Commercial complexity and entrepreneurial finance

By: Troy J. Scott, John T. Scott, and Albert N. Link

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Abstract:

This paper shows that the probability of small business firms obtaining outside financing to support their research and development projects is greater given more complex commercial opportunities – defined as a greater number of different potential applications for a project's anticipated results – for their innovations. The effects on the probability of outside finance found for other factors are consistent with the earlier findings in the literature about innovative entrepreneurial firms.

Keywords: portfolio analysis | financial capital | entrepreneurship | research and development (R&D) | Small Business Innovation Research (SBIR) program

Article:

I. Introduction

In this paper, we introduce and test a new hypothesis about the financing of entrepreneurs who pursue innovation with research and development (R&D) projects. Our new hypothesis is nowhere to be found in the centuries of scholarly examination of entrepreneurial activity – see Hébert and Link (2009) and Westhead and Wright (2013). Simply stated, our hypothesis is that attracting outside finance will be easier for an entrepreneur with a complex R&D project offering a diversity of avenues for commercializing its findings. Such a project is, to some extent, itself analogous to a diversified portfolio approach to project selection as well as to a diversified portfolio approach to maximizing a project's return.

Financial capitalists and other financial investors seek to minimize investment risk and to maximize return. One approach toward this objective is to invest in a diversified portfolio of projects. A second approach is to invest in a portfolio of projects that have complementary outcomes in a way that not only minimizes risk but also maximizes commercial opportunities. A third approach is to invest in projects with expected outcomes that are applicable to a variety of commercial opportunities; and thus, an individual, entrepreneurial R&D project would be expected to be more attractive to outside investors if its findings are applicable to a variety of differing commercial opportunities.

Related to our stated hypothesis above is the proposition that a signal to investors about the potential for commercial opportunities from an R&D project is perhaps best described by the term *commercial complexity*. We define the commercial complexity of the R&D project as the number of different potential applications for the project's anticipated results, and our unique data set affords us the opportunity to capture empirically that information. So defined, commercial complexity measures the commercial opportunities of an R&D project in a straightforward and objective way.[1]

The outside finance necessary to bring R&D projects to commercial success has often been studied and is at the heart of successful R&D and innovation in the most classic of cases at the origins of the industrial revolution – Boulton's financing of the development of Watt's steam engine as described by Scherer (1984). Despite the long history of study of entrepreneurial finance, this paper contributes a new perspective to the literature about the difficulties faced by entrepreneurs seeking outside private finance and about the importance of such finance for the commercialization of the output of entrepreneurial R&D projects.[2] In Section II, we develop our new hypothesis that outside finance will be more readily obtained for an entrepreneur's R&D project when it exhibits commercial complexity. We use a sample of U.S. Small Business Innovation Research (SBIR) projects to test the hypothesis that entrepreneurial R&D projects with complex commercial opportunities have a higher probability of securing outside finance; Section III describes the sample and variables. Section IV presents the results of our hypothesis tests, and Section V concludes the paper.

II. Complex commercial opportunity and outside finance

Figure 1 illustrates the relation between a project's complexity of commercial opportunity and the set of projects for which the entrepreneur and a potential financier can negotiate an agreement about outside finance for the project. The figure follows from the participation constraints for a deal between the entrepreneur and the outside investor. The underlying model is described as follows:

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[1] We use the word 'complexity' in this paper as it is used in common parlance; in particular note that the idea of complexity in the sense used in this paper is not the 'complexity' in the literature about complexity in science and technology. Thus, in this paper, although we address the interaction of entrepreneurs and their financiers, our use of the term complexity is in its ordinary sense. We do not explicitly address complexity as described by Antonelli (2011, 3):

> Complexity is emerging as a new unifying theory to understand endogenous change and transformation across a variety of disciplines, ranging from mathematics and physics to biology. Complexity thinking is primarily a systemic and dynamic approach according to which the outcome of the behavior of each agent and of the system into which each agent is embedded is intrinsically dynamic and can only be understood as the result of multiple interactions among heterogeneous agents embedded in evolving structures and between the micro and macro levels.

[2] To place the contribution of this paper in the context of one segment of the larger literature, because we study the outside third-party finance for entrepreneurial R&D projects that are subsidized by the U.S. SBIR program and use a sample of those projects studied in earlier papers, we add to the discussions in Scott (2000), Gicheva and Link (2013, 2015), Link, Ruhm, and Siegel (2014), and Scott and Scott (2016).

An entrepreneur must obtain a capital investment in the amount I to go forward with an R&D project. Going forward will also require the entrepreneur to exert effort (or forego other opportunities), which has a cost to the entrepreneur of e. If the R&D project goes forward, a new technology will be successfully developed with probability π. Conditional on the technical success of the R&D project, the expected value of commercial opportunities for that new technology is M. If the R&D is unsuccessful, no new technology is developed and there is no revenue with which to compensate the investor and entrepreneur for their outlays of capital and effort.

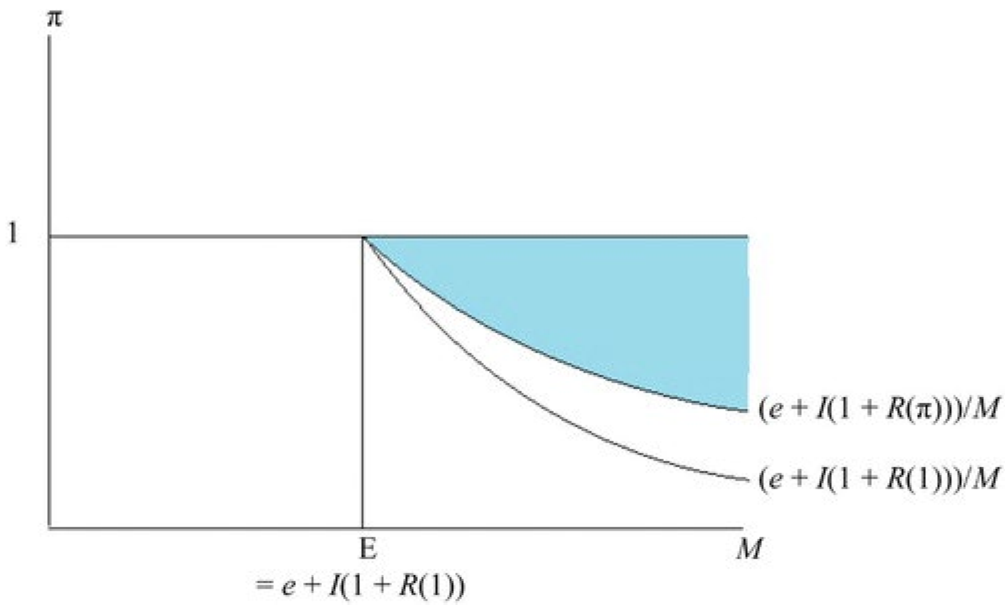

Figure 1. The effect of greater commercial opportunity on the set of projects (described by gross return and its probability) for which outside finance is feasible. Source: adapted from Scott and Scott (2016, Figure 2, 122).

The entrepreneur is privately informed of π. In general, neither the entrepreneur nor the investor is perfectly informed of M. Both entrepreneur and investor may have some independent insight into M, but the best possible assessment of M requires their combined insight: the entrepreneur's into the technical capabilities of the new technology, conditional on its successful development, and the investor's into the commercial applications of such technical capabilities.

We will assume the investor takes an equity stake in the new technology, so that, conditional on technical success of the R&D, the investor receives an expected return of μM and the entrepreneur receives an expected return of $(1-\mu)M$. The investor is willing to invest I as long as the expected return is at least equal to the opportunity cost of capital: $\pi\mu M \geq I(1+R(\pi))$, where $R(\pi)$, with $R'(\pi) < 0$, denotes the risk-adjusted required rate of return. Then, the difficulty of reaching an agreement can be understood as follows:

First, suppose π is known to both parties. Notice that the entrepreneur will want to go forward with the R&D as long as $\pi(1-\mu)M \geq e$, or $\pi M \geq e/(1-\mu)$. The investor is willing as long as $\pi M \geq I(1+R(\pi))/\mu$. Notice that it should be possible to set μ in such a way that the parties' thresholds for M are perfectly aligned, so that as they discuss the technical capabilities of the new technology and its potential commercial applications no situation will ever arise where one party is more eager than the other to convince the other that M is large. We set $e/(1-\mu)$ equal to $I(1+R(\pi))/\mu$ and solve for $\mu(\pi)$:

$$\mu(\pi) = \frac{I(1+R(\pi))}{e + I(1+R(\pi))} \tag{1}$$

The intuitive result is that the respective equity stakes of the two parties should be proportional to their respective opportunity costs. If either party is overcompensated according to this rule, that party will be satisfied to go forward with a lower value for M, and so situations may arise where that party overstates his assessment of either the technical capabilities of the technology (typically the entrepreneur) or the commercial potential of those capabilities (typically the investor) in order to secure an agreement that is to his advantage but not necessarily to his partner's.

Since $R'(\pi) < 0$, the right-hand side of (1) is decreasing with respect to π.[3] The problem caused by π being the private information of the entrepreneur is now plain: the problem of agreeing on an appropriate division of equity is conflated with the problem of agreeing whether to go forward with the project at all. An investor with a lower prior belief about π will be skeptical of the entrepreneur's claims – concerning both π and the technical capabilities of the technology relevant for the assessment of M.

In this paper, we focus on the size of common ground for agreement in the M–π plane, emphasizing that as the actual value of M increases, there is greater likelihood of reaching a mutual understanding of π and M that allows for an agreement over μ to be reached. Specifically, agreement can be reached if both participation constraints can be satisfied simultaneously.

Rearranging the investor's participation constraint to $\mu M/I \geq (1+R(\pi))/\pi$, and rearranging the entrepreneur's participation constraint to $(M-(e/\pi))/I \geq \mu M/I$, a necessary condition for agreement is $(M-(e/\pi))/I \geq (1+R(\pi))/\pi$, which can be rearranged to $\pi \geq [e+I(1+R(\pi))]/M$. The same condition is derived if a debt contract is assumed, which pays the investor a fixed amount conditional on the technical success of the R&D project, suggesting that the essential insight developed here is robust to the form of the agreement.

Recall that we use the term complexity as it is used in common parlance, so herein the term commercial complexity simply refers to greater commercial opportunity as reflected in a larger number of potential commercial applications of the results from the R&D project. By contrast, *technological complexity* increases the difficulty in assessment of π and raises the many problems of information asymmetries between potential investors and the firm, and hence Scott and Scott (2016) focus on the negotiation problem because of those information asymmetries. Commercial complexity, as we have defined it, does not itself create negotiation problems, but instead increases the perceived opportunities for commercializing the results from the R&D project. Thus, for our purposes here where we introduce to the literature the idea of the

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[3] The derivative of $\mu(\pi)$ with respect to π is $eIR'(\pi)$ divided by the squared denominator of (1).

commercial complexity of an R&D project, the key point for our theoretical foundation is that there is common ground for agreement when $\pi \geq [e + I(1 + R(\pi))]/M$. In words, the expected value of the return, πM, must exceed the opportunity costs of both the entrepreneur and the investor for this crucial R&D step. Stated differently, the ratio of those opportunity costs to the expected value of returns, conditional on the technical success of the R&D, must be exceeded by the probability of technical success. In Figure 1, the shaded area in the M–π plane that lies above the curve $[e + I(1 + R(\pi))]/M$ and below the horizontal line for $\pi = 1$ therefore shows the set of points (M,π) for which outside finance is efficient. The theoretical argument underlying our hypothesis (that the commercial complexity – again, given our definition of that complexity – of the R&D project will be associated with a higher probability of obtaining outside finance) is: with a greater number of opportunities for commercial applications from the R&D project's results, M will be larger, and thus the shaded area of efficient agreement will be taller – that is, there will be a wider range of values for π over which Pareto-improving agreements exist. Investors would like to sponsor R&D projects that are more commercially complex, defined as projects having more potential commercial applications, because the commercial opportunities and expected return are greater.

III. The sample and the variables

The sample used in this paper is a sample of R&D projects for small, entrepreneurial, R&D-intensive firms. The R&D projects are all subsidized by the U.S. government; they are SBIR-supported Phase II projects where the R&D is performed after a brief initial look at the potential for the project that was previously subsidized with a Phase I SBIR award.[4]

Our sample of SBIR R&D projects comes from a study (Wessner 2000) conducted by the National Research Council (NRC) of the National Academies. The sample is from the NRC's 1999 evaluation of the SBIR program of the Department of Defense (DoD), and it is the sample used and described in detail in Scott and Scott (2016). That 1999 evaluation included information that made possible the description of the technological complexity of the SBIR Phase II R&D projects and also provided a variable indicating whether the project received outside finance before the beginning of the Phase II project. Those two variables – technological complexity and the presence or not of such *early* outside finance – are needed for our new model of the relationship between commercial complexity and outside finance. The 75 DoD SBIR Phase II projects in the data set for this paper are the DoD SBIR projects that are in the 1999 NRC study *and* that began in 1996 *and* that were continued into the substantial second stage of funding by DoD *and* not dropped by the performing firms and for which all of the variables for our model were available.[5] Because all of our projects received both a Phase I award and a Phase

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[4] All of the R&D projects in our sample received both a Phase I and a Phase II award. Phase I awards support the assessment of an idea's scientific and commercial potential in the context of the funding agency's objectives; the Phase I awards are small and that portion of the project is of short duration, typically six-months. When Phase I succeeds in establishing the feasibility of the idea for the research project, the Phase II awards that follow are focused on the initial steps toward commercialization, and they generally last for two years. Link and Scott (2012a, 19–32) provide a detailed description of the SBIR program and its Phase I and Phase II awards.

[5] The 1999 NRC study, because of its focus on analyzing the DoD's 'Fast Track' program, that encouraged firms to obtain outside finance before the Phase II R&D began, made possible a data set suitable for testing our hypothesis. The Fast Track program was a type of certification program – firms obtaining early outside finance prior to their Phase II award were given priority for receiving the award. To '[c]ertify that the outside funding qualifies as a "Fast

II award, given the variables that we use in our analysis, all of the variables were known at the conclusion of Phase I and before Phase II began. Thus, we study the determinants of whether or not a Phase II project obtained early outside finance, and the determinants are all known at the time that the outside finance was or was not obtained.[6]

The variables that we use for our explanatory variables are chosen for two reasons. First, we want to build on the previous literature (cited in endnote 2) that examines the determinants of outside finance for the entrepreneurial R&D projects of the small firms winning SBIR awards; we have added our new commercial complexity variable to the explanatory variables used and discussed in the previous papers. Second, the explanatory variables chosen are the ones that provide the predetermined characterization of the R&D project as of the end of the Phase I initial, exploratory research and just before the Phase II R&D work begins – in other words, at the time we want to observe whether or not early outside finance is obtained.

For our variable to describe the commercial complexity of the SBIR project, we use responses to the following question that, in the 1999 evaluation, each SBIR award recipient was asked (with affirmative responses coded as 1, and 0 otherwise):

What do you expect to commercialize from your SBIR award? (Select all that apply.)

1) no commercial product, process, or service is planned
2) software
3) intermediate hardware product or component
4) final hardware product
5) process technology

Track investment," and the investor qualifies as an "outside investor," … ' the outside investor had to conform to the DoD guidelines and could 'include such entities as another company, a venture capital firm, an individual "angel" investor, a non-SBIR, non-STTR government program; they do not include the owners of the small business, their family members, and/or affiliates of the small business' (Wessner 2000, 344). The Fast Track program was initiated in October 1995 (Wessner 2000, 22), and the NRC 1999 survey included only firms from the first Fast Track solicitation in the fiscal year for 1996 (Wessner 2000, note 20, p. 22). Thus, all of our sampled R&D projects began in 1996, and then they are observed in the 1999 NRC survey. Although the filtering process results in a data set with only a small number of observations, it is crucial for our hypothesis test that we have R&D projects that all begin at the same time and for which information about early outside finance and about both commercial and technological complexity is available. Just such a data set, albeit with a small number of observations, results from filtering the 1999 NRC DoD SBIR data set. Note that although for these projects that were surveyed in 1999 we know whether or not they had early outside finance, and we know the types of investors that qualified (see just above) as outside investors, we do not have complete information about what the particular type of qualifying outside investment was for each individual project.

[6] A perceptive referee made the interesting and important suggestion that in a more general setting studying the influence of the certification effect of outside investment, it would be interesting first to test the effect of commercial complexity on the probability of receiving outside financing, and then given the outside financing, to ask how that affected the probability of obtaining Phase II financing from the SBIR program or other government funding program. The NRC data set, however, does not have information about firms who applied for Phase II awards and did not receive them. Also, because the DoD Fast Track Program was designed to encourage Phase II applicants, who would be expected to succeed in winning a Phase II grant anyway, to get early outside finance with their reward being priority and a quicker decision about the Phase II award (and with DoD's SBIR program gaining from having more confidence that the award would result in commercialization), the NRC sample is not a good candidate for a study of the impact, on a government agency's funding decision, of certification of a project by outside investors.

6) new or improved service capability

The variable *commercial complexity* is defined as the sum of the five qualitative 0/1 variables that describe the respondent's answers to the question's second, third, fourth, fifth and sixth parts. Respondents that answered affirmatively to the question's first part – and thus had no plans for a commercial product, process, or service, were assigned a value of 0 for *commercial complexity*.[7] Thus, our measure *commercial complexity* ranges from 0 for a project with no planned commercial product, process, or services, through 1 for a SBIR project with single-dimensioned commercial expectations that can be described with a single-dimensioned response about commercial applications, and then upward if multiple commercial applications are expected. In principle, at the maximum, *commercial complexity* could equal 5 for a project for which commercial plans are quite complex and encompass expectations for commercial applications in software, intermediate hardware, final hardware, process technology and service capabilities.

We add the variable *commercial complexity* to the collection of variables used in Scott and Scott (2016) and then ask whether commercial complexity of an R&D project has the positive effect on the probability of obtaining outside finance that we have hypothesized.[8] We now describe the additional variables that we use in our work with the 1999 SBIR data.

The NRC's 1999 data provide information about the SBIR projects that received early outside, third-party funding before their Phase II R&D project began. Such outside finance designated the firm as having 'Fast Track' status in the DoD SBIR program; DoD gave Fast Track firms priority in funding their Phase II R&D. The variable *fast track* equals 1 for projects with Fast Track status and is otherwise equal 0. As shown in Link, Ruhm, and Siegel (2014) and Scott and Scott (2016), outside finance is important for subsequently getting others to assume the various entrepreneurial roles identified by Hébert and Link (2009, 100–101) – not just the financier's role, but the others as well.

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[7] Observe that a possible shortcoming of the 1999 NRC survey instrument is that, because it does not indicate a category for 'other' applications, it is conceivable for a respondent's SBIR project to have a planned commercial application and yet the respondent could not indicate it to be among any of the five categories for which an application could be indicated. There were two such projects (where the question about commercial applications was not completed even though the rest of the survey information was provided) among the 101 in the sample and one among the 76 projects with all of the data needed otherwise for the estimation. Not knowing the appropriate type of commercial application, we drop these two observations and use the remaining 75 projects for our hypothesis test. Another possible shortcoming is that the survey instrument treats each category as independent of another, when it is possible that two categories represent one integrated technology (e.g. software and process technology).

[8] One might a priori be concerned about the effect of including the projects for which 'no commercial product, process, or service is planned'. Projects with no planned commercial applications would not be expected to receive outside financing, while projects with planned potential commercial applications might receive outside financing. That alone might give the result that we hold up as consistent with our commercial complexity hypothesis. Thus, a reader might ask: 'Are observations for which commercial complexity equals zero causing the positive correlation of the presence of outside finance and the measure of commercial complexity?' The answer is no; for our sample, among all of the observations there is only a single observation for which no commercial application was planned. Recall that two of the 101 observations are dropped because of nonresponse. For the 99 remaining observations, only one observation had no commercial plans and hence the measure of commercial complexity equals 0. That one observation is among the 75 observations with all of the variables used in our model, with the measure for commercial complexity having a mean of 1.63, a standard deviation of 0.912, and ranging from 0 to 4.

The variable *technological complexity* is for each entrepreneurial project the number of *broad* technology areas associated with the project. For the 1999 NRC study of the SBIR program, each of the DoD's SBIR projects was associated with up to six technologies by the Small Business Administration. These were chosen from several different technologies within each of seven broad technology areas: computer, information processing and analysis; electronics; materials; mechanical performance of vehicles, weapons and facilities; energy conversion and use; environment and natural resources; and life sciences. As explored by Scott and Scott (2016), the probability of obtaining early outside finance is expected to be less when the R&D project is more *technologically* complex; with more technological complexity, communications costs result in less room for a mutually acceptable bargain between the entrepreneur and the outside investor. With a more technologically complex project, the firm will have a more difficult time explaining the idea to others and securing their investment in the idea.

In addition to the measures of *commercial complexity* and *technological complexity*, the model controls for whether or not the company had previously won a Phase II SBIR award. If there were previous awards, DoD would require more outside support to achieve Fast Track status (Wessner 2000, 344). A lower probability of early outside finance for projects at firms with previous awards is expected, other things being the same, because with the outside investment in the project being larger, the expected rate of return for the outside investor is less.

The estimated model that we use to test the hypothesis about the commercial complexity of the SBIR project also controls for the other variables that have previously been used and discussed in the studies (cited in endnote 2) of the ability of SBIR award winners to obtain outside financing. These variables include whether or not the firm's founders had a business background and whether or not the firm was minority-owned or woman-owned. On one hand, business founders may have human capital that makes their entrepreneurial firms better bets for the outside investors. On the other hand, some outside investors may prefer to provide the business vision themselves. The minority and female ownership variables have been included in earlier studies to address the possibility of discrimination in financial markets.

Apart from the effects associated with the commercial complexity and the technological complexity of the project, with previous Phase II awards, with founders having a business background, and with minority ownership or female ownership of the small business, the model controls for the geographic areas of the entrepreneurial small businesses (because there may be important regional variation in access to outside finance) and also for the primary technology associated with the R&D project to develop the entrepreneur's idea (because the opportunities for commercial potential may vary importantly across technologies).

Table 1 provides definitions for the variables, and Table 2 provides the descriptive statistics for the variables used.[9] Except for the variables measuring commercial complexity and technological complexity, all of the variables are binary (0/1) qualitative variables. The means for those variables, therefore, show the proportion of the sample with a given characteristic.

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[9] To place the present sample in the context of SBIR projects more generally, the descriptive statistics in Table 2 can be compared with those that are provided in Link and Scott (2012a, 2012b) for the samples from the NRC's 2005 evaluation of the SBIR programs of the DoD, the NIH, the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE) and the National Science Foundation (NSF).

Thus, 40.0% of the sample had Fast Track status because significant outside finance was obtained early in the research project; 14.7% of the projects were at minority-owned firms; 28.0% had computers as the primary technology, and so forth. Only one project had materials as its primary technology, and only one had life sciences as its primary technology. Only one project was assigned to the Defense Special Weapons Agency. The commercial complexity variable, described fully above, ranged from 0 to 4. The technological complexity variable, taken to be the number of different *broad* technology areas associated with the project, ranged from 1 to 5; there were up to six different technology areas to which a project could be assigned, and in our sample a given project was assigned to at most 5. The Appendix provides the correlations for the variables.

Table 1. Definition of variables

Variable	**Definition**
Fast track	Binary variable if the project obtained early outside finance
Commercial complexity	Number of commercial applications anticipated for the project
Technological complexity	Number of broad technology areas for the project
Prior Phase II SBIR	Binary variable if the firm had previous Phase II awards
Business founders	Binary variable if the firm had founders with business background
Minority Ownership	Binary variable if the firm is minority-owned
Female Ownership	Binary variable if the firm is woman-owned
Computers	Binary variable if the technology is computers
Electronics	Binary variable if the technology is electronics
Materials	Binary variable if the technology is materials
Mechanical	Binary variable if the technology is mechanical
Energy	Binary variable if the technology is energy
Environment	Binary variable if the technology is environment
Life Sciences	Binary variable if the technology is life sciences
Air Force	Binary variable if the award is from the Air Force
Army	Binary variable if the award is from the Army
BMDO	Binary variable if the award is from BMDO
DARPA	Binary variable if the award is from DARPA
DSWA	Binary variable if the award is from DSWA
Navy	Binary variable if the award is from the Navy
West	Binary variable if the firm is located in the West Census region
Northeast	Binary variable if the firm is located in the Northeast Census region
Midwest	Binary variable if the firm is located in the Midwest Census region
South	Binary variable if the firm is located in the South Census region

Table 2. NRC 1999 data descriptive statistics[a]

Variable	**Mean**	**Standard deviation**
Fast track	0.400	0.493
Commercial complexity	1.63	0.912
Technological complexity	3.53	0.844
Prior Phase II SBIR	0.573	0.498
Business founders	0.480	0.503
Minority ownership[b]	0.147	0.356
Female ownership	0.120	0.327
Primary technology[c]		

Variable	Mean	Standard deviation
Computers	0.280	0.452
Electronics	0.560	0.500
Materials	0.0133	0.115
Mechanical	0.0533	0.226
Energy	0.0800	0.273
Environment	0.0[f]	0.0
Life Sciences	0.0133	0.115
Agency[d]		
Air Force	0.267	0.445
Army	0.213	0.412
BMDO	0.280	0.452
DARPA	0.160	0.369
DSWA	0.0133	0.115
Navy	0.0667	0.251
Geographic area[e]		
West	0.400	0.493
Northeast	0.240	0.430
Midwest	0.0933	0.293
South	0.267	0.445

[a] The number of observations for each variable is 75 rather than 76 as in Scott and Scott (2016) because of the one observation that did not report the information used for our new complexity variable.
[b] Minority status in the data is not broken down among Asian owners, black owners, Hispanic owners, Native American owners, or others. Thus, it measures white and non-white ownership.
[c] Each project's primary technology is used to assign the project to a technology area. The technology areas are computer, information processing and analysis; electronics; materials; mechanical performance of vehicles, weapons and facilities; energy conversion and use; environment and natural resources; and life sciences.
[d] The agencies are the Air Force, Army, Ballistic Missile Defense Office, Defense Advanced Research Project Agency, Defense Special Weapons Agency and the Navy.
[e] The geographic areas are the U.S. Census Bureau Regions for the United States. The NRC data assigned each project to the U.S. state where it was located, and each state has been associated with its geographic region.
[f] No projects had their primary technology in environment and natural resources; however, 14.7% had that technology as one of the technologies associated with their development project.

IV. Evidence

Table 3 shows the results of estimating the probit model of early outside finance; clearly *commercial complexity* has a large positive impact on the probability that a small entrepreneurial firm will obtain early outside finance.

Table 3's estimated coefficients show the marginal effects for each variable on the probit index for the probability of a project having Fast Track status – that is, whether it obtains significant early outside finance. Because the explanatory variables – whether simple dichotomous qualitative variables such as a variable indicating geographic region or our variables measuring commercial and technological complexity – are integer variables, although one can compute the marginal effect of a variable on the probability of outside finance as it changes from one integer level to another while holding all other variables at their means, that would make little sense because none of the variables are ever at their means. Instead, we illustrate the effects of our new variable, *commercial complexity*, for various settings for the variables by computing the probabilities implied by those settings.[10]

Table 3. The probability of outside third-party finance early in the R&D: probit model of *fast track* using NRC 1999 data[a]

Variable	Coefficient (standard error) [*p*-value]	Coefficient (standard error) [*p*-value]
Commercial complexity	0.840 (0.328) [0.010]	0.840 (0.329) [0.011]
Technological complexity	−0.412 (0.261) [0.114]	
(Technological complexity)^2		−0.0677 (0.0406) [0.096]
Prior Phase II SBIR awards	−0.846 (0.476) [0.076]	−0.852 (0.481) [0.076]
Founders with business background	0.947 (0.469) [0.044]	0.901 (0.471) [0.056]
Minority ownership	−1.45 (0.713) [0.042]	−1.50 (0.726) [0.038]
Female ownership	0.0880 (0.696) [0.899]	0.0498 (0.703) [0.944]
Electronics	−0.559 (0.566) [0.323]	−0.594 (0.575) [0.302]
Mechanical	−0.144 (1.93) [0.455]	−1.48 (1.95) [0.447]
Energy	−1.22 (1.10) [0.268]	−1.26 (1.10) [0.251]
Air Force	−2.16 (0.761) [0.005]	−2.18 (0.768) [0.004]
BMDO	−1.69 (0.636) [0.008]	−1.71(0.642) [0.008]
DARPA	−2.33 (0.778) [0.003]	−2.35 (0.784) [0.003]
Navy	−1.96 (1.11) [0.079]	−2.00 (1.11) [0.071]
Northeast	−1.54 (0.653) [0.018]	−1.56 (0.655) [0.017]
Midwest	−0.369 (0.860) [0.668]	−0.332 (0.865) [0.701]
South	−0.401 (0.666) [0.547]	−0.391 (0.675) [0.563]
Constant[b]	2.27 (1.18) [0.054]	1.80 (0.918) [0.051]
Number of observations	75	75
Chi-square (degrees of freedom)	47.0 (16)	47.4 (16)
Probability > chi-square	0.0001	0.0001
Pseudo R^2	0.466	0.469
Log likelihood	−27.0	−26.8

[a]The estimates are for the coefficient of each variable in the probit index for estimating the probability of a project having Fast Track status – that is, whether it obtains significant early outside finance.
[b]Left in the intercept are the geographic region West, the technology Computers, the agency Army, and the primary technology and agency qualitative variables that would predict perfectly because they had only a single observation with the characteristic. The qualitative variable indicating that the project's primary technology is environmental is omitted because none of the projects had the technology as a primary technology. The special-case variables with single observations for the qualitative characteristic are discussed in the text when Table 2 is reviewed.

Using the first specification in Table 3, the probit index for a project in the west and for the Air Force and with primary technology of computers, with no previous Phase II awards, no founders with business backgrounds and with neither minority nor female ownership, and with the greatest amount of technological complexity observed in the sample is: [2.27 − 2.16 + 0.840 (*commercial complexity*) − 0.412(5)]. If *commercial complexity* takes its lowest sample value of zero, then the probit index is –1.95, and the probability of obtaining outside finance is 0.0256. If at the other extreme, *commercial complexity* takes its highest sample value of four, then the probit index is 1.41, and the probability of obtaining outside finance is 0.921.

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[10] The effects of any of the other variables can be illustrated in the same way using the information in Tables 2 and 3.

The impacts of the other control variables are qualitatively the same as found in Scott and Scott (2016). *Technological complexity* of the R&D project makes more difficult agreement between an outside investor and the entrepreneurial firm. The second specification shows that the absolute value of the effect of *technological complexity* increases as that complexity increases. As expected from the discussion in Section III, previous Phase II awards are associated with a lower probability of early outside finance. The ownership variables show that minority ownership also is associated with a lower probability of obtaining such finance.

Although, female ownership is not a significant factor for the DoD SBIR projects in the model of Table 3, Gicheva and Link (2013) show that among the SBIR projects funded by the National Institutes of Health (NIH), whether or not a female owns the firm receiving an SBIR award is an important determinant of whether the firm can obtain outside finance to support the development of their SBIR-funded technology as it becomes an innovation. They find that female-owned firms are less likely to obtain such outside finance, and they explain (Gicheva and Link 2013, 202) why the importance of female-owned firms is more likely to be detected in the NIH sample than in the DoD sample of SBIR projects.

We have identified factors that affect the probability of getting outside finance early in the development of the idea's commercial potential – in particular, at the end of a SBIR project's publicly funded early Phase I trial to examine potential for the idea and before the R&D in Phase II begins. But then, after Phase II has developed the idea to the point where it is ready to become an innovation, some of the small entrepreneurial firms arrange to have other firms play many of the entrepreneurial roles identified by Hébert and Link (2009, 100–101). Link, Ruhm, and Siegel (2014) and Scott and Scott (2016) show that obtaining outside finance increases the probability that small entrepreneurial firms in the SBIR samples will be able to obtain help from other firms with the further development, production, marketing and distribution of their innovations. Combining our results with those observations of previous scholars, we can say that entrepreneurial firms with projects having greater commercial complexity will be more likely to secure outside finance and hence will be more likely to obtain help from other firms for further development, production, marketing and distribution of their innovations.

V. Conclusion

We find that the new concept that we introduce in this paper, namely commercial complexity – the multiplicity of different types of commercial opportunities – is empirically a very important determinant of the probability that an entrepreneur will secure outside finance; greater commercial complexity increases the probability of obtaining outside financial support for the entrepreneurial R&D project. Also, just as in Scott and Scott (2016), there is support for the hypothesis that, other things being the same, an entrepreneur with a more technologically complex idea will have greater difficulty obtaining early outside finance. Thus, the probability of outside finance for an entrepreneurial R&D project is affected by complexity at either end of the innovation pipeline from the initial invention insight (Scott, forthcoming) through the R&D project and ultimately to commercial application in an innovation. Complexity in commercial opportunity increases the probability of outside finance, while technological complexity of the R&D project reduces that probability.

We emphasize that the results are important for understanding where public support for entrepreneurial projects will be especially important because outside finance for those projects has been shown (Link, Ruhm, and Siegel 2014; Scott and Scott 2016) to affect the ability of entrepreneurial firms to obtain commercial agreements with other firms for assistance with further development, production, marketing and distribution; and moreover, outside finance has been shown (Link and Scott 2013) to affect the performance of the resulting innovation in terms of the employment growth that the innovation creates. We have shown that the effects of circumstances making more difficult the securing of outside finance can be offset when an entrepreneurial firm's R&D project has commercially complex results.

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Appendix: Correlations matrix (*n* = 75)

	Fstrk	techcmp	comcmp~y	priorp~i	busfndr	mnrty	woman	comput
Fstrk	1.0000							
techcmp	−0.1299	1.0000						
comcmplxty	0.0961	0.1042	1.0000					
priorphii	−0.2861	0.0987	0.2397	1.0000				
busfndr	0.3051	−0.2612	0.0130	−0.0885	1.0000			
mnrty	−0.1846	−0.0390	−0.1204	0.0528	−0.0211	1.0000		
woman	0.0335	−0.0392	0.1069	0.0697	0.1380	0.1948	1.0000	
comput	0.0364	0.1701	−0.2347	−0.0024	−0.1831	−0.0067	0.1352	1.0000
elect	0.0658	−0.1090	0.0202	−0.0587	0.1527	0.0638	−0.0033	−0.7035
mater	−0.0949	−0.0740	0.0479	0.1003	0.1210	−0.0482	−0.0429	−0.0725
mechan	−0.0727	−0.0094	0.2943	0.0848	0.0095	−0.0984	−0.0876	−0.1480
energy	−0.1405	−0.0117	0.1215	0.0556	−0.0866	0.0167	−0.1089	−0.1839
life	0.1424	−0.0740	−0.0804	−0.1348	0.1210	−0.0482	−0.0429	−0.0725
ARMY	0.5049	0.1346	−0.1087	−0.1430	0.0860	−0.0319	0.0080	0.2552
BMDO	−0.0849	−0.1134	−0.0380	−0.0624	0.0547	0.0772	−0.2303	−0.2566
AF	−0.2462	0.0480	0.2818	0.3373	−0.0966	0.0057	0.3340	0.0269
NAVY	0.0000	−0.1063	0.1101	0.1225	0.0642	0.0403	−0.0987	−0.0476
DARPA	−0.1336	−0.0608	−0.2216	−0.2118	−0.0553	−0.0781	−0.0492	0.0518
DSWA	−0.0949	0.2035	−0.0804	−0.1348	−0.1117	−0.0482	−0.0429	−0.0725
West	0.2222	−0.2273	−0.3245	−0.2861	0.1416	0.0462	−0.2178	0.0364
NE	−0.2039	0.0894	0.1282	0.1060	−0.1025	−0.2330	−0.1114	0.0668
MW	0.0187	0.1787	0.1828	0.1841	0.0587	−0.0035	0.1636	0.0041

	Fstrk	techcmp	comcmp~y	priorp~i	busfndr	mnrty	woman	comput
South	−0.0615	0.0480	0.1154	0.0935	−0.0966	0.1761	0.2412	−0.1074
	elect	**mater**	**mechan**	**energy**	**life**	**ARMY**	**BMDO**	**AF**
elect	1.0000							
mater	−0.1311	1.0000						
mechan	−0.2678	−0.0276	1.0000					
energy	−0.3327	−0.0343	−0.0700	1.0000				
life	−0.1311	−0.0135	−0.0276	−0.0343	1.0000			
ARMY	−0.1285	−0.0605	−0.1236	−0.1536	0.2232	1.0000		
BMDO	0.1938	−0.0725	−0.1480	0.2539	−0.0725	−0.3247	1.0000	
AF	−0.1944	0.1928	0.3936	−0.0667	−0.0701	−0.3140	−0.3761	1.0000
NAVY	0.0215	−0.0311	−0.0634	0.1182	−0.0311	−0.1392	−0.1667	−0.1612
DARPA	0.0938	−0.0507	−0.1036	−0.1287	−0.0507	−0.2273	−0.2722	−0.2632
DSWA	0.1030	−0.0135	−0.0276	−0.0343	−0.0135	−0.0605	−0.0725	−0.0701
West	0.0110	−0.0949	0.0485	−0.0401	−0.0949	0.0399	0.2182	−0.2462
NE	−0.3195	0.2069	0.1445	0.1795	0.2069	0.0122	−0.0723	0.1553
MW	0.0997	−0.0373	−0.0762	−0.0946	−0.0373	0.0567	−0.0980	0.1175
South	0.2308	−0.0701	−0.1431	−0.0667	−0.0701	−0.0932	−0.1074	0.0455
	NAVY	**DARPA**	**DSWA**	**West**	**NE**	**MW**	**South**	
NAVY	1.0000							
DARPA	−0.1166	1.0000						
DSWA	−0.0311	−0.0507	1.0000					
West	−0.0000	0.0148	−0.0949	1.0000				
NE	−0.0250	−0.0749	−0.0653	−0.4588	1.0000			
MW	−0.0857	−0.0150	−0.0373	−0.2620	−0.1803	1.0000		
South	0.0806	0.0658	0.1928	−0.4924	−0.3389	−0.1935	1.0000	