[15] We had no priors about the percent of NIH SBIR projects that had commercialized. The NIH's Phase I selection criteria focus, in part, on the significant of the project's commercialization potential: One criterion question is: "Does the proposed project have commercial potential to lead to a marketable product, process or service?" And, at the Phase II stage, there are additional related criteria, including" "Did the applicant submit a concise Commercialization Plan?" and "Does the project carry a high degree of commercial potential, as described in the Commercialization Plan?" See: http://grants.nih.gov/grants/funding/sbirsttr_ReviewCriteria.htm

[16] Mansfield et al. (1971), for example, reported an average probability of commercial success from R&D projects in three laboratories (one chemical laboratory and two proprietary drug laboratories) of 31 percent. We caution the reader about comparing the probability of commercial success from this, or other similar case studies, to the probability of commercialization from NIH SBIR awards and concluding that businesses receiving NIH SBIR award are more successful. The size and underlying research structure of the two groups of businesses is too different for meaningful comparisons.

relevant information could be acquired through technological research. Thus, to the extent that the presence of additional development funding reflects the ability of the business to conduct more research on its SBIR project, then that project should have a greater probability of commercialization—this, of course, is the objective of Phase III.

Relatedly, Åstebro (2003) argued that independent inventors, who might be similar to the entrepreneurs in the businesses that receive NIH SBIR awards, inherently face problems attracting external financing due to "information asymmetries, moral hazard and coordination problems" (p. 237).[17] Private investors (e.g., venture capitalists, foreign investors) incur significant costs acquiring information about new technologies. When they do invest in a potential technology, it is therefore reasonable to conclude that at least two hurdles have been cleared. One hurdle is that the business receiving the venture capital was selected among all businesses to be scrutinized, and the other hurdle is that the specific business was then selected among all that were scrutinized. This suggests that the probability of commercialization should be greater for NIH SBIR project for which there is additional developmental funding from private investors.

Thus, our empirical model is:

(1) Probability (commercialization) = f (*AddFund*, **X**)

where, commercialization is measured by the dichotomous variable *Commercial*, and where the variable *AddFund* represents additional developmental funding received by the business in support of the technology developed during its Phase II project. *AddFund* equals 1 if any additional developmental funding was received to support the project at some point in time, and 0 otherwise. Just under 59 percent of the projects in the sample received additional developmental funding (see Table 3).

[17] Link and Scott (2000) documented this fact through case studies of DoD SBIR awards.

In some specifications of equation (1) we disaggregate additional developmental funding into five non-mutually exclusive dichotomous categories. *AddFund-Fed* equals 1 if the project received additional non-SBIR funds from federal sources, and 0 otherwise;[18] *AddFund-VC* equals 1 for U.S. venture capital funds, and 0 otherwise; *AddFund-Oth* equals 1 for other private investment funds (e.g., foreign investment, other private equity, or other domestic private company), and 0 otherwise; *AddFund-SLU* equals 1 for state or local government or university funds, and 0 otherwise; and *AddFund-Own* equals 1 for personal and/or internal business funds, and 0 otherwise. Table 3 also shows mean amounts of external funding from each of these sources, denoted with a $ in front of the specified variable (e.g. *$AddFund-Fed* indicates that $ amount of non-SBIR federal funds received).

Five control variables are subsumed in vector **X**. The first represents the knowledge base, or absorptive capacity (Cohen and Levinthal 1989), of the business with respect to the technology being researched during the Phase II project. *KnowlBase* is the number of previous Phase II awards the business has previously received that are related to the project supported by the current Phase II award. Nearly 38 percent of the projects in our sample are related to previous Phase II awards (not shown in Table 3). To the extent there is learning-by-doing, in the sense of Arrow (1962), and/or economies of scope in research from an expanded knowledge base, and to the extent that this enriched knowledge base leads to subsequent research success, we posit a positive correlation between *KnowlBase* and the probability of commercialization.[19]

The second control variable represents the ownership of the business being 51 percent owned and controlled by a female. *Female* equals 1 for such a business, and 0 otherwise. Nearly 18 percent of the Phase II projects in the sample were awarded to female owned and controlled businesses (see Table 3). We do not posit the direction of the correlation

---

[18] Fully 85 percent of businesses receiving non-SBIR federal funds also received funds from other sources, most commonly from personal or internal business funds (received by 59 percent of these projects).

[19] Link and Scott (2005) offered this same argument, and supported it empirically, with respect to various dimensions of success of small internal research projects conducted within the laboratories of the National Institute of Standards and Technology.

between *Female* and the probability of commercialization, but rather offer alternative interpretations of an observed correlation. If female owned and controlled businesses were discriminated against from receiving SBIR awards prior to the 1992 reauthorization, removing that bias should imply that such businesses would now be equally as successful as other businesses, thus there should not be any statistical correlation between *Female* and the probability of commercialization. If female owned and controlled businesses were less qualified, on average, to receive SBIR awards, and reauthorization was interpreted as a mandate for agencies to now fund more of these projects, there should be a negative correlation between *Female* and the probability of commercialization. Conversely, if female owned and controlled businesses were more qualified to receive NIH SBIR awards but were not being objectively evaluated prior to the reauthorization, there should be a positive correlation between *Female* and the probability of commercialization.

The third control variable represents the ownership of the business being 51 percent minority owned and controlled. *Minority* equals 1 for such a business, and 0 otherwise. As shown in Table 3, nearly 5 percent of the Phase II projects in the sample were awarded to minority owned and controlled businesses.[20] Although the 1992 reauthorization did not explicitly focus on increasing minority participation it was nevertheless a stated objective of the 1982 Act. We anticipate that the interpretation of the coefficient on *Minority* will be similar to that for *Female*.

The fourth control variable quantifies if a university was involved with the SBIR project research (*Univ*=1), or not (*Univ*=0).[21] Hall, Link, and Scott (2003) argued that universities are invited to partner with small entrepreneurial research joint ventures to provide research insights that are anticipatory of future research problems. University faculty thus act as ombudsman to oversee the research and help to ensure the project's success. Relatedly Zucker and Darby and their colleagues (1998a, 1998b, 2001) found that when star scientists were involved with small biotechnology enterprises, patenting, product

[20] 2.7 percent of sampled projects are in businesses that were both female and minority owned and controlled.

[21] The survey question asks if ("yes" or "no") there was any involvement by university faculty, graduate students, and/or university developed technologies.

innovations, and the introduction of new products increased. Thus, to the extent that university involvement, albeit broadly defined by the variable *Univ*, helps to ensure the success of research projects, we posit a positive correlation with it and the probability of commercialization.[22] Universities were involved in 53 percent of the sample projects; see Table 3.

And finally, we control for the attributes of the research associated with the Phase II award through a set of binary variables representing the Institute within the NIH that funded each project (defined in the note within Table 3).[23] We have no prior expectation about the correlations between the probability of commercialization and any particular Institute.

A potential empirical concern is selection bias resulting from the relatively low rate (29.2 percent) at which businesses returned the SBIR project surveys. We examined this possibility by estimating equation (1), by maximum likelihood, as a bivariate probit model with selection, simultaneously with a model of the probability of response to the project survey specified by:

(2) Probability (response) = g (*Age*),

where *Age* measures the number of years since the Phase II award, defined as the year of the survey (2005) less the year of the Phase II award (between 1992 and 2001).[24] Our key identification strategy in the selection model is that *Age* is included in the response equation but excluded from the commercialization model. Absent a strong theoretical

---

[22] For a review of the literature related to universities as research partners, see Hall (2004).

[23] As examples of the project variation across Institutes, in 1997 the National Cancer Institute funded a California business to develop an image detector with 100 micrometer spatial resolution applicable to the detection of cancer in small animals; in 1988 the National Heart, Lung, and Blood Institute funded a Virginia business to develop an optical imaging device to measure skin blood glow velocities for the treatment of vascular disease in diabetic patients; in 1999 the National Institute of Drug Abuse funded a New York business to develop an Internet-based dissemination plan for information and methods concerning drug abuse prevention approaches; and in 1994 the National Institute on Deafness and other Communication Disorders funded a Florida business to develop a hearing screener based on noise cancellation techniques to rapidly detect hearing problem in new born infants.

[24] The NRC's (2007) data collection methodology implicitly assumed that recent Phase II awards will be completed and will have had sufficient time to commercialize within four years.

foundation for why some businesses would respond to the survey for a particular project, we posit that the older the Phase II award, the less institutional knowledge there is that still exists within the business for such a project and thus the less likely the business would respond to the survey. Thus, there should be a negative correlation between *Age* and the probability of response. This is confirmed by our econometric estimates.

Conversely, *Age* is not included in the probability of commercialization model: equation (1). One might reason that the probability of commercialization would increase over time as the business was first able to complete its Phase II award project and then seek and receive Phase III funding. However, the data do not support this. In fact, the age distributions of commercialized and non-commercialized projects are virtually identical, and the coefficient on *Age* is small and insignificant when entered as an additional covariate in equation (1).[25] A reasonable interpretation of these findings is that, if commercialization is going to occur, it will take place close to the date that the Phase II award project is completed.

The bivariate probit estimates provided no indication of selection bias. Specifically, the estimates always fail to reject the null hypothesis that the models of response and commercialization are independent of one another (the correlation of the errors in the two models is not significantly different from zero) and the parameter estimates of interest are always very close to those obtained without accounting for selection.[26] For this reason, the results reported below are for single equation models that do not account for selection.

Because probit coefficients can be somewhat difficult to interpret, we report marginal effects for the continuous regressors and predicted effects of changing dichotomous variables from zero to a one, with the other covariates evaluated at the sample means. Robust standard errors are reported in parentheses.

---

[25] For example, the average ages of commercialized and non-commercialized projects were 7.3 and 7.5 years, while the median age was 7.0 years for both. These results are available from the authors on request.

[26] These results are available from the authors on request.

Table 4 provides sample average values of selected variables for commercialized and noncommercialized projects. The last column of the table shows p-values for the null hypothesis that the sample means are the same for the two groups. The most important findings are that commercialized projects are significantly more likely than non-commercialized projects to have received additional developmental funding (74 versus 42 percent), particularly non-SBIR funds from federal sources (9.2 versus 3.5 percent) and from personal or internal funds (63 versus 37 percent). They are also more than twice as likely to receive venture capital funds but, because this occurs infrequently (4.8 versus 2.0 percent), the difference is not significant at the .10 level. Projects are also significantly (at the .10 level) more likely to be commercialized when awarded to firms with a more extensive knowledge base (1.4 versus 0.8 previous related SBIR projects) and to those owned by minorities (6.8 versus 3.0 percent). There are no significant differences by other sources of external funding, female ownership, university involvement or years since the Phase II award. Finally, projects funded by the National Institutes on Drug Abuse and Mental Health are significantly more likely than others to commercialize while those supported by the National Institutes on Aging, Allergy and Infectious Diseases, Arthritis and Musculoskeletal and Skin Disease, National Eye Institute and National Heart Lung and Blood Institute are relatively less likely to do so (not shown in Table 4).[27]

Despite large absolute differences in the magnitudes, none of the variables showing dollar amounts of external funding differ significantly with commercialization status. Consider venture capital funding, which provides the most extreme example. The mean commercialized project received almost $689,000 of venture capital compared to less than $56,000 for non-commercialized projects, yet this difference is not significant at the 0.10 level. The reason is that the receipt of this funding is extremely skewed, with a small number of projects receiving virtually all of the funds. For instance, in our sample, just 10 commercialized projects obtained venture capital, with over 90 percent of all such funds received by just three projects.[28] One implication is that it will be quite difficult to

[27] A table showing a complete set of sample means for commercialized and non-commercialized projects is available on request.

[28] These three commercialized projects received $59.9, $50.1 and $20.0 million of venture capital funding.

econometrically model how the amount of external funding influences commercialization probabilities and that efforts to do so will need to account for the skewness in the distribution.[29]

IV. Econometric Results

The probability of commercialization models, presented in Table 5, fit the data well. With reference to the estimated marginal effects in column (1), projects that received additional developmental funding (*AddFund*=1) have a greater probability of success than projects that received no additional funding (*AddFund*=0). The estimated marginal effect on *AddFund* is positive and significant at the .01 level, and it indicates that additional funding correlates with a 36 percentage point increase in the probability of commercialization.

Likewise, as the number of previous Phase II awards received by the business that are related to the current project (*KnowlBase*) increases, so does the probability of commercialization (by 2.5 percentage points per previous Phase II award). The estimated probit coefficient on *KnowlBase* is positive and significant at the .05 level.

Both of these results support our *a priori* reasoning and are consistent with evidence from the descriptive analysis.

Also, female (*Female*) and/or minority (*Minority*) owned and controlled businesses are not more or less likely to commercialize from a Phase II project than are male and/or non-minority owned and controlled businesses. Neither estimated marginal effect is significantly different from zero. These results are not inconsistent with an absence of disparate treatment.

---

[29] Skewness is also an issue for sources of external funds that are received more frequently. For example, although 63 percent of commercialized projects obtain personal or internal funding, the average amount ($273,421) is over nine times as large as the median ($30,000).

University involvement (*Univ*=1) is positively related to the probability of commercialization; the estimated marginal effect is significant at the .05 level. University involvement increases the probability of commercialization by 12 percentage points.

Finally, as a group the Institute effects are statistically significant at the .01 level, with the highest rates of commercialization for projects funded by the National Institute of Mental Health (*MH*) and the lowest for those funded by the National Eye Institute (*EY*).[30]

The results in column (2) take into account the possibility of diminishing returns to the effect of the knowledge base of the business from previous related Phase II projects on commercialization by controlling for the natural log, rather than level, of related Phase II projects.[31] The estimated marginal effect on ln*KnowlBase* is positive and significant at the .01 level, providing further support for the role of this variable.

AddFunds is a binary variable quantifying additional developmental funding, from any source. The models underlying the results in columns (3) and (4) disaggregate additional developmental funding into the five specific (although non-mutually exclusive) dichotomous categories. The presence of additional non-SBIR federal funds, U.S. venture capital funds, and own funds are all positively related to the probability of commercialization. In column (3), the estimated marginal effect on *AddFund-Fed* is positive and significant at the .01 level and indicates that the receipt of non-SBIR federal funds is correlated with a 29 percentage point increase in the probability of commercialization. The effect of *AddFund-Own* is positive and significant at the .01 level and is coincidentally associated with a 29 percentage point rise in the probability of commercialization. Venture capital support, *AddFund-VC*, has a positive effect as well on the probability of commercialization, at the .05 level, and predicts a 27 percentage point

[30] In an effort to also control for the "structural uncertainty" of each project, in the context of Zeira (1997), we included dummy variables to account for how (i.e., in what non-mutually exclusive form) each project was commercialized (e.g., software, hardware, process technology, drug, biologic, research tool, etc.). Statistically, these dummies were not significant.

[31] In this specification, *KnowlBase* if redefined as the number of related Phase II projects, including the current one, so that there are no (undefined) zero values.

higher commercialization probability. The results are similar in column (4) when the ln*KnowlBase* is included.

The models underlying the results in Table 6 replace the disaggregated binary variables that denoted additional developmental funding, in Table 5, with the dollar amount of such funding. The estimated marginal effects in columns (1) and (2) relate to a linear specification of the dollar amount of alternative funding sources along with a linear and a natural log specification of previous related Phase II awards.[32] Those specifications reveal little, as was expected given the highly skewed distributions for these variables. However, when non-linearity of the dollar amounts of additional developmental is specified, as in columns (3) and (4), the significance pattern is similar to that of corresponding specifications in Table 4 (that used dichotomous variables for disaggregated categories of additional developmental funding), as are the conclusions to be drawn from the results.[33] One difference, however, is these specifications suggest that given amounts of additional developmental funding from non-SBIR federal funds and, particularly, own and/or internal business sources, may have a stronger positive effect on commercialization probabilities than similar amounts of venture capital support, and that the greatest effect is associated with own and/or internal business funding (where there would logically be the greatest information about the potential success of the project).

A summary of the marginal effects obtained from the probit models is useful to motivate a policy discussion in the concluding section of the paper. We find, based on the results in column (4) of Table 6, that a 100 percent increase in developmental non-SBIR federal funding increases the predicted probability of commercialization by 1.5 percentage points; this probability similarly rises by 1.2 percentage points with corresponding growth in venture capital funding, and by 1.8 percentage points with additional developmental funding from the owners or business itself. The probability of commercialization increases

[32] Additional models estimated with a single variable measuring the amount of all additional funding (not shown) also indicate that such funds are statistically significantly positively correlated with the probability of commercialization (at the .05 level).

[33] Zero values for *$AddFunds-Fed*, *$AddFunds-VC*, *$AddFunds-Oth*, *$AddFunds-SLU*, and *$AddFund-Own* were reset to equal 1 so that the log of each would be defined.

when the business' knowledge base has been built through previous related Phase II research; it increases by 9.1 percentage points per 100 percent increase in the number of previous related Phase II awards. Female and minority owned and controlled businesses are equally as likely to commercialize as are other businesses. And, university involvement in Phase II award projects increase the probability of commercialization by 13 percentage points.

V. Conclusions

Before suggesting policy implications based, we offer several words of caution related to a number of caveats associated with limitations to the NRC data.

First, the dataset is rich in a number of dimensions, not the least of which is that the information is at the level of a project rather than at the business level. However, herein we have only measured commercialization dichotomously. While the NRC dataset does contain limited self-reported information on commercialization in dollar terms; the number of projects for which those data are available is small, and, from an assessment perspective, the stated objective of the SBIR program is commercialization *per se*. Second, we do not have information on when a project received additional developmental funds. Some projects may have received these moneys during the Phase II research and others only after they attempt to or do commercialize an initial product/process/service. Or, additional developmental funding may have come in stages such as first obtaining non-SBIR federal funds and then obtaining venture capital funds. Were we able to control for the timing of the additional developmental funds we might have been able to determine more precisely the relative importance of each source. For example, we could not investigate whether there was a halo effect from additional non-SBIR federal support that subsequently increased the likelihood of the business obtaining venture capital funds. And third, our analysis does not control for the nature of the underlying technology being researched and/or commercialized. While we did control for Institute effects, as a proxy for the character of the research, more detailed technology controls would be useful.

Caveats aside, several dimensions of our findings have policy relevance, and we offer piecemeal observations related to policy, and then collectively we offer a numerical illustration of a specific policy recommendation. First, venture capital funding is predicted to positively affect the probability of commercialization. This is precisely the objective of Phase III. However, additional funding from the owner and/or business is much more common and has an equal or greater relative estimated impact on commercialization. Perhaps these results could be replicated in reality if Phase II awards were conditional on a commitment of matching internal funds.[34]

Second, the program's emphasis and funding priorities on female and minority owned and controlled businesses appears to be well-focused in that female and minority owned and controlled businesses commercialize on par with businesses with other ownership profiles. Whether or not female and minority owned and controlled businesses have been discriminated against in the past is less important that the fact that projects awarded to either type of business are now equally as likely to commercialize.

And third, the NIH, and possibly other agencies, might consider incentives for Phase II award recipients to include university faculty and resources in research projects. One mechanism to consider might be to award merit evaluation points during the Phase II award reviews for proposed university involvement, or to increase the funding amount for the same.[35]

Of course, an obvious policy issue is whether increasing the dollar amount of Phase II awards will increase the probability of commercialization. Our theoretical arguments for

[34] A handful of states (e.g., North Carolina) have programs that match federal Phase I awards. The insignificance of the additional developmental funding from state or local government variable in our models might be a cautionary sign to bring about a rethinking of extending such programs to Phase II, assuming that one of the state's objectives in so doing would be to increase commercialization. If commercialization is a state objective, perhaps tying a matching grants program to university involvement is worth consideration.

[35] Our finding related to university involvement increasing the probability of commercialization has other possible implications. University technology transfer offices might broaden the scope of their mission to assisting local and regional small entrepreneurial businesses during the Phase I and Phase II award process in anticipation of later involvement in the Phase II research and the possibility of sharing ownership with whatever is subsequently commercialized.

the specification of equation (1) did not include the size of the award and, more to the point, the NIH regularly exceeds the $750,000 guideline so a policy recommendation to increase the upper bound on Phase II awards would be moot.[36] Empirically, as a descriptive observation, the award amount is not correlated with the probability of commercialization.

To combine aspects of the above three piecemeal policy observations into a single policy recommendation, consider the hypothetical numerical illustration in Table 7. It is based, mathematically, on the estimated probit equation underlying the results in Table 6. As a base point of reference, consider a hypothetical Phase II project in a business that has no knowledge base, $0 own and/or internal business additional developmental funding and no university involvement (and with all other covariates evaluated at the sample means). Under these hypothetical conditions, the calculated base probability that the Phase II project will commercialize a product, process, or service is 26 percent.

Assume next that the business receiving the Phase II SBIR has a knowledge base corresponding to one previous related Phase II SBIR project (ln*KnowlBase* increases from 0 to 0.693). This raises the predicted probability of commercialization to 34 percent. The predicted commercialization probability rises by a similar amount—to 38 percent—when a university is involved in the research but the business has no knowledge base. The increase is much larger conditional on own and/or internal business funding at a level equal to the sample mean of *$AddFund-Own* ($208,911), but with no previous knowledge base or university involvement, in which case the expected commercialization rate is 57 percent.

Thus, our policy recommendation is for the NIH, assuming that it is interested in increasing the probability of commercialization, to condition receipt of a Phase II award on university involvement and own and/or internal business funding. In this case, the commercialization probability is predicted to be 69.1 percent. If, for illustration purposes,

[36] Phase II awards were higher than $750,000 for just over 20 percent of our sample.

and we are not suggesting this as a policy recommendation Phase II awards were also conditioned on the receipt of at least one previous related award, the probability of commercialization would increase even more, to 77 percent.[37]

Additional research is certainly warranted to better understand the nature of commercialization from SBIR awards and to assess more completely that program objective. Hopefully, future research will overcome some of the data limitations of this study. Alternative research methodologies—such as a matched pairs analysis of small entrepreneurial businesses with and without SBIR support—might be useful for investigating both factors associated with the propensity to commercialize as well as the private and social implications from such commercialization.

[37] The SBIR program has made several institutional changes in recent years to increase the rate of commercialization. The Fast Track program permits businesses with projects of high commercialization success to submit the Phase I and Phase II applications for concurrent review. Among other things, projects funded under Fast Track avoid the possibility of a funding gap between the completion of Phase I and the award/receipt of Phase II dollars. See Audretsch, Link, and Scott (2002) for an evaluation of the Fast Track program within the Department of Defense. According to Wessner (forthcoming), less than 6 percent of applicants current apply through the Fast Track Program. In 2002, NIH initiated their Commercialization Assistance Program (CAP) " … to help some of the nation's most promising small life science and healthcare companies develop their commercial businesses and transition their SBIR-funded technologies into the marketplace" through assistance with business development plans, marketing strategies, and formulating roadmaps for licensing. See, http://www.larta.org/nihcap/NIHCAP-ProgramDescription.pdf.

Table 1

SBIR Awards and Dollars, FY2005

Agency	Phase I Awards	Phase I Dollars	Phase II Awards	Phase II Dollars	Total Awards	Total Dollars
DoD	2344	$213,482,152	998	$729,285,508	3342	$942,767,660
HHS	732	$149,584,038	369	$412,504.975	1101	$562,089,013
DoE	259	$25,757,637	101	$77,852,565	360	$103,610,202
NASA	290	$20,183,648	139	$83,014,853	429	$103,198,501
NSF	152	$15,054,750	132	$64,101,179	284	$79,155,929
USDA	91	$7,195,211	40	$11,738,536	131	$18,933,747
DHS	62	$6,158,240	13	$10,241,202	75	$16,399,442
ED	22	$1,646,603	14	$6,749,980	36	$8,396,583
DoC	34	$2,373,433	19	$5,469,846	53	$7,843,279
EPA	38	$2,652,216	14	$3,540,251	52	$6,192,467
DoT	7	$679,154	3	$1,765,468	10	$2,444,622
Total	**4031**	**$444,767,082**	**1842**	**$1,406,264,363**	**5873**	**$1,851,031,445**

Source: U.S. Small Business Administration (2006).

Table 2
Final Sample of NIH Phase II Projects Awarded between 1992 and 2001

Data Reduction	**Number of Projects**
Population of NIH Projects	2,497
Survey Population	1,680
Random Survey Population	1,672
Survey Respondents	488
Respondents with Completed Phase II Project	454
Responses from Institutes with ≥5 Survey Responses	449
Survey Respondents Reporting All Relevant Information	**405**

Table 3
Descriptive Statistics for the Final Sample (n=405)

Variable	Mean	Standard Deviation	Minimum	Maximum
Commercial	.5111	.5005	0	1
AddFund	.5852	.4933	0	1
AddFund-Fed	.0642	.2454	0	1
AddFund-VC	.0346	.1829	0	1
AddFund-Oth	.1580	.3652	0	1
AddFund-SLU	.0568	.2317	0	1
AddFund-Own	.5037	.5006	0	1
$AddFund-Fed	$111,271	$1,325,214	0	2.60e+07
$AddFund-VC	$379,301	$4,021,767	0	5.99e+07
$AddFund-Oth	$488,872	$3,702,643	0	5.50e+07
$AddFund-SLU	$15,028	$126,162	0	1650000
$AddFund-Own	$208,911	$93,3430	0	1.28e+07
KnowlBase	1.0815	3.3324	0	28
Female	.1753	.3807	0	1
Minority	.0494	.2169	0	1
Univ	.5333	.4995	0	1
AA	.0173	.1309	0	1
AG	.0864	.2813	0	1
AI	.1111	.3147	0	1
AR	.0124	.1106	0	1
CA	.1284	.3349	0	1
DA	.0568	.2317	0	1
DC	.0395	.1950	0	1
DK	.0444	.2063	0	1
ES	.0247	.1554	0	1
EY	.0173	.1309	0	1
GM	.0741	.2622	0	1
HD	.0568	.2317	0	1
HG	.0148	.1210	0	1
HL	.1259	.3322	0	1
MH	.0593	.2364	0	1
NR	.0049	.0702	0	1
NS	.0691	.2540	0	1
RR	.0519	.2220	0	1
Age	7.3704	2.6488	4	13

Note: AA=National Institute on Alcohol Abuse and Alcoholism (NIAAA), AG=National Institute on Aging (NIA), AI=National Institute on Allergy and Infectious Diseases (NIAID), AR=National Institute on Arthritis and Musculoskeletal and Skin Disease (NIAMS), CA=National Cancer Institute (NCI), DA=National Institute on Drug Abuse (NIDA), DC=National Institute on Deafness and other Communication Disorders (NIDCD), DK=National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), ES=National Institute of Environmental Health Sciences (NIEHS), EY=National Eye Institute (NEI), GM=National Institute of General Medical Sciences (NIGMS), HD=National Institute of Child Health and Human Development (NICHD), HG=National Human Genome Research Institute (NHGRI), HL=National Heart, Lung and Blood Institute (NHLBI), MH=National Institute of Mental Health (NIMH), NR=National Institute of Nursing Research (NINR), NS=National Institute of Neurological Disorders and Stroke (NINDS), and RR=National Center for Research Resources (NCRR).

Table 4
Selected Sample Means by Commercialization Status

Variable	**Not Commercialized** (n=198)	**Commercialized** (n=207)	**P-Value of Difference**
AddFund	0.4242	0.7391	<0.001
AddFund-Fed	0.0354	0.0918	0.021
AddFund-VC	0.0202	0.0483	0.122
AddFund-Oth	0.1313	0.1836	0.150
AddFund-SLU	0.0505	0.0628	0.594
AddFund-Own	0.3687	0.6329	<0.001
KnowlBase	0.7828	1.3672	0.078
Female	0.1515	0.1981	0.219
Minority	0.0303	0.0676	0.083
Univ	0.5051	0.5604	0.266
Age	7.3939	7.3478	0.861

Note: Table shows sample means separately for commercialized and non-commercialized projects. The last column shows the P-Value for the null hypothesis that the sample means are the same for the two groups.

Table 5
Estimated Marginal Effects of the Probability of Commercialization: Disaggregated Additional Funds as Binary Variables (robust standard errors in parentheses)

Variable	(1)	(2)	(3)	(4)
AddFund	.3622* (.0510)	.3475* (.0515)	—	—
AddFund-Fed	—	—	.2936* (.0942)	.2873** (.0947)
AddFund-VC	—	—	.2701** (.1068)	.2626** (.1093)
AddFund-Oth	—	—	.0049 (.0806)	.0028 (.0813)
AddFund-SLU	—	—	-.0897 (.1352)	-.1020 (.1360)
AddFund-Own	—	—	.2912* (.0534)	.2787* (.0535)
KnowBase	.0250** (.0089)	—	.0226** (.0089)	—
ln*KnowlBase*	—	.1413* (.0445)	—	.1310* (.0443)
Female	-.0125 (.0759)	-.0083 (.0747)	-.0014 (.0768)	-.0007 (.0753)
Minority	.1033 (.1277)	.0819 (.1315)	.1123 (.1235)	.0949 (.1267)
Univ	.1240** (.0556)	.1190** (.0553)	.1281** (.0557	.1223** (.0550)
AA	.0179 (.3516)	-.0247 (.3564)	.0451 (.3618)	.0053 (.3676)
AG	-.2357 (.2651)	-.2440 (.2648)	-.2369 (.2770)	-.2459 (.2759)
AI	-.3101 (.2392)	-.3147 (.2404)	-.2933 (.2580)	-.2979 (.2589)
AR	-.1622 (.3187)	-.1795 (.3165)	-.1675 (.3331)	-.1833 (.3303)
CA	.0443 (.2936)	.0216 (.2978)	.0347 (.3076)	.0148 (.3111)
DA	.1678 (.2828)	.1424 (.2927)	.1586 (.2949)	.1350 (.3038)
DC	.0487 (.3152)	.0091 (.3210)	.0504 (.3247)	.0142 (.3302)
DK	-.2807 (.2490)	-.3123 (.2381)	-.2835 (.2629)	-.3127 (.2510)
ES	-.0567 (.3220)	-.0815 (.3254)	-.0428 (.3428)	-.0654 (.3462)
EY	-.4647 (.1170)	-.4625 (.1228)	-.4847*** (.1055)	-.4813 (.1137)
GM	-.0382 (.3030)	-.0675 (.3044)	-.0095 (.3152)	-.0366 (.3177)
HD	-.0267 (.3027)	-.0694 (.3077)	-.0057 (.3175)	-.0443 (.3204)
HG	.0673 (.3276)	.0587 (.3322)	.0710 (.3424)	.0634 (.3464)
HL	-.3236 (.2355)	-.3423 (.2309)	-.1383 (.2501)	-.3347 (.2459)
MH	.3066 (.2288)	.2822 (.2434)	.3171 (.2283)	.2961 (.2423)
NR	0 (.4010)	-2.0e-15 (.4050)	.0423 (.4330)	.0496 (.4369)
NS	-.2057 (.2761)	-.2379 (.2698)	-.2176 (.2841)	-.2451 (.2782)
RR	-.0961 (.3052)	-.1162 (.3047)	-.0802 (.3205)	-.0968 (.3205)
Pseudo R-squared	.1911	.1928	.1833	.1853
Log Pseudo-likelihood	-227.00	-226.53	-229.18	-226.63
n	405	405	405	405

Note: * = significant at the .01 level, ** = significant at the .05 level, *** = significant at the .10 level.

Table 6
Estimated Marginal Effects of the Probability of Commercialization: Disaggregated Additional Funds in Dollars (robust standard errors in parentheses)

Variable	**(1)**	**(2)**	**(3)**	**(4)**
$AddFund-Fed	-3.98e-09	-4.47e-09	—	—
	(1.63e-08)	(1.66e-08)		
$AddFund-VC	2.12e-08***	1.97e-08	—	—
	(1.25e-08)	(1.24e-08)		
$AddFund-Oth	1.91e-09	2.76e-09	—	—
	(6.34e-09)	(6.38e-09)		
$AddFund-SLU	-1.21e-08	-3.60e-08	—	—
	(1.69e-07)	(1.82e-07)		
$AddFund-Own	4.70e-08	4.46e-08	—	—
	(4.21e-08)	(4.14e-08)		
ln*$AddFund-Fed*	—	—	.0217** (.0099)	.0210** (.0098)
ln*$AddFund-VC*	—	—	.0183*** (.0104)	.0176***(.0105)
ln*$AddFund-Oth*	—	—	.0008 (.0063)	.0007 (.0063)
ln*$AddFund-SLU*	—	—	-.0072 (.0117)	-.0084 (.0118)
ln*$AddFund-Own*	—	—	.0276* (.0049)	.0264* (.0049)
KnowlBase	.0185** (.0091)	—	.0229* (.0089)	—
ln*KnowlBase*	—	.1301* (.0445)	—	.1318* (.0445)
Female	.0052 (.0761)	-.0026 (.0752)	-.0004 (.0764)	.0009 (.0749)
Minority	.1290 (.1188)	.1147 (.1215)	.1334 (.1239)	.1151 (.1269)
Univ	.1101** (.0545)	.1084** (.0544)	.1394** (.0558)	.1333** (.0556)
AA	-.0043 (.0462)	-.0396 (.4070)	.0468 (.3597)	.0066 (.3656)
AG	-.2454 (.3214)	-.2637 (.3141)	-.2437 (.2748)	-.2521 (.2735)
AI	-.2970 (.3022)	-.3083 (.2976)	-.3107 (.2511)	-.3142 (.2522)
AR	-.1732 (.3921)	-.1922 (.3835)	-.1831 (.3281)	-.1974 (.3257)
CA	.0405 (.3597)	.0180 (.3616)	.0211 (.3087)	.0020 (.3116)
DA	.1702 (.3373)	.1430 (.3469)	.1430 (.2996)	.1195 (.3079)
DC	.0665 (.3708)	.0264 (.3765)	.0213 (.3278)	-.0142 (.3314)
DK	-.2774 (.3078)	-.3066 (.2925)	-.3003 (.2553)	-.3278 (.2431)
ES	.0198 (.3912)	-.0110 (.3956)	-.0454 (.3421)	-.0671 (.3452)
EY	-.4116 (.2178)	-.4106 (.2205)	-.4945 (.0921)	-.4914*** (.1000)
GM	-.0199 (.3672)	-.0496 (.3669)	-.0288 (.3155)	-.0551 (.3170)
HD	.0475 (.3668)	-.0003 (.3717)	-.0132 (.3177)	-.0514 (.3201)
HG	.1057 (.3938)	.0924 (.3976)	.0591 (.3443)	.0527 (.3480)
HL	-.2657 (.3168)	-.2884 (.3085)	-.3285 (.2462)	-.3441 (.2420)
MH	.3165 (.2613)	.2918 (.2783)	.3116 (.2312)	.2902 (.2450)
NR	-.0057 (.4981)	-.0051 (.4982)	.0086 (.4263)	.0163 (.4306)
NS	-.1812 (.3431)	-.2170 (.3319)	-.2304 (.2801)	-.2573 (.2738)
RR	.0366 (.3685)	.0095 (.3704)	-.0854 (.3197)	-.1017 (.3195)
Pseudo R-squared	.1239	.1304	.1892	.1908
Log Pseudo-likelihood	-245.85	-244.04	-227.54	-227.08
n	405	405	405	405

Note: * = significant at the .01 level, ** = significant at the .05 level, *** = significant at the .10 level.

Table 7
Probability of Commercialization under Alternative Scenarios

Scenario	Probit Index	Estimated Probability of Commercialization
Baseline Scenario		
KnowlBase=0	-0.649	25.8%
$AddFund-Own=$0		
Univ=0		
One Previous Related Phase II SBIR		
KnowlBase=1	-0.420	33.7%
$AddFund-Own=$0		
Univ=0		
University Involvement		
KnowlBase=0	-0.313	37.7%
$AddFund-Own=$0		
Univ=1		
Average Amount of Own/Internal Funding		
KnowlBase=0		
$AddFund-Own=$208,911	0.163	56.5%
Univ=0		
Average Own/Internal Funding and University Involvement		
KnowlBase=0		
$AddFund-Own=$208,911	0.499	69.1%
Univ=1		
All Three		
KnowlBase=1		
$AddFund-Own=$208,911	0.729	76.7%
Univ=1		

Note: Commercialization probabilities are obtained from the probit model estimated in column (4) of Table 5. The estimated equation for the index function is: Commercial = -0.3589 + 0.0529(ln*$AddFund-Fed*) + 0.0441(ln*$AddFund-VC*) + 0.0018(ln*$AddFund-Oth*) - 0.0212(ln*$AddFund-SLU*) + 0.0663(ln$*AddFund-Own*) + 0.3308(ln*KnowlBase*) + 0.0025(*Female*) + 0.2943(*Minority*) + 0.3359(*Univ*) + 0.0166(*AA*) - 0.6590(*AG*) - 0.8410(*AI*) - 0.5099(*AR*) + 0.0050(*CA*) + 0.3058(*DA*) - 0.035(*DC*) - 0.9031(*DK*) - 0.1684(*ES*) - 1.8230(*EY*) - 0.1384(*GM*) - 0.1290(*HD*) + 0.1331(*HG*) - 0.9320(*HL*) + 0.8075(*MH*) + 0.04086(*NR*) - 0.6760(*NS*) - 0.2563(*RR*).

References

Arrow, Kenneth J. (1962), "The Economic Implications of Learning by Doing," *Review of Economic Studies*, **29** (3): 155-173.

Åstebro, Thomas (1998), "Basic Statistics on the Success Rate and Profits for Independent Inventors," *Entrepreneurship: Theory and Practice*, **23** (2): 41-48.

Åstebro, Thomas (2003), "The Return to Independent Invention: Evidence of Unrealistic Optimism, Rent Seeking or Skewness Loving," *The Economic Journal*, **113** (1), 226-239.

Audretsch, David B., Albert N. Link, and John T. Scott (2002), "Public/Private Technology Partnerships: Evaluating SBIR-Supported Research," *Research Policy*, **31** (1): 145-158.

Cahill, Pete (2006), "National Research Council Survey of Small Business Innovation Research," Preliminary report to the National Research Council.

Cohen, Wesley. M. and Levinthal, Daniel A. (1989), "Innovation and Learning: The Two Faces of R&D," *Economic Journal*, **99** (397): 569-596.

Hall, Bronwyn H. (2004), "University-Industry Research Partnerships in the United States," in *Rethinking Science Systems and Innovation Policies*, edited by Jean-Pierre Contzen, David Gibson, and Manuel Heitor, West Lafayette, IN: Purdue University Press.

Hall, Bronwyn H., Albert N. Link, and John T. Scott (2003), "Universities as Research Partners," *Review of Economics and Statistics*, **85** (2): 485-491.

Hall, Robert E. and Charles I. Jones (2007), "The Value of Life and the Rise in Health Spending," *Quarterly Journal of Economics*, **122** (1): 39-72.

Link, Albert N. (1999), "Public/Private Partnerships in the United States," *Industry and Innovation*, **6** (2): 191-217.

Link, Albert N. (2006), *Public/Private Partnerships: Innovation Strategies and Policy Alternatives*, Norwell, MA: Kluwer Academic Publishers.

Link, Albert N. and John T. Scott (1998), *Public Accountability: Evaluating Technology-Based Institutions*, Norwell, MA: Kluwer Academic Publishers.

Link, Albert N., and John T. Scott (2000), "Estimates of the Social Returns to Small Business Innovation Research Projects," in *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative*, edited by Charles W. Wessner, Washington, DC: National Academy Press.

Link, Albert N. and John T. Scott (2005), *Evaluating Public Research Institutions: The U.S. Advanced Technology Program's Intramural Research Initiative*, London: Routledge.

Link, Albert N. and Donald S. Siegel (2003), *Technology Change and Economic Performance*, London: Routledge.

Mansfield, Edwin, John Rapoport, Jerome Schnee, Samuel Wagner, and Michael Hamburger (1971), *Research and Innovation in the Modern Corporation*, New York: W.W. Norton.

Murphy, Kevin M. and Robert H. Topel (2006), "The Value of Health and Longevity," *Journal of Political Economy*, **114** (5): 871-904.

National Research Council (2004), *SBIR: Program Diversity and Assessment Challenges*, Washington, DC: National Academy Press.

National Research Council (2007), *Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program*, Washington, DC: National Academy Press.

Tibbetts, Ronald (1999), "The Small Business Innovation Research Program and NSF SBIR Commercialization Results," mimeograph.

Turner, James and George Brown (1999), "The Federal Role in Small Business Research," *ISSUES in Science and Technology*, summer: 51-58.

U.S. Small Business Administration (2006), *<http://tech-net.sba.gov/>*.

Wessner, Charles W. (2000), *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative*, Washington, DC: National Academy Press.

Wessner, Charles W. (2007), *SBIR and the Phase III Challenge of Commercialization*, Washington, DC: National Academy Press.

Wessner, Charles W. (forthcoming), *An Assessment of the Small Business Innovation Research Program at the National Institutes of Health*, Washington, DC: National Academy Press.

Zeira, Joseph (1987), "Investment as a Process of Search," *Journal of Political Economy*, **95** (1): 204-210.

Zucker, Lynne G., Michael R. Darby, and Jeff S. Armstrong, (1998a), "Geographically Localized Knowledge: Spillovers or Markets?" *Economic Inquiry,* **36** (1): 65-86.

Zucker, Lynne G., Michael R. Darby, and Marilynn B. Brewer (1998b), "Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises," *American Economic Review*, **88** (1): 290-306.

Zucker, Lynne .G. and Michael R. Darby (2001), "Capturing Technological Opportunity via Japan's Star Scientists: Evidence from Japanese Firms' Biotech Patents and Products," *Journal of Technology Transfer*, **26** (1-2): 37-58.