Innovation capital

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Abstract:

In this paper we compare the relationship between a firm's innovation capital and the likelihood that a firm will commercialize an invention. Our index of innovation capital is the product of the firm's human capital, social capital, and reputational capital. We find from our empirical experiment, which uses Small Business Innovation Research data, that innovation capital is a statistically more important entrepreneurial input to the innovation output of commercialization than any of its components.

Keywords: innovation capital | human capital | social capital | reputational capital | entrepreneurship | commercialization

Article:

Introduction

Much of the relevant literature related to entrepreneurial behavior is based on a relationship between entrepreneurial inputs and innovative outputs. As shown in Table 1, contributions to this literature have generally focused on a primary input that is hypothesized to be related to a dimension of innovative output. In this paper we depart from this traditional approach. We examine the strength of a constructed index of innovation capital, and we compare it to the strength of three separate measures of capital that have been shown to correlate with innovative output.

Table 1. Selected literature related to entrepreneurial inputs and innovative output

References	Entrepreneurial inputs	Innovative output
Audretsch and Link (2019)	Knowledge capital	Sales growth
Audretsch and Stephan (1996)	Scientist's knowledge	Initial public offerings
Lazear (2005)	Human capital	Business startup
Leyden and Link (2015)	Social capital	A theoretical innovation
McKelvie et al. (2018)	Growth orientation	Product innovation
Werner et al. (2018)	Family relationships	Product and process innovation
Yang et al. (2018)	Search and execution effort	Profits

This paper builds on the seminal insight of Dyer and Furr (2018). In their *Forbes* article "Innovation Capital: The Secret Ingredient Behind the World's Most Innovative Leaders," they hypothesize that innovation capital—intangible capital that helps one win resources to commercialize novel ideas—is a critical driver of commercial success. Innovation capital is, within their framework, the amalgam of human capital, social capital, and reputational capital.[1]

In Sect. 2 of this paper, we discuss the data that we use to measure both entrepreneurial inputs and innovative output. In Sect. 3, we hypothesize empirical models that will allow us to compare the independent correlative power of human capital, social capital, and reputational capital with respect to innovative output to the correlative power of innovation capital with respect to innovative output. In Sect. 4, we discuss our findings and offer concluding remarks.

Data used to construct entrepreneurial inputs and innovative output

The data that we use in this paper to construct measures of human capital, social capital, reputational capital, and an index of innovation capital come from the National Research Council's (NRC's) database on Small Business Innovation Research (SBIR) Phase II projects.[2]

The SBIR program is a set aside program created through the Small Business Innovation Development Act of 1982 (Public Law 97-291). The creation of this program by Congress signaled out small firms as vehicles for innovation and economic growth. The Act of 1982 states that:

> [W]hile small business is the principal source of significant innovation in the Nation, the clear majority of federally funded research and development is conducted by large businesses, universities, and Government laboratories; and 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.

And, the legislated purposes of the 1982 Act are:

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.

Purpose (4) is important for this paper because, as discussed below, our measure of innovative output for a firm is measured in terms of whether or not the SBIR-funded project's technology was commercialized.

Government agencies are required to set aside a portion of their extramural funding for small firms (less than 500 employees). The current set aside rate is 3.2% of an agency's extramural

[1] Kijek (2012) provides an excellent literature review of the topic innovation capital.
[2] See, http://www.nasonline.org/about-nas/history/archives/milestones-in-NAS-history/organization-of-the-nrc.html.

research budget. SBIR research awards fall within two categories. Phase I awards generally last for 6 months and are currently funded at not more than $150,000. The purpose of Phase I research is to establish the technical merits of a project as well as its commercial potential of any expected technology. Phase II awards generally last for 2 years and are currently funded at not more than $1,000,000. The purpose of Phase II research is to continue the research from Phase I with the commercialization of a technology being a primary objective.[3]

The SBIR program has been reauthorized by Congress a number of times over the ensuing years. After the SBIR program was reauthorized in 2000, Congress instructed the NRC to conduct a survey of SBIR-funded Phase II projects and to undertake interview-based case studies from which recommendations could be made to Congress on how to improve the SBIR program.[4] The NRC surveyed a random and representative sample of Phase II projects that were funded by the five largest agency SBIR programs: Department of Defense (DOD), the National Institutes of Health (NIH), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the National Science Foundation (NSF).[5]

There is information in the 2005 NRC database on 1878 Phase II projects funded by the above five agencies over the years 1992 through 2001.[6] See Table 2. This database is arguably the most detailed source of U.S. information on publicly supported research activity in small firms.

Table 2. Random sample of SBIR-funded Phase II projects, 1992–2001

Agency	Projects
DOD	891
NIH	495
NASA	177
DOE	154
NSF	161
All agencies (total)	1878

Empirical models of innovative output

With reference to purpose (4) of the 1982 Act, discussed above, we consider two models of innovative output. In each model, innovative output from an SBIR-funded project is measured in terms of whether the funded-firm commercialized a technology that it researched as part of its Phase II award.

$$Commercialization = \mathrm{f}(HumanCapital, SocialCapital, ReputationalCapital, \mathbf{X} \qquad (1)$$

[3] Current funding guidelines allow, under certain conditions, an agency to increase Phase I and Phase II awards by up to 50%.

[4] After the SBIR program was reauthorized in 2008, Congress again asked for a survey and a series of case studies. This second wave of SBIR data was collected in 2011 and 2014. While some data from the second data collection effort was available to us, to maintain confidentiality of the awarded firm the dollar amount of the Phase II award was not available. As discussed below, the amount of that award is conceptually an important regressor in our models; thus, the data used herein are from the 2005 NRC survey.

[5] About 50% of all SBIR Phase II awards are funded by DOD. Additional institutional information on the SBIR program and on the 2005 survey are in Leyden and Link (2015a) and Link and Scott (2010, 2012).

[6] The U.S. SBIR program has been emulated in many countries including Sweden, Russia, the United Kingdom, Japan, Korea, and Taiwan. See Hayter et al. (2018).

and

$$Commercialization = \text{f}(InnovationCapital, \mathbf{X} \quad (2)$$

where the variables in Eqs. (1) and (2) are defined in Table 3 and where **X** is a vector of firm-specific controls.

Table 3. Definition of variables used to estimate the probability of commercialization from Eqs. (1) and (2) (standard errors in parentheses)

Variable	Definition
Commercialization	= 1 if the Phase II project was commercialized, and 0 otherwise The survey question is: "Did a commercial product result from this Phase II project?"
HumanCapital	= 1 if the firm attributed a portion of its growth to the SBR program, and 0 otherwise The survey question is: What percentage of your company's growth would you attribute to the SBIR program after receiving its first SBIR award?
SocialCapital	= 1 if the firm received additional developmental funding from private investments to support its research on its Phase II project, and 0 otherwise The survey questions are: Have you received or invested any additional developmental funding in this project? If YES, did any portion of that additional development funding come from private investments (e.g., venture capital)?
ReputationalCapital	= 1 if the firm had previously received any Phase II SBIR awards related to the project/technology supported by the current Phase II award, and 0 otherwise The survey question is: How many previous Phase II SBIR awards has your company received that are related to the project/technology supported by this Phase II award?
InnovationCapital	= *HumanCapital* × *SocialCapital* × *ReputationalCapital*
Award	The amount of the Phase II award (millions, $2005)
DOD	= 1 if the Phase II project was funded by the DOD, and 0 otherwise
NIH	= 1 if the Phase II project was funded by the NIH, and 0 otherwise
NASA	= 1 if the Phase II project was funded by the NASA, and 0 otherwise
DOE	= 1 if the Phase II project was funded by the DOE, and 0 otherwise
NSF	= 1 if the Phase II project was funded by the NSF, and 0 otherwise

Of course, our empirical measures of human capital, social capital, reputational capital, and innovation capital are constrained by the availability of relevant data in the 2005 NRC database. Thus, our measures have an element of subjectivity. The logic behind our measures, given the data constraint, is as follows.

Regarding human capital, our assumption is that the sales growth of small entrepreneurial firms is a function of the firm's human capital and its technical capital. Because we are holding constant in our models in Eqs. (1) and (2) through vector **X** the amount of the Phase II award (i.e., the R&D resources available for the Phase II project, or a proxy of the firm's technical capital), the driver of sales growth will be the firm's human capital.

Social capital, following Leyden and Link (2015b) is created through personal networks. Our assumption is that the larger the network—the private-sector network—the greater is the likelihood that the firm will raise additional developmental funding to support its current Phase II research.

Regarding reputational capital, our focus is on the firm's research and technology development reputation. Thus, our assumption is that the firm's relevant research and technology development

reputation is mirrored through it having received previous Phase II SBIR awards that are related to the project/technology supported by the current Phase II project.[7] As Audretsch and Stephan (1996) show, signals reflecting the knowledge capabilities of the firm play a particularly important role for entrepreneurial firms where the market context is characterized by a high degree of uncertainty and knowledge asymmetries.

Lastly, we have designed our empirical experiment to be one that compares the relationship between a firm's innovation capital and its commercialization activity to the relationship among its human capital, social capital, and reputational capital and its commercialization activity. In other words, were are testing if the correlative power of innovation capital, measured as the product of its parts, is greater or lesser than the independent correlative power of either human capital, social capital, or reputational capital.

Descriptive statistics on all of the variables are presented in Table 4. Note that the number of projects for which information on each variable is available from the 2005 NRC survey has reduced to 1837.

Table 4. Descriptive statistics on the variables (n = 1837)

Variable	Mean	Standard deviation	Range
Commercialization	0.3195	0.4664	0/1
HumanCapital	0.9439	0.2301	0/1
SocialCapital	0.1949	0.3962	0/1
ReputationalCapital	0.3566	0.4791	0/1
InnovationCapital	0.0871	0.2821	0/1
Award	0.7573	0.2965	0.0193–5.1536

The entrepreneurial inputs (i.e., the capital measures) are all dichotomous as is the measure of innovative output (i.e., the commercialization measure). Thus, Eqs. (1) and (2) are estimated as Probit models. We expect that each of the capital measures will be positively related to commercialization. Also held constant in both models is the amount of the Phase II award and funding agency controls. We expect that the amount of the award to also be positively related to commercialization because it measures the scale and scope of the Phase II research. The greater the scale and scope of a research project, the greater the likelihood that at least a portion of the research output will result in a commercializable technology. The Probit regression results are presented in Table 5.

The Probit regression results in column (1) of Table 5 correspond to Eq. (1) and those results in column (2) correspond to Eq. (2). Focusing first on the results in column (1), each of the coefficients and each of the calculated marginal effects on the capital variables is positive and significant. Among the three capital measures, it is social capital that has the greatest correlation with commercialization. In column (2), our calculated measure of innovation capital is also positive and significant. From Table 4, less than 9% of the Phase II award recipient firms possess innovation capital. Our view of what is important in Table 5 is that the Probit coefficient

[7] While we do not have information on the reasons that a particular firm would receive previous and related Phase II awards, the finds that we present below might be interpreted as suggestive evidence of what Antonelli and Crespi (2013) have called a virtuous Matthew effect.

on *InnovationCapital*, and the calculated marginal effect, are greater in value than any one of the capital variables in the model underlying the results in column (1).

Table 5. Probit regression results of the probability of commercialization from Eqs. (1) and (2) (standard errors in parentheses, calculated marginal effects in brackets) (n = 1837)

Variable	(1) Equation (1)	(2) Equation (2)
HumanCapital	0.3039** (0.1463) [0.1002]	–
SocialCapital	0.5850*** (0.0769) [0.1928]	–
ReputationalCapital	0.4468*** (0.0650) [0.1472]	–
InnovationCapital	–	0.7185*** (0.1060) [0.2460]
Award	0.2681** (0.1124) [0.0884]	0.3232*** (0.1111) [0.0884]
Intercept	− 1.2303*** (0.1823)	− 0.6937*** (0.1155)
Agency controls	Yes	Yes
Log likelihood	− 1068	− 1106
Pseudo R^2	0.0722	0.0391

Agency controls include binary variables for the funding agencies of DOD, NIH, NASA, and DOE. NSF controls are subsumed in the intercept term

***Significant at 0.01-level; **significant at 0.05-level; *significant at 0.10-level

Our interpretation of these results is that innovation capital is more important entrepreneurial input to the innovative output of commercialization than any of the other capital measures. And, our results are supportive of the conceptual importance of the Dyer and Furr (2018) innovation capital framework.

Discussion

It took just one word for Marx (1867) to clarify what matters for economic performance: *Kaptial*, or capital. A century later, Mansfield (1965) provided compelling econometric evidence specifying what exactly constitutes that capital—factories, tools and machines, or what is often characterized as physical capital.

More recently, Schultz (1960, 1961) and Becker (1993) refocused the analysis away from physical capital to human capital, suggesting that individuals can invest in skills, knowledge and capabilities that enhances their underlying economic value (Paldam, 2000). Coleman (1988) and Putnam (2000) subsequently extended the concept to social capital, the form of capital that has the greatest individual impact on the likelihood of commercialization in Table 5 (column (1)). According to Putnam (2000, p. 19):

> Whereas physical capital refers to physical objects and human capital refers to the properties of individuals, social capital refers to connections among individuals – social networks and the norms of reciprocity and trustworthiness that arise from them. In that sense social capital is closely related to what some have called 'civic virtue.'

This paper has operationalized a new empirical concept with a particular focus on the knowledge-driven entrepreneurial economy—innovation capital. Innovation capital, most recently attributable to Dyer and Furr (2018), characterizes the capacity to innovate.[8] Our constructed measure of innovation capital is found to be positively related to the likelihood of an entrepreneurial firm actually engaging in the commercialization of knowledge. While all of the firms analyzed clearly have generated knowledge, it is to the greater extent innovation capital that separates the doers from the (solely) thinkers. As Johan Wolfgang von Goethe observed nearly two centuries ago[9]:

> Knowledge alone does not suffice, it must also be applied. Wanting is not enough, one has to actually do it.

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[8] See Kijek (2012).
[9] Cited from Audretsch and Lehmann (2016).

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