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ljimenez@jotmi.org
Universidad Alberto Hurtado
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Galope, Reynold V.
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What Types of Start-ups Receive Funding from the Small Business Innovation Research (SBIR) Program? Evidence from the Kauffman Firm Survey

Reynold V. Galope

Abstract

This paper integrates the Kauffman Firm Survey with the Small Business Innovation Research (SBIR) recipient dataset to examine in more depth the characteristics of small business start-ups that received R&D subsidy from SBIR. Our selection analysis first shows that SBIR program funds are distributed disproportionately to start-ups whose owner has a post-graduate education. The odds of being granted SBIR R&D subsidies are also higher for those who had prior R&D experience and owned patents at the start of their business operations. Start-ups that are operating in the high-technology sector are also more likely to receive SBIR funds than start-ups in traditional sectors. Surprisingly, start-ups that did not sell goods and services are more likely to receive SBIR grants. Interestingly, location matters but at a different direction: start-ups located in states that are not known for their R&D performance are more likely to receive SBIR funding.

Keywords: small and medium enterprises; research and development (R&D); high-technology start-ups; small business innovation research (SBIR); innovation policy; kauffman firm survey (KFS).

Andrew Young School of Policy Studies, Georgia State University, Atlanta, Georgia 30303, U.S.A.
Economics and Research Department, Asian Development Bank, Mandaluyong City 1550, Metro Manila, Philippines and School of Public Policy, Georgia Institute of Technology, Atlanta, Georgia 30332, U.S.A. Phone: +1404.692.1119. E-mail: rgalope1@gsu.edu

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Introduction

The United States created the Small Business Innovation Research (SBIR) program in the early 1980s to facilitate technological breakthroughs and innovations.[1] The perception at that time was that the U.S. was losing its technological leadership and global competitiveness.[2] The SBIR was meant to leverage the unique capacity of small businesses to innovate (Audretsch, 2003; Cooper, 2003).

The belief in the dynamic role of small and medium enterprises in the national innovation effort is not without theoretical and empirical bases. For example, Wetzel (1982) documented that in the 20th century, half of the most important inventions and innovations in the U.S. originated from small businesses or independent inventors.[3] In a more recent study, Breitzman and Hicks (2008) found that small businesses are more productive in generating patents than their larger counterparts. Perhaps a more nuanced conclusion was provided by Acs and Audretsch (1990), who showed that while large firms were more innovative in traditional industries like agricultural chemicals, general industrial machinery, food products machinery, ammunition, paper industries machinery, primary metal products, small firms introduce more innovations in specialized and highly technical areas such as, electronics and computing equipment, process control instruments, synthetic rubber, fluid meters and counting devices, engineering and scientific instruments, and measuring and controlling devices, leading to what the authors called the "division of labor" between small and large firms in innovation. This division of labor to produce innovations in emerging and mature fields respectively has been validated by more recent studies. For example, Almeida and Kogut (1997) showed that small business start-ups innovate in less crowded technological fields while large firms contribute in established or mature fields.

The SBIR, for all intents and purposes, is an R&D subsidy to small businesses to produce innovation. Several studies have evaluated the effect of SBIR and found a positive effect of the federal technology program on employment, sales, entrepreneurship, research commercialization, and social welfare. [See, for example, Audretsch, Wiegand, and Wiegand (2002), Audretsch, Link, and Scott (2002)[4], Lerner (1999); Link and Scott (2000).] This study differs from prior SBIR evaluation studies by taking a step back to look at the process of SBIR selection. More specifically, it identifies the most important small firm-level characteristics that predict successful SBIR application. This research endeavor is possible, first, through datasets integration. We obtained SBIR recipient dataset from the U.S. Small Business Administration (SBA) and combined it with the Kauffman Firm Survey (KFS) of the Ewing Marion Kauffman Foundation. This process of integrating two datasets allowed us to identify small businesses start-ups that received SBIR funds at the early stage of their operations. The paper's focus on small business start-ups is important; as alluded to earlier, from a Schumpeterian perspective, small and young enterprises are agents of technical change because of their propensity to innovate in less crowded, highly-specialized fields. Second, by estimating a probability model, we identify important attributes of small business start-ups that both self-select into the SBIR program and adjudged potentially innovative by SBIR participating federal agencies. The empirical results help inform both small firm-level strategy and SBIR program administration.

The rest of the paper proceeds as follows. Section 2 describes the data and methods used for the estimation. Section 3 presents basic descriptive statistics and results of the SBIR program selection analysis. Section 4 provides a summary and derives implications for small-firm strategy, specifically for start-up enterprises operating in the high-technology sector, and SBIR program administration.

Data and Method - Data

We used data from the Kauffman Firm Survey (KFS) to analyze the determinants of SBIR program selection. The Ewing Marion Kauffman Foundation has granted us access to their confidential KFS micro-data in the National Opinion Research Center (NORC) data enclave. The KFS is an inflow sample of 4,928 businesses founded in 2004 and tracked ever since.

We also requested the Small Business Administration (SBA) a dataset of SBIR recipients for the 2004-08 period.[5] To identify start-ups in the KFS sample that received SBIR financing, we requested the Kauffman Foundation and the Mathematica Policy Research[6] to integrate the KFS and the SBIR recipient datasets. We used the sampled firm's Data

[1] Innovation is widely acknowledged in the theoretical and empirical literature as the most important determinant of long-run productivity and better standards of living. Other policy interventions in the 1980s include the Bayh-Dole Act, the Stevenson-Wydler Act, and the American Competitiveness Act.

[2] The so-called productivity slowdown in U.S. economic history started earlier around 1973.

[3] This finding is hardly novel. As early as 1958, Jewkes and his colleagues documented that major innovations were developed outside of large firms.

[4] Wallsten (2000), however, did not find any effect of SBIR on total private R&D expenditure. Moreover, while Lerner (1999) found a positive effect of SBIR on employment size and sales, this effect was only true in areas where there was significant venture capital activity.

Universal Numbering System (DUNS), a unique numeric identifier assigned to a single business identity, to merge the two datasets. The integrated KFS-SBIR dataset identified 25 small business start-ups that received SBIR financing to develop new technologies between 2007 and 2008. As far as we know, this research is the first effort to integrate SBIR recipient data with a new sample of business start-ups. Thus, the resultant dataset is an important addition to the data infrastructure for research, innovation, and entrepreneurship policy studies.[7]

We restricted the sample to small businesses by dropping from the analysis all start-ups that have more than 500 employees.

Estimation Approach

We estimated a logistic regression equation to predict the odds and probability of a small business start-up to receive an SBIR grant. Specifically, we estimated the logit regression equation of the form:

$$\log [p(SBIR)i/1-p(SBIR)i] = \beta Xi + \varepsilon i$$

where i refers to an individual small business start-up; p(SBIR) is the probability that a small business start-up receives an SBIR grant; β represents a parameter vector of variables that influence SBIR selection; and ε is an error term. All these parameters were estimated using maximum likelihood estimation (MLE).

The Appendix provides a summary of the variables used in the analysis.

Dependent Variable

The dependent variable in the model is receipt of SBIR grant. Being a dichotomous variable, it takes the value of 1 if a small business start-up received an SBIR award between 2007 and 2008 and 0 otherwise.

Independent Variables

We hypothesize that selection into the SBIR program is affected by the start-up's size, human capital, technological capacity, industry, and location of operation.

Firm Size

Larger business start-ups have more resources to attract quality manpower, withstand random shocks in the external environment, and raise more capital for operation, production, and expansion (Bruderl, Presisendorfer and Ziegler, 1992). Larger firms are also more likely to possess specialized complementary assets (e.g. specialized channels of information) to successfully commercialize a new production technique or product prototype (Teece, 1986).

Firm size can serve as a proxy for the start-up's ability to compete. Because starting a new enterprise is inherently risky, firms that have larger resource endowments at their initial years of operations may be firms that are more confident about the efficiency of their production and operations; and, more optimistic ex-ante about their probability of success in the market. If efficiency and ability to compete underlie the choice of a start-up's initial size, then external parties can use firm size to draw inferences about the quality of the firm. Unlike established small businesses, start-ups do not have a long track record to speak of when applying for SBIR funding. Thus, SBIR grant reviewers can use firm size as a filter to separate start-ups that have the potential to take advantage of the R&D grant from those that do not. We measured firm size by the start-up's number of employees at the start of its operations in 2004.

Human Capital of the Entrepreneur

Human capital refers to the knowledge, skills, and experience that the founders or owners of the start-up possess. It enhances the start-up's ability to compete successfully. At a strategic level, the entrepreneur's knowledge assets are critical in searching for and recognizing new business opportunities that are commercially promising (Shane, 2000). Research in entrepreneurship and creativity has shown that the breadth of one's training and experience strengthens the ability to relate two seemingly unrelated concepts to create something novel and useful (Heinze et al., 2007). At the operational level, greater human capital of the founders increases firm productivity. Owners with more knowledge and experience are more efficient in organizing and more capable at attracting clients and external support (e.g. loans, research grants). More knowledgeable and experienced entrepreneurs also bring with them best-practice organizational routines that are important in running day-to-day operations and planning for the long-term (e.g. new markets

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[5]SBA provided the data through formal Freedom of Information Act (FOIA) request. I purchased the data from SBA for $400.
[6]Mathematica conducted the KFS survey for the Kauffman Foundation.
[7]Subject to the disclosure and confidentiality policies of the Kauffman Foundation and the National Opinion Research Center (NORC), the integrated dataset can be made available to other NORC researchers to further understand the production of new technologies by small business entrants.

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to exploit and new products and processes to develop). In short, like firm size, the founders' human capital can serve as proxy for the expected productivity or efficiency of the new enterprise. Banks, venture capitalists, and other capital providers as well as SBIR grant reviewers can thus use observable characteristics like the founder's human capital to infer about the quality of the business start-up. We measured human capital by the level of education and prior industry experience of the start-up's founders.

Technological Capacity

Technological capacity refers to the ability of the start-up to generate potentially commercially useful research. It is typically measured by prior performance of R&D and patent production. Engaging in R&D is an important innovative activity because it increases absorptive capacity (Cohen and Levinthal, 1990). A firm's innovation and over-all performance is also a function of its ability to scan and exploit the research and innovation of other economic actors in the country or abroad to generate new or better products and processes. A firm cannot take advantage of the innovative ideas of other economic agents without the absorptive capacity to understand the basic science and potential commercial application of these ideas. We measured the start-up's technological capacity with prior performance of R&D and the number of patents it possessed. Because current technological capacity is a good predictor of future innovative activities and outputs, we expect reviewers of SBIR grant applications to favor small business start-ups that have engaged in R&D and/or have produced intermediate innovation outputs like patents.

Industry

The value of R&D and innovation, which can be underwritten by federal grant programs like the SBIR, varies from one industry to another. Thus, start-ups respond to incentives to undertake R&D and develop process and product innovations differently. In SBIR program selection, we expect SBIR funds of the top five participating agencies (i.e., DOD, DHHS, NASA, DOE, and NSF) to accrue disproportionately to small businesses that propose to perform R&D in areas aligned with the federal missions and mandates of these agencies. Based on Black (2004) and Feldman (1994), we created the following seven categorical variables on industrial classification: (1) pharmaceuticals, (2) chemicals, (3) machinery, (4) electronics, (5) electrical equipment, (6) medical and surgical equipment, and (7) R&D and engineering services with other sectors as the omitted or reference category. We expect small business start-ups operating within these seven high-technology sectors to have greater propensity to apply and be selected for SBIR financing than their counterparts in traditional sectors.

Geographical/Locational Effects

Finally, geographical context matters in innovation. Empirical studies have shown that R&D spillovers are prevalent and their magnitude may be quite large. For example, Jaffe (1986) estimated that firms generated, on average, 0.06 patents per million dollars of other firms' R&D. More specifically, Jaffe, Trajtenberg, and Henderson (2002) found that R&D spillovers are localized, i.e., firms from the same state or metropolitan region benefit from each other's innovation. Knowledge spillovers are localized because knowledge is sticky (von Hippel, 1998). Firms need both explicit and tacit knowledge as they experiment on new products and processes that can strengthen their competitive advantage. Tacit knowledge, in contrast to explicit knowledge, lacks extensive codification and thus is not easily transferable. When knowledge is sticky, the degree of difficulty and cost of transfer are high. Learning is not just gaining new information; it is more about building new competencies and learning new skills and applications, which can be accomplished through "learning-by-interacting" (Lundvall, 1992). The transfer of tacit knowledge is thus higher in states, regions, or local innovation systems where the intensity of R&D by firms, universities, and government laboratories is also high. Greater R&D intensity also attracts highly skilled technical manpower further improving the efficiency of conducting R&D and other innovative activities. We thus expect start-ups that are located in states that spend more in R&D to have greater propensity to develop innovative ideas, prepare stronger SBIR research grant proposals, and receive SBIR funding than their counterparts in states that are less known for their R&D activities (e.g. Wyoming and South Dakota).

Empirical Results

In this section, we present descriptive statistics and the results of the SBIR selection analysis. The descriptive analysis discusses the characteristics of small business start-ups prior to receiving SBIR financing. The selection analysis, using a logistic regression model, identifies important characteristics of small business start-ups that contributed to successful SBIR application and selection.

The Recipient Sample

Table 1 presents the baseline characteristics of the 25 SBIR-financed small business start-ups using data from the Kauffman Foundation and the Small Business Administration. Most small business start-ups that received R&D grants from SBIR had at most one employee when they started operation in 2004. Only 28 percent of recipient start-ups had at least two employees and only one hired more than ten employees initially. The median and mean number of employees of the recipient sample are 1 and 1.7 employees respectively.

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Eighty percent of the first owners of SBIR recipients have at least a postgraduate degree. The median is the master's degree category. For details on the educational attainment of the founders of SBIR recipient-start-ups, see Table 2. The owners of recipient start-ups are not only highly educated but also have vast and extensive industry experience. Seventy two percent of owners have at least ten years of experience in the same industry as his firm is competing in. Only one out of 25 owners did not have any industry experience. The mean and median length of industry experience of owners of the recipient sample are 14.4 and 15 years respectively.

Seventeen out of 25 (or 68 percent of SBIR recipients) conducted R&D right at the start of their operations in 2004. In terms of intermediate outputs, close to one-half of the recipient sample already had a patent before applying and receiving SBIR grant. Table 3 provides the distribution of patents owned by SBIR-financed start-ups. Ownership of patents at the start of operations indicates that several recipient start-ups might have been spin-off firms from larger firms or new firms established by academic scientists and engineers who had rights to these patents prior to the start-ups' formation. Of recipient start-ups with at least one patent, 83 percent had more than one patent and 25 percent had more than five patents. Three of these start-ups had 8, 11, and 35 patents respectively.

Baseline Characteristics	Non-recipient (n=4,000+)	Recipient (n=25)	Difference	p-value
Firm Size				
Number of Employees	1.94	1.68	0.26	0.840
Human Capital				
Post-Graduate Education	0.20	0.80	-0.60	0.000
Industry Experience	0.55	0.72	-0.17	0.095
Technological Capacity				
Prior R&D Performance	0.21	0.68	-0.47	0.000
Number of Patents	0.15	3.24	-3.09	0.000
Positive Sales	0.91	0.65	0.26	0.000
High-Tech Industry				
Pharmaceutical	0.01	0.08	-0.07	0.000
Chemicals	0.02	0.08	-0.06	0.014
Machinery	0.04	0.08	-0.04	0.350
Electronics	0.04	0.24	-0.20	0.000
Electrical Equipment	0.01	0.04	-0.03	0.204
Medical/Surgical Equipment	0.002	0.12	-0.118	0.020
R&D Services	0.20	0.28	-0.08	0.346
Geographical Location				
Location in R&D Intensive States (e.g. CA, MA)	0.84	0.80	0.04	0.594

Table 1. Baseline Characteristics of Recipient and Non-recipient Start-ups

Level of Education	Valid Percent	Cumulative Percent
Bachelor's Degree	8.0	8.0
Some Graduate School but No Degree	12.0	20.0
Master's Degree	36.0	56.0
Doctorate or Professional School	44.0	100.0

Table 2. Distribution of Level of Education of Owners of SBIR-financed Small Business Start-ups

Seven SBIR recipient start-ups are operating in R&D and engineering services and six are electronics firms. The other 40 percent are in surgical and medical equipment (12 percent), pharmaceuticals (8 percent), chemicals (8 percent), machinery (8 percent), and electrical equipment (4 percent). Other SBIR recipients (8 percent) are in broad woven fabric mills and business support services.

Twenty SBIR recipients (or 80 percent of the entire recipient sample) located their businesses in R&D intensive states. Twenty SBIR recipients received funding from a single agency, four from two agencies, and one from three agencies. For single-agency SBIR recipients, nine received SBIR R&D grants from the Department of Defense (DoD), six from the Department of Health and Human Services (HHS), three from the National Science Foundation (NSF), and one each from the Department of Energy (DOE) and the Department of Agriculture (USDA). Three recipient start-ups received funding from both DOD and NSF and a fourth start-up obtained the R&D subsidy from both the NSF and HHS. The lone recipient start-up with three agency sources of funding received grants from the DOD, HHS, and NSF. Fifty-two percent of the treated start-ups are minority-owned (i.e., at least one of the owners is non-White) and fifty-six percent are women-owned (i.e., at least one of the owners is a woman). See Table 4.

SBIR Program Selection Analysis

This part identifies the most important firm-level characteristics of small business start-ups that contribute to their successful application and selection into the SBIR program. The analysis is interesting for many reasons, chief of which is the fact that the program selection model involves small firms that were new to the industry at that time and thus had no prior track record or established reputation to stand on. A track record of success or at least a strong indication of potential to succeed is important in securing scarce R&D resources. Table 5 shows the empirical results of the SBIR program selection analysis, reporting logit coefficients as well as unstandardized and standardized odds ratios.

Number of Patents	Valid Percent	Cumulative Percent
0	52.0	52.0
1	8.0	60.0
2	8.0	68.0
3	8.0	76.0
5	12.0	88.0
8	4.0	92.0
11	4.0	96.0
35	4.0	100.0

Table 3. Distribution of Volume of Patents of SBIR-financed Small Business Start-ups at the Start of Operations

Agency	Valid Percent	Cumulative Percent
DOD only	36.0	36.0
HHS only	24.0	60.0
NSF only	12.0	72.0
DOE only	4.0	76.0
USDA only	4.0	80.0
DOD and NSF	12.0	92.0
HHS and NSF	4.0	96.0
DOD, HHS and NSF	4.0	100.0

Table 4. Agency Funding Sources of SBIR-financed Small Business Start-ups

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In the sample, employment size has a negative effect on the probabilities of being awarded SBIR grant in 2007-08. Start-ups with more employees are less likely to be selected into the SBIR program. The estimated standard error, however, is too large to generalize such a conclusion from the sample back to the larger population from which the KFS sample was drawn. The same is true for the industry experience of the owner-entrepreneurs: it had the expected sign but the estimated logit coefficient is also not statistically significant. The estimate of its effect is less than two standard errors from zero, indicating that random chance or variation cannot be ruled out as an explanation for the difference in the likelihood of being awarded an SBIR subsidy between start-ups that have owners with at least 10 years of industry experience and those that do not, all things being equal. It is possible that this type of human capital of small business start-ups do not have an effect on the odds and probabilities of receiving an SBIR award.

The level of education of the start-ups' owners has a positive impact on the likelihood of receiving an SBIR subsidy. The odds that a start-up whose owner has a postgraduate

Variables	Logit Coefficient (b)	Odds Ratio (e^b)	Standardized Odds Ratio (e^{bStdX})	Z-statistics	p-value
Firm Size					
Number of Employees	-0.03	0.97	1.20	-0.48 (0.068)	0.634
Human Capital					
Post-Graduate Education	1.99	7.33	2.27	3.63 (0.549)	0.000
Industry Experience	0.22	1.24	1.11	0.43 (0.507)	0.667
Technological Capacity					
Prior R&D Performance	1.28	3.60	1.70	2.53 (0.506)	0.011
Number of Patents	0.04	1.04	1.10	1.87 (0.088)	0.061
Positive Sales	-1.15	0.32	1.38	-2.23 (0.518)	0.026
High-Tech Industry					
Pharmaceutical	3.28	26.51	1.33	3.03 (1.081)	0.002
Chemicals	3.31	27.27	1.50	3.12 (1.059)	0.002
Machinery	2.74	15.45	1.73	2.51 (1.091)	0.012
Electronics	3.24	25.64	1.82	3.74 (0.808)	0.000
Electrical Equipment	3.02	20.55	1.40	2.38 (1.271)	0.017
Medical/Surgical Equipment	5.23	186.51	1.30	4.57 (1.144)	0.000
R&D Services_	1.38	3.98	1.75	1.60 (0.861)	0.109
Geographical Location					
Location in R&D Intensive States (e.g. CA, MA)_	-1.00	0.37	1.44	-1.77 (0.564)	0.077

Table 5. SBIR Program Selection Model
Note: N=3,886, LR =103.49, Prob>LR=0.000. Standard errors are in parentheses.

degree or training will receive an SBIR grant are 7.3 times as high as the odds of a start-up without an owner with such advanced academic training, all things being equal.

Conducting R&D at the start of operations also predicts a start-up's selection into the SBIR program. A start-up's odds of receiving SBIR if it performed prior R&D are 3.6 times as high as the odds of a non-R&D performing start-up, holding the other variables in the selection model constant. The number of patents a start-up possessed at the initial year of operation also positively impacts the likelihood of being granted an R&D subsidy from the SBIR program. As the number of patents rises by one, the odds of receiving an SBIR award rises by 4 percent, ceteris paribus.

SBIR selection is also a function of the type of industry where the start-up operates and competes. As expected most industries that are classified as high-tech have a significant advantage in securing SBIR funds over traditional sectors like agriculture and mining and the services sector like education and banking and finance. The odds of a start-up operating in the pharmaceuticals, chemicals, machinery, electronic, electrical equipment, and medical/surgical equipment industries of receiving SBIR grant respectively are 26.5, 27.3, 15.4, 25.6, 20.6 and 186.5 times as high as the odds of a start-up in the low-technology sector. The differences in the odds of six high-tech sectors and the traditional sectors, which is the omitted category, are all significant at the 5 percent level. In contrast, start-ups in R&D and engineering services have no significant odds advantage in securing SBIR subsidy over traditional and service sectors.

Geographical location is statistically significant at the less restrictive 10 percent level.[8] The odds of a start-up that is located in R&D intensive states like California and Massachusetts receiving an SBIR grant are only 0.37 times as high as the odds of a start-up operating in states that conduct less R&D. This result may provide empirical evidence for the distributional function of the SBIR program. SBIR R&D subsidy grants are more likely to be distributed to small business start-ups that lack the advantage of knowledge spillovers from intense research and development activities of universities, research laboratories, and firms within their respective local innovation systems.

Using standardized odds ratios, the postgraduate education of the start-ups' owners has the strongest impact on the odds of being selected into the SBIR program, followed by operating in the electronics sector. Among covariates with significant logit coefficients, the number of patents that a start-up possessed prior to application appears to have the weakest impact; a one standard deviation increase in the volume of patents increases the odds of receiving SBIR only by 10 percent. Having sales, on the other hand, decreases the odds of being granted an SBIR subsidy by 38 percent.

Discussion and Conclusion

Financially successful start-ups are significantly different from the typical or average start-up (Shane, 2008). The application for public financing for R&D specifically SBIR grants tells the same story: those who applied for and were eventually granted with SBIR funds are significantly different from the typical start-up that started operations in 2004.

As expected, the training and education ($p<0.001$) of owners of small business start-ups significantly predict SBIR selection. Indeed, the education of the entrepreneurs captures the cognitive ability to sense and seize technological opportunities that others may fail to perceive as both technically feasible and commercially promising. These promising technology research areas are pursued and proposed by highly educated entrepreneurs and also more likely to have been judged technically and commercially sound by SBIR grant reviewers. Because the breadth of one's training and education can increase the ability to combine unrelated concepts to create something that consumers value, it is thus plausible that highly educated entrepreneurs are more creative, more sophisticated in packaging R&D grant proposals, more technically savvy in pointing to the technological gaps that their proposed R&D will fill, and thus, tend to be more successful in SBIR application and selection. Secondly, the entrepreneur's advanced level of education can also serve as proxy for the extent of his or her network in the scientific or academic community. The priority research areas of the SBIR program are not created in a vacuum; SBIR agencies consider technical inputs from academic scientists and engineers as well as entrepreneurs in the high-technology sector. Highly educated entrepreneurs are more likely to have interacted with this network of scholars/researchers and high-technology entrepreneurs, and thus, may be more likely to spot opportunities within current priority SBIR research areas.

As also expected, performing R&D ($p<0.05$) and owning knowledge assets, specifically patents ($p<0.10$), increase the likelihood of receiving SBIR grants. There are at least two reasons for this empirical result: internal and external. First, those who perform R&D are more likely to sense techno-

[8] Assuming the null hypothesis, there is one out of ten chance of concluding that the odds advantages are real when in fact there are no differences between the odds and probabilities of receiving SBIR funds between the two geographical locations in the larger population, holding the rest of the variables in the selection model constant.

logical dead-ends, and thus, are more likely to propose technologically sound SBIR proposals. This ability to separate technically promising areas from technological dead-ends, which can be acquired by performing prior R&D, increases the probability of SBIR funding. The external reason has something to do with the reputation of the proponent small firm. Reviewers of SBIR grant applications are more likely to favor proponent-firms that have engaged in R&D, believing that R&D experience increases the firm's absorptive capacity, which enhances success in producing innovations from federal R&D grants. In addition to indicating successful innovation record, owning patents may further encourage firms to apply for R&D grants. Because innovation is highly complex, that is, it might take a combination of multiple patents to produce a product, process, or service that consumers value, it is plausible that patent-owning start-ups are thinking of generating new patents out of the public R&D grant, which they will combine with what they currently own to generate innovations with unique competitive advantage. In sum, patent owners are more likely to sense they need a portfolio of knowledge assets to produce innovation, and thus, are more likely to exploit external R&D resources (e.g. SBIR grants) in order to be more successful in orchestrating inputs for innovation.

The industry where the start-up chose to compete or operate significantly predicts the probability of SBIR participation. The odds of receiving SBIR funds of small business start-ups in the pharmaceutical ($p<0.01$), chemical ($p<0.01$), machinery ($p<0.05$), electronics ($p<0.001$), electrical equipment ($p<0.05$), and medical and surgical equipment ($p<0.001$) are at least 15 times as high as the odds of those in the traditional sectors including the services sector. Of course, this empirical result is hardly surprising. The goal of the SBIR is to stimulate technological innovation, specifically along the mission areas of the 11 participating SBIR agencies. The seven high-tech industries are more likely to correspond with the federal missions and mandates of at least the top five SBIR agencies: DOD, HHS/NIH, NASA, DOE, and NSF. Ninety-six percent (i.e., 24 out of 25) of SBIR recipient small business start-ups obtained their SBIR R&D funding either from the DOD, HHS/NIH, NSF and DOE or a combination of these. For a review of agency funding sources, see Table 4. The hypothesis that firm size ($p<0.70$) positively contributes to SBIR selection is not supported. A possible reason is that basic technology research by start-ups is owner-specific. The quality of SBIR grant proposals may depend on the owner-entrepreneur more than his or her own employees. The industry experience ($p<0.70$) of the owner, however, does not matter in SBIR selection. While we hypothesized that more experienced entrepreneurs were more likely to bring with them best-practice organizational routines that are important in running day-to-day operations including R&D, these routines may not be that important in developing quality proposals and therefore in obtaining SBIR awards. Surprisingly, start-ups without sales ($p<0.05$) are more likely to receive SBIR awards. We can proffer at least two explanations. First, start-ups that are looking at long-term R&D as their source of future competitive advantage are more likely to forego production and sales in favor of more R&D. Second, small firms without any short-term inclination or plan to sell goods and services are being created by opportunistic entrepreneurs just for the sole purpose of securing SBIR funds. These two explanations/hypotheses can be tested in future research on SBIR recipient firms. SBA can redesign the SBIR program to discourage opportunistic behavior.

Finally, there is some evidence that geographical location ($p<0.10$) matters, but surprisingly, it works at the opposite direction, that is, start-ups in states that are known for R&D and innovative activities are less likely to receive SBIR grants. The literature on knowledge and technological spillovers predicts that the innovating firm benefits from the R&D conducted by universities, government research laboratories, and other firms within its local innovation system. These spillovers can enhance the quality of firms' R&D including their proposal for public R&D grants. It appears that a different mechanism might be at play here. First, start-ups in less R&D intensive locations may correctly perceive that they are at a disadvantage (due to less technological spillovers) and decide to conduct more R&D on their own with the help of federal R&D grants. Thus, it is plausible that start-ups at less R&D intensive states are more likely to apply for SBIR grant in order to conduct R&D on their own instead of relying on research spillovers, which may or may not come (Feldman, 1994). Second, SBIR participating agencies may also sense that small firms in locations with few technological spillovers are at a disadvantage and may decide to distribute SBIR awards evenly between R&D intensive states (e.g. CA and MA) and those that are not well known for their R&D activities, without having to sacrifice the quality of funded SBIR R&D projects. The empirical finding that SBIR funding (at least for small business start-ups) are geographically distributed or dispersed is important at least from a public policy perspective. It can offer a political explanation why the SBIR continues as a federal technology program while others like the Advanced Technology Program (ATP) have been terminated. Start-ups from states (e.g. Wyoming and South Dakota) that are not known for their R&D may also benefit from the SBIR program.[9] Specifically in our KFS-SBA sample, start-ups from Utah, Vermont, South Carolina,

[9]South Dakota and Wyoming, ranked 50th and 51st in R&D performance respectively, spent only $149 million and $98 million in 2004. In contrast, California spent $59.6 billion in R&D in the same period.

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and Montana also received SBIR funding.[10] Elected political representatives in the U.S. Congress are more likely to support public programs that benefit their respective constituencies. The wider this political constituency is, the broader the political support is in Congress.

From the determinants of SBIR program selection, we derive the following theoretical and practical implications and areas for future research.

First, the owner-entrepreneur has a role in high-technology research. The ability to sense technological opportunities, which are initially submitted for federal R&D support through the SBIR program, is a function of the advance training and education of the owner-entrepreneur. Post-graduate training improves the entrepreneur's cognitive ability to select commercially promising and scientifically sound areas of technology research that are also deemed worthy of public R&D support by SBIR participating agencies (e.g. DOD, NIH, NSF). Promoting high-technology entrepreneurship may require attracting more academic scientists and engineers to commercialize their scientific discoveries and inventions by starting new business ventures. More scientists and engineers becoming high-tech entrepreneurs increases the quality of the applicant pool for federal R&D grants. However, this may also require training potential entrepreneurs in the art and science of managing high-tech ventures while they are being trained in their respective scientific and engineering disciplines (e.g. physics, chemistry, biochemistry, biology, mechanical engineering, electronics and communications engineering). Georgia Tech's Technological Innovation: Generating Economic Results (TI:GER) is an excellent model for the entrepreneurship training for doctoral students in science and engineering. As Hill (2007) and Bhide (2010) have argued, cutting edge technological success may not depend on specialization but on integration – on synthesis, design, creativity, and imagination. If this is the case, what the U.S. innovation economy may need are more creative scientists and engineers – which may require curriculum change away from too much emphasis on mathematics and science towards design and synthesis. Innovation is not entirely science-based or science-driven; the management skill to marshal necessary human, material, and financial resources and come up with a business model that provides customer value is also critical.

Second, industry matters in federal R&D funding. The odds that a start-up in high-technology industries receives an SBIR grant are at least more than six times as high as the odds of their counterparts in traditional and service sectors. Not all industries are created equal in SBIR funding. This fact reflects primarily the missions and priority research areas of SBIR participating agencies. R&D funding from the DOD, DOE, HHS, and the NSF favors new technology research in the areas of pharmaceuticals, chemicals, electronics, electrical equipment, medical/surgical equipment, and machinery. Porter's (1980) advice more than three decades ago on developing a competitive position through differentiation is still relevant today, even in the application for federal R&D funding.

Third, prior R&D and innovation record are a market signal on the ability of start-ups to innovate. It is not entirely accurate that small business start-ups do not have a track record to stand on when applying or competing for scarce public R&D resources against established businesses. Performing R&D right at the start of business operations can signal the start-up's intent to continue performing R&D in the future. SBIR participating agencies judge R&D performers more favorably. Because learning is cumulative, success in producing knowledge assets and innovation in the past underpin future innovation performance. Having patents signals the knowledge and experience the firm's owners have acquired over time. These patents may have been applied for and approved by the United States Patent and Trademark Office (USPTO) prior to the establishment of the firm (e.g. when the owner was still affiliated in a university as a graduate student or a faculty member), but just the same, it sends a credible signal that the small business start-up has learned something substantial in the past and is more likely to succeed in producing innovations in the future.

Finally, an equally important part of evaluation is process evaluation, in which we ask whether SBIR participating agencies are executing the right process to implement the program effectively. The selection mechanism is an important part of the implementation process. A good program with the right set of objectives cannot achieve its goals without the right process.[11] Evidence from our integrated KFS-SBA sample indicates the SBIR participating agencies (at least for DOD, HHS, NSF, DOE, and USDA are concerned) have the right selection mechanism to screen start-ups that have the potential to generate cutting-edge technologies. The SBIR selection model showed that SBIR resources are going to start-ups with prior R&D experience, patents, owners who have advanced training and education and those that

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[10]Montana is ranked 48th in R&D performance, spending only $295 million in 2004. The 25th ranked state, Missouri, spent $ 3 billion in R&D in the same period.

[11]Most program evaluations start with process evaluation before proceeding to the more difficult and more rigorous impact evaluation. It does not make any sense estimating the benefits of a policy or program or project that is not being implemented well. Only well-run programs (from a process perspective) deserve to be evaluated as to its impact.

operate in the high-technology sector. It seems that SBIR participating agencies believe that the ability to generate innovation (from public R&D funding) is firm-specific, that is, it is dependent on its prior innovation record and the knowledge and experience of its owners and entrepreneurs. However, the SBA and participating SBIR agencies (e.g. NIST) must re-examine these results and the selection criteria they use in driving these results. Are they picking "winners" by taking a conservative strategy of awarding funds to prior innovators? Or, are they picking "losers" by not taking sufficient risks on small business start-ups that have no innovation record?

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