Biomedical Academic Entrepreneurship Through the SBIR Program

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ABSTRACT

This paper describes the U.S. Small Business Innovation Research (SBIR) program as a policy fostering academic entrepreneurship. We highlight the two main characteristics of the program that make it attractive as an entrepreneurship policy: early-stage financing and scientist involvement in commercialization. Using unique data on NIH supported biomedical researchers, we trace the incidence of biomedical entrepreneurship through SBIR and describe some of the characteristics of these individuals. To explore the importance of early-stage financing and scientist involvement, we complement our individual level data with information on scientist-linked and non-linked SBIR firms.

The U.S. Small Business Innovation Research (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. In this paper we suggest that the SBIR program also fosters academic entrepreneurship. Except for some initial work by Audretsch et al. (2002), this perspective of the SBIR program has been largely ignored.

There are two main characteristics of the program and make it attractive as a policy for academic entrepreneurship. First, since most university-based technologies are characterized by a high degree of technical and market uncertainty, external financing is difficult to obtain from private sources like venture capital (Bhide (2000)). The SBIR program, on the other hand, will fund promising but unproven technologies earlier than private investors as a result of both the program's structure and selection process. This provides academic entrepreneurs with a source of financing for commercialization of early-stage technologies that otherwise would not exist. Related to this, Lerner (1999) points out that participation in the SBIR program may have a "certification" effect that increases the chances for obtaining follow-on private investment.

Second, the SBIR program requires academic entrepreneurs to commit "full-time" to the commercialization process throughout the duration of the project. In complex technological fields, like biomedicine, there is mounting evidence that faculty involvement in the commercialization of university-based technologies is important for success. In a stream of research focusing on "star" scientists in biotechnology, Zucker et al. (1998a, 1998b, 2002) point out that scientific discoveries embody tacit knowledge that can only be communicated through "bench-level" interaction. Their work suggests that firms are more successful when discovery scientists are involved in the development of their ideas for commercial application. Using a survey of university technology transfer offices, Thursby et al. (2001) find that faculty-inventor involvement is important for commercial development after licensing. Case study research by Lowe (2001) and Murray (2004) also supports this finding, particularly in biomedical discoveries.

Under the assumption that these two SBIR policy characteristics are important for academic entrepreneurship, we expect to observe three behavioral outcomes. First and foremost, we expect to observe university researchers choosing to commercialize their discoveries through the SBIR program. While compiling systematic data on individual academic entrepreneurs is a persistent problem for research in this area, the SBIR program provides a unique opportunity to track individuals as they venture from research into business since many of the principal investigators (PIs) on SBIR projects were researchers at universities and other non-profit research institutions. Focusing on biomedical scientists, we use these data to investigate the incidence of academic entrepreneurship from the beginning of the SBIR program up to 1996. Moreover, we are able to provide some descriptive information about SBIR academic entrepreneurs such as whether these individuals are "star" scientists or not.

Our second and third behavioral outcomes are more direct consequences of the two SBIR policy characteristics. With respect to funding early-stage discoveries, Lerner points out that this type of policy may be valuable to the extent that it "certifies" new firms as an attractive investment opportunity for follow-on private investment. We examine the certification hypothesis for SBIR firms as well as for "scientist-linked" SBIR firms by looking at the probability of obtaining follow-on venture capital investment. Finally, we want to investigate the importance of involving discovery scientists in the SBIR commercialization process. To do this, we examine whether scientist-linked SBIR firms are more successful than non-linked SBIR firms in terms of program completion and patenting.

Our data indicate that the SBIR program does foster academic entrepreneurship and further suggests that public policy sharing the dual characteristics of early-stage financing and active involvement of the discovery scientist is a potentially fruitful design. Since 1991, there has been a steady growth in the number of SBIR academic entrepreneurs. While 14% of these researchers can be labelled "stars" in terms of cumulative research awards from the NIH, we find that the average SBIR academic entrepreneur is not a star. The likelihood of follow-on venture capital funding is higher for firms that complete the SBIR program. Firms associated with an academic entrepreneur have an even higher probability of follow-on venture capital funding. We interpret this as evidence supporting Lerner's certification hypothesis. These scientist-linked SBIR firms also have a greater probability of completing the SBIR program and patent more. Academic entrepreneurs that are NIH stars, however, make no additional contribution to program completion or patenting beyond their status as an academic entrepreneur. While these results shed new light on aspects of the SBIR program and its role as an academic entrepreneurship policy, our empirical tests should be viewed as suggestive rather than definitive given the data limitations that prevent more extensive firm level controls in our regressions.

The rest of the paper proceeds as follows. The next section describes the background of the SBIR program and its role in funding early-stage technology companies. This section also develops our three behavioral hypotheses in greater depth. Section III discusses the data and methodology. Section IV presents our results and concluding comments appear in section V.

II. The SBIR Program and Its Role in Financing Early-stage Technology

SBIR Background

Created by the Small Business Innovation Development Act of 1982, the SBIR program made its first financial awards in 1983. The original legislation mandated that all federal agencies with an extramural research budget greater than $100 million set aside 1.25% of these funds for this program.[1] 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 un-funded 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.

There are many differences across SBIR agencies in the focus and administration of the program. Agencies differ in the degree to which program announcements are targeted to specific mission-oriented needs. The U.S. Dept. of Defense and NASA represent the most targeted programs and the NIH and NSF represent the least targeted. For those targeted programs, SBIR awards bring a relatively close working relationship with the agency. These agencies use the program as an extension of their procurement contracting process to smaller companies. On the other hand, agencies like the NIH have broadly defined program announcements covering scientific areas and they encourage investigator-initiated proposals. These agencies rely much more on external peer review versus internal administrative review to determine scientific and commercial merit. There are also differences in the technology areas funded by the agencies. While there is some overlap, the NIH funds the dominant share of health-oriented projects.

Academic Entrepreneurship and Role of SBIR

Academic entrepreneurship is a particular form of technology transfer. It takes place when researchers in universities and non-profit institutions decide to participate in the commercialization of a technology that originated or was substantially developed within their institutions. An academic entrepreneur is no longer just a scientific investigator but an active participant in business oriented functions. In its most extreme form, the academic entrepreneur actually leaves the non-profit research environment to pursue commercialization of the "university-based" technology full-time in the private sector by starting a firm or joining an exiting firm.

With the exception of Audretsch et al. (2002), the policy and academic literatures have not focused on the SBIR program as an incentive structure inducing academic entrepreneurship but instead have focused on evaluating the impact of the SBIR program on project and firm performance measures.[2] Audretsch and his coauthors suggest that the SBIR program induces scientists and engineers to change their career trajectories to pursue commercialization as a result of winning an SBIR award. Using 12 case studies and survey data from 20 SBIR participant firms in Indiana, they find that most firm founders came from universities. Over half of the survey respondents agreed that the SBIR award influenced their decision to start a new firm or continue the firm. Only 15% would have pursued other sources of financing to start their firm. They also find some limited evidence of a "demonstration effect" in which a scientist's decision to pursue commercialization through SBIR was influenced by observing the success of others.

Like Audretsch and his coauthors, we believe the SBIR program provides an incentive structure that fosters academic entrepreneurship. For full-time academic entrepreneurs, particularly those seeking to pursue commercialization through the formation of a new firm, we expect the SBIR program to be an attractive financing option relative to other sources. Its attractiveness will depend on, among other things, the entrepreneur's available financing options and the relative cost of SBIR funds.

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 technical and market uncertainty.[3] 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 technical and market uncertainties that are diminished over time as 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)).

According to this theory, public investors will invest earlier than private investors in university-based technologies if they are more patient or if public investors put less weight on technical and market uncertainties when evaluating the investment option. Surely, the government is among the most patient risk capital investors, particularly relative to venture capital sources. Lowe (2001) and Shane (2004) present case study evidence supporting this view. Greater patience leads public investors to discount future returns less heavily and decreases the value of waiting. So, holding other factors constant, public funds should be available to academic entrepreneurs for commercialization sooner than alternative private sources.

Even more importantly, both the structure and selection process of the SBIR program leads public investors to put less weight on technical 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 technical merit of the proposed concept – a proof of concept study. So, rather than interpreting technical uncertainty as a reason not to invest, the SBIR program is designed to accept higher levels of technical 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. For example, in his case study research of academic entrepreneurship in the University of California system, 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)

This real options view of investment into university-based technologies helps to clarify the mechanism by which participation in the SBIR program can "certify" firms for follow-on private investment as postulated by Lerner (1999). 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 technical 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.

This suggests two empirical tests of the certification hypothesis. A more stringent test would ask if follow-on venture capital funding is more likely when small firms participate in the SBIR program and win a Phase 2 award. Unfortunately, we do not have data on non-SBIR participants to perform this test. Since we have SBIR participant firms, we can perform a less stringent test: Conditional on already being in the SBIR program, is follow-on venture capital funding more likely for those small firms that win a Phase 2 award. Additionally, network effects and social ties of academic entrepreneurs, discussed below, may increase the likelihood of follow-on venture capital for those scientist-linked SBIR firms.

Alternative forms of early-stage financing, when available, will typically have a higher cost to an academic entrepreneur in terms of both risk and return. Personal funds reduce savings and imply a higher personal risk than an SBIR subsidy. Banks loans require collateral, interest payments, and repayment. Venture capitalists and angels require in depth market due diligence, although angels appear to be less demanding, and take an equity interest in the company, usually preferred stock. As a subsidy, SBIR funds do not require repayment or loss of ownership. The SBIR Phase 1 allows academic entrepreneurs time to investigate the technical feasibility of their ideas and to prepare the market due diligence private investors require. Successful completion of both phases should significantly increase the market value of their firm and thereby allow the entrepreneur to retain a greater equity interest in their company and its subsequent return stream.

Discovery Scientist Involvement in Commercialization

Consistent with the fact that most university-based technologies are very early-stage, there is broad agreement in the academic entrepreneurship and technology transfer literatures that some form of faculty involvement is critical.[4] The most common forms of faculty involvement are consulting and sponsored research but recall the SBIR program requires the PI to be employed full-time at the firm. This level of commitment is likely to benefit the firm in its pursuit of follow-on private financing. Asymmetric information between academic entrepreneurs and potential investors reduces the chances of obtaining funding. To maximize their returns, investors want to limit their risk of opportunistic behavior by entrepreneurs (Shane and Cable (2002)). In the presence of asymmetric information, a full-time commitment by the discovery scientist may signal credibility of the investment opportunity.

There is also evidence that full-time commitment by entrepreneurs improves the performance of the firm. 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)

In our empirical work, we explore the hypothesis that full-time commitment by the academic entrepreneur is associated with better performance by SBIR firms measured in terms of program completion (winning a Phase 2 award) and patenting. To do this we compare scientist-linked SBIR firms with non-linked SBIR firms. Since non-linked SBIR firms may have any number of contractual and informal relationships with university researchers that we do not observe, our test of the importance of full-time commitment should be a fairly strong.

Zucker and coauthors have an important stream of 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 on new semiconductor firms.

In the empirical section, we explore whether SBIR biomedical academic entrepreneurs are star scientists using cumulative NIH research awards as our indicator of academic achievement. Cumulative NIH grants should be positively related to academic publications. In fact, Leibert (1977) finds that past research publications are strongly related to successful grant getting. Following the spirit of Zucker et al. (2002), we will examine if NIH stars are associated with higher rates of SBIR program completion (winning a Phase 2 award) and firm patenting.

Murray (2004), Shane and Stuart (2002), and Shane and Cable (2002) present evidence that the contribution of discovery scientists to commercial development extends beyond their intellectual human capital. 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.

While the social capital of an entrepreneur appears to be important, our data on SBIR academic entrepreneurs are not rich enough to separately explore the impact of social network ties on SBIR firm venture funding or performance. Our empirical results will capture both the human and social capital contributions on scientist-linked SBIR firms.

III. Data and Methodology

Data Sources

Our empirical work draws on five sources of data. First, we use the NIH Computer Retrieval of Information on Scientific Projects (CRISP) database to identify the population of biomedical researchers that received at least one research award between 1972 and 1996. (After 1996, the NIH stopped publicly reporting the award amounts for individual grants and contracts.)

For each award, the database includes the grant number, research activity code, grant title and abstract, the PI name, the NIH awarding institution, the fiscal year, the award amount, the institutional affiliation of the PI at the time of award, the institution's street address, city, state, and an NIH award type code. These data include all Dept. of Health and Human Services (DHHS) SBIR awards.

The second source of data is the Small Business Administration's SBIR/STTR public use database. SBA is the coordinating agency for the SBIR and STTR programs and their public data cover the 1983 to 1998 period. 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. Because the SBA data do not include the PI name, we supplemented these data with the PI names from four of the largest SBIR agencies for 1983-1998. These are: Dept. of Defense, NASA, NSF, and DHHS.

The NIH and supplemented SBA data are enough to identify SBIR academic entrepreneurs and compare them along some dimensions to other non-SBIR biomedical researchers but we require additional information on each firm's venture funding and patenting activity to test our hypotheses. We use Securities Data Corporation's (SDC) VentureXpert database (1977-1998) to identify which SBIR firms received venture capital and the date of their first round. For patenting activity, we use the NBER patent database to identify all patents assigned to SBIR participant firms (Hall et al. (2001)).

Identifying Academic Entrepreneurs

To identify SBIR biomedical academic entrepreneurs we match individual PIs by name between the NIH researcher database the supplemented SBA SBIR database. Name matching is a difficult process but can be done fairly accurately if there is enough cross-referencing information. The first step was to standardize the format and insure the consistency of the names within each separate database. This was done manually for each. The NIH database required a month of full-time manual labor to review over 610,000 individual records. There were various errors in spelling, married names, hyphens, spacing, etc. As described above, the other data items in each record were used to cross-reference and identify errors. In the end, we had 79,967 unique NIH PIs and 24,287 unique SBIR PIs. For SBIR at NIH, there were 4,196 unique PIs between 1983 and 1996.

Matching names across the two PI databases proved quite difficult. The central problem was the lack of cross referencing information common to both files. So, we had to "blacklist" very common names, like Thomas Jones and John Smith, and exclude them from the possible matching group. (We could have included them if we checked every case by hand but limited resources did not permit this.) When we performed the matching and looked at the SBIR awarding agency, we found a fairly large number of NIH researchers getting SBIR awards from DOD. However, upon closer inspection, most of these were false matches revealed by the complete incongruity between the NIH research topic and the DOD SBIR topic. It was never the case in our matching that an NIH researcher *only* won SBIR awards from other agencies (NSF, NASA, DOD). Sometimes, while relatively few, biomedical researchers would win their first SBIR from NSF, NASA, or DOD but in *all* cases they also won an SBIR from NIH. While somewhat surprising, this is consistent with the difference across agencies in their technology focus. Consequently, we rely on the consistency in the NIH PI database to identify biomedical academic entrepreneurs.

Using the NIH database, our name matching produced 693 potential academic entrepreneurs. However, we eliminated those NIH researchers that received their prior research award while associated with a firm or policy oriented institution. Almost all were firm associated matches and this reduced our potential academic entrepreneur group to 514 people. Next, there were a number of individuals whose last NIH research grant was more than four years prior to their first SBIR award. Because we are unsure if they changed jobs during this interval, we eliminated those people and reduced our potential matches to 387. Finally, there were a number of people that won an SBIR award *first* and then moved to academic institutions to do research. These people might be graduate students who tried to commercialize but we are not sure so we eliminated those individuals. Our final group of academic entrepreneurs came to 337 people. We manually checked these people to verify that they were, in fact, biomedical researchers before they won their first SBIR award. It should also be noted that a fair number of these people won NIH research awards subsequent to their SBIR. This could indicate either of two possibilities. First, their proof of concept failed and they returned to academic research or their SBIR experience was successful but they delegated further development to others, perhaps retaining a consulting and equity position in the firm.

Overall, our sample of SBIR biomedical academic entrepreneurs is conservative. This group is only 0.4% of the total unique NIH PIs in the CRISP database and 1.4% of all unique SBIR PIs across the four major SBIR awarding agencies. In our matching work, we found that NIH researchers using the SBIR program always had at least one award from NIH. The more appropriate comparison group should be those SBIR PIs from NIH and, among this group, our academic entrepreneurs account for 8% of the PIs. It is quite possible that we missed some SBIR biomedical academic entrepreneurs in the matching process. It's difficult to know how many and, given the available data, a more complete accounting would require a very significant investment of person-hours. However, to the extent that scientist-linked SBIR firms are really different from non-linked firms, under counting will bias our coefficient estimates downward and reduce our chances of finding a statistically significant contribution of discovery scientists to follow-on venture capital funding and firm performance. In this sense, our statistical tests are stronger.

Regression Analysis of Scientist-linked SBIR Firms

The results section of the paper presents the findings from three sets of regressions. The first set of regressions examines two hypotheses. First, does the presence of a full-time academic entrepreneur increase the probability of follow-on venture capital funding? As discussed in the last section, we expect that it does both because of the signaling effect of full-time commitment and because of the human capital and social ties of the discovery scientist. Second, does completion of the SBIR program increase the likelihood of follow-on venture capital funding? If progress through the SBIR program sufficiently reduces technical and market uncertainties, we expect the probability of VC funding to increase. It should not increase, however, for those firms that only complete Phase 1. This is a test of Lerner's (1999) certification hypothesis. We use a dummy variable indicating if the firm received a Phase 2 award as our indicator of SBIR program completion.

We use a Probit model to test these hypotheses. The dependent variable is a dummy indicating whether the SBIR firm received its first round of venture capital funding after its first SBIR award. The model for firm i in year t:

$$(1)\quad \Pr(VCafter = 1 | \mathbf{X})_{it} = \Phi(\beta_0 + \beta_1 PatentStk_{it-1} + \beta_2 AE_{it} + \beta_3 Star_{it} + \beta_4 P2_{it} + \beta_5 NIHfield_{it} + \beta_6 MA_i + \beta_7 CA_i)$$

where *PatentStk* is the cumulative number of patents granted to the firm by application year t; *AE* is a dummy variable indicating if the firm is linked to a biomedical academic entrepreneur in year t; *Star* is a dummy variable indicating if the academic entrepreneur is also "star" NIH scientist; *P2* is a dummy variable indicating the firm won a SBIR Phase 2 award in year t; *NIHfield* broadly captures the firm's technology area through its association with any of 15 NIH awarding components across time (i.e. National Cancer Institute, National Eye Institute, etc.); *MA* and *CA* are dummies for Massachusetts and California.

Our second set of regressions examines the probability of completing the SBIR program as indicated by wining a Phase 2 award. Here, we are interested to see if scientist-linked SBIR firms have a greater chance of program completion relative to non-linked SBIR firms. To the extent that full-time commitment by the discovery scientist is important to the commercialization process, we expect scientist-linked firms to have a greater chance of completing the program. The dependent variable is a dummy indicating whether the firm received a SBIR Phase 2 award (*P2* above). The model for firm i in year t:

(2) $\Pr(P2 = 1 | \mathbf{X})_{it} = \Phi(\beta_0 + \beta_1 PatentStk_{it-1} + \beta_2 AE_{it} + \beta_3 Star_{it} + \beta_4 NIHfield_{it} + \beta_5 MA_i + \beta_6 CA_i)$

where the variable are defined as above.

Our third set of regressions examines firm patenting behavior. Based on the existing literature, particularly the work by Zucker and coauthors, we expect scientist-linked firms to be more successful at patenting than non-linked firms. We investigate this by looking at both the probability of patenting and the number of patents granted by application year. Our empirical models for firm i and year t are:

(3) $\Pr(P2 = 1 | \mathbf{X})_{it} = \Phi(\beta_0 + \beta_1 PatentStk_{it-1} + \beta_2 AE_{it} + \beta_3 Star_{it} + + \beta_4 \$SBIR_{it} + \beta_5 P2_{it} + \beta_6 NIHfield_{it} + B_7 MA_i + \beta_7 CA_i)$

(4) $E[NumPatents_{it} | \mathbf{X_{it}}] = \exp(\beta_0 + \beta_1 PatentStk_{it-1} + \beta_2 AE_{it} + \beta_3 Star_{it} + \beta_4 \$SBIR_{it} + \beta_5 P2_{it} + \beta_6 NIHfield_{it} + \beta_7 MA_i + \beta_8 CA_i)$

where all variables are defined as above except *$SBIR*, which is the total dollar value of SBIR awards won by the firm in year t.

Regression Database

To implement these models we use panel data on all DHHS (NIH) SBIR firms. The database covers the years 1983 to 1996, however, due to the lag from patent application to grant, we restrict our sample to end in 1993. There are 4,582 unique firms that participated in the program over this period. Our 337 biomedical academic entrepreneurs are associated with 323 firms. Some of these people joined the same firm but at different times. For these cases we use the year in which the first academic entrepreneur to joined the firm. *[We still have some manual matching to do to link firm IDs across databases so the preliminary regression results below use fewer than 337 academic entrepreneurs and fewer linked firms.]* Table 1 provides descriptive statistics for our firm variables grouped by scientist-linked and non-linked.

IV. Empirical Findings

Characteristics of SBIR Academic Entrepreneurship

Our identification procedure found 337 biomedical academic researchers that chose to pursue commercialization through the SBIR program over the fourteen year period, 1983 to 1996. Nationally, this is an average of 24 people per year. However, these entrepreneurs have not entered the program uniformly over time. As seen in Figure 1, following a jump in 1985, SBIR biomedical academic entrepreneurship declined until 1991 but has shown steady growth thereafter. This growth period, 1991-1996, is also a time when venture capital investments grew rapidly. Lerner (2000) notes that the growth in venture capital might diminish the role of the SBIR program in funding small firms; however, the program appears to be attracting more biomedical academic entrepreneurs in spite of greater venture capital investment.

Nevertheless, biomedical academic entrepreneurship is a small share of the overall SBIR program. Figure 2 shows the share of phase 1 awards going to academic entrepreneurs for the NIH program. (We chose the NIH program as the reference group because of the similarity of the technologies being pursued.) Not only is this share small but it remains roughly constant over time as the NIH budget has grown. Figure 3 looks at NIH phase 2 awards and shows that academic entrepreneurs are capturing an increasing share of these awards. Together these figures suggest that scientist-linked firms have been more successful at progressing through the NIH program.

Tables 2 and 3 list the top 15 U.S. states and research institutions "spawning" SBIR academic entrepreneurs (see Gompers et al. (2003) for corporate spawning). California and Massachusetts are clearly the leaders and account for 30% of the 337 biomedical research scientists pursuing SBIR commercialization. The distribution across states is consistent with the overall geographic distribution of SBIR awards. *[verify this and/or show relative to total NIH awards.]* Looking at the top research institutions, the University of Utah jumps out as the clear leader. We plan on exploring the factors driving institutional variation in SBIR academic entrepreneurship in future work. Shane (2004) reviews the current literature and Di Gregorio and Shane (2003) provide a statistical analysis across 101 U.S. universities.

What about the SBIR biomedical academic entrepreneurs themselves? Are they different from their non-SBIR peers? To get a descriptive first cut at this issue with our data, we compare these groups on three dimensions. Figures 4 and 5 illustrate the distribution of cumulative NIH awards by number and dollar value for SBIR academic entrepreneurs and non-SBIR NIH researchers across institutional affiliation. The totals are for the 1972-1996 period and an individual researcher's awards may be associated with more than one institution type. The most notable difference occurs in the not-for-profit research institutions category. It suggests that relatively more SBIR academic entrepreneurs are associated with this type of institution prior to commercialization than is typical of other NIH researchers. Otherwise, the two groups are broadly similar in both number and value of awards.

As we discussed in Section II, Zucker and coauthors have emphasized the central role of star scientists in the commercialization process of university-based technologies, specifically in biotechnology. While there is no single measure of "starness," the measures in the literature use absolute "productivity" to define stars. Underlying these measures, of course, is some time dimension so that most stars are likely to be older researchers. Following suit, we use a biomedical researcher's cumulative value of NIH research awards to define stars. Taking the top decile as the appropriate cut-off, we find that 14% of the SBIR academic entrepreneurs are stars. This indicates that there is a greater concentration of stars among these entrepreneurs than in the non-SBIR NIH researcher group. We continue to identify these stars in our regression analyses below.

However, we also ask if the average SBIR biomedical academic entrepreneur is a star. This is important because it indicates who is taking advantage of the SBIR program for commercialization. To do this we run a simple Probit regression explaining a researcher's probability of being a star scientist as a function of being an SBIR academic entrepreneur, the researcher's years in the NIH system, their institutional affiliation and their field of research as indicated by the NIH awarding agency. The results are presented in Table 4. Column A reaffirms the "absolute" star definition and shows that SBIR academic entrepreneurs are more likely to be stars. As we add in our controls, being an academic entrepreneur is no longer significantly associated with being a star. These results show that, on average, an SBIR academic entrepreneur is not a star scientist. Looking at Figure 5 on the cumulative value of awards provides a visual confirmation of this result.

SBIR Certification Hypothesis

Table 5 presents our Probit estimates of Equation (1) looking at the probability of receiving follow-on venture capital investment. The table reports the estimated coefficients and their standard errors. Notice that the NIH star academic entrepreneur variable is no longer in the model. Among the 45 SBIR star entrepreneurs, there were no cases in which venture capital funding occurred *after* the SBIR award. This is consistent with the common practice among venture capitalists of approaching scientists with the purpose of identifying opportunities and forming companies. In fact, it appears that many venture capitalists are using the SBIR program to leverage their own private funds. This is not SBIR certification.

Column A in Table 5 shows that scientist-linked SBIR firms have a higher probability of receiving follow-on VC than non-linked firms. Calculating the marginal impact, the probability getting VC increases by 1.8% if a non-linked firm becomes a scientist-linked SBIR firm. This triples the firm's expected probability of follow-on financing. The findings support the hypothesis that full-time commitment of discovery scientist is valuable; however, we cannot distinguish the exact mechanism through which this value is transmitted. Section II suggests that both a possible signal from full-time commitment and benefits from the discovery scientist's human and social capital.

Column B adds the other SBIR variables. The firm's total SBIR award amount increases the probability of follow-on VC. The firm's stock of patents one year prior, however, significantly decreases the chances for follow-on VC. We suspect that firms with more patents might also have more revenue through sales or collaborative agreements. These firms would be less likely to need follow-on VC investment. Better firm data would help to sort out these competing effects. Wining a Phase 2 award increases the probability of follow-on VC. At the margin, winning a Phase 2 award doubles the firm's expected chances. This is consistent with the idea that SBIR program participation allows firms to sufficiently reduce technical and market uncertainties. We see this as confirmation of Lerner's certification hypothesis. So, certification seems to work but not when the discovery scientist is a star.

Scientist full-time Involvement on Performance

Contact between firms and academic scientists take numerous forms, the most extreme of which is full-time involvement by academic researchers. Our results in this section reflect the contribution of full-time commitment that is above and beyond these other arrangements. It's highly likely that most of our non-linked SBIR firms have these other types of university contacts given that 59% of all awardees are biotechnology, pharmaceutical, chemical, and medical device firms (NIH (2003)).

Table 6 presents our results on the probability of completing the SBIR program as indicated by the chance of winning a Phase 2 award. Focusing on the results in column B, which include the dollar value of Phase 1 awards, we find that firms with an academic entrepreneur are 2.8% more likely to finish the program (marginal impact not shown in table). This doubles the expected probability of winning a Phase 2 award. Interestingly, once Phase 1 awards are held constant, firm location in California is no longer a significant predictor of program completion. This suggests that there are a lot of firms in California that only win Phase 1 awards. Perhaps more "SBIR mills" are located there.

Table 7 shows at the effect of academic entrepreneurs on firm patenting performance. Column A reports the Probit results for the probability of any patenting activity. Consistent with our other findings, full-time scientist-linked SBIR firms have a greater probability of patenting relative to their non-linked counterparts. Contrary to Zucker et al. (2002), we do not find that star scientists increase the chance of patenting beyond their status as an academic entrepreneur. Column B reports our findings using a Negative Binomial model for the number of firm patents. These results are consistent with our earlier findings. Scientist-linked SBIR firms patent more that non-linked firms. We interpret these results as confirmation that university scientist involvement is important for commercialization and, even more, that full-time involvement improves performance.

V. Conclusions

This paper has explored the role of the SBIR program as an entrepreneurship policy, looking specifically at biomedical researchers that chose to pursue commercialization through this program. Even though entrepreneurship was not an explicit legislative aim of the program, we believe the SBIR program does have a useful role to play in funding early-stage university-based technology firms by increasing the availability of financial capital and allowing entrepreneurs time to reduce technical and market uncertainties surrounding their ideas.

Our empirical work indicates that biomedical academic entrepreneurship through the program is small in terms of the number and dollar value of awards but, since 1991, the number of research scientists using SBIR as a commercialization channel is on the rise. While the typical SBIR biomedical academic entrepreneur is not a star scientist, their SBIR firms have a higher probability of follow-on venture capital investment, program completion and better innovative performance as measured by patents. Interestingly, the NIH stars within this group of entrepreneurs do not significantly contribute to any of our financing or performance measures beyond their status as an academic entrepreneur. Finally, we find support for Lerner's (1999) certification hypothesis. That is, firms that complete the SBIR program are more likely to receive follow-on venture capital funding.

It is important to keep in mind that our empirical work is based on a limited set of firm level control variables. We see our results as suggestive but by no means definitive. Data limitations required us to work at a fairy high level of generality. For instance, one cannot tell from our work exactly how the academic entrepreneur is transferring her human and social capital to the firm nor can we tell the relative importance of these types of capital. Nevertheless, this research does lay the groundwork for future research to probe deeper into these issues.

Notes

1. There are currently eleven federal agencies participating in the SBIR program. These are: Department of Defense, Department of Commerce, Department of Agriculture, Department of Education, Department of Health and Human Services, Department of Energy, Department of Transportation, Department of Homeland Security, Environmental Protection Agency, National Science Foundation, and National Aeronautics and Space Administration.

2. Lerner (1999) also considers the SBIR program as an entrepreneurship policy, calling it "public venture capital", however, his analysis focuses on evaluating the effects of the program on participant firms relative to non-participant firms. Other studies that focus on evaluating various aspects of the SBIR program include: Archibald et al. (2003), Audretsch (2003), Audretsch et al. (2002), NIH (2003), and Wallsten (2000).

3. See, for instance, Colyvas et al. (2002), Lowe (2001), Shane (2004), Thursby et al. (2002) and the references therein.

4. See, for instance, Lowe (2001), Shane (2004), Thursby et al. (2001, 2003) and the references therein.

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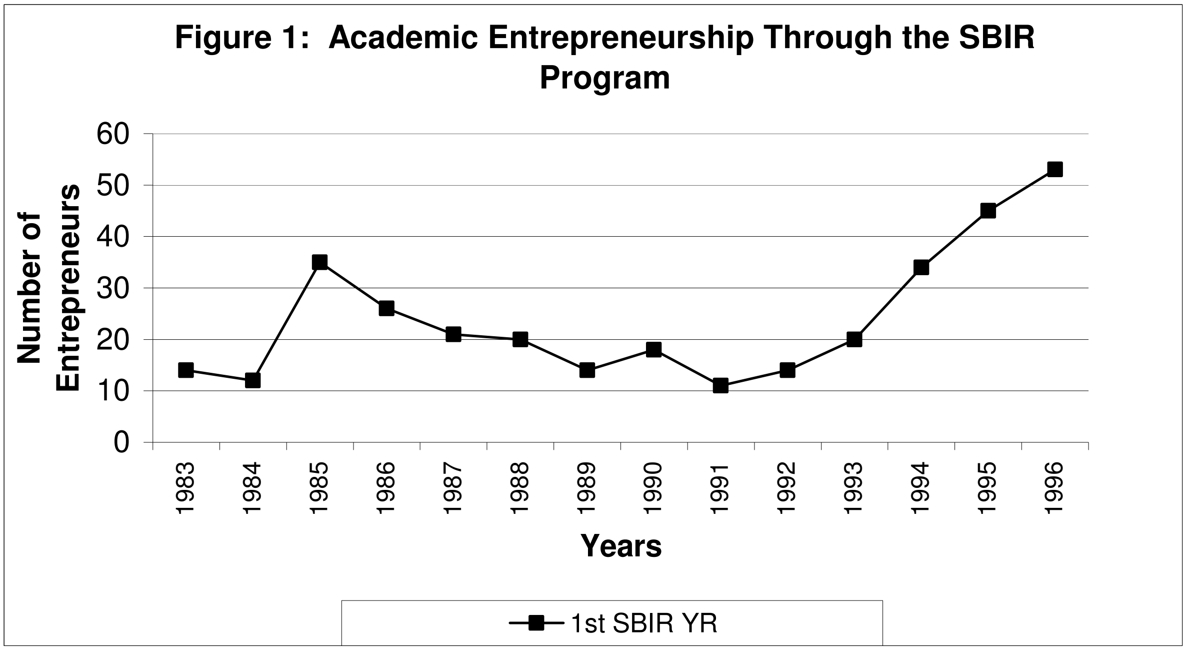
Figure 1: Academic Entrepreneurship Through the SBIR Program
60
50
40
30
20
10
0
Number of Entrepreneurs
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
Years
1st SBIR YR

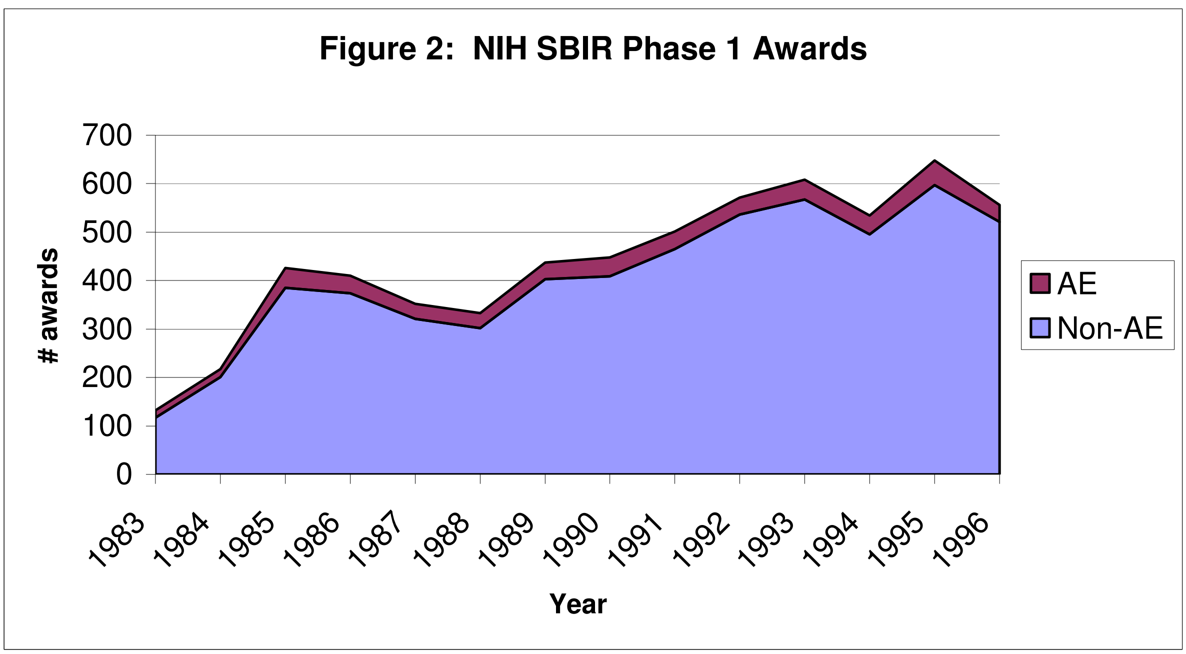
Figure 2: NIH SBIR Phase 1 Awards
700
600
500
400
300
200
100
0
awards
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
Year
AE
Non-AE

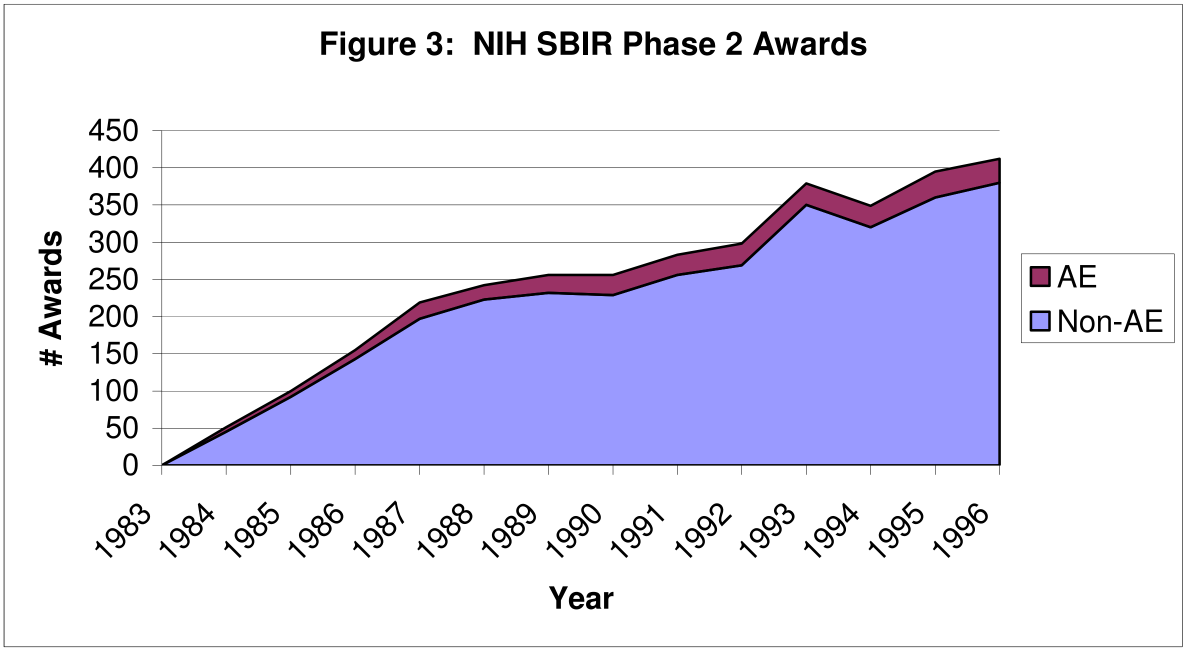

Figure 3: NIH SBIR Phase 2 Awards
450
400
350
300
250
200
150
100
50
0
Awards
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
Year
AE
Non-AE

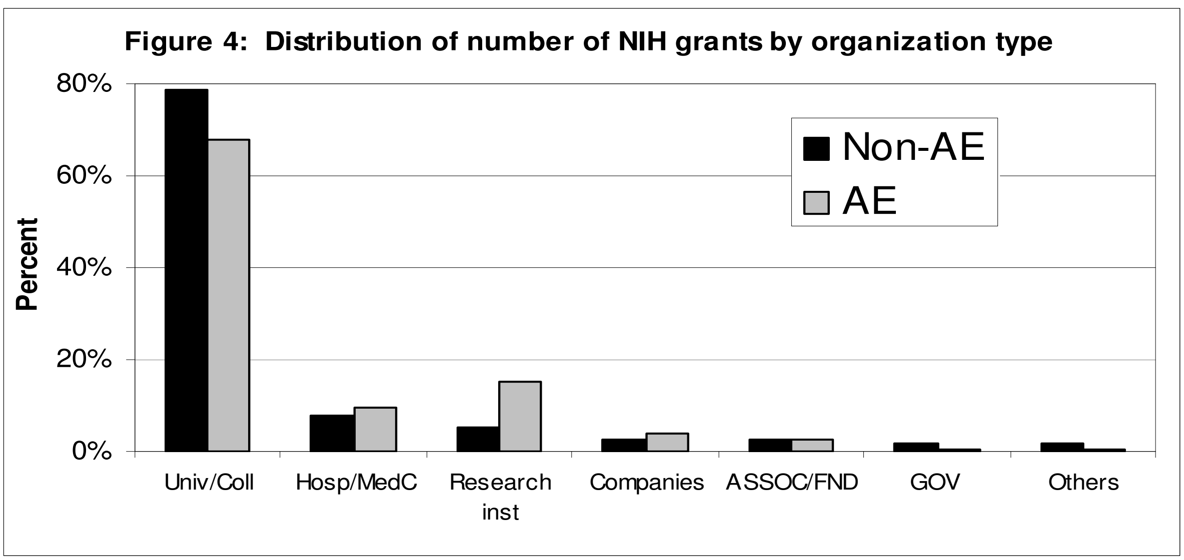

Figure 4: Distribution of number of NIH grants by organization type
80%
60%
40%
20%
0%
Percent
Non-AE
AE
Univ/Coll
Hosp/MedC
Research inst
Companies
ASSOC/FND
GOV
Others

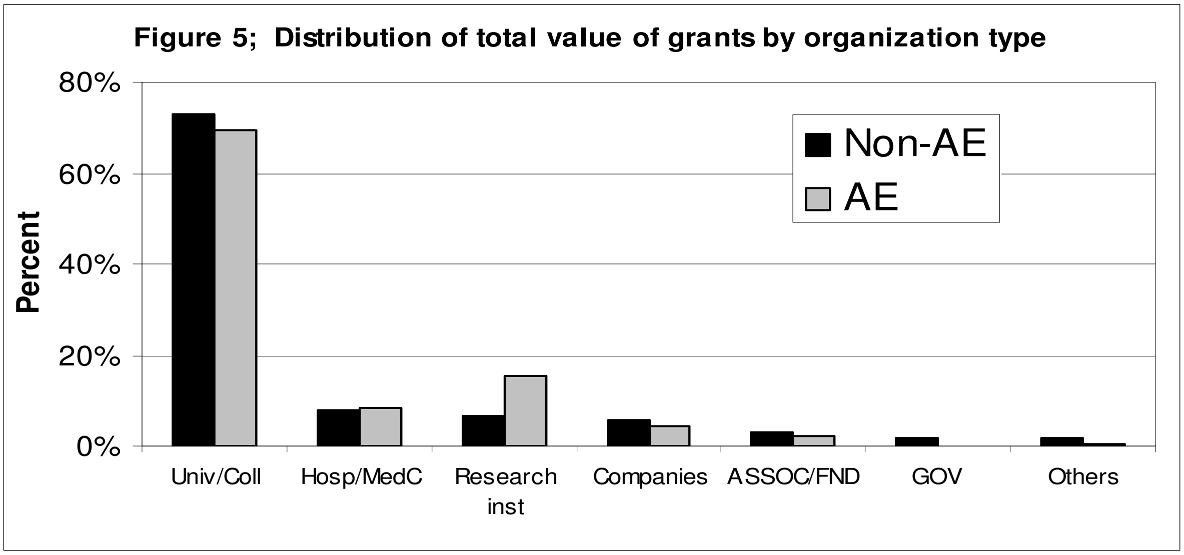

Table 1

Descriptive Statistics - DHHS SBIR Firms

	Scientist-linked Firms (Obs = 3,091)				Non-linked Firms (Obs = 47,377)			
Variable Name	Mean	Std.Dev.	Min	Max	Mean	Std.Dev.	Min	Max
Patents	0.230	1.117	0	18.00	0.080	0.585	0	26
Patent Dummy	0.084	0.278	0	1.00	0.038	0.191	0	1
Patent Stock	0.535	2.790	0	44.47	0.210	1.600	0	62.66
Academic Entrep.	0.381	0.486	0	1.00				
Star scientist	0.065	0.247	0	1.00				
SBIR ($ per year)	0.037	0.156	0	2.38	0.027	0.177	0	7.3
Phase 2 ($ per year)	0.026	0.136	0	1.80	0.019	0.145	0	5.71
Phase 1 ($ per year)	0.011	0.038	0	0.57	0.008	0.046	0	2.13
Phase 2 Dummy	0.045	0.207	0	1.00	0.032	0.176	0	1
California	0.192	0.394	0	1.00	0.198	0.398	0	1
Massachusetts	0.142	0.349	0	1.00	0.119	0.324	0	1

Table 2
Top 15 States for SBIR Academic Entrepreneurship

State Name	Number of AEs	Percent of Total
CALIFORNIA	57	17%
MASSACHUSETTS	45	13%
NEW YORK	24	7%
PENNSYLVANIA	20	6%
WASHINGTON	17	5%
UTAH	16	5%
OHIO	15	4%
MICHIGAN	13	4%
ILLINOIS	12	4%
TEXAS	11	3%
MARYLAND	9	3%
NORTH CAROLINA	9	3%
INDIANA	8	2%
CONNECTICUT	7	2%
FLORIDA	7	2%

Table 3
Top 15 Institutions Affiliated with SBIR Academic Entrepreneurs

State Name	Number of AEs	Percent of Total
UNIVERSITY OF UTAH	14	4%
UNIVERSITY OF MINNESOTA TWIN CITIES	6	2%
UNIVERSITY OF PENNSYLVANIA	6	2%
UNIVERSITY OF CALIFORNIA SAN FRANCISCO	6	2%
UNIVERSITY OF MICHIGAN AT ANN ARBOR	5	1%
DANA-FARBER CANCER INSTITUTE	5	1%
UNIVERSITY OF CALIFORNIA SAN DIEGO	5	1%
BOSTON UNIVERSITY	5	1%
UNIVERSITY OF WASHINGTON	5	1%
BOSTON BIOMEDICAL RESEARCH INSTITUTE	4	1%
UNIVERSITY OF ALABAMA AT BIRMINGHAM	4	1%
UNIVERSITY OF CALIFORNIA LOS ANGELES	4	1%
HARVARD UNIVERSITY	4	1%
SCRIPPS CLINIC AND RESEARCH FOUNDATION	4	1%
BETH ISRAEL HOSP (BOSTON)	4	1%

Table 4				
	Dependent variable: star dummy			
Variables	A	B	C	D
Academic Entrepreneur	0.193 **	-0.057	-0.132	-0.166
	(0.088)	(0.105)	(0.105)	(0.106)
Researcher Years		0.138 ***	0.138 ***	0.133 ***
		(0.001)	(0.001)	(0.001)
Intercept	-1.282 ***	-2.800 ***	-2.852 ***	-2.962 ***
	(0.006)	(0.019)	(0.019)	(0.022)
Test on joint significance of organization dummies: $\chi^2(2)$			246.31***	162.47***
Test on joint significance of field dummies: $\chi^2(17)$				739.90***
# of obs.	71802	71802	71802	71802
McFadden-R^2	0.0001	0.405	0.410	0.426
Log-Likelihood	-23341.05	-13898.45	-13779.39	-13402.44

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

Table 5		
	Dependent variable: VC after SBIR	
Variables	A	B
Patent Stock (t-1)	-0.016	-0.048 **
	(0.014)	(0.023)
Academic Entrepreneur	0.559 ***	0.543 ***
	(0.096)	(0.098)
California	0.154 ***	0.151 ***
	(0.049)	(0.049)
Massachusetts	.0283 ***	0.254 ***
	(0.053)	(0.054)
SBIR (total $ per year)		0.287 ***
		(0.085)
Phase 2 dummy		0.252 **
		(0.112)
Intercept	-2.43 ***	-2.852 ***
	(0.060)	(0.019)
Test on joint significance of field dummies: $\chi^2(10)$	47.91***	54.32***
# of obs.	50266	50266
McFadden-R^2	0.024	0.035
Log-Likelihood	-1942.218	-1922.026

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

Table 6

Variables	Dependent variable: Phase 2 Award A	B
Patent Stock (t-1)	0.050 ***	0.030 ***
	(0.005)	(0.004)
Academic Entrepreneur	0.457 ***	0.318 ***
	(0.058)	(0.065)
NIH Star	0.022	0.048
	(0.136)	(0.154)
California	0.070 **	0.030
	(0.029)	(0.031)
Massachusetts	.254 ***	0.123 ***
	(0.032)	(0.036)
Phase 1 ($ per year)		9.34 ***
		(0.329)
Intercept	-2.14 ***	-2.236 ***
	(0.044)	(0.046)
Test on joint significance of field dummies: $\chi^2(8)$	116.71***	78.66***
# of obs.	41292	41292
McFadden-R^2	0.034	0.186
Log-Likelihood	-6730.988	-5677.828

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

Table 7		
Variables	Dependent variable: Patent Dummy A	Dependent variable: Number Patents B
Patent Stock (t-1)	0.311 ***	0.626 ***
	(0.015)	(0.022)
Academic Entrepreneur	0.435 ***	1.015 ***
	(0.064)	(0.131
NIH Star	-0.158	-0.452
	(0.148)	(0.343)
SBIR (total $ per year)	0.332 ***	0.554 ***
	(0.068)	(0.187)
Phase 2 Dummy	.300 ***	0.601 ***
	(0.065)	(0.161)
California	0.142 ***	0.358 ***
	(0.27)	(0.061)
Massachusetts	0.112 ***	0.251 ***
	(0.034)	(0.076)
Intercept	-2.30 ***	-4.012 ***
	(0.049)	(0.110)
Test on joint significance of field dummies: $\chi^2(10)$	120.30***	112.76***
# of obs.	50468	50468
McFadden-R^2	0.237	0.135
Log-Likelihood	-6566.1348	-10018.766

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