

The Relationship between public and private investment in early-stage biotechnology firms: Is there a certification effect?

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ABSTRACT

While various public financing programs exist in the United States and European Union to fund small innovative biotechnology firms, there is little understanding of how these financing programs interact with alternative private sources of investment like venture capital. In this paper we use a real options approach to investment as described by Dixit and others to lay out the various ways in which a public financing program can fruitfully contribute. One mechanism to emerge from this framework is the potential for public agencies to “certify” small firms. Public investment may allow the firm the opportunity to reduce scientific and market uncertainties surrounding their product ideas. If public programs have this function, then we should observe follow-on private funding by investors like venture capitalists.

The empirical portion of this research investigates the relationship between government funding of small firms, some of which are university-based biotechnology companies, and follow-on venture capital funding. Our empirical work tests the certification hypothesis. We draw on detailed firm-level data for participants in the U.S. Small Business Innovation Research (SBIR) program and data on venture capital investment to develop our database. To test our hypotheses we employ a Probit model to look at the probability of venture capital funding *after* participation in the SBIR program. Our findings are consistent with a certification effect from participation in the SBIR program. We also find that firms using biotechnology methods or employing a former university scientist have a greater chance for follow-on venture capital investment. The marginal impact of public investment in product development activities, which are designed to reduce market uncertainties, is greater for biotechnology firms relative to other technology areas. However, beyond the basic certification effect, there is no evidence that public investment in product development is enhanced by the presence of a former university scientist.

Introduction

Despite the growing public and private investment in biotechnology and the observation that a large part of scientific discovery has originated at universities throughout the world, there has been scant analysis on the interrelationships between university scientists, and public and private funders. This paper takes a first step to analyzing the economics of this interaction with a particular emphasis on value creation through a mix of public and private (venture capitalist) funding. To motivate this paper by highlighting the barriers that impede the commercialization of university-based discoveries. We then build an economic framework that shows why public investment in biotechnology can be justified if its societal value exceeds the private value. This framework is based on the real option paradigm which argues that delays in financing and hence the project go-ahead can be tied to underlying scientific, technical and market uncertainties. These uncertainties are highest in the early stage of development and public policy can play two roles. First the government through its agencies can underwrite the risk, and second it can provide early stage capital through grants and other financial arrangements. We argue that the public's role is in essence to underwrite the risk, thereby making the follow-on financing through venture capitalists more attractive on a (reduced) risk and (higher) reward basis. We support these arguments empirically using cross-sectional data of biotechnology companies that received US SBIR funding.

Barriers to the Commercialization of University-based Biotechnology Discoveries

Numerous studies both in the U.S. and abroad point out that the technologies discovered in research institutions are “embryonic” and characterized by a high degree of scientific and market uncertainty (see Colyvas et al. (2002), Lowe(201), Shane (2004), Thursby et al. (2002)). Investments required to commercialize these technologies share three basic characteristics. First, the investment is substantially sunk. That is to say, it is rarely possible to recoup much of the investment since most of the funds are used for follow-on research and development. Second, the investment opportunity is characterized by scientific and market uncertainties that may diminish over time as new information becomes available. Third, the opportunity to invest in

university-based technologies is seldom completely dissipated away through competition among rivals.

These basic characteristics combine to create a positive option value for waiting to invest as described by the economic theory of investment under uncertainty (Dixit (1992) and Pindyck (1991)). Their framework shows that it is optimal for private investors like venture capitalists to wait instead of investing in university-based discoveries, even when the private net present value is positive. How long private investors choose to wait depends on the magnitude of the option value which, in turn, depends on the investor's patience and the degree of uncertainty characterizing the opportunity. The option value is larger when investors are impatient because they discount the return stream more heavily. Shane (2004) and Lowe (2001) present case study evidence highlighting the short-term or "near market" preferences of venture capitalists based on the experiences of entrepreneurs commercializing discoveries from MIT and the campuses of the University of California. For instance, Lowe quotes an entrepreneur as saying, "Our technology was early-stage. We could only describe where we were going, but we didn't have any prototype to show (venture capitalists). They want to see that you're going to have a product soon." (Lowe (2001), p. 199) Moreover, the option value also increases as the level of scientific and/or market uncertainties increase, which we know are especially high for university-based discoveries.

Even without information asymmetries in private capital markets, the option to wait creates an investment "timing gap" for potentially valuable university discoveries. Taking the time preferences of investors as fixed, the only way to attract private investment for university discoveries is to reduce the option value of waiting by reducing the level of scientific and/or market uncertainties for these discoveries. Unfortunately, neither individual faculty nor university technology transfer offices (TTOs) have any incentive to undertake the necessary steps required to reduce these uncertainties. Absent private investment, individual faculty, who are motivated to pursue scientific discovery and publication goals, are not rewarded for spending time and money on commercialization activities. While university TTOs focus on licensing discoveries, the TTOs themselves do not have the money or expertise to reduce scientific or market uncertainties characterizing their portfolio of invention disclosures. Consequently, many (or most) university discoveries remain "on the shelf" – too early-stage for private investors and requiring research that is too commercial for the university. There is no mechanism to close the investment timing gap.

A second barrier to commercialization derives from the complex nature of the underlying university science. Zucker and coauthors have an important stream of economic research exploring the movement of university discoveries into private sector commercialization in biotechnology. They emphasize the movement of ideas in people based on the observation that intellectual human capital is often tacit knowledge held by the discovery scientist that is difficult to codify and communicate except through person-to-person interaction in the laboratory. To empirically measure the degree of tacit knowledge exchange through bench-level interaction, they use counts of articles co-authored between firm scientists and university scientists, some of whom have changed employment to firms. Their findings suggest that various measures of firm success including patenting and products in development significantly increase with the degree of involvement by discovery scientists.

Their work emphasizes the central role played by “star” scientists in the commercialization process. They define star scientists as those individuals with 40 or more genetic sequence discoveries as reported in the Genbank database prior to 1990. Zucker et al. (1998b) find that the location and timing of new firm formation is related to where and when these stars are publishing. Torero (2000) investigates the star researcher hypothesis in the semiconductor industry. Defining stars based on patent citation counts for the listed inventors, Torero finds that stars are positively and significantly related to the formation of new semiconductor firms. For firms that participated in the US Small Business Innovation Research (SBIR) program, Toole and Czarnitzki (2005) find that NIH star scientists, identified based on cumulative research grants, do *not* contribute more than other “non-star” NIH researchers to firm program completion or patenting.

Because of the complexity of science-based university discoveries, there is broad agreement in the academic entrepreneurship and technology transfer literatures that some form of faculty involvement is critical for successful commercial development (see Lowe(2001), Shane (2004), Thursby et al. (2001, 2003)). The most common forms of faculty involvement are consulting and sponsored research but there is mounting evidence that “full-time” commitment by the discovery scientist is better. Studying university spinoffs in the UK and Ireland, Blair and Hitchens (1998) found that full-time commitment by the entrepreneur was necessary to meet the numerous demands of running a new firm. In his interviews with founders, Shane (2004) finds that university spinoffs perform better when there is full-time commitment. He quotes an MIT

academic entrepreneur as saying, “The major lesson I learned from founding this company is that you need to find a way to put your entire soul into it. It certainly reaffirmed the notion that if you don’t do it full time, it goes slowly – that’s exactly what happened.” (Shane (2004, p. 249) Toole and Czarnitzki (2005) provide evidence that SBIR firms employing a full-time academic entrepreneur perform better than firms not associated with a full-time academic scientist.

Full-time commitment by the discovery scientist to the commercialization process may also increase the chances of securing private investment. It may be difficult for academic scientists to effectively communicate the details and nuances of the scientific basis of the discovery. Asymmetric information between discovery scientists and potential investors reduces the chances of obtaining funding. To maximize their returns, investors also want to limit their risk of opportunistic behavior (Shane and Cable (2002)). Consequently, a full-time commitment by the discovery scientist may signal credibility of the investment opportunity.

Finally, there is a body of research that suggests the contribution of discovery scientists to commercial development extends beyond their intellectual human capital (see Murray (2004), Shane and Stuart (2002), Shane and Cable (2002)). Using interviews and quantitative data from 12 biotechnology firms, Murray (2004) suggests that discovery scientists also contribute their social capital to start-up firms. She highlights the importance of the scientist’s “local laboratory” network, which includes their graduate students, as well as the scientist’s “cosmopolitan” network, which captures their reputation and broader network of contacts. Shane and Stuart (2002) using data on MIT start-ups, find that social network ties to investors (angels or VC) decrease the probability of failure and increase the likelihood of venture capital funding. Based on survey data from venture capital and angel investors, Shane and Cable (2002) find that the probability of seed-stage funding increases when entrepreneurs have a previous social tie to investors.

In sum, the early-stage nature of most university-based discoveries are characterized by a high degree of scientific and market uncertainty that leads to an investment timing gap in which private investors prefer not to invest but to wait until the uncertainties have been further diminished. Individual faculty and TTOs, however, do not have the necessary incentives to resolve these commercially related uncertainties. University discoveries are not commercialized because the timing gap never closes. Further, the complex nature of many science based technologies requires the continued involvement of the discovery scientist in the commercial

development process. This continued involvement, especially if it is full-time, appears to be critical to successful knowledge transfer from the university to the private sector.

The Role of Public Investment in the Commercialization Process

In principle, public investment may serve a useful “bridging” function that addresses the investment timing gap for university-based discoveries. Lerner (1999) suggests that public subsidy programs may be valuable if they “certify” small firms for follow-on private investment, particularly from venture capitalists. The real options framework discussed above helps to clarify the mechanism by which participation in a public subsidy program may certify firms. In particular, if public subsidies are used to support the research necessary to reduce scientific and market uncertainties, private investors will find these opportunities more attractive since this initial investment reduces their option value of waiting.

To help clarify the potential impact of a first stage public investment, consider the following net present value (NPV) model where investment occurs in two-stages. Start-up investment is K_0 and follow-on funding at time T is given by K_T . The investment NPV is risky with the probability of success $\theta(K_0)$, which depends on K_0 , and assume $\theta'(K_0) \geq 0$ (increases in start-up funding increase the probability of success). If $\theta(K_0) > 0$ then a second stage investment is made by private investors and, if the investment is successful, it will return a present value of $V(K_0, K_T)$. When discounted at the rate r , the NPV of this problem is given by

$$(1) \quad NPV = -K_0 + \theta(K_0)[V_T(K_0, K_T) - K_T]e^{-rT}$$

Taking the derivative of the NPV with respect to investment yields

$$(2) \quad \frac{\partial NPV}{\partial K_0} = \left[\frac{\partial \theta}{\partial K_0} V_T() + \theta \left[\frac{\partial V_T()}{\partial K_T} \frac{\partial K_T}{\partial K_0} + \frac{\partial V_T()}{\partial K_0} \right] \right] e^{-rT} - 1 \geq 0$$

and

$$(3) \quad \frac{\partial NPV}{\partial K_T} = \theta \left[\frac{\partial V_T(\cdot)}{\partial K_T} - 1 \right] e^{-rT} \geq 0$$

where (2) represents the change in expected NPV given the initial funding and (3) represents the change in NPV with respect to follow-on funding. Of course, there is no requirement that initial and follow-on funding come from the same source. Suppose that K_0 is public funding from a program targeted at small technologically innovative companies. The first term in (2) represents the change in probability of success due to the public startup funds. If the initial phase is unsuccessful, perhaps due to the unanticipated failure of necessary scientific or technical requirements, this initial capital is lost. But as written the purpose of the initial investment is to increase the probability of success by reducing these uncertainties. The second term of (2) has two parts. The first part captures the cross-effects between public start-up and private follow-on funding, assuming the two are related. If this cross-effect is positive, then public investment gets “leveraged” by follow-on private investment. This is also referred to as “additionality” in the R&D literature. Of course, if the two are not related then there is no purpose in public funding of research since the follow-on funding is independent of the initial funding. The second term represents the increase in the value of the opportunity as a result of public investment, a social return. This portion of the present value gets appropriated by the follow-on private investors. The marginal private return is given in (3). Note that in (3) there is no transfer of wealth from the private investors to the public investor.

In this simple model, the term $\theta(K_0)$ in (1) incorporates the influence of both scientific and market uncertainties on the decision to invest. For early-stage university discoveries, private investors see $\theta(K_0)$ as too low to justify private start-up investment today. Since $\frac{\partial \theta}{\partial K_0} \geq 0$, as seen in (2), there is a potentially valuable role for public start-up investment. Essentially the social return from public investment is in first keeping the project alive by reducing the probability of failure. As uncertainty is reduced, follow on venture capital investment increases with an increased probability. This relationship is governed by $\theta \frac{\partial V_T(\cdot)}{\partial K_T} \frac{\partial K_T}{\partial K_0}$ in equation (2)

which simply states that the relationship between public and private investment is governed by the probability of success. The probability of success is in turn governed by public investment.

Given the potentially valuable role of initial public investment, an obvious question is why the government should undertake this investment in the first place. There are two economic justifications for a public role in early-stage investment. First, the social value of commercializing university discoveries is greater than the privately appropriated value by the commercializing firm. This rationale relies on positive externalities or spillovers resulting from the commercialization of the university discovery. Griliches (1991) reviews the R&D literature studying agriculture and manufacturing. He finds social returns to R&D investment are substantially higher than private returns. The public investors therefore must judge whether the indirect or intangible benefits from the investment, in whatever form it takes including health or employment, exceeds the level of public investment. This political decision will ultimately require a judgment that the direct marginal social benefits from an investment of K_0 be at least as great as the left hand side of (2). Government investment is also justified if there are information asymmetries in private capital markets that lead private investors to under-invest in early-stage university discoveries. The evidence supporting this is primarily qualitative. Case studies of the commercialization process for university discoveries, in particular Lowe (2001) and Shane (2004), suggest information asymmetries are particularly important for university discoveries.

However, there is another, related point of view that examines the timing of investment in relationship to its underlying risk. Reference has previously been made to the real options model which in some forms hold that increasing ambiguity or uncertainty about future probabilities can delay investment. From time to time it may not be in the public interest, for reasons of health or international competition, to delay commercialization, so it may be in the public interest to accelerate development. A slight modification of the calculus shows how this may be done in a public setting.

$$(4) \quad \frac{dNPV}{d\theta} = \frac{\partial NPV}{\partial T} \frac{\partial T}{\partial \theta} = -r \left[\theta(K_0) [V_T(K_1, K_T) - K_T] e^{-rT} \right] \frac{\partial T}{\partial \theta} > 0$$

In (4) the change in the NPV with respect to risk is enhanced by the public objective that $\frac{\partial T}{\partial \theta} < 0$. In other words, there exists an overt policy to invest public funds immediately to reduce risk sufficiently to encourage follow-on financing and hence commercialization sooner than later. This has the additional benefit of increasing the NPV of the project, which in turn makes it

more attractive to venture capitalists. It is in fact an explicit statement that the initial public investment in the early stage is in part a means to purchase, by indirect means, a portion of the option to wait by venture capitalists and other follow-on funding opportunists.

Certification in the US SBIR Program

To empirically examine the possibility that initial public investment may “certify” and thereby increase the chances of follow-on private investment, we analyze the relationship between project funding through the US SBIR program and the probability of follow-on venture capital investment. We develop our hypotheses below using the structure of the SBIR program.

The SBIR program was established in 1982 to address concerns about the competitiveness of U.S. industry. The legislation aims to increase the share of procurement contracts going to small firms from the largest federal R&D agencies and to increase commercialization of federally funded research. While entrepreneurship was not explicitly part of the legislative mandate, Toole and Czarnitzki (2005) present evidence that the program is used by university faculty to pursue commercialization of their research discoveries.

The original legislation authorizing the SBIR program required that all federal agencies with an extramural research budget greater than \$100 million set aside 1.25% of these funds for this program. (There are currently 11 federal agencies participating in the program.) After the program was reauthorized in 1992, the set-aside was increased to its current level of 2.5%. The program is now authorized through September 30, 2008.

The SBIR program has become the largest commercialization program focused on small firms in U.S. history. According to the Small Business Administration (SBA), the program awarded \$8.6 billion in direct subsidies between 1983 and 1996. Funds awarded under SBIR have generally grown each year because its budget is a fixed proportion of each agency’s extramural R&D budget. This has been especially true for the two largest SBIR agencies, the Department of Defense and the Department of Health and Human Services. Beginning in 1997, annual awards across all agencies exceeded \$1 billion and a recent figure from the National Research Council estimates the total value of awards made in 2003 to be over \$1.6 billion (NRC (2004)).

The SBIR program has eligibility requirements limiting which firms may apply as well as restricting the employment of SBIR principal investigators. The program is open to all for-profit firms that have 500 or fewer employees and are at least 51% owned by U.S. citizens. SBIR PIs are the scientific and technical project leaders and are the primary people who interact with the agency program administrators. To qualify as a PI, individuals must be employed “full-time” at the small business at the time of award and throughout the duration of the project. Full-time means at least 51% of the PI’s time and precludes full-time employment at any other institution including universities and non-profit research institutions.

The legislation established three phases to the SBIR program. All applicants must start with a Phase 1 proposal. The Phase 1 project is intended to test the feasibility of a new idea. The feasibility study lasts from six to twelve months and the Phase 1 awards can be up to \$100,000. If the results of the feasibility study are favorable, firms may apply for a Phase 2 grant to move their idea into product development. The Phase 2 award is up to \$750,000 and lasts for a two-year period. Finally, there is a Phase 3 to the SBIR program. This is an unfunded phase in which the companies are expected to commercialize their product or process. Sometimes agencies award non-SBIR funds to firms that have made into Phase 3.

Both the structure and selection process of the SBIR program leads public investors to put less weight on scientific and market uncertainties implying that these funds will be available sooner than alternative private sources. Phase 1 of the program is explicitly intended to finance a feasibility study to investigate the scientific merit of the proposed concept – a proof of concept study. So, rather than interpreting scientific uncertainty as a reason not to invest, the SBIR program is designed to accept higher levels of this uncertainty. With respect to market uncertainty, the SBIR application for a Phase 1 study must identify and discuss the intended market opportunity for the innovation but no business plan or detailed market evaluation is required. This stands in stark contrast to more extensive market definition and research required by most private investors. Quite simply, the limited market due diligence required by SBIR implies that proposal evaluators place less weight on market uncertainties and will, therefore, invest earlier.

Venture capitalists and other private investors are not going to simply invest in a company because SBIR reviewers and administrators have approved a proposal and provided initial financial support. (For borderline cases, lowering the cost of commercialization through

the subsidy might be enough to create a positive net present value and make the investment attractive.) For most cases, the increased probability of follow-on private investment comes from the SBIR firm's success at reducing scientific and market uncertainties. It comes from the successful completion of Phase 1's proof of concept and Phase 2's product and market strategy development. So, except for borderline cases, there should not be any certification effect for companies that win only a Phase 1 SBIR award and fail to move past proof of concept.

Hypothesis #1: Winning only Phase 1 SBIR awards does not increase a firm's probability of follow-on venture capital investment since these projects are shown to be infeasible.

Hypothesis #2: Winning Phase 2 SBIR awards will increase a firm's probability of follow-on venture capital investment since scientific and market uncertainties have been diminished through participation in the SBIR program

In addition to these broader hypotheses, we also examine if SBIR firms utilizing biotechnology methods or SBIR firms employing a former university scientist have a higher probability of follow-on venture capital funding. In this regard, there could be both direct and indirect effects. The direct effect of a biotechnology focus captures differences in how venture capitalists perceive the technological opportunities in biotech relative to other fields. The indirect effect, which would work through an interaction term on Phase 2 SBIR funding, indicates if the marginal impact of public funding on follow-on private funding is greater for biotech firms relative to SBIR firms focused in other technology fields. Likewise, we build on earlier work by Toole and Czarnitzki to examine the direct and indirect impact of employing a university scientist. A direct effect would capture the combined impact of an academic researcher's intellectual and social human capital as well as any possible signaling related to the investment opportunity. An indirect effect, measured by an interaction term with Phase 2 funding, would indicate if the marginal impact of public funding on follow-on private funding is greater when the firm employs a former university researcher.

Data and Methodology

Our empirical work draws on three sources of data. The primary database is drawn from the US Small Business Administration (SBA). SBA is the coordinating agency for the SBIR program and their public data cover the 1983 to 2000 period for all participating agencies. These data provide the firm name, street address, city, state, SBIR phase, year of award, awarding agency, award amount, topic, and indicators for minority or woman owned. To link public funding to follow-on private investment, we use Securities Data Corporation's (SDC) VentureXpert database (1977-1998) to identify which SBIR firms received venture capital, the firm's founding date, and the date of their first round of VC. Our third data source was purchased from a private consulting firm that compiles information on SBIR firms. From this company, we purchased information on the founding dates of SBIR participating firms. These data, however, are not available for all SBIR firms since most participating companies are small private firms with limited public information.

The results section of the paper presents our regression findings. Our database is composed of a cross-section of firms that received at least one SBIR award over the period 1983-1997 from any one of the participating US agencies. We have information on 10,165 SBIR firms over this period compiled from the SBA. However, when we also require data on a firm's founding date, our total number of observations falls to 1,699.

Table 1 presents descriptive statistics for our variables by group where the group is determined by whether we observe the firm's founding date or not. The two groups are quite different and having the firm's founding date improves our data by allowing us to control for the age of the firm when it enters the SBIR program and allowing us to identify startup firms. Focusing on this group, about 9% of the firms receive VC after winning an SBIR award, 12.5 % employ a university scientist, and 15.5% are involved in the biotech sector. This biotech group can be further subdivided into those firms focused on biotech instruments, tools, software versus those using the laboratory methods like recombinant DNA, gene expression and monoclonal antibodies. About 12.6% of these are lab biotech.

To perform our empirical analysis we use cross-sectional Probit models. The dependent variable in our analysis is an indicator that takes the value 1 if the SBIR firm received its first infusion of venture capital after it received its first SBIR (phase 1) award and 0 otherwise. There are firms that receive both SBIR and venture capital in the same year. We code the indicator for these firms as 1, VC after SBIR, since the SBIR proposal review process takes a minimum of six

months. Given that our data are annual, we do not observe the exact dates of regarding when the firm's SBIR proposal was submitted to the public agency. Our basic firm-level regression model is:

$$(5) \Pr(VCAfter = 1 | \mathbf{X})_i = \Phi(\beta_0 + \beta_1 Phase1\$_i + \beta_2 Phase2\$_i + \beta_3 Biotech_i + \beta_4 UNIV_i + \beta_5 (Phase2\$ * Biotech)_i + \beta_6 (Phase2\$ * UNIV)_i + \beta_7 (Startup)_i + \beta_8 (Age)_i)$$

where *Phase1\$* is the cumulative value of SBIR phase 1 awards to the firm up to 1997; *Phase2\$* is the cumulative value of SBIR phase 2 awards to the firm up to 1997; *Biotech* is a dummy variable indicating if the firm uses biotechnology methods; *UNIV* is a dummy variable indicating if the firm employs a former university scientist full-time by 1997; *Startup* is a dummy variable indicating if the firm won an SBIR award in the first two years after it was founded; *Age* is a age of the firm in years at the time it won its first SBIR award.

Empirical Results

Tables 2 and 3 report our Probit results using the regression coefficients not the marginal effects. Table 2 uses the full sample while the models appearing in Table 3 use only those observations for which we have the founding date of the firm.

Model (1) in Table 2 shows that the probability of a firm receiving follow-on venture capital investment actually falls if the firm only wins SBIR phase 1 awards. Since only winning Phase 1 awards indicates that the firm's projects are never shown to be scientifically feasible, this result is expected and reasonable. The model in column (2) includes those firms that also progress past the Phase 1 award to win at least one Phase 2 award for product development. Both Phase 1 dollars and Phase 2 dollar are included since Phase 2 awards are only given after the successful completion of Phase 1. The results show that greater Phase 2 awards are associated with a higher probability of follow-on VC funding while Phase 1 awards are insignificant. These results are consistent with our hypotheses that public investment aimed at reducing scientific and market uncertainties increases the chances for private investment by making the firms projects more attractive. The fact that Phase 1 dollars are insignificant but Phase 2 dollar are significant suggests that once a project's scientific feasibility is established, it

is primarily the prototype development stage of the SBIR program that attracts private investors. Recall that the University of California entrepreneur interviewed by Lowe and quoted earlier in this paper made the same point. That is, venture capitalists find prototypes and “near market” investment opportunities the most attractive.

Columns (3) and (4) include our variables identifying biotechnology firms and firms that employ a former university scientist. Having a biotechnology focus increases the probability of VC investment relative to other technology foci. Most probably, this captures the VC’s taste for biotech firms due to underlying perceptions about relative technological opportunities. The results also show that having a former academic scientist employed by the firm significantly increases the probability of venture capital investment after an SBIR award. Earlier we highlighted three reasons to expect this result. It could be the scientist’s intellectual human capital, social capital, or a signaling effect to investors regarding the opportunity. Unfortunately, with these data, we can not distinguish between these possibilities.

The indirect effects of biotechnology and university scientist are interesting. Recall that these measure the how biotech and university scientists influence the marginal impact of Phase 2 SBIR funding. For biotechnology firms, column (4) shows that increasing the size of the Phase 2 award increases the probability of follow-on VC investment. Given long-term and complex nature of innovation using biotech methods, it makes sense that greater funding in the product development stage would increase the attractiveness of these firms to VCs. Interestingly, with a former academic scientist running the project, greater Phase 2 funding becomes less effective and lowers the probability of follow-on private financing. While not expected, this is consistent with the point of view espoused by Shane (2004). He suggests that academic scientists are not the best people to head up product development in the commercialization process since they are traditionally inexperienced in this area and have an inclination for academic inquiry. Our results are supportive of his viewpoint.

Using our sub-sample with firm founding dates, the results reported in Table 3 allow us to control for the firm’s age at the time of their first SBIR award and whether the firm is a startup. Columns (1)-(4) repeat the analysis of Table 2. The results are quite similar. We still find evidence consistent with the idea that initial public investment can certify firms by allowing them to resolve scientific and market uncertainties that would otherwise remain unaddressed. The new variables appear in the model of column (5). Among SBIR participants, being a startup

firm, defined as a company receiving their first SBIR award less than two years after founding, significantly increases the chances of follow-on venture capital. Holding the number of startup firms constant, older firms at the time of first SBIR award have a higher probability of follow-on VC financing.

Conclusion

This research highlights a potentially fruitful role of public investment in early-stage technology firms. Lerner (1999) suggested that public programs may be useful to the extent that they certify firms to private investors. We have used the real options framework to suggest the mechanism through which this certification effect may take place. Our empirical analysis of the US SBIR program finds evidence consistent with this viewpoint. While our data do not “prove” SBIR certification, there is a strong association for those firms that move through Phase 1 feasibility into Phase 2 product development and follow-on venture capital investment. At the same time, there is a negative impact for those firms that never make it past the Phase 1 feasibility research designed to reduce scientific uncertainties about the investment opportunity. Our results also suggest that the marginal impact of public investment in product development is greater for biotechnology firms than for firms in other technology areas. Moreover, having a former academic scientist running the SBIR project increases the chances of follow-on venture capital even though the impact of the marginal public dollar invested into product development appears to fall. Academic scientists may be more skilled at resolving scientific uncertainties and less adept at resolving market uncertainties associated with product development.

Table 1
Descriptive Statistics - SBIR Firms

Variable Name	Firms (No founding date, Obs = 8,466)				Firms (Founding date, Obs = 1699)			
	Mean	Std.Dev.	Min	Max	Mean	Std.Dev.	Min	Max
VC After SBIR	0.003	0.055	0	1	0.092	0.29	0	1
Only Phase 1	2.9	5.6	1	107	9.3	25.5	1	529
Phase 1 (1000\$)	183	374	3	7416	623	1704	5	35800
Phase 2 (1000\$)	509	1264	0	26900	1682	4769	0	87500
Univ. Scientist	0.021	0.145	0	1	0.125	0.331	0	1
Biotech	0.0158	0.1248	0	1	0.155	0.362	0	1
Lab Biotech	0.012	0.109	0	1	0.128	0.335	0	1
Biotech tools	0.004	0.062	0	1	0.026	0.161	0	1
Startup					0.400	0.490	0	1
Age					13.304	7.535	1	51

Table 2 – Probit Regression (full sample)

Dependent Variable: VC after SBIR				
	(1)	(2)	(3)	(4)
Only Phase 1	-0.2082***			
Phase1\$		-4.26×10^{-8}	$-1.48 \times 10^{-7} *$	-1.34×10^{-7}
Phase2\$		$4.92 \times 10^{-8} *$	$7.78 \times 10^{-8} ***$	$7.72 \times 10^{-8} **$
Biotech Dummy			0.791***	0.712***
Univ. Scientist			0.633***	0.731***
(Phase2\$ * Biotech dummy)				$2.26 \times 10^{-7} **$
(Phase2\$ * Univ. Scientist)				$-1.50 \times 10^{-7} *$
Constant	-2.01***	-2.13***	-2.25***	-2.26
# of Obs.	10165	10165	10165	10165
McFadden-R ²	0.007	0.012	0.08	0.085
Log-Likelihood	-910.564	-905.208	-842.884	-838.373

*** (**, *) indicate a significance level of 1% (5, 10%),

Table 3 – Probit Regression (founding date sample)					
Dependent Variable: VC after SBIR					
	(1)	(2)	(3)	(4)	(5)
Only Phase 1	-0.0297				
Phase1\$		-1.18×10^{-8}	$-1.70 \times 10^{-7} *$	-1.70×10^{-7}	-1.79×10^{-7}
Phase2\$		5.12×10^{-8}	$6.76 \times 10^{-8} **$	$7.01 \times 10^{-8} **$	$6.68 \times 10^{-8} **$
Biotech Dummy			0.332***	0.244**	0.315***
Univ. Scientist			0.298***	0.417***	0.428***
(Phase2\$ * Biotech dummy)				$1.78 \times 10^{-7} **$	$1.87 \times 10^{-7} **$
(Phase2\$ * Univ. Scientist)				-1.34×10^{-7}	$-1.73 \times 10^{-7} **$
Startup					0.903***
Age					0.025***
Constant	-1.316***	-1.342***	-2.25***	-1.44***	-2.24***
# of Obs.	1699	1699	1699	1699	1699
McFadden-R ²	0.0001	0.034	0.08	0.0279	0.102
Log-Likelihood	-523.359	-521.625	-511.831	-508.80	-470.27

*** (**, *) indicate a significance level of 1% (5, 10%),

REFERENCES

- Archibald, Robert B., and David H. Finifter. (2003). "Evaluating the NASA small business innovation research program: preliminary evidence of a trade-off between commercialization and basic research," *Research Policy*, Vol. 32, pp. 605-619.
- Audretsch, David B. (2003). "Standing on the Shoulders of Midgets: The U.S. Small Business Innovation Research Program (SBIR)," *Small Business Economics*, Vol. 20, pp. 129-135.
- Audretsch, David B., Albert N. Link and John T. Scott. (2002). "Public/private technology partnerships: evaluating SBIR-supported research," *Research Policy*, Vol. 31, pp. 145-158.
- Audretsch, David B., Juergen Weigand and Claudia Weigand. (2002). "The Impact of the SBIR on Creating Entrepreneurial Behavior," *Economic Development Quarterly*, Vol. 16, No. 1, February 2002, pp. 32-38.
- Bhide, Amar V. (2000). The Origin and Evolution of New Business, New York, NY: Oxford University Press.
- Branscomb, Lewis M. and Philip E. Auerswald. (2001). Taking Technical Risks: How Innovators, Managers, and Investors Manage Risk in high-Tech Innovations, Cambridge, MA: MIT Press.
- Blair Desmond M., David M W N Hitchens. (1998). Campus Companies – UK and Ireland, Aldershot, England: Ashgate Publishing Ltd.
- Brown, George E Jr., and James Turner. (1999). "Reworking the Federal Role in Small Business Research," *Issues in Science and Technology*, Summer 1999, pp. 51-58.
- Cockburn, Iain, M., Rebecca Henderson. (1997). "Public-private Interaction and the Productivity of Pharmaceutical Research," *NBER Working Paper No. 6018*, Cambridge, MA, April 1997.
- Colyvas, Jeannette, Michael Crow, Annetine Gelijns, Roberto Mazzoleni, Richard R. Nelson, Nathan Rosenberg, Bhaven N. Sampat. (2002). "How do university inventions get into practice?" *Management Science*, Vol. 48, No. 1, January 2002, pp. 61-72.
- Di Gregorio, Dante and Scott Shane. (2003). "Why do some universities generate more start-ups than others?" *Research Policy*, Vol. 32, pp. 209-227.
- Dixit, Avinash. (1992). "Investment and Hysteresis," *Journal of Economic Perspectives*, Vol. 6, No. 1, Winter 1992, pp. 107-132.

- Gans, Joshua S. and Scott Stern. (2000). "When Does Funding Research by Smaller Firms Bear Fruit?: Evidence from the SBIR Program," *Economics of Innovation and New Technology*, Vol. 12, pp.361-84.
- Gompers, Paul, Josh Lerner, and David Scharfstein. (2003). "Entrepreneurial Spawning: Public Corporations and the Genesis of New Ventures, 1986-1999," *NBER Working Paper No. 9816*, Cambridge, MA, July 2003.
- Lerner, Josh. (1999). "The Government as Venture Capitalist: The Long-run Impact of the SBIR program," *Journal of Business*, vol.72, no. 3, pp. 285-318.
- Lerner, Josh. (2000). "The Problematic Venture Capitalist," *Science*, Vol. 287, No. 5444, pp. 977-979.
- Lowe, Robert A. (2001). "The Role and Experience of Start-ups in commercializing Inventions: Start-up Licensees at the University of California, in Entrepreneurial Inputs and Outcomes: New Studies of Entrepreneurship in the United States, Gary D. Libecap, ed. New York, NY: Elsevier Science.
- Murray, Fiona. (2004). "The role of academic inventors in entrepreneurial firms: sharing the laboratory life," *Research Policy*, Vol. 33, pp. 643-659.
- National Institutes of Health, Office of Extramural Research. (2003). National Survey to Evaluate the NIH SBIR Program, Dept. of Health and Human Services, July 2003.
- National Research Council. (1999). The Small Business Innovation Research Program: Challenges and Opportunities. Charles W. Wessner, ed. Washington, D.C.: National Academy Press.
- National Research Council. (2004). An Assessment of the Small Business Research Program: Project Methodology. Committee on Capitalizing on Science, Technology, and Innovation. Washington, D.C.: National Academy Press.
- Pindyck, Robert S. (1991). "Irreversibility, Uncertainty, and Investment," *Journal of Economic Literature*, Vol. 29, No. 3, September 1991, pp. 1110-1148.
- Shane, Scott. (2004). Academic Entrepreneurship: University Spinoffs and Wealth Creation. New Horizons in Entrepreneurship, Sankaran Venkataraman, ed. Northampton, MA: Edward Elgar Publishing.
- Shane, Scott and Daniel Cable. (2002). "Network Ties, Reputation, and the Financing of New Ventures," *Management Science*, Vol. 48, No. 3, March 2002, pp. 364-381.
- Shane, Scott and Toby Stuart. (2002). "Organizational Endowments and the Performance of University Start-ups," *Management Science*, Vol. 48, No. 1, January 2002, pp. 154-170.

- Torero, Maximo. (2000). "Analyzing the Spillover Mechanism on the Semiconductor Industry in the Silicon Valley and Route 128," Econometric Society World Congress 2000 Contributed Paper 0090, Econometric Society, available at <http://ideas.repec.org/pto34.html>
- Thursby, Jerry G., R. Jensen, and Marie C. Thursby. (2001). "Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major U.S. Universities," *Journal of Technology Transfer*, Vol. 26, pp. 59-72.
- Thursby, Jerry G., Marie C. Thursby. (2002). "Who Is Selling the Ivory Tower? Sources of Growth in University Licensing," *Management Science*, Vol. 48, No. 1, January 2002, pp. 90-104.
- Thursby, Jerry G., Marie C. Thursby. (2003). "Are Faculty Critical? Their Role in University-Industry Licensing," *NBER Working No. 9991*, Cambridge, MA, September 2003.
- Toole, Andrew A., Dirk Czarnitzki. (2005). "Biomedical Academic Entrepreneurship through the SBIR Program," NBER Working paper #????, June 2005.
- Wallsten, Scott. (2000). "The effects of government-industry R&D programs on private R&D: the case of the Small Business Innovation Research Program," *Rand Journal of Economics*, Vol. 31, No. 1, Spring 2000, pp. 82-100.
- Zucker, Lynne G., Michael R. Darby, and Jeff S. Armstrong. (1998a). "Geographically Localized Knowledge: Spillovers and Markets," *Economic Inquiry*, Vol. 36, No. 1, January 1998, pp. 65-86.
- Zucker, Lynne G., Michael R. Darby, and Marilyn B. Brewer. (1998b). "Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises," *American Economic Review*, Vol. 88, No. 1, March 1998, pp. 290-306.
- Zucker, Lynne G., Michael R. Darby, and Jeff S. Armstrong. (2002). "Commercialization Knowledge: Capture, and Firm Performance in Biotechnology," *Management Science*, Vol. 48, No. 1, January 2002, pp. 138-153.