Public/private technology partnerships: evaluating SBIR-supported research.

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Abstract:

This paper evaluates public support of private-sector research and development (R&D) through the Department of Defense's (DoD's), Small Business Innovation Research (SBIR) Program. Based on alternative evaluation methods applicable to survey data and case studies, we conclude that there is ample evidence that the DoD's SBIR Program is stimulating R&D as well as efforts to commercialize that would not otherwise have taken place. Further, the evidence shows the SBIR R&D does lead to commercialization, and the net social benefits associated with the program's sponsored research are substantial.

Keywords: small businesses | innovation | public/partnership | research & development | program evaluation | research partnerships | research policy

Article:

1. Introduction

As greater attention is paid to public support of private-sector research and development (R&D) by participants in the innovation process, it becomes imperative for policy makers to offer an economic rationale for their support of public/private technology partnerships as well as to formulate and demonstrate means for evaluating such relationships. While scholars and policy makers have long debated the economic role of government in the innovation process and the importance of market failure as an element of that rationale, Baron (1998) has offered a focused rationale for the Small Business Innovation Research (SBIR) Program: "[T]he rational for SBIR is the same as the general argument for government R&D—positive externalities (meaning) social benefits exceeding private ones."

When market failure is the broad justification for public support of R&D performed in the private sector, the situation is not only one where social benefits exceed private benefits. As a consequence of the divergence of social benefits and costs there must be, absent support from the government, underinvestment in R&D from society's perspective. The fact that social benefits exceed private benefits is not sufficient to establish underinvestment.1 Furthermore, if government wants to justify public support with an argument based on market failure, policy makers must establish that government failure would not prevent improving R&D performance with a proposed policy.2

The government has at its disposal mechanisms to address market failure and hence, to overcome private-sector underinvestment in R&D.3 These mechanisms include creating and maintaining an economic environment conducive for innovation. Examples of such mechanisms include the patent system and the passage of the National Cooperative Research Act of 1984 to encourage research joint ventures; tax incentives to stimulate innovative investments through, for example, the 1981 R&E tax credit and its periodic renewals; and direct public/private technology partnerships to subsidize R&D, with the SBIR Program being one of several such programs.4

In addition to its important role in surmounting market failure, government should also be held accountable for its legislated policies. As Link and Scott (1998) point out, the concept of public accountability in the US traces at least to the early 1920s. But, the passage of the Government Performance and Results Act (GPRA) of 1993 emphasized the social importance of performance accountability, especially in the areas of science and technology, and has brought accountability back to center stage.

Our focus in this paper is on the SBIR Program. We do not debate the appropriateness of the government's support of that program but take that as a historical given and turn directly to evaluating the program's results.5 In Section 2, we briefly describe the SBIR Program, with particular emphasis on the Department of Defense's (DoD's) SBIR Program. In Section 3, we outline our evaluation methodology and present our findings with an emphasis on the social returns associated with SBIR-funded research. Concluding remarks are presented in Section 4.

2. An overview of the SBIR Program

The SBIR Program began at the National Science Foundation in 1977.6 At that time, the goal of the program was to encourage small businesses—considered by many to be engines of innovation in the US economy—to participate in NSF-sponsored research, especially research that had commercial potential. Because of the early success of the program at NSF, Congress passed the Small Business Innovation Development Act of 1982. The 1982 Act required all government departments and agencies with external research programs of greater than US$ 100 billion to establish their own SBIR Program and to set aside funds equal to 0.2% of their external research budget.7

The 1982 Act states the following objectives of the program:

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.

In 1987, the funding percentage increased to 1.25%. The Act was later reauthorized by the Small Business Innovation Research Program Reauthorization Act of 1992, and the funding percentage increased to 1.5%. Since 1997, agencies have set aside 2.5% of their external research budgets for SBIR.

Justification for the reauthorization, as stated in the 1992 Act, was that the program:

> … has effectively stimulated the commercialization of technology development through federal research and development, benefiting both the public and private sectors of the Nation.

Clearly, given the complete list of stated objectives of the program dating from the 1982 Act, its rationale would be broader than the objective of correcting the market failure of underinvestment in R&D. In addition to addressing underinvestment in R&D, the SBIR Program has as well the goal of promoting diversity per se in the population of firms doing R&D.8 Here, we focus on the market failure, underinvestment justification for the SBIR Program.

The DoD’s SBIR Program solicits proposals from eligible small businesses twice a year, and the awards are of three types.10 Phase I awards are relatively small, generally less than US$ 100,000. The purpose of these awards is to help firms assess the feasibility of the research they propose to undertake for the agency in response to the agency’s objectives. Phase II awards are larger, averaging about US$ 750,000. These awards are for the firm to undertake and complete its proposed research, ideally leading to a commercializable product or process. So-called Phase

III awards do not come from DoD, but rather from the private sector to the researching company to pursue commercialization. Table 1 provides a funding history of DoD's SBIR Program.

Table 1. DoD SBIR budgets and awards, by fiscal year [a]

Fiscal year	Budget (US$ (M))	Phase I awards	Phase II awards
1983	16.70	281	0
1984	42.79	368	115
1985	79.00	513	282
1986	153.00	1031	254
1987	202.00	1264	401
1988	221.80	1056	334
1989	234.40	1021	362
1990	239.26	1140	415
1991	233.53	963	318
1992	241.84	1063	434
1993	384.82	1285	535
1994	276.19	1371	417
1995	445.25	1263	575
1996	453.46	1372	613
1997	543.02	1526	639
1998	553.44	1286	674
1999	541.31	1393	569

a Source: http://www.sbirsttr.com/sbirmisc/annrpt.html.

3. A methodology for evaluating the SBIR Program

Our methodology for evaluating DoD's SBIR Program, which can be applied to other programs, includes three elements:

1. A broad-based statistical analysis of SBIR recipients.

2. A case-based investigation of recipients regarding the impacts associated with SBIR awards.

3. A case-based investigation of the social rate of return from SBIR-funded research.

Data limitations associated with the SBIR Program, as well as with most public/private partnerships, and the multi-faceted nature of program evaluation per se, led us to adopt a broad-based evaluation methodology. Although survey-based information on SBIR recipients is used to conduct what some may view as a traditional evaluation exercise (Section 3.1), we are reluctant to draw program evaluation conclusions from only that analysis since the respondent sample is limited in size and since there is a limited literature to which these econometric findings could be compared.11 We have relied on case studies (3.2 and 3.3) to complement our statistical analysis and to facilitate asking broader evaluation questions. Of course, case studies are not without their limitations including representativeness issues and possible interview biases. However, as a whole, our approaches are complementary and our findings are robust, both of which are important elements of a systematic evaluation effort. We conclude that DoD's SBIR Program is encouraging commercialization from research that would not have been undertaken without SBIR support; and, moreover, it is overcoming reasons for market failure that cause the private sector to underinvest in R&D.

3.1. Innovation and commercialization efforts of SBIR awardees

As noted above, two of the legislated goals of the SBIR Program are "to stimulate technological innovation" and "to increase private sector commercialization of innovations derived from federal research and development." As a first step toward an evaluation of the DoD's SBIR Program, we sought to understand the extent to which innovation and commercialization have been achieved among SBIR awardees. This background analysis in and of itself does not constitute an evaluation of the SBIR Program, but rather it provides some initial insight into the magnitude of the commercialization that occurs, and the characteristics of companies that are commercializing SBIR-funded products.

We rely on data collected by the National Academy of Sciences (NAS) for a representative sample of DoD SBIR awardees.12 The Academy's mail survey went to a sample of 379 SBIR companies that received a Phase II award, since 1992. A total of 232 surveys were returned partially or totally completed. The 112 completed surveys with all of the information needed for our analysis are analyzed here.

Since, the purpose of this background analysis was to gain a better understanding of the commercialization activity that has occurred, we considered a model to explain cross-company differences in actual sales realized to date (the survey was administered in early 1999) from the technology developed during the DoD-funded Phase II project (ActSales).13 Thus, our model is

$$\text{ActSales}_i = f(\boldsymbol{X}_i)$$

where the subscript *i* indexes each awardee company and the vector ***Xi*** contains company-specific characteristics as described in Table 2. The dependent variable in Eq. (1), ActSales, is the actual sales realized to date from the technology developed during the Phase II project, measured in dollars. Although the mean of ActSales is US$ 175,021, that reflects the fact that 78 of the 112 projects reported no sales. For the 34 projects reporting sales, the mean of ActSales is US$ 576,539.

Table 2. Characteristic variables in Eq. (1) (*n*=112)

Variables	Definition	Mean	Range	S.D.
AgeBus	Age of the company measured in years	11.13 years	1–36	7.417
ExpFounder	Equals to one, if the most recent employment of the company founder(s) was in another private company as opposed to a university or government agency, and zero otherwise	0.786	0/1	0.412
Revenues	Company revenues were reported in ranges: less than US$ 100,000; US$ 100,000–499,999; US$ 500,000–999,999; US$ 1,000,000–4,999,999; US$ 5,000,000–19,999,999; and over US$ 20,000,000. The midpoint of each range was used with US$ 50,000 defining the midpoint of the lower bound and US$ 25,000,000 defining the midpoint of the upper bound	US$ 5,547,321	US$ 50,000–25,000,000	7162364
PhaseII	Number of previous Phase II awards	6.01 awards	0–81	12.384
Complete	Equals to one, if the current Phase II award is completed, and zero otherwise	0.366	0/1	0.484
Market	Equals to one, if the company has underway or has completed a marketing plan, and zero otherwise	0.589	0/1	0.494
Active	Number of years since the awarding of the most recent Phase II award	2.82 years	1–6	1.195
Electronics	Equals to one, if the relevant technology area of the award is electronics, and zero otherwise	0.500	0/1	0.502

Computer	Equals to one, if the relevant technology area of the award is computer, information processing, and analysis, and zero otherwise	0.214	0/1	0.412
Materials	Equals to one, if the relevant technology area of the award is materials, and zero otherwise	0.071	0/1	0.259
Mechanical	Equals to one, if the relevant technology area of the award is mechanical performance of vehicles, weapons, and facilities, and zero otherwise	0.045	0/1	0.207
Energy	Equals to one, if the relevant technology area of the award is energy conservation and use, and zero otherwise	0.098	0/1	0.299
Environment	Equals to one, if the relevant technology area of the award is environment and natural resources, and zero otherwise	0.045	0/1	0.207
LifeScience	Equals to one, if the relevant technology area of the award is life sciences, and zero otherwise	0.027	0/1	0.162
FastTrack	Equals to one, if the Phase II award was a Fast Track award, meaning that outside private-sector funding was committed to the project before the SBIR award was made, and zero otherwise	0.161	0/1	0.369
ProbResponse	Probability of response to the original NAS survey (the Probit model predicting probability of response used variables that were available for 109 of the 112 observations)	0.659	0.271–0.998	0.175

One clear implication of these survey data is that SBIR awardees do commercialize products and services based on their SBIR-sponsored research. That general finding does show the two stated purposes of the SBIR Program noted above—stimulation of socially desirable R&D and innovation that would not occur without the SBIR Program and commercialization of the R&D results—are met. We turn now with an econometric model to details of the commercialization.

Least-squares analysis is not appropriate for estimating Eq. (1) since the dependent variable is truncated at zero.14 Least-squared results do not explicitly use the information about threshold effects on sales, and thus, such estimation would predict negative sales for some observations. We use the tobit model to estimate Eq. (1); the tobit model can be interpreted as predicting a measure of the value of sales from the SBIR project. If the predicted value is positive, then the company commercializes a product or service and then has sales; otherwise, sales are zero. The results for the tobit estimations are in Table 3.15

Table 3. Estimated tobit results from Eq. (1) (asymptotic *t*-statistics in parentheses)

Variable	Estimated coefficient	Estimated coefficient
Intercept	−2310466 (−3.161)***	−1406461 (−1.292)
AgeBus	−13045.5 (−0.457)	−11542.7 (−0.419)
ExpFounder	−43146.1 (−0.127)	11598.1 (0.034)
Revenues	0.0532968 (2.250)**	0.0432694 (1.760)*
Phase II	−7401.9 (−0.521)	−6718.9 (−0.476)
Complete	707243.6 (2.117)**	536615.9 (1.583)
Market	1147888 (3.082)***	1171060 (3.213)***
Active	62991.5 (0.414)	29066.1 (0.178)
Computer	654036.6 (1.801)*	597507.1 (1.660)*
Materials	849108.7 (1.773)*	899354.4 (1.884)*
Energy	379947.9 (0.769)	254938.4 (0.519)
Environment	919731.2 (1.710)*	821494.6 (1.555)
LifeScience	124461.1 (0.165)	20594.2 (0.028)
FastTrack	−82285.4 (−0.213)	2868.0 (0.007)
ProbResponse	–	−1078063 (−1.134)
Log likelihood	−540.98	−539.41
χ^2	41.95 (13)***	43.15 (14)***
n d.f.	112	109

* Significant at the 0.10 level.

** Significant at the 0.05 level.

*** Significant at the 0.01 level.

The tobit results in column (2) of Table 3 lead us to conclude that companies are indeed commercializing products from their SBIR projects. Those that have done so to date are the larger companies in the computer technology area, materials technology area, and environmental technology area that have both completed their Phase II research as well as have formulated a marketing plan.16 The specification reported in column (3) includes an additional explanatory variable, ProbResponse. If the probability of responding to the NAS survey is associated with actual sales (ActSales), and if that response effect in the error term is correlated with the variables included in X, the estimates in column (2) of Table 3 could be biased, hence, the inclusion of the variable ProbResponse.17

Using the tobit models in Table 3, we estimated for each project the expected value of sales conditional on the tobit index function being greater than zero (and hence, conditional on the realized sales being greater than zero). Formally, we estimate the conditional mean of the tobit index function in the positive part of its distribution for each observation. The average of these conditional means is US$ 603,231 for the specification without the control for response bias and US$ 598,698 for the specification with the control.18 Estimating the expected sales for each observation given Xi (that is, the probability weighted sum of the outcome of US$ 0 of sales as well as the positive outcomes), we find on average for all of the observations the expected sales are US$ 217,267 for the specification without control for response bias and US$ 223,244 for the specification with the control.19

These findings, along with case-based information that in the absence of SBIR support the SBIR firms would not have pursued Phase II research or would have pursued it on a very limited scale, lend support for our preliminary conclusion that the program is meeting two of its stated goals.20 We reach these conclusions based on our interpretation of the statistically significant tobit coefficients and models.

However, because two program goals are being met, in total or in part, is in our opinion insufficient information upon which to base even a preliminary economic evaluation of the overall program. What must be shown is that companies would not have undertaken the research on their own because of insufficient private returns and that SBIR funding overcomes market failures benefiting society with a large social return. In the following two sections, we, therefore, add two more elements of evaluation. We use case studies to show that the SBIR Program encourages new entrepreneurs, actually changing the career paths of some researchers and bringing their talents and ideas into the commercial world. Then, additional case studies are used to demonstrate the large social return from the projects that are made possible by the SBIR Program.

3.2. Entrepreneurial behavior and the SBIR Program

To develop information about the extent to which the SBIR Program changes the behavior of knowledge workers and thereby helps to create a science-based entrepreneurial economy, Audretsch et al. (2000b) use case studies along with responses to a survey of a broader sample of firms with SBIR projects. Although the authors emphasize that their results are exploratory and based on a small sample, their results do show that the SBIR Program has influenced the career paths of scientists and engineers by facilitating the startup of new firms. Additionally, the experience of those knowledge workers in commercializing products and services with a small business has had a spillover effect by influencing the career trajectories of their colleagues.

Audretsch et al. report that both their survey and their case studies provide consistent evidence that:

1. A significant number of the firms would not have been started in the absence of the SBIR Program.

2. A significant number of the scientists and engineers would not have become involved in the commercialization process in the absence of the SBIR Program.

3. A significant number of other firms are started because of the demonstration effect by the efforts of scientists to commercialize knowledge.

4. As a result of the demonstration effect of SBIR funded commercialization, a number of other scientists alter their careers to include commercialization efforts.

Especially for scientists and engineers without previous experience with knowledge-based small firms, the SBIR Program appears to encourage the development of knowledge about commercialization possibilities and facilitate commercialization from research-based knowledge.

3.3. Estimating social returns from SBIR-supported projects

3.3.1. Conceptual framework for analysis

It is well known that risk and the closely related difficulties of appropriating return to investments in technology—R&D specifically—will lead to a divergence between private and social benefits. The social rate of return will be greater than the private rate of return as illustrated in Fig. 1.21 The purpose of this simple heuristic device is to characterize private sector projects with returns not only less than the expected social returns but also less than the private hurdle rate for projects normally undertaken by the firm. In those cases, the divergence of private from social returns can imply the market failure of private underinvestment in socially desirable R&D.

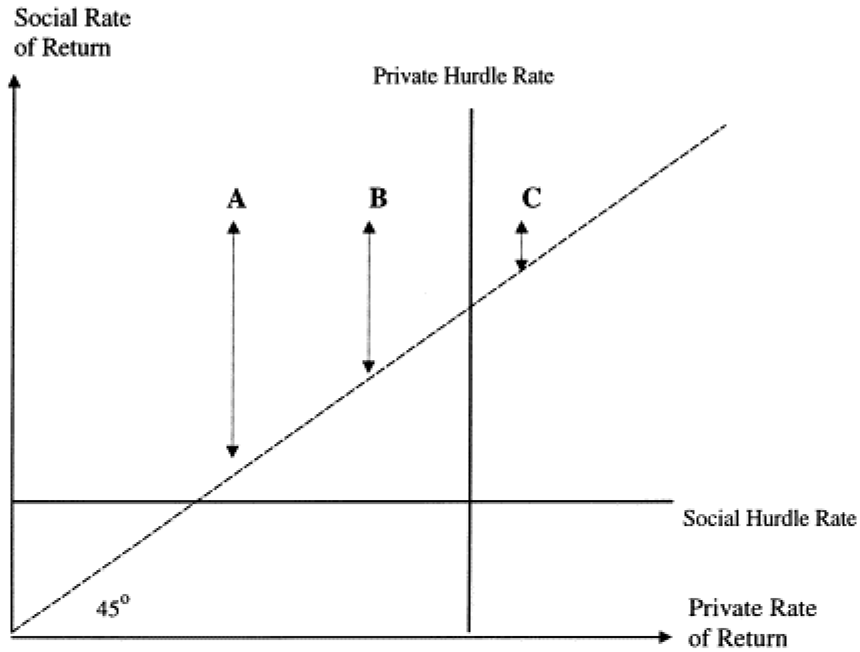

Fig. 1. Gap between social and private rates of return to R&D projects.

The social rate of return is measured on the vertical axis of Fig. 1 along with society's hurdle rate on investments in R&D. The private rate of return is measured on the horizontal axis along with the private hurdle rate on investments in R&D. A 45° line (dashed line) is imposed on the figure to emphasize that for the projects depicted the social rate of return from an R&D investment exceeds the private rate of return from that same investment. The three illustrative projects discussed below are labeled as project A, B, and C.

For project C, the private rate of return exceeds the private hurdle rate, and the social rate of return exceeds the social hurdle rate. The gap (short vertical double arrow line) between the social and private rates of return reflects the spillover benefits to society from the private investment. However, the inability of the private sector to appropriate all benefits from its investment is not so great as to prevent the project from being adequately funded by the private firm. Hence, it is not a candidate for public support.

Consider projects A and B. The gap between social and private returns is larger than in the case of project C; neither project will be adequately funded by the private firm. To address this market failure the government has two alternative policy mechanisms. It can use a tax policy to address the private underinvestment in R&D or it can rely on public/private partnerships as a direct funding mechanism.

If the private return to project B is less than the private hurdle rate because of the risk and uncertainty associated with R&D in general, then tax policy may be the appropriate policy mechanism to overcome this underinvestment. Risk is inherent in a technology-based market, and there will be certain projects for which the rewards from successful innovation are too low for private investments to be justified. Tax policy, such as the R&E tax credit, may in these situations reduce the private marginal cost of R&D sufficiently to provide an incentive for the project to be undertaken privately. For projects like project B, a tax credit may be sufficient to increase the expected return so that the firm views the post-tax credit private return to be sufficient for the project to be funded.

However, for projects like project A, a tax credit may be insufficient to increase the expected return enough to induce the private firm to undertake the project. Such projects could include for example projects expected to yield an innovative product that would be part of a larger system of products. Even if technically successful there might be substantial risk that the product would not interoperate or be compatible with other emerging products, and direct funding rather than a tax credit may be the appropriate policy mechanism to stimulate socially desirable investments in systems.

A priori, it is difficult to generalize about the way that any one firm's under-funded projects will be distributed in the area to the left of the firm's private hurdle rate. However, some generalizations can be made about the portfolio of private sector firms' projects in general. For those R&D projects, like project B, for which the firm will appropriate some returns but for which the overall expected return is slightly too low, a tax credit may be sufficient to increase the expected return to the point that the expected return exceeds the private hurdle rate. Such projects may be of a product or process development nature and are likely to be a part of the firm's ongoing R&D portfolio of projects. For those R&D projects, like project A, for which the firm has little ability to appropriate returns even if the marginal cost of the project is reduced through an R&E tax credit, the firm may not respond to such a tax policy but may respond to a direct funding policy mechanism. Such projects may be of a generic or fundamental technology nature, that is technology from which subsequent market applications are derived and that enable downstream applied R&D to be undertaken successfully. Thus, the economic rationale for public/private partnerships is that such partnerships represent one direct-funding R&D policy appropriate to overcome market failure and that they are more likely to be necessary, compared to fiscal tax incentives, when the R&D is generic or fundamental in nature.

Drawing upon the foregoing arguments, we maintain that a candidate project for SBIR awards is one like project A in Fig. 1. That is, given that the proposed research aligns with the technology mission of DoD, SBIR should fund such projects for which there is a significant potential social benefit but also that are characterized by substantial downside risk such that the firm’s expected private return is well below its private hurdle rate.

Case-study information reported by Link (2000) and Scott (2000a) confirms for a small sample of SBIR-supported projects that not only are the firms’ private returns less than their private hurdle rates but also that outside investors are unwilling to sponsor fully the research because of both technical and market risk. Hence, at the outset of an SBIR project, not only is a firm’s private hurdle rate not expected to be met, neither is the required return for a third party. In conjunction with the evidence presented below that the projects have high social returns, the findings support the belief that the SBIR Program corrects the market failure of underinvestment in socially-valuable research in emerging technologies.

3.3.2. Preliminary estimates of social returns

Link and Scott (2000) interviewed SBIR award recipients for 44 projects in 43 companies for this part of the evaluation study. Each was interviewed toward the end of its Phase II award period. Information collected made possible the calculation of a lower-bound of the prospective expected social rate of return associated with each project and a comparison of that expected social rate of return to both the expected private rate of return to the firm had it pursued the project in the absence of SBIR support and the private rate of return expected by the firm with its SBIR support. The analysis clearly indicates that SBIR is funding projects like project A in Fig. 1, and given such funding the projects have become similar to project C.

The sample of projects studied may not be statistically representative of all projects funded by SBIR. To make such a claim, all would have to be interviewed to obtain information similar to the information collected. This was not done because of resource constraints and the availability of SBIR staff to identify specific individuals to be interviewed and to make initial contacts. Thus, the sample of 44 projects is simply one sample, and the findings are not necessarily representative of all SBIR projects. However, because the findings are strong, and because the anecdotal information obtained from SBIR staff indicates the sample was a reasonable cross-section of funded companies, we are comfortable generalizing to some degree about the findings. In any event, the methodology of Link and Scott (2001) is sufficiently general to be applied to other samples.22

Table 4 lists the variables required for the implementation of the model. As noted in the table, data on selected variables were independently available from DoD project files, but all such information was also verified during the interview process and corrected when discrepancies were found. Descriptive statistics for these variables are in Table 5.

Table 4. Variables for the prospective expected social rate of return calculations

Variable	Definition	Source
d	Duration of the SBIR project	DoD files, verified and updated as necessary during interviews
C	Total cost of the SBIR project	DoD files, verified and updated as necessary during interviews
A	SBIR funding	DoD files, verified and updated as necessary during interviews
r	Private hurdle rate	Interview
z	Duration of the extra period of development beyond Phase II	Interview
F	Additional cost for the extra period of development [a]	Interview
T	Life of the commercialized technology	Interview
v	Proportion of value appropriated	Interview
L	Lower bound for expected annual private return to the SBIR firm	Derived
U	Upper bound for expected annual private return to the SBIR firm	Derived

a The additional costs considered were research and development costs and not the costs associated with searching for or negotiating with venture capitalists. See Gans and Stern (2000).

Table 5. Descriptive statistics on variables used in the social rate of return model (*n*=44)

Variable	Mean	Range	S.D.
d	2.68 years	2–3.5	0.36
C	US$ 1,027,199	US$ 448,000–3,450,000	461901
A	US$ 782,000	US$ 448,000–1,099,966	127371
r	0.33	0.2–0.5[a]	0.08
z	1.30 years	−0.375–5.0[b]	1.07
F	US$ 1,377,341	US$ 0–15,000,000	2972266
T	10.56 years	1–30[c]	7.23
v	0.16	0.0045–0.60	0.16
L	US$ 902,738	US$ 34,842.6–5,300,500	1228850
U	US$ 1,893,001	US$ 258,830–8,666,330	1733581

a Eight of the respondents were uncomfortable estimating the private hurdle rate that outside financiers would apply to their projects at their outset. For those, the average value of *r* for the respondents in their region was used in the calculations.

b One observation for *z* has a negative value because commercial returns started before the end of Phase II.

c One respondent reported that *T* would be several decades, and another reported that *T* would be forever. In both cases, *T* was conservatively entered as the value 30 years. However, because the relevant discount rates are so high, the difference between 30 years and “forever” is not significant. In the integrals in the mathematical model, the term with *T* entered negatively as an exponent would become zero, but with a large value of *T* the term is very small in any case.

Phases I and II values for project duration, total cost, and SBIR funding, were combined into one value to cover both Phases I and II of the project. That is, each project is viewed from the time that Phase I began, and expectations from that point forward are estimated. It is at that point in time that the market failure issues discussed above are especially relevant. Respondents reported the additional period of time beyond the expected completion of Phase II until the research would be commercialized and the additional cost required during that period.

The variable ν, the proportion of value appropriated, deserves some explanation. Firms cannot reasonably expect to appropriate all of the value created by their research and subsequent innovations. First, the innovations will generate consumer surplus that no firm will appropriate, but that society will value. Link and Scott ignore consumer surplus in the calculations of the prospective expected social returns thus motivating the claim that the estimates are lower-bound estimates. Second, some of the profits generated by the innovations will be captured by other firms. Larger firms, for example, will observe the innovation and will successfully introduce imitations. Each respondent as part of the interview process was asked to estimate the proportion of the returns to producers (themselves and other firms) generated by their anticipated innovation that they expect to capture. Then, in an extended conversation, other possible applications of the technology developed during the SBIR project were explored. Each respondent was asked to estimate the multiplier to get from the profit stream generated by the immediate applications of the SBIR project to the stream of profits generated in the broader applications markets—beyond the applications to be made by the SBIR firm—that would reasonably be anticipated. We calculated ν as the product of two proportions. The first is the proportion anticipated by the SBIR firm of the profits from the development and commercialization of the specific applications it planned for the technology being developed. The second is the proportion of profits from all possible applications—including those beyond the applications that the SBIR firm anticipated making itself—taken by the respondent's planned applications of the generic technology being researched and developed in the SBIR project. Thus, ν is the total proportion of the value of the technology appropriable by the researching firm. For example, if an SBIR firm anticipated appropriating 50% of the profits generated by its planned types of applications of its SBIR technology, and if the profits from the types of applications planned by the SBIR firm were expected to be 50% of the profits from all applications of the technology, then the SBIR firm would expect to earn 50% of a profit stream that itself was 50% of the total profit stream attributable to the SBIR generated technology. The firm, therefore, would anticipate appropriating 25% of the profits generated by its SBIR project.

Link and Scott then find the lower bound for the annual private return to an SBIR-sponsored project by solving their investment model for the amount that the private firm must earn to meet its private hurdle rate, or its required rate of return, on the portion of the total investment that the firm must finance.23 The firm would not invest in the SBIR project on its own unless it expected at least that lower bound for the annual private return on its investment.

To determine the upper bound for the annual private return, the investment model is solved for the expected annual return that if exceeded would imply that the expected rate of return earned by the private firm would be greater than its hurdle rate in the absence of SBIR support, and therefore, SBIR support would not be required for the project.

Sequentially, Link and Scott estimate the average expected annual private return to the firm as the average of the upper and lower bounds, U and L. Knowing the average expected annual private return is ((L+U)/2) and knowing the portion of producer surplus that is appropriable, ν, then total producer surplus equals ((L+U)/2ν). This value for total producer surplus is a lower bound for the expected annual social return. Again, it is a lower bound because consumer surplus has not been measured.

The expected private rate of return without SBIR support is the solution for the internal rate of return—the rate of return that just equates the present value of the expected annual private return to the firm to the present value of research and post-research commercialization costs to the firm in the absence of SBIR funding.

Finally, the lower bound on the social rate of return is found by solving the investment model for the internal rate of return with the average expected annual private return ((L+U)/2), replaced with the lower bound for the average expected annual social return ((L+U)/2ν).

The investment model was estimated for each of the 44 SBIR-sponsored projects. Mean values of the two resulting important rates of return, averaged across the 44 projects, are shown in Table 6. There are two important points to be seen in Table 6. First, the average of the expected private rate of return in the absence of SBIR support is 25%, clearly less than the average self-reported private hurdle rate of 33% (see Table 5). Thus, in the absence of SBIR support the sample of firms would not have undertaken the research, and in fact each of the sampled firms stated that explicitly during the interviews. Further, the expected social rate of return (lower bound) associated with SBIR funding of these projects is at least 84%, and hence, the projects are expected to be socially valuable.

Table 6. Rates of return for the average SBIR project (*n*=44)

Variable	Definition
$i_{private} = 0.25$	Expected private rate of return without SBIR funding
$i_{social} = 0.84$	Lower bound for expected social rate of return

We cannot conclude that a social rate of return of at least 84% is “good” or “bad,” or “better” or “worse” than expected. However, we can compare the estimate of the lower bound of the social rate of return to the opportunity cost of public funds promulgated by the US Office of Management and Budget (OMB). Following the guidelines set forth by OMB (1992) mandating a real discount rate of 7% for constant-dollar benefit-to-cost analyses of proposed investments and regulations, clearly a nominal social rate of return of 84% is above that rate and thus, reflects projects that are socially worthwhile in terms of the OMB standard.24

The expected private rate of return with SBIR support for each of the 44 projects can be calculated as the solution for the internal rate of return in the investment model given the actual time series of private investments and private returns. The estimated private rate of return with SBIR support averages 76% for the 44 cases, this value is noticeably above the average private hurdle rate of 33%. However, there is no way for the SBIR Program to have calculated the optimal level of funding for these 44 projects, or for any projects, unless, as part of the Phase I application all relevant data, including hurdle rates, could have been assessed. In the absence of such information, which in practice would be difficult to obtain because of, if nothing else, self-serving reporting by proposers, the funding implemented by the SBIR Program may be as close to optimal as possible.25

Fig. 2 summarizes the estimated values for the average SBIR-sponsored project. Based on the sample of 44 projects, the average gap between the lower-bound social rate of return and the estimated private rate of return without SBIR funding support is 59%.

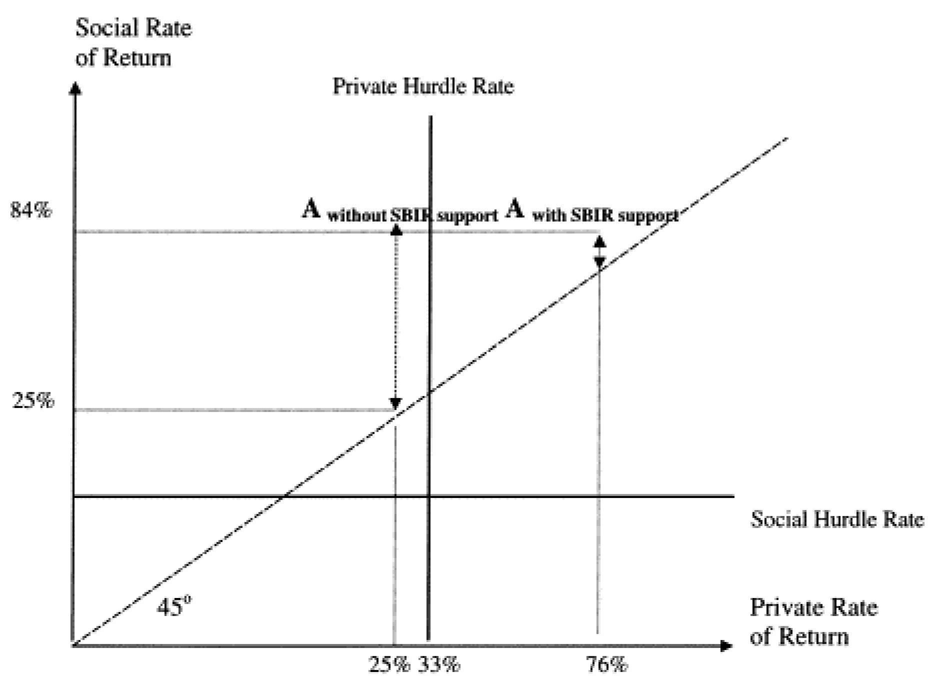

Fig. 2. Gap between social and private rates of return to the average SBIR project, n=44.

Two points need to be emphasized, along with our previous comments about the statistical representativeness of the sample of 44 companies. First, the social rates of return estimated for the SBIR projects are very conservative, lower-bound estimates because they do not include consumer surplus in the benefit stream. Second, some might be skeptical about the SBIR awardees' earnest belief that without SBIR funding the projects would not have been undertaken or at least would not have been undertaken to the same extent or with the same speed. With the SBIR Program in place, certainly the pursuit of SBIR funding would perhaps be a path of least resistance. However, if the research would have occurred without the public funding, the estimated upper bound and (hence the average of the upper and lower bounds for the expected private returns) would be too low, and the actual lower bounds for the social rates of return would be even higher than estimated. Further, the gap would remain, although that would not in itself necessarily justify the public funding of the projects.

4. Concluding remarks

Based on our three-part evaluation analysis, and the caveats associated with each, there is ample evidence to support the conclusion that the net economic benefits associated with DoD's SBIR Program are positive. More specifically, our broad-based statistical analysis of SBIR recipients demonstrates that two of the program's objectives—stimulating technological innovation and increasing private sector commercialization of innovations derived from federal research and development—are being met. In addition, the case-based analyses demonstrate that the SBIR Program redirects the efforts of award recipients toward commercial activity that would not otherwise have taken place, and that commercial activity and its attendant spillover effects generate substantial positive net social benefits.

Although our conclusions are robust, it is important to emphasize that our analysis is specific to DoD's SBIR Program. Until studies of other agencies' SBIR programs take place, one should be extremely cautious about generalizing from our DoD SBIR findings to the entire SBIR Program.26

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An earlier version of this paper was presented at the January 2000 American Economic Association meetings in the session “Government as Venture Capitalist: Evaluating the SBIR Program.” We appreciate the comments and suggestions from participants at that session as well as those from two anonymous referees.

1 See Baldwin and Scott (1987).

2 While closure on the economic rationale for government policies supporting innovation may be at hand, Klette et al. (2000) explain that documenting both market failure and successful government programs to overcome it is quite difficult (and when government programs are not successful in overcoming market failure there is government failure). Kealey (1997) even challenges the conventional wisdom that government support for science is useful.

3 Martin and Scott (2000) associate various policy mechanisms with sector-specific market failures that the mechanisms address.

4 See Link (1999) for a review of public/private partnerships in the United States.

5 See Lerner (1999) for a discussion of the appropriateness of the government as a venture capitalist through SBIR Programs. See also Lerner and Kegler (2000) for a review of the literature related to SBIR Programs.

6 Tibbetts (1999) provides a history of the development of this program.

7 As a set aside program, the SBIR Program redirects existing research funds rather than appropriating new research funds.

8 Scott (2000b) shows that the private sector is much less likely to provide funding to DoD SBIR-funded projects that are in certain technology areas, in certain geographic regions, or minority-owned. Such projects may well address underinvestment, but they could also promote diversity as an independent goal in itself.

9 For an overview of the program, see http://www.acq.osd.mil/sadbu/sbir/overview.html.

10 An eligible independently owned (at least 51% owned by US citizens) and operated company must be for-profit with 500 or fewer employees.

11 See Lerner and Kegler (2000) for a review of this literature.

12 These data are described in Cahill (2000).

13 See Audretsch et al. (2000a) for a preliminary analysis of expected sales.

14 However, in the present case, the results reported regarding the signs and significance of the explanatory variables and the general conclusions about commercialization do obtain in the corresponding least-squares regressions. The least-squares results were presented in the earlier version of this paper that was presented at the American Economic Association’s meetings, and they are available on request from the authors.

15 The intercept reflects an effect for electronics and mechanical technologies. There are just five firms in the mechanical technology area, and a dummy variable for that technology area is a perfect predictor for the occurrence of US$ 0 of sales. However, our a priori knowledge of projects in that area tells us that the probability of sales is not zero; rather, with just five observations, it was happenstance that none of those projects had actual sales. We have included these five cases, along with the 56 firms in the electronics technology area, 44 of which have US$ 0 in actual sales, in the intercept term. In alternative tobit estimations (available upon request from Link or Scott), we deleted these mechanical technology cases from the sample, and the qualitative findings (signs and significance and approximate magnitudes) are unchanged.

16 As shown in Audretsch et al. (2000a), Fast Track projects have higher expected sales, other things held equal in an OLS estimation, but those projects did not begin until 1996, and

therefore, by 1999 they had realized less actual sales than the older projects, although the effect is not significant.

17 There are just 109 observations available for the specification including ProbResponse, because three of the 112 observations did not have all of the variables used in the probit model of response. We also calculated a response hazard rate but its inclusion in Eq. (1) in place of ProbResponse gives results similar to those reported in column (3) of Table 3 (results are not reported here but are available upon request from Link or Scott).

18 There is little qualitative difference between the results when a response hazard rate is substituted for the probability of response in the specification. Using the response hazard rate, the average of the conditional means is US$ 602,483.

19 For the specification that replaces the probability of response with the hazard rate, the average value of expected sales is US$ 223,450.

20 See Link (2000), and Scott (2000a) for case-based information that these companies report that in the absence of SBIR support they either would not have pursued Phase II research, or would have done so on a very limited scale.

21 A more complete explanation for this figure and for the theoretical model underlying the derivation of social and private returns is in Link and Scott (2001). See also Jaffe (1998) for an application of a similar figure to the Advanced Technology Program.

22 A complete description of the sample of companies is available upon request.

23 The theoretical mathematical model is available from either Link or Scott. A complete and detailed description of the model, along with an illustrative implementation of it based on project data from the Advanced Technology Program is in Link and Scott (2001).

24 Link and Scott (1998) discuss the use of this guideline for NIST economic impact assessments.

25 Scott (1998) has proposed using a bidding mechanism that, if applied, would result in the SBIR funding being just sufficient to ensure that the private participants earn just a normal rate of return. The proposal is a novel one, however, it is yet untried. Successful implementation would require additional development in order to reduce it to practice.

26 As these studies take place, by agency, consideration should be given to having matched samples of firms, that is firms with and without SBIR support, to obtain comparative evaluation estimates of the marginal impact of the program. See Wallsten (2000).