From discovery to commercialization: accretive intellectual property strategies among small, knowledge-based firms

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Abstract:

This paper explores the use of publications and patents and their covariates among small, knowledge-based firms pursuing technology commercialization. It does so through an empirical examination of 1180 small firms' R&D projects, all of which were funded through Phase II U.S. Small Business Innovation Research (SBIR) awards. As such, the paper responds to recent calls to investigate not only how small, knowledge-based firms utilize specific IP strategies but also how accretive logic specifically differs from competitive publishing and patenting logic.

Keywords: patents | publications | intellectual property | R&D | strategy

Article:

Introduction

New knowledge provides the seeds for economic growth and prosperity, and scholars have recently shown that small firms publish and patent to disclose and appropriate, respectively, the returns to their investments in research and development (R&D) (Hayter and Link 2018). These findings seemingly contradict three decades of theoretical scholarship framing publishing and patenting as independent and opposing firm-level strategies.

Traditional scholarship posits that large firms favor patent-based strategies that take advantage of a temporary monopoly, so-granted by national patent regimes, to exclude competitors (Amoroso and Link 2019). Smaller firms with fewer resources may respond through informal strategies such as defensive publications as a more cost-effective intellectual property (IP) protection strategy to preempt or invalidate would be patents from larger, better-resourced competitors (Anton and Yao 2003; Chen and MacMillan 1992). According to some scholars, competitive logic has even motivated the rapid growth of defensive publishing among large firms (Baker and Mezzetti 2005; Hicks 1995), but, as related to this paper, it has also motivated an increase in defensing publishing among small firms (Johnson 2014).

Hayter and Link (2018), in contrast, introduced to this literature accretive logic, which views publishing and patenting as complementary IP strategies used by small, knowledge-based firms to obtain financial resources, to bolster their scientific reputation, to attract new technologies, and to enhance their development. Accretive logic views new knowledge as cumulative (Scotchmer 1991; Gallini and Scotchmer 2002) and critical to firms' success in rapidly growing knowledge-based industries such as biotechnology, computers, software, and semiconductors. In these industries, entrepreneurial firms, in particular, depend on and are adept at utilizing new knowledge created by research universities and incumbent firms (Audretsch et al. 2015; Gill 2008; Hopenhayn et al. 2006).

Though studies acknowledge the signaling value of patents, especially related to attracting early-stage capital, most scholars have nonetheless remained silent on the role of publishing (Barney 1991; Harhoff 2009; Hottenrott et al. 2015). Further, in her review of the empirical patenting literature, Hall (2019) questions, rhetorically, the per se value of patents noting that some firms seemed to perform well with only patent applications (including unsuccessful applications) or even without applications to provide patent protection. In sum, scholars continue to raise the possibility that the value of publishing and patenting may not stem from their guarantee IP rights, but instead from a gain in importance as proxies for the underlying quality of the firm and its developed technology.

This paper contributes to the strategic entrepreneurship literature by exploring the utilization of publications and patents and their covariates among small, knowledge-based firms pursuing technology commercialization. It does so through an empirical examination of 1180 small, knowledge-based firms' R&D project, all of which were funded through Phase II U.S. Small Business Innovation Research (SBIR) awards. As such, the paper responds to recent calls to investigate not only how small, knowledge-based firms utilize specific IP strategies (Link and van Hasselt 2020) but also how accretive logic specifically differs from competitive publishing and patenting logic.

This paper finds, using descriptive analyses, that patenting and publishing are not only employed as separate approaches among firms that commercialize their technology, but also they are, in contrast to their conceptualization in the IP literature, complementary accretive strategies. We also find evidence of firms that similarly commercialize their technology but neither publish nor patent. Hypothesized rationales are offered based on further descriptive and economic analyses, while implications for research are also discussed.

The remainder of the paper is organized as follows. In Section II, we discuss in greater detail competing logics associated with publishing and patenting as well as knowledge spillover-based views of entrepreneurship (Audretsch 1995; Audretsch and Lehmann 2005). In Section III, we describe our research approach and relevant variables of interest followed by a summary of our empirical findings in Section IV. In Section V, we compare our findings to existing conceptualizations of entrepreneurial IP strategies, and we offer IP-related propositions based on our findings that might influence future studies of IP protection strategies especially among small, knowledge-based firms. Section VI concludes this chapter with summary remarks.

Competing logics

Competitive logic

Scholars have traditionally assumed that firms utilize publications and patents to achieve advantages over market competitors. These views are based on nuances within the U.S. patenting system, an infrastructure through which individuals obtain a temporary monopoly to new inventions and technologies in exchange for public disclosure of the details of their inventions and technologies (Teece 2000). Patents are thus considered the strongest form of IP protection and therefore a tool to enhance firm-level strategies (Hall et al. 2014; Link and van Hasselt 2020).

Studies show that while patents are relatively less effective for appropriating R&D investments in high-technology industries (Cohen et al. 2000), small, knowledge-based firms nonetheless utilize patents strategically for invalidation and preemption purposes (Hall and Ziedonis 2001; Lichtman et al. 2000). Given that patents are awarded based on novelty and nonobviousness, invalidation occurs if an invention is "known or used by others ... or patented or described in a printed publication ... before the invention thereof by the applicant" (35 U.S.C. § 102(a)). Firms similarly use patents to signal dominant market strength and technical capability thus preempting inventive activity and segmenting entry among competitors (Anton and Yao 2003; Gill 2008; Lichtman et al. 2000).

Firms also employ so-called defensive publishing as a cost-effective strategy to invalidate would be patents among competitors, preserve their technological field of use, and provide competitive parity if they lag behind technologically (Anton and Yao 2003; Gill 2008; Graham and Sichelman 2008; Henkel and Pangerl 2008; Parchomovsky 2000).[1] Defensive publishing is especially appealing to small firms given that they rarely have the resources to develop and sustain large patent portfolios (Johnson 2014).

Accretive logic

Knowledge spillover entrepreneurship perspectives presume that new knowledge is a critical source of innovation, economic dynamism, and growth (Ács and Audretsch 2009; Romer 1990). Decades of research show that new knowledge is created by research universities and incumbent firms, yet it often remains unexploited (Audretsch et al. 2015; Cunningham and Link 2021). In other words, in contrast to traditional economics theorizations, not all knowledge is economically useful, nor does all knowledge spill over effortlessly among firms and institutions. New knowledge is instead subject to technological uncertainties and information asymmetries, as well as institutional and firm-level barriers (Ács et al. 2009; Braunerhjelm et al. 2010).

Research shows that entrepreneurship is an effective vehicle to mobilize new knowledge, overcome asymmetries and institutional barriers, and commercialize derivative technologies

[1] Field of use is defined as the right for a firm to utilize a specific technology that would otherwise require licensing from competitors or nonpracticing entities. Nonpracticing entities (otherwise known as "patent trolls") generally have no in-house technical capability but patent or obtain exclusive licenses from an inventor in order to profit from patent prosecutions. See Cohen et al. (2019) for a more in-depth discussion.

(Audretsch et al. 2015; Hayter 2016). While entrepreneurial firms can utilize patents to appropriate R&D investments, greater relative value may be obtained as a signal to obtain early-stage capital (Audretsch et al. 2012; Hottenrott et al. 2017). In her review of the empirical patenting literature, Hall (2019, p. 15) similarly finds that studies show patents serve as "…[a] proxy for the quality of the underlying firm and its technology" as compared to value arising from specific IP rights.

Other studies show that patents are a relatively ineffective signal to obtain finances for nascent firms unless they are accompanied by prototypes (Audretsch et al. 2012) or research alliances as well as an experienced team (Hoenig and Henkel 2015). Further, nascent firms with patent applications, enjoy similar levels of survival and growth as patenting firms, just as several studies show that firms often survive without any patent applications (Hall 2019).

Hayter and Link (2018) extended accretive logic to publications, positing that firm publishing, long viewed as a strategy for IP invalidation and preemption, can also have signaling value based on the extent to which firms—especially small firms—accrete new knowledge. Accretive logic also aligns conceptually with the development of entrepreneurial competencies, which enable knowledge-based firms to achieve credibility and commercialization success (Rasmussen et al. 2011; Rasmussen and Wright 2015). Accretive logic thus opens the possibility that publications and patents are complementary strategies to enhance the success of knowledge-based entrepreneurial firms.

However, left unanswered is an understanding of the extent of the relationship between the two logics, and under what circumstances does that relationship exist. Initial answers are the intent of this exploratory paper.

Research approach

This paper explores the utilization of publications and patents as well as their covariates among small, knowledge-based firms pursuing technology commercialization. Data analyzed for this study are drawn from a 2005 National Research Council (NRC) survey of 1180 small firms that had received between 1992 and 2001 a Phase II SBIR award.[2,3] Established by the Small Business Innovation Development Act of 1982 (Public Law 97–219), the mission of the SBIR program is to (1) stimulate technological innovation, (2) meet Federal research and development needs, (3) foster and encourage participation in innovation and entrepreneurship by women and

[2] As part of the SBIR program's reauthorization in 2000, the U.S. Congress commissioned the National Research Council (NRC) of the U.S. National Academies to conduct a survey of a representative sample of Phase II projects as a study to inform Congress prior to the scheduled 2008 reauthorization of the program. Congress authorized the NRC to conduct follow-up surveys in 2011 and in 2014, but not all of the relevant data from those surveys are available for this study.

[3] The population of phase II projects is 1878; however, a number of phase II projects were deleted from the study. Those deleted were project that failed, that is were terminated for technical or other reasons prior to completion; projects that had not yet been completed at the time of the 2005 survey, and projects for which some of the relevant variable information was missing.

socially or economically disadvantaged persons, and (4) increase private-sector commercialization of innovations derived from Federal research and development funding.[4]

The program's awards are divided into phase I and phase II awards. A phase I project is a proof-of-concept project to document the technical merit and commercial potential of the proposed R&D effort. Phase I projects generally have a 6-month duration and are currently limited legislatively to no more than $150,000. Firms with successful phase I projects are invited to apply for a competitive phase II award during which awardees are expected to develop and commercialize their technology. Phase II projects generally have a duration of up to 2 years, and they are generally not funded at not more than $1 million.[5]

Table 1. Definition of variables

Variable	Definition
Publishing	= 1 if the firm published from its phase II project; 0 otherwise
Patenting	= 1 if the firm patented (a patent application or a patent award) from its phase II project; 0 otherwise
PublishOnly	= 1 if the firm published from its phase II project but did not patent from its phase II project; 0 otherwise (phase II project that did both or neither are deleted from the sample)
PatentOnly	= 1 if the firm patents from its phase II project but did not publish from its phase II project; 0 otherwise (phase II projects that did both or neither are deleted from the sample)
PublishPatent	= 1 if the firm both published from its phase II project and also patented from its phase II project; 0 otherwise
NeitherPublishPatent	= 1 if the firm neither published from its phase II project nor patented from its phase II project; 0 otherwise
Commercialization	= 1 if the firm commercialized the technology from its phase II project; 0 otherwise
Projectyears	= Year 2005 minus the year of the phase II award
Awardintensity	= The phase II award amount ($2005) divided by the number of employees in the firm at the time the phase II proposal was submitted to the funding agency. This variable enters the regression model as a natural logarithm.
University	= 1 if a university was involved in the phase II project; 0 otherwise
Businessfounders	= 1 if one of the firm's founders had a business background; 0 otherwise
Academicfounders	= 1 if one of the firm's founders had an academic background; 0 otherwise
PreviousPhI	=1 if the firm had received at least 1 previous phase I award related to the technology of the phase II project; 0 otherwise
Womanowner	= 1 if the firm is owned by a woman; 0 otherwise
DOD	= 1 if the phase II project was awarded by the Department of Defense; 0 otherwise
DOE	= 1 if the phase II project was awarded by the Department of Energy; 0 otherwise
NASA	= 1 if the phase II project was awarded by the National Aeronautics and Space Administration; 0 otherwise
NIH	= 1 if the phase II project was awarded by the National Institutes of Health; 0 otherwise
NSF	= 1 if the phase II project was awarded by the National Science Foundation; 0 otherwise

To understand better how small, knowledge-based firms utilize publications and patents, as well as to identify important covariates, we employ an exploratory empirical strategy. We first

[4] More detailed discussions of the history of the SBIR program and of the 2005 NRC survey and its related phase II data are in, for example, Link and Scott (2012), Link (2013), and Leyden and Link (2015).

[5] There are exceptions to the upper limit on both phase I and phase II awards. Often the funding agency can broaden the scope of the initially funded phase II project, thus increasing the total budget above $1 million. It is not uncommon for this to happen among selected phase II projects funded by the Department of Defense.

examine the descriptive relationship between firm-level commercialization and publishing and patenting strategies. We then examine correlational relationships among covariates in an effort to explicate the role of publishing and patenting among firms seeking to commercialize their technology. Then, we consider a limited descriptive analysis of the likelihood of commercialization among phase II projects with and without patents and the likelihood of commercialization among phase II projects with and without publications. Finally, we consider a binary Probit model, holding constant phase II project characteristics as well as firm characteristics, to estimate across-phase II project differences in the likelihood of patenting or publishing conditional on commercializing from the phase II project. Table 1 defines these variables, with descriptive statistics presented in Table 2.

Table 2. Descriptive statistics on all of the variables ($n = 1180$)

Variable	Mean	Standard deviation	Range
Patenting	0.422	0.494	0/1
Publishing	0.518	0.499	0/1
Commercialization	0.825	0.380	0/1
Projectyears	7.144	2.652	4–13
Awardintensity	139,875	278,159	1377–8,039,641
University	0.376	0.485	0/1
Businessfounders	0.446	0.497	0/1
Academicfounders	0.664	0.472	0/1
PreviousPhI	0.589	0.492	0/1
Womanowner	0.100	0.300	0/1
DOD	0.468	0.499	0/1
DOE	0.089	0.285	0/1
NASA	0.091	0.287	0/1
NIH	0.262	0.439	0/1
NSF	0.091	0.287	0/1

Empirical findings

Among the 1180 firms in the present sample, 973 (82.5% of the total) phase II project firms commercialized their technology, keeping in mind that commercialization is an explicit descriptor in the SBIR program's mission albeit only one metric of performance.
Table 3 illustrates that among firms that commercialized their technology, 244 projects only published (25.1%) and 173 projects only patented (17.8%), with 253 projects (26.0%) both publishing and patenting. Interestingly, 303 firms (31.1%) that commercialized from their phase II projects neither published nor patented.

Table 3. Patenting and publishing among firms that commercialized from phase ii projects ($n = 973$)

	Did not patent	Patent
Did not publish	303	173
Publish	244	253

Table 4. Correlation matrix of the variables ($n = 1180$)

Variable	Patenting	Publishing	Commercialization	Projectyears	Awardintensity	University	Businessfounders	Academicfounders	PreviousPhI	Womanowner	DOD	DOE	NASA	NIH	NSF
Patenting	1														
Publishing	**0.138**	1													
Commercialization	**0.069**	− 0.030	1												
Projectyears	− 0.043	− 0.017	**− 0.098**	1											
Awardintensity	0.049	**0.078**	0.036	0.037	1										
University	**0.059**	**0.168**	0.045	− 0.039	0.012	1									
Businessfounders	0.024	0.009	0.015	− 0.002	− 0.028	0.011	1								
Academicfounders	− 0.043	0.036	**0.078**	− 0.007	− 0.055	**0.111**	− 0.049	1							
PreviousPhI	0.057	**0.164**	0.009	**− 0.055**	0.018	0.043	0.016	− 0.053	1						
Womanowner	**− 0.079**	0.005	0.042	**− 0.062**	− 0.001	− 0.037	0.002	− 0.053	− 0.026	1					
DOD	− 0.034	**− 0.064**	**− 0.112**	− 0.013	**0.051**	− 0.188	− 0.017	− 0.147	0.026	− 0.012	1				
DOE	0.034	0.045	**− 0.012**	0.053	− 0.020	0.003	0.001	**− 0.011**	− 0.036	− 0.055	**− 0.293**	1			
NASA	**− 0.067**	− 0.020	− 0.079	0.049	− 0.049	− 0.056	− 0.016	− 0.019	− 0.049	− 0.017	**− 0.296**	**− 0.099**	1		
NIH	0.006	0.058	**0.189**	− 0.029	0.021	**0.178**	− 0.007	**0.199**	0.026	**0.071**	**− 0.558**	**− 0.186**	**− 0.188**	1	
NSF	**0.083**	− 0.002	**− 0.002**	− 0.034	− 0.052	**0.108**	0.055	− 0.019	− 0.001	− 0.017	**− 0.296**	**− 0.099**	**− 0.099**	**− 0.188**	1

Correlation coefficients significant at the .05-level or better are in bold.

Among commercialized projects, 663 (68.1%) have academic founders, 576 (58.2%) have prior phase I awards, and 376 (38.6%) had a university research partners on their phase II project. Among commercialized projects with an academic founder, 279 (42.0%) included a university research partner (and 384 did not), while universities were involved in only 97 commercialized projects without an academic founder. Further, more than one-half of the academic founders in firms that had commercialized are associated with prior SBIR phase I awards.

Correlational relationships among project variables are presented in Table 4. The positive and significant correlation coefficient between publishing and patenting may imply that the two IP strategies are complementary. Publishing also correlates positively with prior receipt of a Phase I SBIR award (PreviousPhI), university involvement (University), and award intensity (Awardintensity), and negatively with DOD SBIR funding. Patenting correlates positively with commercialization, university involvement (University), and receipt of a phase II award from the NSF, yet negatively with female ownership (Womanowner) and NASA funding. Commercialization is also positively and significantly correlated with academic founders (Academicfounders) and NIH funding, while relationships with the age of the phase II project (Projectyears) and DOD, DOE, and NSF SBIR funding are negative and significant.

Given the legislated importance of commercialization to the SBIR program, Table 5 provides a comparison of the likelihood of commercialization between projects that resulted in a patent versus those that resulted in a publication. The table also compares firm-level phase II projects that resulted in patents (patenting = 1) with those that did not (patenting = 0); the likelihood of technology commercialization is about 5 percentage points greater for the former group. A comparison of firm-level phase II projects resulting in publications (publishing = 1) with those that did not (publishing = 1) shows that the mean likelihood of commercialization is about 2 percentage points lower for the latter group. While these patterns might suggest that there may be a marginal tradeoff between patenting and publishing related to the likelihood of commercialization, it is important to recall that overlap exists between both (253 projects; see Table 3), and that patenting and publishing are both positively related to commercialization (see Table 5).

Table 5. Comparison of the likelihood of commercialization among patenting and publishing phase II projects ($n = 1180$)

Variable	n	Mean commercialization
Patenting = 0	682	0.802***
Patenting = 1	498	0.855***
Publishing = 0	569	0.837*
Publishing = 1	611	0.813*

***Statistically different means at 0.01-level, *statistically different means at 0.10-level

Table 6 presents the findings from a bivariate Probit model, holding constant whether or not the phase II project commercialized, as well as other project and firm characteristics. With reference to the directional effects, the likelihood of patenting (publishing) is greater (lesser) among phase II projects that commercialized from their phase II project as might have been expected from the descriptive information presented above. To the extent that the award intensity of a phase II project approximates the scope of research of the project, greater scope is associated more with the likelihood of publishing than of patenting. Likelihood of publishing is also associated with

university involvement and prior research experience (Academicfounders) vis-à-vis a prior phase I award related to the phase II technology. And, firms with female owners have a lesser likelihood of patenting.[6]

Table 6. Bivariate probit regression coefficients (standard errors) ($n = 1180$)

Variable	Patenting	Publishing	
Commercialization	0.214** (0.101)	− 0.185* (0.101)	–
Projectyears	− 0.017 (0.014)	− 0.002 (0.014)	–
lnawardintensity	0.068** (0.029)	0.108*** (0.029)	–
University	0.098 (0.079)	0.394*** (0.079)	–
Businessfounders	0.038 (0.075)	0.0219 (0.075)	–
Academicfounders	− 0.127 (0.081)	0.075 (0.081)	–
PreviousPhI	0.101 (0.077)	0.393*** (0.077)	–
Womanowner	− 0.361*** (0.129)	0.052 (0.129)	–
Agency fixed effects	Yes	Yes	–
Log likelihood	–	–	− 1547
Rho	–	–	0.198*** (0.046)

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

With reference to the average marginal effects in Table 7, especially with reference to the average marginal effects related to commercialization, the likelihood of patenting is 8.1 percentage points greater for firms that also commercialized from their phase II project, and the likelihood of publishing is 7.0 percentage points lesser for firms that commercialized from their project.

Table 7. Calculated average marginal effects from bivariate probit regressions ($n = 1180$)

Variable	Patenting	Publishing
Commercialization	0.081**	− 0.070*
Projectyears	− 0.006	− 0.001
lnawardintensity	0.026**	0.041***
University	0.037	0.148***
Businessfounders	0.015	0.008
Academicfounders	− 0.048	0.028
PreviousPhI	0.038	0.148***
Womanowner	−0.137***	0.019

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

Discussion

Following the extant literature, this study shows that patenting is generally associated with SBIR phase II project commercialization. Our contribution, however, is illuminating a number of other covariates, including publishing, that may provide a conceptual foundation for future inquiry related to the performance of small, knowledge-based firms.

[6] See Link and Strong (2016) and Link and Morrison (2019) for a review of the relevant literature on ownership gender and the innovative behavior of firms. See also Audretsch et al. (2019) for a study of knowledge spillovers from university involvement in research.

First, our findings show that among SBIR projects that achieve commercialization, some are associated only with patents, others only with publications, with many firms employing both. As discussed above, the patenting literature traditionally framed patenting and publishing as substitutable competitive IP strategies. However, accretive logic holds that patents and publications can also be utilized as signals to attract new knowledge and entrepreneurial resources.

Our findings follow Li and colleagues (2015) who observe a positive relationship between patenting and publishing. While the authors suppose that firms transition from publishing to patenting as they develop commercial applications (Shapira et al. 2011), the strong positive correlation between patenting and publishing in our sample may denote greater complementarity. Hottenrott and colleagues (2015), for example, describe investor preference for understanding patent quality in lieu of patent quantity among less established firms, an information asymmetry that may be conceivably addressed through publications.

Though we find in Tables 6 and 7 a negative statistical relationship between publishing and commercialization, we nonetheless find 244 firms in our sample that only publish and nonetheless commercialize their technology, perhaps due to other observed and unobserved factors. Further, a plurality of firms that commercialize their technologies utilize neither publications nor patents. Li and colleagues (2015) describe the propensity of nanotechnology firms to publish when their technology is based on public science—and avoid publishing when their technology is more radical as measured by the number of technology factors underlying their patents. Employing competitive logic, the authors assume that these firms employ secrecy instead of publication (Hayter and Link 2018).

Competitive logic might, of course, explain how 303 firms in our sample commercialized their technology without publishing or patenting, deliberately choosing to protect their innovations through secrecy. However, characterizing the firm-level decision to forego publishing (or patenting) for reasons related to secrecy neglects possible accretive rationales. (Hoenig and Henkel 2015) find, for example, that a venture's research alliances and team experience provide venture capitalists with a more compelling technology quality signal than patents. In other words, the signaling role of publications and patents must be viewed within the context of other types of signals that may indicate how small firms are accreting new knowledge and the quality (based on the reputational effects of a partner) of that knowledge (Hoenig and Henkel 2015). Further, the literature highlights the importance of intangible factors in the performance of knowledge-based ventures, including entrepreneurial motivations, social networks, and culture (Guerrero and Urbano 2014; Hayter 2011, 2016; Lam 2011).

Accretive rationales for firm publications are often tied to relationships with research universities (Hayter and Link 2018; Li et al. 2015). Research universities are a critical source of new knowledge and studies show that firms can accrue a number of technological and performance-related benefits from academic partnerships (Wang and Shapira 2012). In our sample, publishing behavior is similarly associated with university involvement, though negatively associated with commercialization. University involvement is nevertheless correlated with Patenting and Academicfounders, covariates associated with commercialization.

We hypothesize that academic publications motived by formal university involvement is distinct from publications for signaling purposes (i.e., among firms that commercialize). This may explain why a correlational relationship does not exist between publishing and the presence of academic founders, but indeed exists between publishing and university involvement. Academic founders associated with technology commercialization may have developed an entrepreneurial, commercialization-focused mindset, may be connected to relevant non-academic networks, and may have chosen to discontinue or eschew formal university relationships thus viewing internal firm-level publications differently than university scientists who have not. Conversely, formal university involvement and associated academic publication may indicate that firms remain technology lifestyle or "living dead" companies that advance goals of academic scientists but "survive" for years with negligible sales or profits (Harrison and Leitch 2010; Hayter 2011, 2015).

Though a majority of commercialized phase II projects are at least partially derived directly or indirectly from university research (as indicated through academic founders or university involvement), we speculate that receipt of prior phase I awards mediates the relationship between academic partnerships and commercialization. SBIR phase I awards serve as a proof-of-concept for the technical merit and possible commercial potential of the proposed R&D effort that, if successful, may lead to a phase II award. As discussed, academic founders associated with prior phase I awards are more often associated with technology commercialization than those who are not. We speculate that while academic founders endow their firms with new knowledge derived from university research, prior phase I awards enable firms to experiment with and refine their technological proof-of-concept prior to the phase II research/commercialization phase. Further, the significant, negative correlation between Projectyears and PreviousPhI as well as Commercialization may indicate that firms with prior phase I award experience may possess the knowledge base to rapidly achieve commercialization through phase II SBIR research.

The knowledge spillover literature has long emphasized differences between codified and tacit knowledge, the former comprised of publications and patents and the latter embodied in individual knowledge agents and their interpersonal relationships (Ács et al. 2009; Braunerhjelm et al. 2010).[7] Accretive logic extends conceptualization of publications and patents beyond their role as codified outputs used in IP protection, to include their conjoint role as complementary strategic signals, singular use of publication as a signal to investors, partners, and customers that promotes commercialization, and the possibility that early-stage, small knowledge-based firms may choose to forego IP protection and signaling through patents and publications altogether.

Common within our sample, a strategy of foregoing IP protection or signaling through publications or patents raises interesting questions for future research. First, while scholars have discussed the role of patents and other formal and informal mechanisms for IP protection (e.g., Hall et al. 2014; Amoroso and Link 2019), a question remains: To what extent do these mechanisms complement or conflict with the signaling power of publications and research alliances? This question seems especially relevant for firms in our sample that employ neither publications nor patents.

[7] See also Audretsch and Link (2018, 2019).

Second, what are the implications of our findings for understanding of university technology transfer? Scholars have long used patenting activity by technology transfer offices to help to explain and demonstrate the role of universities in entrepreneurship and economic development (Hayter et al. 2018). Many firms in our sample have lineage to government-funded research conducted in research universities through academic founders or university involvement in the phase II project. Yet, a large number of firms in our sample also have academic founders and commercialize their technology without a patent and with little formal involvement by a university. These firms may exemplify challenges associated with what Bradley et al. (2013) term the patent-centric linear model of university technology transfer, a heuristic that at best overlooks the iterative and evolutionary nature of commercialization and at worst may inhibit the dissemination of new publicly funded knowledge with implications for future innovation.

Finally, the relationship between commercialization and academic founders with prior phase I awards not only highlights the iterative nature of innovation, but also it highlights the importance of time-related or temporal considerations. Though our data do not allow detailed examination of temporal aspects associated with publishing and patenting, many scholars have recognized the importance of these factors for understanding commercialization. More rapid patenting is generally associated with better licensing and commercialization outcomes (Elfenbein 2007; Markman et al. 2005). However, might scenarios exist whereby publication and patenting might slow time-to-market or possess little accretive value? Scholars could do well to consider temporal aspects when continuing to disentangle the role of publication, patenting, and the relationship between the two.

Concluding remarks

To the best of our knowledge, this is the first empirical study to systematically consider the relationship between publishing and patenting as accretive strategies. As such, the study is characterized as exploratory. However, based on a study of SBIR-awarded projects, several pathways are offered for consideration for future studies of small, knowledge-intensive firms. The intent of these pathways is to engender among researchers a broader vision of publication and patenting than presented in the extant IP-focused literature.

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