

## **The fountain of knowledge: an epistemological perspective on the growth of U.S. SBIR-funded firms**

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### **Abstract:**

The premise of this paper is that a basis for firms receiving Small Business Innovation Research (SBIR) research awards to develop commercializable technologies is not only their proposed creative ideas but also their endowment of attendant knowledge necessary to develop the technology being proposed. Based on this premise, we propose that those firms that have higher growth rates attributable to their SBIR awards are also those firms that are more creative and have more knowledge endowments. Empirically, we quantify a firms creativity and its sources of research knowledge in terms of its past experiences, and we find that firms with more technical experience and sector experience are those that have realized higher growth rates from their SBIR-funded research.

**Keywords:** knowledge | creativity | entrepreneurship | SBIR program | technology

### **Article:**

#### **Introduction**

The premise of this paper is that a basis for firms receiving Small Business Innovation Research (SBIR) research awards (discussed in “Background on the SBIR Program” section) to develop commercializable technologies is not only their proposed creative ideas but also their endowment of attendant knowledge necessary to develop the technology being proposed.<sup>1</sup> Thus, for one to understand why SBIR-funded firms are successful in obtaining SBIR awards, and to understand why many of these firms have grown over time due to their SBIR research endeavors, we propose that one must first understand the genesis of these firms’ creative ideas and the sources of their endowments of research knowledge that lead to their research successes.

It follows from our starting premise that if one were to compare two similar SBIR-funded firms that experienced different growth rates that were directly attributable to their SBIR research, one

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<sup>1</sup> This premise is reflected in the peer review process used to evaluate applications for SBIR awards. For details of the process, see: <https://www.nap.edu/catalog/11989/an-assessment-of-the-sbir-program>. We use information on SBIR awards in the empirical analysis below, but application review scores are confidential for each project.

might ask the question: *How do the ideas and knowledge foundations of each funded firm differ?* Or stated differently: *Does one funded firm have a greater endowment of ideas and attendant research knowledge than the other?* Our approach to address these questions is to identify covariates with the growth rate of SBIR-funded firms that is directly attributable to their SBIR awards and to relate those growth rates to metrics that quantify the genesis of their ideas and the sources of their attendant knowledge.

We argue herein that the genesis of firms' ideas and the sources of their knowledge are related to varying dimensions of firms experiences—experiences embodied in firms through the background of their founders and through the firms' previous related experiences.<sup>2</sup>

Our argument for focusing on the experience of founders and their firms is certainly not original to us. For centuries philosophers have emphasized that the genesis of ideas and the sources of one's knowledge is based on one's experiences. For example, reflecting on the wisdom of John Locke in *An Essay Concerning Human Understanding*, first published in 1689 (1996, pp. 33–34):

Every man being conscious to himself, that he thinks, and that which his mind is employed about whilst thinking being the ideas, that are there, 'tis past doubt, that men have in their minds several ideas ... *All ideas come from sensation or reflection.*

For Locke (1996, p. 34), sensations and reflections “convey into the mind” one's perception of things, and the ideas that one has depend wholly on one's perceptions. Sensations and reflections are one's “fountains of knowledge,” and the precursor to knowledge is one's experiences.

David Hume, in *An Enquiry Concerning Human Understanding*, originally published in 1748, wrote (2007, p. 8):

When we analyze our thoughts or ideas, however, compounded or sublime, we always find that they resolve themselves into such simple ideas as were copied from a precedent feeling or sentiment [i.e., experience]. Even those ideas, which, at first view, seem the most wide of this origin, are found, upon a nearer scrutiny, to be derived from it ... we shall always find that every idea which we examine is copied from a similar impression.

Even centuries after the writings of these philosophers, one continues to find that scholars from a variety of disciplines focus on one's experiences as one's source of ideas and one's basis of knowledge. For example, Stinchcombe (1965) was among the first modern organizational scholars to point out that the founding history of an organization (e.g., a firm) directly influences the present structure and conduct of the organization.<sup>3</sup>

Also, economist and Nobel Laureate T.W. Schultz wrote (1975, p. 828):

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<sup>2</sup> The origin of this paper traces to our earlier writings on sources of knowledge and entrepreneurial behavior. See, for example, Audretsch and Link (2019).

<sup>3</sup> Baron et al. (1996, 529) interpreted, from their background as eminent sociologists, Stinchcombe's pioneering reasoning in the follow way: “... founding conditions become imprinted on organizations and mold their subsequent development.”

Our knowledge of a person's abilities consists of inferences drawn from his performance. An ability is thus perceived as the competence and efficiency with which particular acts are performed.

More recent writers refocused these ideas for their own purposes of, for example, explaining the growth of small entrepreneurial firms (and not necessarily small technology-based firms). For example, Storey (1994, p. 123), an entrepreneurship and management scholar, posited that prior "managerial experiences" and "sector experiences" are directly related to the growth of small entrepreneurial firms.

The remainder of this paper builds on the arguments of the above scholars about founder's and thus firm's experiences being a basis for the genesis of the firm's creative ideas and knowledge-based performance. In "Background on the SBIR Program" section, we overview the institution background of the U.S. SBIR program.<sup>4</sup> In "SBIR data set and empirical findings" section, we describe the SBIR project data that we use to explore the relationship between founder/firm experiences and firm growth, and we discuss our findings. "Concluding remarks" section concludes the paper with summary remarks and a suggestion for future research.

### **Background on the SBIR program**

The U.S. Small Business Act of 1953, Public Law 85–536, created the Small Business Administration (SBA). Through this legislation, Congress emphasized that small firms are a vehicle for stimulating economic growth. A prototype for what was to become the SBIR program began in 1977 at the National Science Foundation (NSF) (Tibbetts 1999). The NSF program was so successful that President Jimmy Carter emphasized it in his 1979 Domestic Policy Review<sup>5</sup>:

Small innovative firms have historically played an important role in bringing new technologies into the marketplace. They are also an important source of new jobs. ... I propose the enhancement by \$10 million of the Small Business Innovation Research Program of the National Science Foundation. ... Further, the National Science Foundation will assist other agencies in implementing similar programs ... .

The Small Business Innovation Development Act of 1982, Public Law 97–219, is generally known as the 1982 Act. It was passed by Congress on July 22, 1982 as an amendment to the Small Business Act of 1953.

The 1982 Act is premised on the following statement that reflected Congress' point of view:

1. technological innovation creates jobs, increases productivity, competition, and economic growth, and is a valuable counterforce to inflation and the United States balance-of-payments deficit;

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<sup>4</sup> We have written about the institutional background of the SBIR program many times so duplication of text is inevitable. For example, see Link (2014).

<sup>5</sup> See, <https://www.presidency.ucsb.edu/documents/industrial-innovation-initiatives-message-the-congress-administration-actions-and>

2. while small business is the principal source of significant innovations in the Nation, the clear majority of federally funded research and development is conducted by large businesses, universities, and Government laboratories; and
3. small businesses are among the most cost-effective performers of research and development and are particularly capable of developing research and development results into new products.

The legislated purposes of the 1982 Act are<sup>6</sup>:

1. to stimulate technological innovation;
2. to use small business to meet Federal research and development needs;
3. to foster and encourage participation by minority and disadvantaged persons in technological innovation; and
4. to increase private sector commercialization of innovations derived from Federal research and development.

The SBIR program is a set aside program. Agencies with an annual extramural R&D budget greater than \$100 million are currently required to set aside 3.2% of their budget each year to allocate to small firms through Phase I and/or Phase II awards. Phase I SBIR awards are small, generally not more than \$150,000 for 6-months, and they are intended to support research into the feasibility of an idea's scientific and commercial potential in response to the funding agency's objectives. Phase II awards are generally not more than \$1,000,000 for 2-years, and they are focused on the development of a commercializable technology.<sup>7</sup>

The eligibility requirements for a SBIR award are that the firm must be: organized and operated for profit, with a place of business in the United States, which operates primarily within the United States or which makes a significant contribution to the U.S. economy through payment of taxes or use of American products, materials, or labor; more than 50% owned and controlled by one or more individuals who are citizens or permanent resident aliens of the United States; and have not more than 500 employees, including affiliates.

The SBIR program has been reauthorized periodically. The year 2000 authorization mandated that the National Research Council (NRC) of the National Academies conduct an evaluation of the economic benefits associated with the program.<sup>8</sup> Toward this end, the NRC developed and administered a comprehensive survey of Phase II projects in 2005 that were funded by the largest five agencies participating in the SBIR program: the Department of Defense (DOD), the National

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<sup>6</sup> Purpose (3) was changed in the 1992 reauthorization of the program as: “[To] foster and encourage participation in innovation and entrepreneurship by women and socially or economically disadvantaged persons.” See Link and van Hasselt (2019) on gender and the patenting performance of SBIR-funded firms.

<sup>7</sup> There are conditions under which an agency may increase Phase I and Phase II awards by as much as 50%.

<sup>8</sup> The NRC is the operating arm of the National Academies of Science, Engineering, and Medicine. The Council was created in 1916 by President Woodrow Wilson to “bring into cooperation government, educational, industrial, and other research organizations with the object of encouraging the investigation of natural phenomena, and increased use of scientific research in the development of American industries, the employment of scientific methods in strengthening the national defense, and such other applications of science as will promote the national security and welfare.” See, <http://www.nasonline.org/about-nas/history/archives/milestones-in-NAS-history/organization-of-the-nrc.html>

Institutes of Health (NIH), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the National Science Foundation (NSF).

### **SBIR data set and empirical findings**

One portion of the 2005 survey was devoted to obtaining Phase II project-specific information related to the most recently funded research project, and another portion was developed to obtaining firm-specific information about the overall SBIR program to understand better how firms have benefitted from their awards. The firm-specific survey question about the program in general that motivates this paper is<sup>9</sup>: *What percentage of your firm's growth would you attribute to the SBIR program after receiving its first SBIR award?* We interpret this survey question literally meaning that we accept that the responding firm knows the extent to which its growth is attributable to the SBIR program. Responses to this question form the dependent variable for our empirical analysis.<sup>10</sup>

The independent variables used to explain across firms differences in the percent of growth attributable to the SBIR program relate broadly to the experience base of the firm's founders, which proxies the genesis of their project ideas and their sources of attendant knowledge.<sup>11</sup> In particular, we focus on the managerial expertise of a founder, the sector expertise of a founder, the technical experience embodied in the firm, the accumulated human capital experience of a founder, and the business and academic background of a founder.

As an aside, according to Winter (1984, p. 297):

An entrepreneurial regime is one that is favorable to innovative entry and unfavorable to innovative activity by established firms; a routinized regime is one in which the conditions are the other way around.

Firms with high levels of technical (i.e., creative) experience might thus be characterized as being in an entrepreneurial regime—a regime that is more conducive to a stronger growth performance. By contrast, firms with high levels of managerial (i.e., establishment) expertise might thus be characterized as being in a routinized regime—a regime that is less conducive to stronger growth.

See Table 1 for a definition of these experience measures and other variables used in our analysis. See Table 2 for descriptive statistics on all of the variables.

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<sup>9</sup> The survey instrument used in the 2005 survey is not consistent in its use of the word *company* and the word *firm*. When the survey question used the word *company*, we changed it to the word *firm* for consistency in the text of this paper.

<sup>10</sup> The survey instrument does not define the growth metric of interest, but the juxtaposition of this survey question to other questions on the survey imply that growth refers to employment growth.

<sup>11</sup> The project-specific and program-specific questions are the same for each of the five agencies that participated in the 2005 survey. See, for example, Appendix A in the National Research Council's final report to Congress: <https://www.nap.edu/catalog/11989/an-assessment-of-the-sbir-program>.

**Table 1.** Definition of the variables

| Variable                 | Definition   |
|--------------------------|--|
| Growth                   | Percent of firm growth attributable to the SBIR program after receiving its first SBIR award.                                    |
| Managerial Experience    | Number of other firms started by one or more of the founders.  |
| Sector Experience        | Equal to 1 if one or more of the founders' most recent employment before founding this firm was the private sector; 0 otherwise. |
| Technical Experience     | Number of previous Phase II research awards the firm has received.   |
| Human Capital Experience | Number of founders of the firm.  |
| Business Background      | Equal to 1 if one or more of the founders had a business background; 0 otherwise.  |
| Academic Background      | Equal to 1 if one or more of the founders had an academic background; 0 otherwise.   |
| Years                    | Number of years since the firm received its first Phase II SBIR award.   |
| Age                      | Age of the firm equal to 2005 minus the year the firm was founded.   |
| DoD                      | Equal to 1 if the firm was funded through the Department of Defense's SBIR program; 0 otherwise.                                 |
| NASA                     | Equal to 1 if the firm was funded through NASA's SBIR program; 0 otherwise.  |
| NIH                      | Equal to 1 if the firm was funded through the National Institutes of Health's SBIR program; 0 otherwise.                         |
| DOE                      | Equal to 1 if the firm was funded through the Department of Energy's SBIR program; 0 otherwise.                                  |
| NSF                      | Equal to 1 if the firm was funded through the National Science Foundation's SBIR program; 0 otherwise.                           |

**Table 2.** Descriptive statistics on the variables ( $n = 1732$ )

| Variable                 | Mean     | Standard Deviation | Range |
|--------------------------|----------|--------------------|-------|
| Growth                   | 48.84844 | 29.16047           | 12–88 |
| Managerial Experience    | 1.35912  | 2.26247            | 0–18  |
| Sector Experience        | 0.70092  | 0.45799            | 0/1   |
| Technical Experience     | 19.83256 | 42.27877           | 1–233 |
| Human Capital Experience | 2.11836  | 1.49460            | 1–20  |
| Business Background      | 0.45208  | 0.49784            | 0/1   |
| Academic Background      | 0.67725  | 0.46766            | 0/1   |
| Years                    | 11.15358 | 5.30062            | 1–34  |
| Age                      | 18.26386 | 10.74736           | 4–105 |
| DoD                      | 0.48152  | 0.49980            | 0/1   |
| NASA                     | 0.09988  | 0.29993            | 0/1   |
| NIH                      | 0.24885  | 0.43247            | 0/1   |
| DOE                      | 0.08256  | 0.27530            | 0/1   |
| NSF                      | 0.08718  | 0.28218            | 0/1   |

The total number of surveyed firms was 1878; however, due to missing data (i.e., the respondent to the survey did not know a correct response) only 1732 firms are included in the analysis in this paper

The upper value of the range on the variable *Technical Experience* and on the variable *Age* are not outliers. A frequency distribution for each variable is available on request from the authors

None of the variance inflation factors (VIFs) on the economic variables in the model is greater than 2

From Table 2, we see that about 70% of the founders of the firms in the sample were previously employed in the private sector (*Sector Experience*). These firms had, on average just over 2 founders (*Human Capital Experience*) and at least one of those founders had previously started another firm (*Managerial Experience*). On average, these firms have had nearly 20 previous

Phase II awards (*Technical Experience*) over an average of about 11 years (*Years*). On average, the founders of these firms have more academic backgrounds (*Academic Background*) than business backgrounds (*Business Background*) that might be expected because an academic background mirrors the research experience which is critical for research award success. About 68% of the firms having a founder with an academic background compare to 45% of the firms with a founder with a business background. Finally, the age of the firms in the sample is, on average, 18 years (*Age*), but the range is large reflecting, perhaps, that some of the firms are so-called SBIR mills (i.e., they exist only to win SBIR awards).

**Table 3.** Ordinary least squares regression results (standard errors in parentheses, *p*-values in brackets, *n* = 1732)

| Variable                     |   |
|------------------------------|---|
| <b>Managerial Experience</b> | <b>0.27484</b><br><b>(0.32316)</b><br><b>[0.3952]</b> |
| Sector Experience            | 3.66238**<br>(1.54309)<br>[0.0177]                    |
| Technical Experience         | 0.12877***<br>(0.01952)<br>[0.001]                    |
| Human Capital Experience     | -3.60012***<br>(0.47847)<br>[0.001]                   |
| Business Background          | -3.09038***<br>(1.38765)<br>[0.0261]                  |
| Academic Background          | 2.43470*<br>(1.48061)<br>[0.0967]                     |
| Years                        | 0.36707**<br>(0.16268)<br>[0.0242]                    |
| Age                          | -1.00115***<br>(0.07385)<br>[0.001]                   |
| Intercept                    | 64.01417<br>(3.18098)<br>[0.001]                      |
| Agency controls              | yes   |
| R-squared                    | 0.1434  |
| F-value                      | 23.97***<br>[0.001]                                   |

\*\*\* significant at 0.01-level, \*\* significant at 0.05-level, \* significant at 0.10-level

Projects funded through NSF's SBIR program are subsumed in the intercept term

The ordinary least squares regression results from our model to explain across firm differences in growth rates, *Growth*, are presented in Table 3.<sup>12</sup>

<sup>12</sup> The NRC survey about firm growth had categorical responses to the question about growth. The four categories of responses are "less than 25%, 25% to 50%, 51% to 75%, and more than 75%." Responses to this survey question

The regression results in Table 3 suggest the following. Not all experience measures are positively related to firm growth, that is are directly attributable to the SBIR program after the firm received its first SBIR award. Managerial experience, as we have measured it in terms of the previous number of firms started by founders, is not a significant covariate. This finding is not in concert with Storey's prediction about managerial experience being important in small firms in general, but it does allow our extrapolation, following Winter, about managerial experience characterizing firms in a routinized regime. SBIR-funded firms are nascent and technology based. Perhaps the lack of statistical significance of our measure of managerial experience reflects the fact that at this early stage of the development and maturation of these firms routinized experience is not what drives growth; rather, what drives growth is broader experience about private sector markets.

Sector experience is an important covariate with firm growth. Firms with founders whose previous employment was in the private sector are more likely to have experienced greater growth from the SBIR program than firms without such sector experience. This finding does complement Storey's prediction. The estimated coefficient on *Sector Experience* is 3.66, and it is significant; firms with a founder with prior sector experience have realized about 3.7 percentage points greater growth than firms without this element of experience, other factors held constant.

Technical experience is also a positive and significant covariate with *Growth*, although the magnitude of the effect of technical experience is small. This statistical finding supports our extrapolation, following Winter, about a firm with technical experience being characterized as in an entrepreneurial regime. An increase of 10 previous Phase II awards is associated with an increase in *Growth* of 1.3 percentage points.

Human capital experience, measured in terms of the number of founders of the firm, holding constant the age of the firm, is negatively related to *Growth*, and the estimated coefficient is significant. We interpret this result to mean that "too many cooks have spoiled the broth." Other factors held constant, more founders is not necessarily supportive of firm growth as measured herein.

Firms with founders with an academic background are associated with greater growth, likely because of the research experience of such founders, but the estimated coefficient on *Academic Background* while positive is only marginally significant. Firms with founders with a business background are associated with less firm growth. And, the magnitude of the estimated coefficient on *Business Background* is greater than the estimated coefficient on *Academic Background* in absolute value and more significant. We suggest that this finding might suggest that in those

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follow a uniform distribution. Note that the mean value of *Growth* in Table 2 is about 50%. We imputed a mean value to each category: 12%, 37.5%, 63.5%, and 88." This was done for the ease of interpreting the regression results in Table 3. However, if one estimated our reduced form model using an ordered probit specification, the results are identical to the values in Table 3 in terms of algebraic signs and levels of significance. These results, and the calculated marginal effects, are available from the authors on request. Finally, the implications from the regression results in Table 3, using data from all funding agencies and controlling for fixed agency effects, are the same if the underlying model was estimated separately by funding agency. These results are available from the authors on request.

firms with a mix of founder backgrounds, those with founders with academic backgrounds does not offset the negative growth influence of those with founders with business backgrounds.

Finally, firms that received their first Phase II award longer ago have enjoyed greater growth. The estimated coefficient on *Years* is positive and significant. It is, however, not the case for firms that are simply older. Firm age per se, *Age*, might proxy a degree of stagnation within the firm with regard to factors associated with growth.

### **Concluding remarks**

To the best of our knowledge, no other research has been conducted on the broad impact that the SBIR program has had on firms that had previously received Phase II awards. There is a rich literature that has examined covariates with project success, such as if the funded Phase II project resulted in the commercialization of a new technology or not (Link and Scott 2010, 2012a); and some research has been pursued to determine how well the SBIR program has met its legislated goals (Link and Scott 2018) and how well firms have internalized the results from the publicly funded research (Link and Scott 2012b). But, little is known about the lasting impact of the program on funded firms.

While the findings that we present in this paper suggest that certain forms of experience are more relevant for sustained firm growth than others, our findings should still be interpreted with caution. First, the estimated regression coefficients are small in value, suggesting that there are other founder-specific and firm-specific factors associated with growth that are not accounted for in our analysis. Second, the mean age of the firms in the SBIR data set is over 18 years, and the mean time period between the award of the first Phase II to the firm and the 2005 survey is over 11 years. Respondents to the SBIR survey might not have been firm founders and thus respondents might not have had access to firm records that have the same degree of accuracy. It may be the case that there is greater uncertainty about the reported value of *Growth* in older firms.

Our analysis suggests at least two broad observations. First, the firms in our sample, which is a representative sample of SBIR-funded firms, report mean growth of nearly 49% (i.e., *Growth*) that is directly attributable to the SBIR program. Our descriptive statistics also show that the mean number of years since firms received their first SBIR award is about 11 years (i.e., *Years*), and on average these firms have existed for about 18 years (i.e., *Age*). Thus, growth during the majority portion of their existence, they have growth on average at about 4.6% per year, and that is a growth rate that is higher than the economy-wide growth rate. Second, technical experience, and market knowledge (i.e., *Technical Experience* and *Sector Experience*) are the main drivers of these SBIR-funded firms. Likely, as these firms mature over time, managerial experience will begin to have a greater influence. Nevertheless, the arguments that we posed in this paper and our empirical findings are new to the literature and, in our view, sufficient to warrant greater study of the longer term impacts of publicly funded technology programs either through case studies or statistical analyses.

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