Government as entrepreneur: Evaluating the commercialization success of SBIR projects.

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Abstract:

Thinking of government as entrepreneur is a unique lens through which to view a subset of government actions. The lens is not a template for an evaluation of government policy; rather, it is a characterization that underscores the government's purposeful intent, ability to act in new and innovative ways, and willingness to undertake policy actions that have uncertain outcomes. Our focus is on the U.S. Small Business Innovation Research (SBIR) program. We argue that the innovative action of government – the innovative use of public resources through the SBIR program to target and support research in small firms – does lessen innovation barriers that cause small firms to underinvest in R&D. However, this government action is subject to entrepreneurial risk, namely the a priori uncertainty that the funded research will result in a commercialized product, process, or service. We quantify the uncertainty that the government accepts in the context of innovation supported by the SBIR program; or stated alternatively, we quantify the probability that a project funded by the SBIR program will fail to commercialize its results. Our empirical results show that the entrepreneurial risk that characterizes the SBIR program is, on average, somewhat more than the probability of failing to get heads on the toss of a fair coin. Importantly, however, our evidence shows that there is a large range in the entrepreneurial risk that the government accepts—across the projects, the predicted probability of failure covers essentially the entire range from 0 to 1.0.

Keywords: government entrepreneur | small business innovation research | research and development | research policy | economics | entrepreneurship

Article:

1. Introduction

Government, the aggregation of public-sector agents, acts as entrepreneur in the provision of technology infrastructure when its involvement in the overall process of technological change is both innovative and characterized by entrepreneurial risk (i.e., uncertainty). Government, primarily at the national level, provides technology infrastructure through public and quasi-

public institutions, as well as through public and quasi-public goods and services that leverage the innovation process. Through its actions providing technology infrastructure, government supports mechanisms, institutions, and platforms to lessen innovation barriers that cause market failure for investments in all stages of technology-based economic activity. Furthermore, government supports the design, deployment, and use of both individual technology-based component goods and the systems of such component goods that enhance a knowledge-based economy. Government is also involved in the provision of services that leverage innovation by making private sector R&D more effective. By perceiving opportunity and acting on that perception to provide such technology infrastructure – institutions, goods, and services – and assuming the entrepreneurial risk associated with providing it, government acts as entrepreneur.2

Our conceptualization of government as entrepreneur – providing technology infrastructure when its involvement is both innovative and characterized by entrepreneurial risk – draws from the intellectual thought of Cantillon, who built upon his idea that the entrepreneur is an agent of innovation who assumes the risk associated with uncertainty – entrepreneurial risk – and Baudeau and Schumpeter, who fostered the idea that the entrepreneur is one who innovates, creatively as opposed to adaptively, and applies new techniques. In Section 2, we briefly review key ideas from these writers.

Thinking of government as entrepreneur is a unique lens through which to view a subset – clearly not all government endeavors are entrepreneurial – of government actions. The lens is not a template for an evaluation of government policy; rather, it is a characterization that underscores the government's purposeful intent, ability to act in new and innovative ways, and willingness to undertake policy actions that have uncertain outcomes.

Building on the arguments of Link and Link (2009), we do not take the position, much less advocate, that government should be more or less entrepreneurial. Rather, we argue that a new aspect of a taxonomy of government policy actions should be considered, and we are sanguine about its usefulness. Viewing particular policy actions through an entrepreneurial lens could be useful in at least two broad dimensions. First, viewing particular government policy actions – the U.S. Small Business Innovation Research (SBIR) program in the case of this paper – as entrepreneurial underscores the forward looking nature of policies as well as the need to evaluate their social outputs and outcomes in terms of broad spillover impacts. And second, the concept of government as entrepreneur emphasizes parallels between the government's policies and similar activities that occur in the private sector. Baumol et al. (2007, p. 2) recently suggested that: “if the United States wishes to continue enjoying rapid growth, it must find a way both to launch and promote the growth of innovative entrepreneurial enterprises…” Viewing government as entrepreneur, albeit in selected areas and for selected policies, measures the

government's entrepreneurial activities against the reality of technological change because it compares entrepreneurial government policy actions with the analogous private sector activities that have led to economic growth and prosperity in all industrial nations.

In Section 3, we review the public institution, the SBIR program, that is the focus of this paper, and we argue that the innovative action of government – the innovative use of public resources through the SBIR program to target and support research in small firms – does lessen innovation barriers that cause small firms to underinvest in R&D. However, this government action is subject to entrepreneurial risk, namely the a priori uncertainty that the funded research will result in a commercialized product, process or service.

The remainder of this paper is an empirical analysis of the commercialization success of SBIR-funded projects. The empirical analysis quantifies the level of entrepreneurial risk that characterizes the SBIR program. In Section 4 we provide an overview of the data we use to estimate the probability of commercialization of an SBIR-funded research project. In Section 5 we report and discuss our empirical findings. We conclude in Section 6 with a restatement of our view of government as entrepreneur and our conclusion that the SBIR program is characterized by entrepreneurial risk. We also discuss the interpretative limitations of the paper and set forth an agenda for future empirical research in this area.

2. Intellectual thought underlying government as entrepreneur[3]

Cantillon (1680–1734) is associated with the view that the entrepreneur is one who deals with the business risks resulting because individuals do not have perfect foresight. Cantillon (1931) depicted the entrepreneur as one who exercises business judgment in the face of uncertainty. Cantillon took uncertainty for granted as something inherent in the economic activity of the marketplace. Although he did not provide a detailed analysis of the nature of risk and uncertainty, he did relate the function of the entrepreneur to uncertainty.[4] Cantillon argued that the origin of the entrepreneur lies in individuals' lack of perfect foresight. Uncertainty is a pervasive fact of everyday life, and those who must deal with it continually in their economic decisions are entrepreneurs. Consequently, it is the function of the entrepreneur, not his/her personality, which counts for economic analysis. Cantillon was quite emphatic that this function lies at the very heart of a market system, and that without it, the market as we know it, does not operate.

Baudeau (1730–1792) and Schumpeter (1883–1950) are among those who emphasized the innovative nature of the entrepreneur. Baudeau (1910) treated the agricultural entrepreneur as a risk bearer, in the manner of Cantillon (i.e., the view of the entrepreneur facing general business uncertainty), but he added a distinctive twist. He made the entrepreneur an innovator as well, one who invents and applies new techniques or ideas in order to reduce his costs and thereby raise his profit. This new aspect of entrepreneurship, innovation, represents an important advance over Cantillon's theory because it anticipated the 20th-century reformulation of entrepreneurship by Schumpeter.

The entrepreneur is the key figure for Schumpeter because, quite simply, he is the persona causa of economic development. For Schumpeter, the main instrument of change in a theory of economic development is the entrepreneur. Development is a dynamic process, a disturbing of the economic status quo.5 The leadership that constitutes innovation in the Schumpeterian sense is not homogeneous. An aptitude for leadership stems in part from the use of knowledge, and knowledge has aspects of a public good. People of action who perceive and react to knowledge do so in various ways; each internalizes the public good in potentially a different way. Schumpeter's entrepreneurial leader is distinct from a manager. According to Schumpeter (1928, p. 380), different aptitudes for the routine work of “static” management result merely in differential success at what all managers do, where different leadership aptitudes mean that “some are able to undertake uncertainties incident to what has not been done before; [indeed] … to overcome these difficulties incident to change of practice is the function of the entrepreneur.”

3. The SBIR program

In the following description of the SBIR program, we argue that government acts as entrepreneur by leading in accepting innovative risks in circumstances where the private sector would not do the entrepreneurial action even though it would be socially beneficial. The SBIR program is a public/private partnership that provides grants to fund private sector 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.6 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 success of the program at NSF, Congress passed the Small Business Innovation Development Act of 1982 (P.L. 97-219; hereafter, the 1982 Act).7

The 1982 Act required all government departments and agencies with external research programs of greater than $100 million to establish their own SBIR program and to set aside funds equal to 0.20% of the external research budget.8 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, and

(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).9 Phase I awards are small, less than $50,000 for the 6-month award period in the program's early years.10 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.11 Phase II awards were capped at $500,000; they generally lasted for 2 years. These awards are for the business to develop further its proposed research, ideally leading to a commercializable product, process, or service.12 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.13 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 1986, the 1982 Act was extended through 1992 (P.L. 99-443). In 1992, the SBIR program was reauthorized again 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%; the 1992

reauthorization raised that amount over time to 2.50% and re-emphasized the commercialization intent of SBIR-funded technologies (see point (4) of the 1982 Act above).14 The reauthorization also increased Phase I awards to $100,000 and Phase II awards to $750,000.15 The 1992 reauthorization broadened objective (3) above to focus also on women: “to provide for enhanced outreach efforts to increase the participation of … small businesses that are 51% owned and controlled by women.” The Small Business Reauthorization Act of 2000 (P.L. 106-554) extended the SBIR program until September 30, 2008, kept the 2.50% set aside, and did not increase the amounts of Phase I and Phase II awards.16

Congress did not reauthorize the SBIR program by September 30, 2008; rather, it temporarily extended the program until March 20, 2009 (P.L. 110-235). The Senate version of the reauthorization bill, S. 3029, included among other things an increase in Phase I funding to $150,000 and an increase in Phase II funding to $1,000,000 with provisions for these funding guidelines to be exceeded by 50%. Also, the current 2.5% set aside would increase to 3.5% at a rate of 0.1% per year over 10 years, except for the National Institutes of Health which would stay at 2.5%. On March 19, the House and Senate reauthorized the SBIR program until July 31, 2009 (P.L. 110-10); it was again reauthorized through September 30, 2009 through a Senate continuing resolution (S. 1513); on September 23, 2009 a House bill (H.R. 3614) extended SBIR until October 31, 2009; and finally a Senate bill (S. 1929) again extended the program until April 30, 2010.17 The issues continue to be whether the existing Phase I, Phase II, and Phase III processes should remain, whether the dollar size of Phase I and Phase II awards should be changed, and whether venture capitalists should be involved in the SBIR process.

Eleven agencies 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 (HHS, particularly the NIH), Transportation (DoT), and, most recently, Homeland Security (DHS). In 2005 (the year of the survey from which the data analyzed herein come, as discussed below), DoD maintained the largest program, awarding about 51% of total dollars and funding about 57% of total awards in that year. Five agencies – DoD, HHS, NASA, DOE, and NSF – account for nearly 97% of the program's expenditures, with HHS (which includes the NIH) being the second most important, accounting for 30% of total dollars and 19% of total awards in 2005 (see Table 1).18

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[a]	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

a The National Institutes of Health (NIH) is under the Department of Health and Human Services (HHS).

The economic role of the SBIR program is illustrated in Fig. 1.19 For project Awithout SBIR, the private rate of return is less than the private hurdle rate because of barriers to technology. As such, the private firm will not choose to invest in project A, although the social benefits from undertaking the project would be great. The vertical distance measured by the distance from isocial to the 45-degree line at iprivate for project Awithout SBIR is the spillover gap; it results from the additional value society would receive above what the private firm would receive if project Awithout SBIR were undertaken. Project Awithout SBIR is precisely the type of project in which the public should invest, namely one in which the private sector would not invest because of market failure and one from which society would greatly benefit.

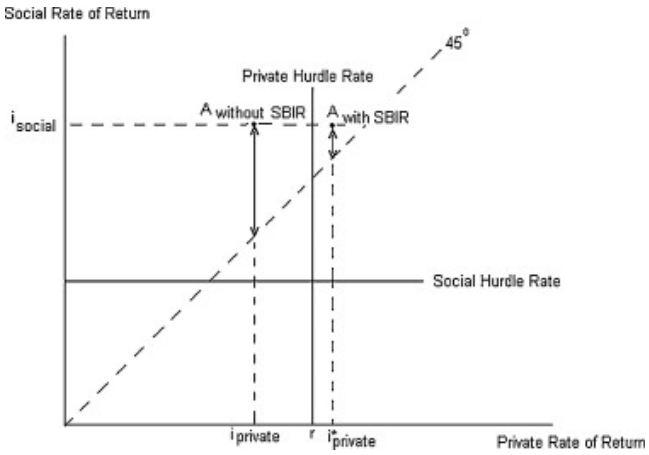

Fig. 1. Spillover gap between social and private rates of return to SBIR-funded research.

In Fig. 2, we alternatively illustrate that reduction in risk in terms of a rightward shift in the distribution of the rate of return for the private firms.20 The rightward shift of the distribution, and the concept of reducing the probability of returns lower than acceptable to the private investors, applies equally well to the absolute level of net return (absolute return minus private investment) expected from the project. As shown in Fig. 2, SBIR support increases the firm's expected private rate of return and thereby reduces the downside risk associated with undertaking R&D.21 For each distribution – without-SBIR funding (left distribution) and with SBIR funding (right distribution) – the expected rate of return is shown.22 As drawn, with SBIR funding the expected private rate of return and the variance in the private rate of return from the research project will increase. One can generalize that this will always be the case.23

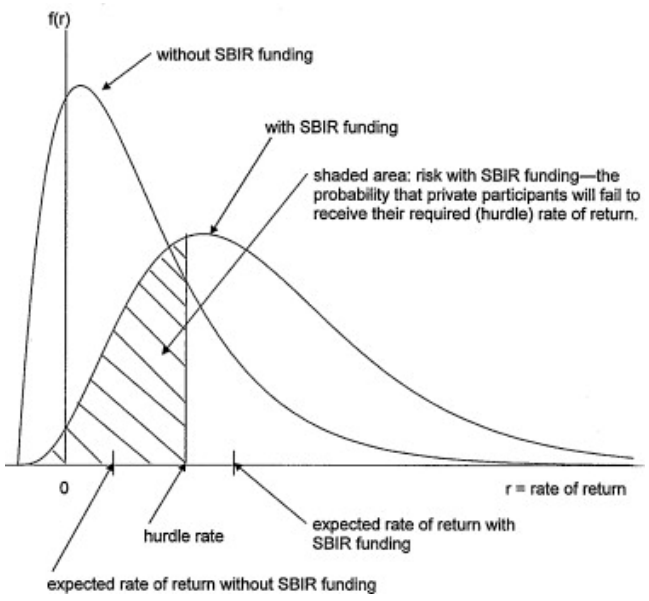

Fig. 2. Private risk reduction resulting from SBIR funding.

Consider the left distribution—the distribution of the rate of return for the private firm without-SBIR funding. As drawn, the private hurdle rate is to the right of the expected rate of return without-SBIR funding, implying that the private firm will not undertake this research because the firm will not receive its required rate of return. The risk of the project equals the area under this without-SBIR distribution that is to the left of the private hurdle rate. For those used to thinking of the variance of the distribution as the measure of risk, the downside risk – which is the probability of a rate of return less than the hurdle rate – might seem unusual. Variance measures the possibility that outcomes can differ from the expected outcome, while the downside risk measures the probability of an outcome departing to the downside of the hurdle rate. Note that the technical risk and the market risk for the project are reflected in the variance of the distribution—the technical goals may exceed or fall short of expectations and market acceptance of the project's technical outcomes could do the same. The downside risk refers to the outcomes that fall short of the hurdle rate.

Consider the distribution on the right in Fig. 2—the distribution of the rate of return for the private firm with SBIR funding. With SBIR funding, the private firm will expect a return greater than its hurdle rate—the expected private rate of return with SBIR funding is drawn to the right of the private hurdle rate.24 While SBIR funding will not itself increase the probability that the research will be successful, assuming hypothetically that it were undertaken absent SBIR funding, it will however reduce private risk by increasing the expected private rate of return because the expected rate of return will be based on a smaller private outlay.25 Hence, SBIR funding leverages the private firm's investment as illustrated by a greater expected return and a greater variance in the distribution as explained above.

The shaded area in Fig. 2 is what we call the downside risk of the project—that is, it is the probability that the project will yield a rate of return less than the private hurdle rate even with SBIR funding. Hence, the amount of downside risk with SBIR funding is visually less than the downside risk associated with the research project in the without-SBIR funding case.

4. The National Research Council Database

The Small Business Reauthorization Act of 2000 stated:

> [E]ach agency with a budget of more than $50,000,000 for its SBIR program for fiscal year 1999, in consultation with the Small Business Administration, shall, not later than 6 months after the date of the enactment of this Act [December 21, 2000], cooperatively

> enter into an agreement with the National Academy of Sciences for the National Research Council to … conduct a comprehensive study of how the SBIR program has stimulated technological innovation and used small businesses to meet Federal research and development needs…

As part of the National Research Council (NRC) study, a survey-based database was constructed (Wessner, 2008). In 2005, the NRC conducted an extensive and balanced survey based on a population of 11,214 projects completed from Phase II awards by five agencies: DoD, NIH within HHS, NASA, DOE, and NSF. These five agencies accounted for nearly 97% of the program's expenditures in 2005 (see Table 1). Only those Phase II awards made between 1992 and 2001 were in the NRC sample; it was assumed as part of the sampling methodology that Phase II awards made in 2001 would be completed by 2005.

The data reduction in Table 2 shows the number of Phase II projects for which relevant data were available, and these are the projects analyzed here, by agency.

Table 2. Final sample of Phase II projects awarded from 1992 to 2001.

Data reduction	Number of projects				
	DoD	NIH	NASA	DOE	NSF
Population of projects	5650	2497	1488	808	771
Survey population	3055	1678	779	439	457
Random survey population[a]	3026	1677	775	436	456
Survey respondents	891	495	177	154	161
Survey respondents reporting all relevant information	761	388	155	135	136

a Not all projects selected for the survey were randomly selected. By intent, the NRC added projects because they had realized significant commercialization and the NRC wanted to be able to describe for Congress outstanding success stories. Only randomly selected projects were included in the econometric analysis discussed.

According to Wessner (2008, p. 109): “Comparisons between SBIR programs at different agencies … must be regarded with considerable caution. … widely differing agency missions have shaped the agency SBIR programs, focusing them on different objectives and on different mechanisms and approaches.” Accordingly, our analysis of the commercialization success of SBIR projects is conducted on an agency by agency basis. We do discuss cross-agency differences in our econometric results in the following section, but by doing so we are only emphasizing behavioral differences in agency projects; we are not advocating that our findings

are a motivation for restructuring one agency's program based on results for another agency's program.

5. Model of commercialization success and econometric findings

Our econometric model of the probability of commercialization of an SBIR-funded project incorporates all available information from the NRC database. Our intent is to estimate the probability of commercialization subject to all available controls. By so doing we argue that we are able to calculate the predicted probability of success of an SBIR project that has a given set of characteristics using full information and thus make a statement about the a priori uncertainty that the funded research will be commercially successful.

The explanatory variables considered in this econometric strategy are divided into four groups as shown and defined in Table 3. Descriptive statistics are reported in Table 4, by agency.

Table 3. Definitions of the variables in the commercialization models.

	Definition
Dependent variable	
dsales	0/1 with 1 indicating if to date (i.e., 2005) there has been commercialization, defined as sales of products, processes, services, rights to the technology, or spin off companies; and 0 otherwise
Non-SBIR funding variables	
non-sbir-federal-to-total-investment	Ratio of additional developmental funding during the Phase II project from non-SBIR federal funds to total investment (including the SBIR Phase II award) in the Phase II project
U.S.-private-venture-capital-to-total-investment	Ratio of additional developmental funding during the Phase II project from U.S. private venture capital investment to total investment (including the SBIR Phase II award) in the Phase II project
foreign-private-investment-to-total-investment	Ratio of additional developmental funding during the Phase II project from foreign private investment to total investment (including the SBIR Phase II award) in the Phase II project
other-private-equity-investment-to-total-investment	Ratio of additional developmental funding during the Phase II project from other private equity investment to total investment (including the SBIR Phase II award) in the Phase II project
other-domestic-private-firm-	Ratio of additional developmental funding during the Phase II project from other domestic private firm investment to total investment (including the SBIR Phase II

	Definition
investment-to-total-investment	award) in the Phase II project
state-or-local-government-funding-to-total-investment	Ratio of additional developmental funding during the Phase II project from state or local government funding of investment to total investment (including the SBIR Phase II award) in the Phase II project
colleges-or-universities-funding-to-total-investment	Ratio of additional developmental funding during the Phase II project from colleges or universities funding of investment to total investment (including the SBIR Phase II award) in the Phase II project
own-firm-funding-to-total-investment	Ratio of additional developmental funding during the Phase II project from the SBIR firm's (including borrowed funds) own investment to total investment (including the SBIR Phase II award) in the Phase II project
personal-funds-to-total-investment	Ratio of additional developmental funding during the Phase II project from the principals' investment of personal funds to total investment (including the SBIR Phase II award) in the Phase II project
prior_sbir_fndg	0/1 with 1 indicating that (excluding the Phase I, which proceeded this Phase II) prior to the Phase II award, the firm received funds from the SBIR for research or development of the technology in the Phase II project
prior_nonsbir_fed	0/1 with 1 indicating that prior to the Phase II award, the firm received funds from non-SBIR federal R&D for research or development of the technology in the Phase II project
prior_ventcap	0/1 with 1 indicating that prior to the Phase II award, the firm received funds from venture capital for research or development of the technology in the Phase II project
prior_other_priv	0/1 with 1 indicating that prior to the Phase II award, the firm received funds from another private firm for research or development of the technology in the Phase II project
prior_priv_inv	0/1 with 1 indicating that prior to the Phase II award, the firm received funds from a private investor for research or development of the technology in the Phase II project
prior_intrnl_co	0/1 with 1 indicating that prior to the Phase II award, the firm received funds from internal company investment (including borrowed money) for research or development of the technology in the Phase II project
prior_stateorlocal	0/1 with 1 indicating that prior to the Phase II award, the firm received funds from state or local government for research or development of the technology in the Phase II project
prior_univ_fndg	0/1 with 1 indicating that prior to the Phase II award, the firm received funds from a college or university for research or development of the technology in the Phase II project

	Definition
prior_other	0/1 with 1 indicating that prior to the Phase II award, the firm received funds from other sources than those specified in the foregoing qualitative variables for research or development of the technology in the Phase II project
Other Phase II project variables	
award_amt	Amount of the Phase II award
ln *award_amt*	Natural logarithm of the amount of the Phase II award
prj_age	Age of the Phase II project
reltd_phII	Number of the firm's Phase II awards that are related to the Phase II project as of the time that the project was funded
ln *reltd_phII*	Natural logarithm of the firm's Phase II awards that are related to the Phase II project as of the time that the project was funded
nocom	0/1 with 1 indicating no planned commercial use for project's results
software	0/1 with 1 indicating the project planned to commercialize software
hardware	0/1 with 1 indicating the project planned to commercialize hardware
process	0/1 with 1 indicating the project planned to commercialize process technology
service	0/1 with 1 indicating the project planned to commercialize a service
drug	0/1 with 1 indicating the project planned to commercialize a drug
biologic	0/1 with 1 indicating the project planned to commercialize a biologic
research	0/1 with 1 indicating the project planned to commercialize a research tool
education	0/1 with 1 indicating the project planned to commercialize educational material
other	0/1 with 1 indicating the project planned commercialization not covered in the other categories
Firm variables	
firm revenue	Firm's total revenue
ln *revenue*	Natural logarithm of firm's total revenue
sbir_fnd	0/1 with 1 indicating if the firm was founded at least in part because of the SBIR program

	Definition
business_fndrs	Number of company founders with business backgrounds
academic_fndrs	Number of company founders with academic backgrounds
phII_tprj	Number of Phase II awards that the firm had received over time as of the time of the project award
ln *phII_tprj*	Natural logarithm of the number of Phase II awards that the firm had received over time as of the time of the project award
late_eval	0/1 with 1 indicating late evaluation of the commercial potential for the Phase II project
num_svyd	Number of the firm's Phase II projects surveyed
phII_tsvy	Firm's number of Phase II awards that were among the population of 1992–2001 projects for sampling in the survey
ln *phII_tsvy*	Natural logarithm of the firm's number of Phase II awards that were among the population of 1992–2001 projects for sampling in the survey
sbir_patents	Number of patents that have resulted at least in part from the firm's SBIR and/or STTR awards
sbir-r&d-to-total-r&d	Percentage of firm's total R&D effort (man-hours of scientists and engineers) devoted to SBIR activities during the most recent fiscal year
Geographic variables	
ne	0/1 with 1 indicating that the firm is in the northeast
south	0/1 with 1 indicating that the firm is in the south
midwest	0/1 with 1 indicating that the firm is in the midwest
west	0/1 with 1 indicating that the firm is in the west

Table 4. Descriptive statistics on variables used in subsequent regression models.

	DoD	NIH	NASA	DOE	NSF
	Mean (S.D.) [range] *n* = 761	Mean (S.D.) [range] *n* = 388	Mean (S.D.) [range] *n* = 155	Mean (S.D.) [range] *n* = 135	Mean (S.D.) [range] *n* = 136
Dependent variable					
dsales	0.4560 (0.4984) [0/1]	0.4897 (0.5005) [0/1]	0.4581 (0.4999) [0/1]	0.5259 (0.5012) [0/1]	0.4926 (0.5018) [0/1]
Non-SBIR funding variables					
non-sbir-federal-to-total-investment	0.07763 (0.1840) [0–0.9869]	0.02175 (0.1025) [0–0.8853]	0.03892 (0.1285) [0–0.7121]	0.05735 (0.1580) [0–0.8897]	0.07586 (0.1883) [0–0.9464]
U.S.-private-venture-capital-to-total-investment	0.01620 (0.1047) [0–0.9723]	0.01340 (0.08470) [0–0.7778]			0.01209 (0.07542) [0–0.6723]
foreign-private-investment-to-total-investment	0.003598 (0.03290) [0–0.4643]	0.006188 (0.04094) [0–0.3843]		0.008853 (0.08406) [0–0.9535]	
other-private-equity-investment-to-total-investment	0.02019 (0.09813) [0–0.8889]	0.02312 (0.1008) [0–0.8532]	0.003654 (0.03014) [0–0.3571]	0.02109 (0.08871) [0–0.4828]	0.04716 (0.1531) [0–0.9091]
other-domestic-private-firm-investment-to-total-investment	0.02748 (0.09828) [0–0.7834]	0.01854 (0.09704) [0–0.8529]	0.02364 (0.08460) [0–0.4568]	0.05830 (0.1425) [0–0.7696]	0.05527 (0.1384) [0–0.7245]
state-or-local-government-funding-to-total-investment	0.004079 (0.02712) [0–0.2811]	0.007909 (0.04757) [0–0.6471]		0.001953 (0.01500) [0–0.1533]	0.02000 (0.07640) [0–0.4778]
colleges-or-universities-funding-to-total-investment	0.001048 (0.01688) [0–0.4000]	0.0004175 (0.003479) [0–0.04243]			
own-firm-funding-to-total-investment	0.05051 (0.1218) [0–0.9474]	0.08447 (0.1613) [0–0.8813]	0.07886 (0.1752) [0–0.8096]	0.07418 (0.1534) [0–0.8571]	0.06466 (0.1317) [0–0.6281]
personal-funds-to-total-investment	0.007534 (0.03901) [0–0.4545]	0.01879 (0.06527) [0–0.5715]	0.003100 (0.01796) [0–0.1799]	0.004421 (0.02340) [0–0.2107]	0.02787 (0.08335) [0–0.5334]

	DoD	NIH	NASA	DOE	NSF
	Mean (S.D.) [range] *n* = 761	Mean (S.D.) [range] *n* = 388	Mean (S.D.) [range] *n* = 155	Mean (S.D.) [range] *n* = 135	Mean (S.D.) [range] *n* = 136
prior_sbir_fndg	0.2076 (0.4059) [0/1]	0.1469 (0.3545) [0/1]		0.2667 (0.4439) [0/1]	0.2132 (0.4111) [0/1]
prior_ventcap	0.02234 (0.1479) [0/1]	0.04897 (0.2161) [0/1]		0.02963 (0.1702) [0/1]	0.02206 (0.1474) [0/1]
prior_univ_fndg	0.01577 (0.1247) [0/1]	0.04124 (0.1991) [0/1]		0.02963 (0.1702) [0/1]	0.04412 (0.2061) [0/1]
prior_nonsbir_fed	0.1156 (0.3200) [0/1]	0.04897 (0.2161) [0/1]		0.1407 (0.3490) [0/1]	0.1471 (0.3555) [0/1]
prior_other_priv	0.08410 (0.2777) [0/1]	0.07474 (0.2633) [0/1]		0.08148 (0.2746) [0/1]	0.1471 (0.3555) [0/1]
prior_priv_inv	0.06439 (0.2456) [0/1]	0.09794 (0.2976) [0/1]		0.04444 (0.2068) [0/1]	0.1397 (0.3480) [0/1]
prior_intrnl_co	0.2733 (0.4460) [0/1]	0.3273 (0.4698) [0/1]		0.3111 (0.4647) [0/1]	0.3529 (0.4797) [0/1]
prior_state_or_local	0.01708 (0.1297) [0/1]	0.05928 (0.2364) [0/1]		0.02222 (0.1480) [0/1]	0.05882 (0.2362) [0/1]
prior_other	0.04336 (0.2038) [0/1]	0.06186 (0.2412) [0/1]		0.02963 (0.1702) [0/1]	0.08088 (0.2737) [0/1]
Other Phase II project variables					
award_amt	719,900.0 (358,900.0) [69,670–6,191,000]	654,200.0 (211,800) [14,830–1,644,000]	567,200.0 (73,390.0) [350,000–1,125,000]	683,300.0 (104,000.0) [347,700–900,000]	374,400.0 (74,880.00) [213,300–500,000]
ln *award_amt*	13.41 (0.3805) [11.15–15.64]	13.32 (0.4268) [9.605–14.31]	13.24 (0.1230) [12.77–13.93]	13.42 (0.1716) [12.76–13.71]	12.81 (0.2043) [12.27–13.12]
prj_age	7.481 (2.821) [4–13]	7.260 (2.585) [4–13]	8.084 (2.923) [4–13]	7.778 (2.736) [4–13]	6.941 (2.491) [4–13]
reltd_phII	1.879 (1.632) [1–29]	2.139 (3.396) [1–29]	1.748 (1.527) [1–13]	1.926 (1.637) [1–13]	1.801 (1.387) [1–10]
ln *reltd_phII*	0.4372 (0.5661) [0–	0.4276 (0.6464) [0–	0.3597 (0.5577) [0–	0.4294 (0.6152) [0–	0.3987 (0.5641) [0–

	DoD	NIH	NASA	DOE	NSF
	Mean (S.D.) [range] *n* = 761	Mean (S.D.) [range] *n* = 388	Mean (S.D.) [range] *n* = 155	Mean (S.D.) [range] *n* = 135	Mean (S.D.) [range] *n* = 136
	3.367]	3.367]	2.565]	2.565]	2.303]
nocom	0.02102 (0.1436) [0/1]	0.01289 (0.1129) [0/1]			
software	0.2155 (0.4114) [0/1]	0.2758 (0.4475) [0/1]	0.1419 (0.3501) [0/1]	0.1407 (0.3490) [0/1]	0.25 (0.4346) [0/1]
hardware	0.3942 (0.4890) [0/1]	0.2577 (0.4380) [0/1]	0.4323 (0.4970) [0/1]	0.4074 (0.4932) [0/1]	0.4044 (0.4926) [0/1]
process	0.1551 (0.3622) [0/1]	0.09794 (0.2976) [0/1]	0.1355 (0.3433) [0/1]	0.2370 (0.4268) [0/1]	0.2059 (0.4058) [0/1]
service	0.1196 (0.3247) [0/1]	0.1108 (0.3143) [0/1]	0.1226 (0.3290) [0/1]	0.1556 (0.3638) [0/1]	0.1618 (0.3696) [0/1]
drug		0.01546 (0.1235) [0/1]			
biologic		0.03866 (0.1930) [0/1]			
research	0.1051 (0.3069) [0/1]	0.2603 (0.4394) [0/1]	0.1484 (0.3566) [0/1]	0.1037 (0.3060) [0/1]	0.1618 (0.3696) [0/1]
education	0.01445 (0.1194) [0/1]	0.1443 (0.3519) [0/1]	0.03226 (0.1773) [0/1]	0.02963 (0.1702) [0/1]	0.09559 (0.2951) [0/1]
other	0.06176 (0.2409) [0/1]	0.07732 (0.2674) [0/1]	0.04516 (0.2083) [0/1]	0.05926 (0.2370) [0/1]	0.05882 (0.2362) [0/1]
Firm variables					
firm revenue	1.40e+07 (2.65e+07) [50,000–1.25e+08]	8,259,000 (1.92e+07) [50,000–1.25e+08]	1.64e+07 (2.93e+07) [50,000–1.25e+08]	1.10e+07 (2.17e+07) [50,000–1.25e+08]	7,214,000 (1.47e+07) [50,000–6.00e+07]
ln *revenue*	15.02 (1.854) [10.82–18.64]	14.14 (2.010) [10.82–18.64]	15.07 (1.946) [10.82–18.64]	14.72 (1.910) [10.82–18.64]	14.22 (1.974) [10.82–17.91]
sbir_fnd	0.2181 (0.4133) [0/1]	0.2603 (0.4394) [0/1]	0.2065 (0.4061) [0/1]	0.2519 (0.4357) [0/1]	0.2059 (0.4058) [0/1]

	DoD	NIH	NASA	DOE	NSF
	Mean (S.D.) [range] *n* = 761	Mean (S.D.) [range] *n* = 388	Mean (S.D.) [range] *n* = 155	Mean (S.D.) [range] *n* = 135	Mean (S.D.) [range] *n* = 136
business_fndrs	0.6899 (1.012) [0–8]	0.6624 (1.463) [0–18]	0.6839 (1.018) [0–6]	0.6444 (0.9885) [0–5]	0.7426 (0.9428) [0–5]
academic_fndrs	1.076 (1.277) [0–8]	1.312 (1.048) [0–7]	1.181 (1.360) [0–6]	1.096 (1.239) [0–5]	1.132 (1.216) [0–7]
phII_tprj	9.534 (26.60) [1–194]	3.121 (7.266) [1–80]	14.75 (36.56) [1–223]	8.230 (18.77) [1–117]	5.5 (12.78) [1–91]
ln *phII_tprj*	0.9584 (1.269) [0–5.268]	0.5850 (0.8102) [0–4.382]	1.145 (1.472) [0–5.407]	1.087 (1.227) [0–4.762]	0.7557 (1.104) [0–4.511]
late_eval	0.1445 (0.3519) [0/1]	0.04897 (0.2161) [0/1]	0.09032 (0.2876) [0/1]	0.1333 (0.3412) [0/1]	0.1029 (0.3050) [0/1]
num_svyd	4.112 (6.030) [1–31]	2.196 (2.593) [1–27]	5.258 (7.645) [1–31]	3.274 (4.718) [1–27]	3.015 (3.994) [1–27]
phII_tsvy	13.98 (27.39) [1–127]	4.812 (10.54) [1–120]	19.86 (35.14) [1–127]	10.33 (21.90) [1–120]	9.397 (19.07) [1–120]
ln *phII_tsvy*	1.507 (1.386) [0–4.844]	0.8942 (0.9715) [0–4.787]	1.705 (1.548) [0–4.844]	1.375 (1.234) [0–4.787]	1.148 (1.326) [0–4.787]
sbir_patents	8.285 (20.94) [0–125]	3.005 (6.606) [0–66]	12.75 (27.08) [0–125]	7.474 (13.22) [0–66]	7.934 (13.64) [0–66]
sbir-r&d-to-total-r&d	41.11 (31.02) [0–100]	40.80 (36.27) [0–100]		37.34 (34.67) [0–100]	39.51 (33.78) [0–100]
Geographic variables					
ne	0.3127 (0.4639) [0/1]	0.3273 (0.4698) [0/1]	0.2903 (0.4554) [0/1]	0.2889 (0.4549) [0/1]	0.3382 (0.4749) [0/1]
south	0.2497 (0.4331) [0/1]	0.25 (0.4336) [0/1]	0.2323 (0.4236) [0/1]	0.1630 (0.3707) [0/1]	0.1618 (0.3696) [0/1]
midwest	0.1196 (0.3247) [0/1]	0.1856 (0.3893) [0/1]	0.09677 (0.2966) [0/1]	0.1407 (0.3490) [0/1]	0.1544 (0.3627) [0/1]
west	0.3180 (0.4660) [0/1]	0.2371 (0.4259) [0/1]	0.3806 (0.4871) [0/1]	0.4074 (0.4932) [0/1]	0.3456 (0.4773) [0/1]

Note: For each agency, only the subset of the variables used in the estimation is described.

Although not the focus of this paper, we draw particular attention to the independent impact of outside private investments on the probability of commercial success. Link and Scott (2009) argued that the presence of outside investment funding should be positively correlated with such success for at least three reasons. One reason is that outside private investors have useful information about the commercial prospects of the output of a Phase II project and they signal that information by investing in the projects that are likely to be the most successful.26 A second reason is that the presence of outside private investors provides useful business and management guidance to small (and often newly formed) firms. Finally, firms that have undertaken an internal assessment of a project's commercial potential, and thus believe that their project will be successful, may be able to identify appropriate outside private investors more easily than other firms.

Two econometric issues relate to the estimation of the probability of commercialization. The first issue is sample selection and the second issue is potential endogeneity.

Given the data reduction process summarized in Table 2, we cannot assume that error in the model of response to the NRC survey is uncorrelated with the error in the model of commercialization. We therefore estimate the commercialization models with control for selection into the samples by response. Although we do not offer a formal theory for the probability of response to the project survey, we do consider what we believe are four intuitive variables: ln award_amt, prj_age, num_svyd, and ln phII_tsvy. Simply, firms receiving larger awards (award_amt) might be more inclined to respond as a quid pro quo for the greater SBIR support. Firms might be less likely to respond to the survey the older the project (prj_age) because institutional memory may have faded and would be costly to recover. Firms might be less likely to respond to the survey the greater the number of a firm's Phase II projects that were surveyed (num_svyd) if a larger reporting burden lowers the probability of response. Yet, such firms may be more likely to respond because those having more surveyed projects had received more awards and may respond in gratitude. Additionally, the firm's number of previous Phase II awards (phII_tsvy) is a proxy for firm size, and larger firms might have the internal resources to respond to the survey request. Award amount and previous Phase II awards are measured by their natural logarithms to account for any diminishing effects.

Firm revenue (revenue) might be endogenous; error in a model (see Table 5) for commercialization success from a Phase II project is not necessarily independent of error in the process determining the revenue of the firm. Thus, ln revenue is instrumented because of the

possibility that the error in the model of the probability of commercialization is not independent of the error in firm revenue. When the null hypothesis of exogeneity of ln revenue is rejected, instrumental variables are used and listed in the regression output tables.

Table 5. Estimation strategy.

Agency	Regression model	Regression results	Comments
DoD	Probit	Table 6	Probit models of commercialization and of sample selection are independent; ln *revenue* is not endogenous
NIH	Probit with selection	Table 7	Probit models of commercialization and of sample selection are *not*independent; ln *revenue* is not endogenous
NASA	Probit	Table 8	Probit models of commercialization and of sample selection are independent; ln *revenue* is not endogenous
DOE	Probit with instrumental variables	Table 9	Probit models of ommercialization and of sample selection are independent; null hypothesis of exogeneity of ln *revenue* is rejected at the 0.10 level of significance
NSF	Probit with instrumental variables	Table 10	Probit models of commercialization and of sample selection are independent; null hypothesis of exogeneity of ln *revenue* is rejected at the 0.001 level of significance

Note: All unreported regression results are available upon request from the authors.

Table 5 summarizes the results of our consideration of these econometric issues and outlines the regression models presented in Table 6, Table 7, Table 8, Table 9 and Table 10.27 Observe that for each agency, there is a positive correlation, ceteris paribus, between the probability of commercial success and some form of outside private investment, as expected based on the earlier discussion of the reasons for such a correlation.

Table 6. Probit regression results for commercialization (*dsales*) in the DoD sample (n = 761).

Variable	Coefficient	S.E.
non-sbir-federal-to-total-investment	0.4088	0.4055
U.S.-private-venture-capital-to-total-investment	0.9734*	0.5528
foreign-private-venture-capital-to-total-investment	−1.325	1.673
other-private-equity-investment-to-total-investment	2.358****	0.7058
other-domestic-private-firm-investment-to-total-investment	2.305***	0.7822
state-or-local-government-funding-to-total-investment	−0.7015	2.620

Variable	Coefficient	S.E.
college-or-universities-funding-to-total-investment	−2.578	1.792
own-firm-funding-to-total-investment	1.763***	0.5733
personal-funds-to-total-investment	−1.448	1.585
prj_age	0.06810***	0.02323
ln *reltd_phII*	0.1410	0.1213
nocom	2.640****	0.4287
software	1.577****	0.2016
hardware	1.275****	0.1558
process	0.4820**	0.1997
service	0.9030****	0.2379
research	0.5799**	0.2649
education	0.9726	0.6992
other	0.5855*	0.3540
ln *revenue*	0.1474****	0.04294
sbir_fnd	0.2403	0.1686
business_fndrs	−0.1216*	0.07008
academic_fndrs	−0.08321	0.05292
ln *phII_tprj*	−0.09938*	0.05128
late_eval	−0.2164	0.2149
ne	0.02616	0.1649
south	−0.03267	0.1996
midwest	0.04160	0.2647
constant	−4.109****	0.6784
Wald chi^2 (df)	244.6 (28)****	

Variable	Coefficient	S.E.
Pseudo R^2	0.4184	
Log pseudo-likelihood	−304.9	

Note: Estimation with probability weights (also called sampling weights). Standard errors are robust and are adjusted for clusters by firm because for some firms multiple Phase II SBIR projects are sampled. The clustering allows for intra-group correlation in the errors for the multiple projects of a firm.

* Significance level (two tails excepting chi-squared): 0.10.

** Significance level (two tails excepting chi-squared): 0.05.

*** Significance level (two tails excepting chi-squared): 0.01.

**** Significance level (two tails excepting chi-squared): 0.001.

Table 7. Probit regression results with sample selection for commercialization (*dsales*) in the NIH sample (*n* = 382).

Variable	Coefficient	S.E.
non-sbir-federal-to-total-investment	1.098	0.9097
U.S.-private-venture-capital-to-total-investment	1.965**	0.8242
foreign-private-venture-capital-to-total-investment	−1.984	1.628
other-private-equity-investment-to-total-investment	−0.1334	0.8146
other-domestic-private-firm-investment-to-total-investment	0.7892	0.6513
state-or-local-government-funding-to-total-investment	3.178**	1.622
college-or-universities-funding-to-total-investment	−40.30**	17.03
own-firm-funding-to-total-investment	1.339**	0.5981
personal-funds-to-total-investment	2.120**	1.071
prj_age	0.03420	0.03137
ln *reltd_phII*	0.2125**	0.1062
nocom	0.8615	0.5437
software	0.7293****	0.223
hardware	0.6552***	0.2234

Variable	Coefficient	S.E.
process	0.4117	0.2765
service	−0.2740	0.3007
biologic	0.4135	0.3495
research	0.6455***	0.2400
education	1.236****	0.3375
other	0.2987	0.3467
ln *revenue*	0.09647**	0.04032
sbir_fnd	0.0000903	0.1733
business_fndrs	0.1344	0.1177
academic_fndrs	−0.1184	0.08378
ln *phII_tprj*	0.03611	0.09639
late_eval	−0.05997	0.3298
ne	0.05840	0.2154
south	0.2634	0.2372
midwest	0.05805	0.2344
constant	−3.399****	0.6298
Selection		
ln *award_amt*	0.1350	0.09104
prj_age	−0.04174***	0.01429
num_svyd	0.002032	0.05387
ln *phII_tsvy*	0.1900**	0.09243
constant	−2.321*	1.212
Rho	0.5388*	0.2358
Wald chi^2 (df)	58.16 (29)****	

Variable	Coefficient	S.E.
Log pseudo-likelihood	−1608.0	
Wald chi-squared (1) test of independent equations (rho = 0)	3.29*	

Notes:

drugs (*n* = 6) predicted perfectly and was thus dropped.

The model is estimated with 1564 observations including 1182 censored observations and 382 uncensored observations. There are 495 Phase II projects reporting *dsales*, but only 388 of those report all of the explanatory variables in the model. Thus, there are potentially 388 uncensored observations. There are 1677 Phase II projects for which we have the explanatory variables for the model of response, but 495 − 388 of those report *dsales* but are missing some of the explanatory variables for the commercialization model. Thus there are 1677 − (495 − 388) = 1570 total observations that could be used in the model − 388 uncensored observations and 1677 − (495 − 388) − 388 = 1182 censored observations. However, for six observations a variable predicted success perfectly and they are therefore not used in the model, leaving 1564 total observations with 1182 censored and 382 uncensored. The 495 − 388 = 107 observations reporting *dsales* are not really censored with regard to the variable being studied and are omitted from the estimation of the model with control for selection.

Estimation with probability weights (also called sampling weights). Standard errors are robust and are adjusted for clusters by firm because for some firms multiple Phase II SBIR projects are sampled. The clustering allows for intra-group correlation in the errors for the multiple projects of a firm. The significance level for the parameter rho is the significance level for the estimated coefficient (not shown) from which rho is derived.

* Significance level (two tails excepting chi-squared): 0.10.

** Significance level (two tails excepting chi-squared): 0.05.

*** Significance level (two tails excepting chi-squared): 0.01.

**** Significance level (two tails excepting chi-squared): 0.001.

Table 8. Probit regression results for commercialization (*dsales*) in the NASA sample (*n* = 155).

Variable	Coefficient	S.E.
non-sbir-federal-to-total-investment	3.859***	1.289
other-private-equity-investment-to-total-investment	9.831**	4.174
other-domestic-private-firm-investment-to-total-investment	3.686*	1.904
own-firm-funding-to-total-investment	0.4807	0.7869
personal-funds-to-total-investment	−4.484	5.106
prj_age	0.02704	0.0526
ln *reltd_phII*	−0.08835	0.2906
software	2.482****	0.6148

Variable	Coefficient	S.E.
hardware	2.114****	0.3141
process	0.4259	0.4726
service	−0.2158	0.6645
research	1.175*	0.6806
education	0.9786	0.7455
other	2.004*	1.059
ln *revenue*	0.1034	0.08818
sbir_fnd	0.9628***	0.3309
business_fndrs	0.2979**	0.1188
academic_fndrs	−0.08957	0.1206
ln *phII_tprj*	−0.02109	0.08497
late_eval	0.3172	0.3895
ne	0.5829	0.3668
south	0.03610	0.4544
midwest	0.01384	0.6035
constant	−4.183***	1.580
Wald chi^2 (df)	148.4 (23)****	
Pseudo R^2	0.5536	
Log pseudo-likelihood	−47.74	

Note: Estimation with probability weights (also called sampling weights). Standard errors are robust and are adjusted for clusters by firm because for some firms multiple Phase II SBIR projects are sampled. The clustering allows for intra-group correlation in the errors for the multiple projects of a firm.

* Significance level (two tails excepting chi-squared): 0.10.

** Significance level (two tails excepting chi-squared): 0.05.

*** Significance level (two tails excepting chi-squared): 0.01.

**** Significance level (two tails excepting chi-squared): 0.001.

Table 9. Probit regression results for commercialization (*dsales*) in the DOE sample (*n* = 131).

Variable	Coefficient	S.E.
ln *revenue*	0.4785**	0.2146
non-sbir-federal-to-total-investment	1.571	1.138
foreign-private-venture-capital-to-total-investment	−0.03780	1.330
other-private-equity-investment-to-total-investment	0.7495	1.545
other-domestic-private-firm-investment-to-total-investment	4.739****	1.338
state-or-local-government-funding-to-total-investment	−27.47***	9.314
own-firm-funding-to-total-investment	1.579*	0.8401
personal-funds-to-total-investment	28.14***	10.21
prj_age	−0.0002769	0.04573
ln *reltd_phII*	−0.009011	0.2437
software	1.245**	0.5557
hardware	1.202****	0.3777
process	0.9083**	0.3787
service	−0.2543	0.5454
research	0.9143	0.5938
other	1.554**	0.6178
sbir_fnd	0.1545	0.3814
business_fndrs	0.04665	0.1445
academic_fndrs	−0.3446**	0.1524
ln *phII_tprj*	−0.3243**	0.1606
late_eval	−0.8608*	0.4563
ne	0.2654	0.3676
south	0.1941	0.3694

Variable	Coefficient	S.E.
midwest	−0.7210	0.5167
constant	−7.869***	2.853
Rho	−0.6111*	0.2704
Sigma	1.158*	0.09535
Wald chi^2 (df)	205.1 (24)****	
Wald test of exogeneity chi-squared (1)	2.71*	
Log pseudo-likelihood	−503.2	

Notes:

education (*n* = 4) predicted perfectly and was thus dropped.

Estimation with probability weights (also called sampling weights). Standard errors are robust and are adjusted for clusters by firm because for some firms multiple Phase II SBIR projects are sampled. The clustering allows for intra-group correlation in the errors for the multiple projects of a firm.

Sigma is the estimate of the standard deviation of the error in the reduced form equation for ln *revenue*, and rho is the estimate of the correlation between that error and the error in the probit model. The significance levels for the parameters rho and sigma are the significance levels for the estimated coefficients (not shown) from which rho and sigma are derived.

Instrumented: ln *revenue*.

Instruments: *non-sbir-federal-to-total-investment, foreign-private-investment-to-total-investment, other-private-equity-investment-to-total-investment, other-domestic-private-firm-investment-to-total-investment, state-or-local-government-funding-to-total-investment,own-firm-funding-to-total-investment, personal-funds-to-total-investment, prj_age,* ln *reltd_phII, software, hardware, process,service, research, other, sbir_fnd, business_fndrs, academic_fndrs,* ln *phII_tprj, late_eval, ne, south, midwest, prior_sbir_fndg,prior_ventcap, prior_univ_fndg, prior_nonsbir_fed, priorother_priv, prior_priv_inv, prior_intrnl_co, prior_stateorlocal, prior_other,sbir_patents, sbir-r&d-to-total-r&d*.

* Significance level (two tails excepting chi-squared): 0.10.

** Significance level (two tails excepting chi-squared): 0.05.

*** Significance level (two tails excepting chi-squared): 0.01.

**** Significance level (two tails excepting chi-squared): 0.001.

Table 10. Probit regression results for commercialization (*dsales*) in the NSF sample (*n* = 123).

Variable	Coefficient	S.E.
ln *revenue*	−0.5377****	0.1276
non-sbir-federal-to-total-investment	1.400	1.001

Variable	Coefficient	S.E.
U.S.-private-venture-capital-to-total-investment	−0.6896	1.748
other-private-equity-investment-to-total-investment	1.497**	0.6360
other-domestic-private-firm-investment-to-total-investment	1.290*	0.6893
state-or-local-government-funding-to-total-investment	−1.144	1.714
own-firm-funding-to-total-investment	2.790**	1.255
personal-funds-to-total-investment	−1.004	2.203
prj_age	−0.005479	0.04834
ln *reltd_phII*	0.2736	0.2595
software	2.233***	0.7226
hardware	1.321***	0.4919
process	0.6202*	0.3470
service	0.07500	0.3939
research	−0.5710	0.3846
other	−0.6659*	0.3756
sbir_fnd	0.5565	0.3617
business_fndrs	0.4786***	0.1836
academic_fndrs	0.1706	0.1291
ln *phII_tprj*	0.6452****	0.1264
late_eval	−0.9800**	0.4342
ne	−0.4062	0.4271
south	−0.01436	0.4678
midwest	0.1892	0.4360
constant	5.193**	2.235
Rho	0.9005****	0.08168

Variable	Coefficient	S.E.
Sigma	1.203***	0.08686
Wald chi^2 (df)	250.9 (24)****	
Wald test of exogeneity chi-squared (1)	11.67****	
Log pseudo-likelihood	−410.8	

Notes:

education (*n* = 13) predicted perfectly and was thus dropped.

Estimation with probability weights (also called sampling weights). Standard errors are robust and are adjusted for clusters by firm because for some firms multiple Phase II SBIR projects are sampled. The clustering allows for intra-group correlation in the errors for the multiple projects of a firm.

Sigma is the estimate of the standard deviation of the error in the reduced form equation for ln *revenue*, and rho is the estimate of the correlation between that error and the error in the probit model. The significance levels for the parameters rho and sigma are the significance levels for the estimated coefficients (not shown) from which rho and sigma are derived.

Instrumented: ln *revenue*.

Instruments: *non-sbir-federal-to-total-investment, foreign-private-investment-to-total-investment, other-private-equity-investment-to-total-investment, other-domestic-private-firm-investment-to-total-investment, state-or-local-government-funding-to-total-investment,own-firm-funding-to-total-investment, personal-funds-to-total-investment, prj_age,* ln *reltd_phII, software, hardware, process,service, research, other, sbir_fnd, business_fndrs, academic_fndrs,* ln *phII_tprj, late_eval, ne, south, midwest, prior_sbir_fndg,prior_ventcap, prior_univ_fndg, prior_nonsbir_fed, prior_other_priv, prior_priv_inv, prior_intrnl_co, prior_stateorlocal, prior_other,sbir_patents, sbir-r&d-to-total-r&d*.

* Significance levels (two tails excepting chi-squared): 0.10.

** Significance levels (two tails excepting chi-squared): 0.05.

*** Significance levels (two tails excepting chi-squared): 0.01.

**** Significance levels (two tails excepting chi-squared): 0.001.

Relevant to the purpose of the paper, Table 11 presents the predicted probability of commercial success from the relevant regression results. Because there are several dichotomous explanatory variables, given the probit index's nonlinear impact on predicted probabilities, it is best not to make the predictions with the independent variables evaluated at their means. Instead, the probability predicted for each agency is the average of the probabilities predicted for each of its sampled SBIR projects with the variables set at their actual values for each project. In all cases, the predicted average probability of commercialization is somewhat less than 0.50, the probability of heads on the toss of a fair coin. For the NIH sample where selection was important, the predicted probability of commercialization conditional on response is essentially one-half, but the predicted probability based only on the characteristics of the observations, excluding the effect because of the correlation in the errors of the response and commercialization models, is somewhat less than one-third. Importantly, the evidence also

shows large variation in the probability of commercialization—the predicted probability of commercialization ranges across the projects from essentially zero to essentially 1.0.

Table 11. Predicted probability of commercialization.

Agency	*n*	Mean predicted probability of commercialization	S.D.	Minimum	Maximum
DoD	761	0.4480	0.3430	0.00926	1.000
NIH	382	0.3094	0.2556	0.004762	0.9949
Conditional on selection	382	0.4957	0.2967	0.01889	1.000
NASA	155	0.4679	0.3901	0.0005967	1.000
DOE	131	0.4928	0.3457	0.000702	1.000
NSF	123	0.4791	0.3514	0.0000406	1.000

Note: Observe the effect of selection in the NIH sample−the only one where selection was important for the commercialization model. The probability of success conditional on response is predicted to be 0.50, but is only 0.31 for the marginal probability given the characteristics for the observations apart from the fact that they responded.

Thus, the evidence in Table 11 quantifies the uncertainty that government accepts in the context of innovation supported by the SBIR program; or stated alternatively, Table 11 quantifies the probability that a project funded by the SBIR program will fail to commercialize its results. The results show that the entrepreneurial risk that characterizes the SBIR program is on average slightly more than the probability of failing to get heads on the toss of a fair coin. The shaded area in Fig. 2 shows the a priori probability that an accepted SBIR project's rate of return will fall below the private hurdle rate. After studying our samples of projects, at the time the commercialization decision is made that probability is on average apparently at least somewhat more than 0.5.

6. Conclusions

As Hébert and Link (2009, p. xvii) note:

The historical economics literature gives no fewer than 12 identities to the entrepreneur:

1. The entrepreneur is the person who assumes the risk associated with uncertainty.

2. The entrepreneur is the person who supplies financial capital.
3. The entrepreneur is an innovator.
4. The entrepreneur is a decision-maker.
5. The entrepreneur is an industrial leader.
6. The entrepreneur is a manager or superintendent.
7. The entrepreneur is an organizer and coordinator of economic resources.
8. The entrepreneur is the owner of an enterprise.
9. The entrepreneur is an employer of factors of production.
10. The entrepreneur is a contractor.
11. The entrepreneur is an arbitrageur.
12. The entrepreneur is an allocator of resources among alternative uses.

In this paper we have emphasized the first and the third concepts of the entrepreneur as we posited a definition of government as entrepreneur. Of course, there are additional clear overlaps between the observed roles of government and the historical characterizations of the entrepreneur. In the SBIR program, government provides financial capital, is a decision-maker, is an organizer and coordinator of economic resources, and is an allocator of resources among alternative uses. Moreover, in many cases the government is a contractor, purchasing the commercial product or service that results from the SBIR research. Our conceptualizing of government as entrepreneur relates to its provision of technology infrastructure when its involvement is both innovative and characterized by entrepreneurial risk, and in the SBIR program, the government is redirecting R&D resources toward the development of technologies that the market alone would not have developed. In its solicitations of SBIR proposals and subsequent funding of awards, the government is organizing, coordinating and allocating scarce resources among competing uses. As emphasized in Fig. 1 and Fig. 2, the government's role in providing financial capital is a key part of its entrepreneurial activity. We have chosen to view government activity through an entrepreneurial lens because it is the one that has been overlooked by others, for the most part, and because it is the one that is critical to the long-run growth of our economy.

Our findings are not generalizable to all small firms engaged in R&D; our findings are specific to those small firms doing R&D that was funded through SBIR. Indeed, it might be useful to compare the probability of commercialization among non-SBIR supported firms to our findings. However, because of the unique nature of research undertaken by SBIR recipient firms, a matched-pair sample of reasonable quality may not be possible to construct.

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This paper examines entrepreneurial risk by using samples developed in Link and Scott (forthcoming), where the focus was the employment effects of the Small Business Innovation Research (SBIR) program. We are grateful for support, allowing the development of those samples, from the W.E. Upjohn Institute for Employment Research.

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