Knowledge-based information and the effectiveness of R&D in small firms

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Abstract:

This paper explores the impact that external sources of information have on the effectiveness of R&D in small, entrepreneurial firms. The effectiveness of R&D is measured in terms of two probabilities: the probability that a firm that received and completed a Phase I SBIR-funded research project is invited to submit a proposal for a Phase II award, and given such an invitation, the probability that a firm receives the Phase II award. Information from competitors is an important, in a statistical sense, covariate with the probability of being asked to submit a Phase II proposal, whereas information from suppliers and customers is an important covariate with the probability of receiving a Phase II award.

Plain English Summary: Tweetable headline: Market information, especially from suppliers, customers, and competitors, increases the effectiveness of publicly funded R&D among small, entrepreneurial firms. The R&D considered in this paper came from research awards from the National Institutes of Health's Small Business Innovation Research (SBIR) program. The analysis presented shows a relationship between the effective use of the SBIR research awards and the use of several external sources of information—namely, suppliers, customers, and competitors—related to the market demand for the technology resulting from the funded research. This finding has a policy implication. For government agencies that participate in the SBIR program to be diligent stewards of public resources, small, entrepreneurial firms who receive such funding should be advised on how to identify and use relevant external source of market information.

Keywords: small business innovation research (SBIR) program | small firms | entrepreneurial firms | R&D | knowledge sources | program evaluation

Article:

1 Introduction

The antecedents and consequences of innovative behavior are well known topics to both academic scholars and public policy makers. On the input side of innovative behavior, the literature is replete with studies at varying levels of aggregation that associate investments in research and development (R&D), especially private sector R&D (Hall, Mairesse, and Mohnen, 2010; Lerner & Stern, 2012), with innovation-related metrics. Studies that associate levels of investments in public sector R&D and either private sector or public sector innovative behavior are fewer and often take the form of case studies (Cunningham & Link, 2022). On the output side of innovative behavior, there is a growing body of literature that associates innovative behavior with aggregate economic progress and growth (Atkeson et al., 2019). Both sides of the coin, so to speak, are important not only from a general economics perspective but also from a public policy perspective. However, from the public policy perspective, a more complete understanding of the R&D → innovative behavior → economic progress and growth paradigm is necessary.

What appears to be missing from the paradigm is the precursor to what drives the effectiveness of the initial R&D investments, especially a precursor with an emphasis on small, entrepreneurial firms.Footnote1 Understanding the origin of knowledge-based information and its impact on the R&D process is our starting point to begin to address this void. Thus, the purpose of this paper is to explore empirically the relationship between alternative knowledge-based sources of information—market, institutional, and other sources—and the effectiveness of R&D investments.

The remainder of this paper is organized as follows. In Section II, we reflect on classical and contemporary writings about sources of knowledge. This review then becomes in Section III our springboard for an exploratory empirical investigation of the extent to which knowledge-based information is associated with R&D-related innovative behavior. Therein, we identify the informational sources considered in this paper. In Section IV, we discuss the data used in our analysis as well as our empirical findings. The data used come from small, entrepreneurial firms that have received research support from the US Small Business Innovation Research (SBIR) program. In Section V, we summarize our findings with an eye toward public policies that might subsequently enhance innovation behavior.

2 Reflections on knowledge-based information

There is a rich literature on sources of knowledge from which to draw insight about innovative behavior.Footnote2 That literature traces at least to the writings of Locke who emphasized, in 1690, that all ideas emanate from one's senses and one's experiences (Locke, 1996, original 1690, p. 33–34)Footnote3:

> Let us then suppose the mind to be, as we say, white paper, void of all characters, without any ideas; how comes it to be furnished? … To this I answer, in one word, from experience; in that, all our knowledge is founded; and from that it ultimately derives itself.

The thoughts of Locke and Hume are arguably foundational to the views of more contemporary scholars.Footnote5 For example, Schultz (1975) explored the relationship between education, experience, and human capital; and Machlup (1980), indirectly reflecting on the ideas of Schultz, argued that formal education is only one source of knowledge because knowledge is also gained experientially and at different rates by different individuals. Foray's (2004, p. 14) perspective on the source of knowledge is somewhat different. He envisioned an endogenous circular flow between knowledge and inventive activities:

> Much knowledge is produced by invention, that is, it does not exist as such in nature and is 'produced' by man. Other types of knowledge stem from discoveries, that is, the accurate recognition of something which already existed but which was concealed. Invention is the result of production; discovery the result of revealing.

In Foray's (2004, p. 14) discussion involving the challenges facing the reproduction of knowledge, he acknowledged the related contributions of PolanyiFootnote6:

> Polanyi (1966), who introduced us to the concept of tacit knowledge, points out an essential aspect of knowledge that makes its reproduction difficult. Tacit knowledge cannot be expressed outside the action of the person who has it. In general, we are not even aware of the fact that we have such knowledge, or else we simply disregard it.

Antonelli and Fassio highlight yet another important aspect in the development of thought around the generation of knowledge and ideas (2014, p. 16):

> [K]nowledge is not homogeneous. Instead, it should be regarded as a highly differentiated bundle of knowledge items.

Generalizing from Antonelli's and Fassio's insight about the heterogeneity of knowledge, and building on the view of Foray and Polanyi, it follows that discoveries are not homogeneous; discoveries are influenced by differing knowledge-based information sources. Relatedly, Hayek (1948, pp. 77–78) argued that the economics problem society seeks to solve or explain is essentially one of knowledge utilization by varying individualsFootnote7:

> The economic problem of society is thus not merely a problem of how to allocate 'given' resources … It is rather a problem of how to secure the best use of resources known to any of the members of society …

The analysis that follows identifies empirically the knowledge-based information sources that are associated with measures of the effectiveness of R&D investments and the activities those investments support.

3 External sources of knowledge-based information

The United Nations Educational, Scientific and Cultural Organization (UNESCO, 2015) identified categories for access of innovation-related external sources of information. Table 1 summarizes UNESCO's taxonomy of external sources of information potentially relied on by innovation-active manufacturing firms. All of these information sources embody elements of experiential knowledge.Footnote8 The internal decision to access market, institutional, or other sources of information not only reflects internal experiential knowledge about the usefulness of such sources but also about the experiential knowledge embodied in those sources (e.g., tacit experiential knowledge embodied in customers or universities; codified experiential knowledge embodied in scientific journals).

Table 1 External sources of information used by innovation-active manufacturing firms

External sources of information	Location
Market sources	Suppliers of equipment, material, components, or software Clients or customers Competitors of other enterprises in your sector Consultants, commercial labs, or private R&D institutes
Institutional sources	Universities or other higher education institutions Government or private research institutes
Other sources	Conferences, trade fairs, exhibitions Scientific journal and trade/technical publications Professional and industry associations

Source: UNESCO (2015, p. 72).

4 Empirical analysis

The current mission statement of the SBIR programFootnote9:

> … is to support scientific excellence and technological innovation through the investment of Federal research funds in critical American priorities to build a strong national economy. … is to support scientific excellence and technological innovation through the investment of Federal research funds in critical American priorities to build a strong national economy.

And the goals of the SBIR program are toFootnote10:

> (1) Stimulate technological innovation.
>
> (2) Meet Federal research and development needs.
>
> (3) Foster and encourage participation in innovation and entrepreneurship by women and socially or economically disadvantaged [emphasis added] persons.Footnote11
>
> (4) Increase private-sector commercialization of innovations derived from Federal research and development funding.

These goals are met through research funding to small firms, that is, firms with 500 or fewer employees, through Phase I and Phase II competitive research awards.Footnote12 Phase I awards fund research to establish the technical merit, feasibility, and commercial potential of the proposed research and to determine the quality of performance of the small business awardee's organization prior to providing further Federal support in Phase II. Phase II awards fund research that extends the Phase I project and that has the potential to led to a commercializable technology (see goal 4 above).

Regarding Phase I and Phase II funding amounts, Gallo (2021, pp. 4–5) pointed out that:

> Generally, SBIR Phase I awards are not to exceed $150,000, adjusted for inflation, though the law provides agencies with the authority to issue awards that exceed this amount (the Phase I award guideline) by as much as 50%. In addition, agencies may request a waiver from the SBA [Small Business Administration] to exceed the award guideline by more than 50% for a specific topic. In general, the period of performance for Phase I awards is up to six months, though agencies may allow for a longer performance period for a particular project … [G]enerally, SBIR Phase II awards [are limited] to $1 million, adjusted for inflation, (the Phase II award guideline), though the directive provides agencies with the authority to issue an award that exceeds this amount by as much as 50%. As with Phase I grants, agencies may request a waiver from the SBA to exceed the Phase II award guideline by more than 50% for a specific topic. In general, the period of performance for Phase II awards is not to exceed two years, though agencies may allow for a longer performance period for a particular project. Agencies may make a sequential Phase II award to continue the work of an initial Phase II award. The amount of a sequential Phase II award is subject to the same Phase II award guideline and agencies' authority to exceed the guideline by up to 50%. Thus, agencies may award up to $3 million, adjusted for inflation, in Phase II awards for a particular project to a single recipient at the agency's discretion, and potentially more if the agency requests and receives a waiver from the SBA.

Eleven public-sector agencies and organizations currently participate in the SBIR program. They are (alphabetically) the Departments of Agriculture (USDA), Commerce (DOC), Defense (DOD), Education (ED), Energy (DOE), Health and Human Services (HHS), Homeland Security (DHS), Transportation (DOT), and the Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF). Herein, we focus on Phase I awards by NIH within HHS. NIH has the largest SBIR program, second only to DOD, in terms of number of Phase I awards and funds allocated to those awards.Footnote13

4.2 NIH Phase I data

Data on the use of the information sources described in Table 1 were obtained through an electronic survey administered in December 2021 to the principal investigators (PIs) on Phase I research projects funded in the fiscal years 2016 through 2018. Judgment was used to delimit the years for which Phase I award information was collected. First, the identified Phase I PI had to be located, that is he/she had to have remained in the firm in which the Phase I project was undertaken in order to receive a survey instrument. Second, the survey instrument asked for information on whether the firm was invited to submit a related Phase II award and whether the firm then received one. Thus, a 3-year minimum lag was imposed on the survey strategy; in other words, a firm that was funded in 2018 was assumed to have completed the Phase I research and would have applied for and received a Phase II award at least within a 3-year window of time. That window is larger for those Phase I funded firms funded in 2016 and 2017.

Based on public domain information about NIH Phase I awards,Footnote14 1,724 Phase I awards were identified for which there was an active email address for the identified project's PI. An electronic survey was sent to those PIs, along with the title and description of the Phase I project of interest; and 246 completed surveys were returned. The returned surveys represent a 14.3 percent response rate.Footnote15

Figure 1 shows the mean Phase I award for the sampling population of 1,724 NIH-funded Phase I projects in 2016 through 2018 along with the mean Phase I award for the survey sample of 246 funded projects. In all cases, the mean Phase I award is greater than the general upper limit for a Phase I award, although the quoted passage above by Gallo (2021) offers an explanation for this. In 2016, the mean award from the survey sample is noticeably greater than that for the population, but in 2017 and 2018, the mean amounts are about the same.

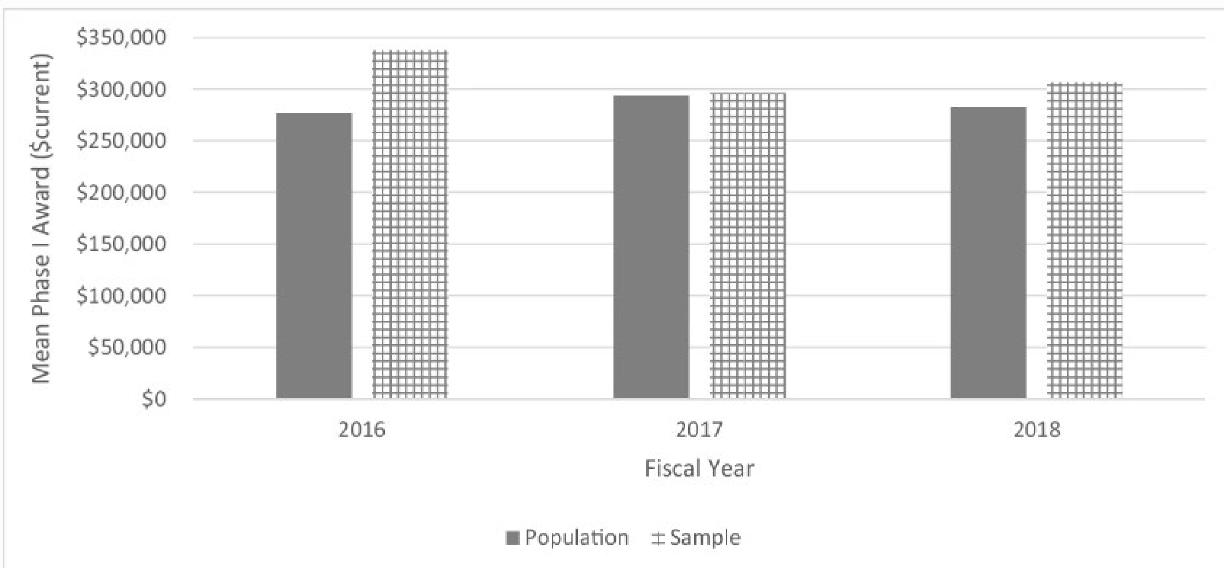

Fig 1. Mean Phase I awards for the sampling population of awards and for the survey sample of awards

Regarding the descriptive statistics in Table 3, the most relied on external sources of information for the idea and execution of Phase I research are scientific journal and trade/technical publications (Journals) followed by universities or other higher education institutions (Universities). Both external sources reflect either the findings from basic research or the involvement in basic research, and Phase I research focuses on technical merit, feasibility, and commercial potential of the proposed research. The knowledge-based codified information in scientific journals likely has more of a public good aspect compared information obtainable from university sources. The latter information source represents newer information that has not yet entered the public domain through publications. The least relied on external source of information is government or public research institutes (PublicInstitutes).

Also seen in Table 3 is that nearly 70 percent of firms that received a Phase I award—and for nearly 40 percent of the firms this Phase I award was their first such award—was invited to submit a proposal for Phase II research. However, the likelihood that a firm that received a Phase I award will subsequently receive a Phase II award is slightly less than 50 percent.

4.4 Empirical analysis

To explore the implications of the use of knowledge-based external sources of information on the effectiveness of R&D, we consider the following models.Footnote16 The first model considers the probability of being invited to submit a proposal for a Phase II award as the dependent variable,

Table 2. Questions asked on the electronic survey (variable names in italics)

Regarding the SBIR Phase I NIH-funded project(s) above, which of the following external sources of knowledge did you rely on for the idea and execution of your research. Please select all that apply

[] Suppliers of equipment, materials, components or software (*Suppliers*)
[] Clients or customers (*Customers*)
[] Competitors or other businesses in your sector (*Competitors*)
[] Consultants, commercial labs or private R&D institutes (*Consultants*)
[] Universities or other higher education institutions (*Universities*)
[] Government or public research institutes (*PublicInstitutes*)
[] Conferences, trade fairs, exhibitions (*Conferences*)
[] Scientific journal and trade/technical publications (*Journals*)
[] Professional and industry associations (*IndAssociations*)
[] None of the above (*None*)

2) Was this the first SBIR Phase I award that your company received? If you have multiple awards listed, was one of these the first SBIR Phase I award that your company received? (*FirstAward*)

[] Yes = 1
[] No = 0

3) Did your company submit a proposal for an SBIR Phase II award to continue the research of the listed award(s)? (*SubmittedPhaseII*)

[] Yes = 1
[] No = 0

4) Did your company receive any Phase II awards to continue the research of your Phase I award(s)? (*ReceivedPhaseII*)

[] Yes = 1
[] No = 0

Table 3 Descriptive statistics on responses to the electronic survey question and other variables, n = 246

Variable name	Mean	Standard deviation	Minimum	Maximum
Suppliers	0.222	0.415	0	1
Customers	0.317	0.466	0	1
Competitors	0.268	0.444	0	1
Consultants	0.321	0.468	0	1
Universities	0.646	0.479	0	1
PublicInstitutes	0.215	0.412	0	1
Conferences	0.264	0.442	0	1
Journals	0.720	0.450	0	1
IndAssociations	0.232	0.423	0	1
FirstAward	0.370	0.484	0	1
SubmittedPhaseII	0.683	0.466	0	1
ReceivedPhaseII	0.492	0.501	0	1
PhaseIAward	319,085	266,236	50,000	2,575,794
Employees (*n* = 224)	11.69	26.721	1	225
Number	3.203	2.181	0	9

Award is measured in $2018.

and the second model considers the probability of receiving a Phase II award conditional on being invited to apply for the award as the dependent variable. Herein, it is assumed that the effectiveness of the R&D investments from the Phase I award is measured in terms of being invited to submit a Phase II proposal and separately in terms of the receipt of a Phase II award. The covariates (i.e., independent variables) associated with these probabilities are the resource base of the firm and the firm's use of external sources of information for the idea and execution of the Phase I research.

The resource base of the firm is measured in terms of three productive capital elements. The first element is the technical capital (i.e., R&D) available to the firm from the Phase I award (Award).Footnote17 The above-described probabilities reflect the effectiveness of the use of the Phase I award, namely being invited to submit a proposal for a Phase II award and receiving a Phase II award.

The second element is the human capital within the firms as measured by the number of employees in the firm at the time of the Phase I award (Employees). Both Award and Employees enter the estimating equations as natural logarithms to control for possible non-linearity.

The third element is the experiential capital of the firm measured dichotomously as whether the firm received prior Phase I awards (FirstAward).Footnote18

The Probit estimates from these models are in Tables 4 and 5. The results in column (1) of Table 4 refer to the probability of the firm being invited to submit a Phase II proposal. None of the productive capital measures are related, in a statistical sense, to this measure of the effective use of the R&D from the Phase I award. What is significant is the information gained from competitors and somewhat ($p = 0.11$) from universities. Codified information from scientific journals is negatively related to the probability that the firm is invited to submit a Phase II proposal. While both universities and scientific journals are complements to basic research, it is perhaps not surprising that the Probit coefficient on scientific journals is negative given our supposition about the public good nature of such knowledge. In comparison, the information gleaned from universities complements the firm's strategy to compete through frontier research on a new technology.

The results in column (1) of Table 5 refer to the probability of the firm receiving a Phase II award conditional on being invited to submit a Phase II proposal. Here, technical capital is important. Firms that received larger Phase I awards are associated with a higher probability of receiving a Phase II award; the calculated marginal effect on lnAward implies that a 10 percent increase in the Phase I award amount is associated with a 1.37 percent increase in the probability of receiving a Phase II award. Also, information from suppliers and from customers are important covariates. These are relevant sources to guide the firm on commercializing its Phase II technology, and we note in the following section with an eye toward a policy recommendation.

We considered the possibility that the more sources of information that a firm relied on the greater the effectiveness of the use of its Phase I R&D. The variable Number is a count of the number of external information sources that were used by the firm. As shown in Table 3, the range on the number of external information sources is 0 to 9. The results in column (2) in both Table 4 and 5 show that more is not better. The Probit coefficients on Number are not significant, and neither are any of the Probit coefficients on the productive capital variables.Footnote19

Table 4 Covariates with the probability of being invited to submit a Phase II proposal (n = 224)

Variable	(1)	(2)
lnAward	-0.029 (0.188)	-0.036 (0.177)
lnEmployees	0.137 (0.091)	0.122 (0.088)
FirstAward	-0.057 (0.199)	-0.118 (0.191)
Suppliers	-0.256 (0.233)	–
Customers	0.342 (0.228)	–
Competitors	0.554** (0.263)	–
Consultants	0.092 (0.209)	–
Universities	0.333 (0.209)	–
PublicInstitutes	-0.474* (0.251)	–
Conferences	-0.033 (0.245)	–
Journals	-0.642*** (0.225)	–
IndAssociations	0.203 (0.237)	–
Number	–	0.033 (0.041)
Log likelihood	22.597	3.857

Probit coefficients are reported in the table with standard errors in parentheses.
*** significant at 0.01-level, ** significant at 0.05-level.
The sample size was reduced from 246 to 224 because of missing information on the number of employees in the firm at the time of receiving the Phase I award.

Table 5 Covariates with the probability of receiving a Phase II award conditioned on being invited to submit a Phase II proposal (n = 154)

Variable	(1)	(2)
lnAward	0.457* (0.249) [0.137]	0.248 (0.225)
lnEmployees	0.084 (0.102)	0.082 (0.099)
FirstAward	− 0.239 (0.250)	− 0.273 ((0.238)
Suppliers	0.852*** (0.348)	–
Customers	0.626** (0.296)	–
Competitors	− 0.213 (0.331)	–
Consultants	− 0.232 (0.263)	–
Universities	0.213 (0.266)	–
PublicInstitutes	− 0.322 (0.355)	–
Conferences	− 0.126 (0.318)	–
Journals	0.172 (0.272)	–
IndAssociations	− 0.300 (0.285)	–
Number	–	0.041 (0.046)
Log likelihood	21.654	5.174

Probit coefficients are reported in the table with standard errors in parentheses. The average marginal effect is also reported for lnAward in brackets.
*** significant at 0.01-level, ** significant at 0.05-level, * significant at 0.10-level.
The sample size was reduced from 168 to 154 because of missing information on the number of employees in the firm at the time of receiving the Phase I award.

5 Summary remarks

The purpose of this paper is to explore the impact that external sources of information have on the effectiveness of R&D in small firms. Firms eligible for SBIR funding are small; the average firm in our sample had 12 employees at the time of the Phase I award. Also, these firms are relatively new to the SBIR program; the Phase I awards studied were the first such award to nearly 40 percent of the firms in our sample. As such, it is not unreasonable to assume that firm managers and the principal investigators in the Phase I research were naïve about the relevance of various external sources of information. And, as this paper shows, having knowledge about external course of information, and using that information, does have an impact on the effectiveness of R&D. The effectiveness of R&D was measured in terms of the probability that a firm that received and completed a Phase I SBIR-funded research project would be invited to submit a proposal for a Phase II award, and given such an invitation, the other metric of the effectiveness of R&D is measured as the probability that a firm will receive a Phase II award. The covariates with these probabilities are different.

No measure of productive capital is correlated with the probability of being invited to submit a Phase II award, although the R&D amount of the Phase I award is positively correlated with the probability of receiving a Phase II award. The firm's endowment of human capital, as measured by the number of employees in the firm when the Phase I award (i.e., technical capital) was made, is not correlated with either measure of the effectiveness of the Phase I R&D award. Additionally, experiential capital is also uncorrelated with the effectiveness use of the Phase I R&D. Finally, information from competitors is an important, in a statistical sense, covariate with the probability of being invited to submit a Phase II proposal, whereas information from suppliers and customers is an important covariate with the probability of receiving a Phase II award.

To the best of our knowledge, this is not only the first empirical study of Phase I SBIR awards, but also it is the first study to address the relationship between external information sources and the effectiveness of SBIR-funded Phase I awards. As such, it is exploratory, and thus any generalizations from our findings should be done with care.Footnote20

From a policy perspective, the NIH SBIR program, or other SBIR programs funded by other agencies, can possibly benefit from our findings to the extent that they provide information to potential applicants and currently funded firms to ensure the SBIR program's public R&D investments are used as effectively as possible. Stated differently, an implication of our findings for the SBIR program, or perhaps for any entrepreneurial-focused program, is that there are benefits in coaching and encouraging small firms to be engaged in a market discovery process.Footnote21

Notes

1. The notion of a systematic relationship between scientific ideas (i.e., knowledge) and inventive or innovative behavior traces at least to Siegel (1962), but small, entrepreneurial firms were not emphasized much less distinguished from large, mature firms.

2. For a comprehensive survey of the literature around scientific discovery more generally, see Schickore (2018).

3. In terms of the rest of this paper, senses might be thought of in terms of scientific discovery, and experiences might be thought of in terms of customer discovery and commercial merit.

4. Audretsch and Link (2019) developed a framework, based on the ideas of Locke and Hume, to conceptualize the relationship between experience, knowledge, and entrepreneurial behavior. See also, Audretsch et al. (2021).

5. See Okasha (2002) and Rosenberg (2008) for modern empiricist views of epistemology. Musgrave (1993, pp. 85–106) discuss and referred to the Lockean-Humean theory of "sense-data" as "idea-ism.".

6. Machlup (1980) also discussed Polanyi's concept of tacit knowledge. Hess and Ostrom (2007, p. 8) have argued, citing Polanyi: "Acquiring and discovering knowledge is both a social process and a deeply personal process" (Polanyi, 1974, original 1958). See also Polanyi (1966) for further discussion of tacit knowledge.

7. The utilization of knowledge varies across individuals who are endowed with varying abilities to utilize resources, be they homogeneous or heterogeneous resources. One might draw a relationship between this Hayekian idea and the later writings of Machlup (1980, p. 182) who stressed that the acquisition of knowledge is related to an individual's differential abilities: "Some alert and quick-minded persons, by keeping their eyes and ears open for new facts and theories, discoveries and opportunities, perceive what normal people of lesser alertness and perceptiveness, would fail to notice. Hence new knowledge is available at little or no cost to those who are on the lookout, full of curiosity, and bright enough not to miss their chances.".

8. These are the same general categories of sources of knowledge that are asked about on the Eurostat 2010 and 2012 Community Innovation Survey.

9. See https://www.sbir.gov/about.

10. See https://www.sbir.gov/about.

11. See, https://seedfund.nsf.gov/fastlane/definitions/. Socially or economically disadvantages individuals are defined to be a "member of any of the following groups: Black Americans, Hispanic Americans, Native Americans, Asian-Pacific Americans, Subcontinent Asian Americans, other groups designated from time to time by the Small Business Administration (SBA) to be socially disadvantaged, and any other individual found to be socially and economically disadvantaged by SBA pursuant to Sect. 8(a) of the Small Business Act, 15 U.S.C.; 637(a).".

12. A descriptive overview of the SBIR program is in Leyden and Link (2015) and Link and Van Hasselt (forthcoming).

13. We chose to study Phase I NIH awards rather than Phase I DOD awards in an effort to avoid survey respondents claiming that requested information was, for national purposes, confidential.

14. See https://www.sbir.gov/sbirsearch/award/all.

15. It is difficult to interpret a 14.3 percent response rate for several reasons. First, there is no comparable information on academic surveys of Phase I SBIR projects. In fact, to the best of our knowledge, there has not been a systematic study of Phase I awards from any agency. Two, the survey was requesting information about research projects conducted as many as 6 years ago. Three, although COVID concerns about when and how individuals were to return from their virtual work locations to their physical work location had diminished by December 2021, the due diligence of PIs to deal with older emails is unknown.

16. The variance inflation factors (VIFs) in the models considered in this paper are all less than 2.0. This suggest that collinearity among the independent variables is minimal.

17. Award is measured in $2018. The 2016 and 2017 award information were inflated using the GDP deflator (2018 = 100).

18. The relevant survey question asked if the Phase I award in question was the first Phase I award that the firm received. Here, that variable is recoded to equal 1 if the Phase I award was not the first the firm had received and 0 otherwise.

19. We also considered that the choice to use particular external sources of information might be related to the firm characteristics in our models. Insufficient observations, and a limited number of independent variables, prohibited us to undertake a series of, say, bivariate Probit models. However, as we noted in footnote 16, collinearity among the independent variables was not an issue.

20. We thank an anonymous reviewer for pointing out that the effectiveness of R&D might also be due to agglomeration issues. Future research into the effectiveness of R&D, be it SBIR-funded R&D or not, should include locational variables in the specification of the empirical models.

21. For example, see the SEED program within NIH: https://seed.nih.gov/.

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