Journal of Business Research 67 (2014) 2860–2866

Contents lists available at ScienceDirect

Journal of Business Research

Appropriating innovation's technical value: Examining the influence of exploration

John Meyer [a,1], Mohan Subramaniam [b,*]

[a] Hagan School of Business, Iona College, 715 North Avenue, New Rochelle, NY 10801, United States
[b] Carroll School of Management, Boston College, 140 Commonwealth Avenue, Chestnut Hill MA 02467, United States

ARTICLE INFO

Article history:
Received 3 May 2011
Accepted 3 July 2012
Available online 25 July 2012

Keywords:
Appropriation
Exploration
R&D
Patents

ABSTRACT

In this study we examine how different approaches to exploratory search are used to generate an innovation influence appropriation of its technical value. Technical value is the benefit a firm derives from utilizing the underlying knowledge embedded in an innovation to stimulate and generate further innovations. Based on a sample of 772 patents from the ink jet printing field, we find that exploratory search that spans *technical* domains enhances appropriation of innovations' technical value; conversely, exploratory search spanning *industry* domains diminishes appropriation of innovations' technical value. These effects are further influenced by the age of the knowledge explored. In addition, we find that appropriation of innovations' technical value enhances the market share of the innovators. We discuss the implications of these findings for both future research and for improving business practice.

1. Introduction

Innovations notably influence the competitiveness of organizations in the marketplace. They can, for example, enhance cash flows and profits and make organizations attractive to investors. Indeed, the significance of an innovation's value to organizations is evident from several empirical studies that find innovation irrefutably linked to a wide range of market performance outcomes such as sales growth, market share, profitability, and share price valuations (e.g., Bowen, Rostami, & Steel, 2010; Jimenez-Jimenez & Sanz-Valle, 2011).

Even as market performance is a more apparent value of innovations, a different and not as conspicuous an aspect of its value stems from the new underlying knowledge that innovations embed in themselves. This new knowledge often provides a foundation for ensuing knowledge advancement and a consequent flow of continuing innovations. For example, when *aspirin* was introduced by Bayer as an innovation, it embodied new knowledge of a chemical called acetyl salicylic acid (ACA) that reduced pain and fever (Sneader, 2000). This knowledge of ACA eventually generated a novel understanding of how the blocking of platelets in blood can prevent heart attacks (Julian, Chamberlain, & Pocock, 1996), thereby spawning a subsequent set of innovations and a new class of drugs such as *Plavix* and *Reopro* (Randall & Neil, 2004). We distinguish such value as an innovation's *technical* value.

An innovation's technical value usually takes longer to realize compared to market performance outcomes. Also, while an innovation's market performance related benefits are clearly enjoyed by the innovator, the benefits related to an innovation's technical value can spill over to other organizations and are not always retained by the innovator. After an innovation enters the public domain, its underlying knowledge may become visible and accessible to the world. Consequently, the benefits of its technical value also become potentially available to other interested organizations, which are frequently competitors. These rival organizations can use this underlying knowledge to advance their trajectories in their own way and exploit it to generate their own set of innovations. *Bayer*, for instance, was not the only company to benefit from the new knowledge about ACA embodied in its innovation, *aspirin*. A host of other companies used that knowledge not only to develop alternative mechanisms for reducing pain and fever (such as *Motrin* and *Aleve*) but also to develop a new class of drugs for other medical applications such as to prevent strokes and heart attacks (Randall & Neil, 2004).

Our study attempts to understand the factors that influence how organizations advance *their own* innovation trajectory from the knowledge embedded in their innovations. Put another way, we examine how organizations *appropriate* for themselves the technical value of their innovations. We define technical value *as the extent to which the underlying knowledge embedded in an innovation stimulates subsequent innovations*. We further define the appropriability of an innovation's technical value *as the extent to which the locus of subsequent innovations stimulated by an innovation is retained within the organization initiating that innovation.*

2. Research framework

Most studies on innovation have limited their focus to its more immediate and apparent market value, such as market share or

* Corresponding author. Tel.: +1 617 552 0435.
E-mail addresses: jmeyer@iona.edu (J. Meyer), mohan.subramaniam@bc.edu (M. Subramaniam).
[1] Tel.: +1 914 633 2189.

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doi:10.1016/j.jbusres.2012.07.001

profitability (Brown & Eisenhardt, 1995). Little attention has gone into comprehending how an innovation may subsequently spawn further innovations or enhance its technical value. Similarly, research on the appropriation of an innovation's value (e.g., Teece, 1986) also has focused almost exclusively on understanding how to capture the primary commercial value of an innovation, not how to appropriate value from the subsequent trajectory of ensuing innovations or its technical value.

To address these gaps, our study builds on three theoretical domains. First, we use studies on *exploratory search* (e.g., Gupta, 2006; March, 1991) to theorize the antecedents of technical value. Second, we use and extend prior insights on *complementary assets* (e.g., Kostopoulos, Papalexandris, Papachroni, & Ioannou, 2011; Teece, 1986) to conceptualize the special circumstances in which an innovation's technical value can be appropriated. Third, we also use the concept of *situated knowledge* (e.g., Sherwood & Covin, 2008; Tyre & von Hippel, 1997) to understand how firms can influence their complementary assets and impact appropriating their innovations' technical value by directing their exploratory search on situated versus non-situated knowledge.

2.1. Literature review

Search comprises scanning activities aimed at probing through various technological options and improving an organization's prevailing knowledge and technology (Nelson & Winter, 1982). Search is exploratory when scanning activities are broad and probe through multiple new and unfamiliar knowledge or technology domains (March, 1991).

As exploratory search emphasizes experimenting with a variety of new technological options and incorporating fresh combinations of knowledge, it more likely results in radical breakthroughs in products and technologies (Miner, Bassoff, & Moorman, 2001). Furthermore, the new knowledge embedded in such innovations is also likely to make substantial departures from prevailing knowledge (Subramaniam & Youndt, 2005). Greater intrinsic novelty among innovations based upon exploratory search consequently can provide more fertile ground for further extensions of its trajectory and subsequent innovations. For example, in developing new *stents* (devices that artificially keep arteries dilated to facilitate blood flow without clots), *Medtronics* (a manufacturer of medical devices) scanned and searched across multiple knowledge domains, including those of material science, fluid dynamics, physiology, biochemistry, and pharmacology. Inputs from some of these domains—particularly those from biochemistry and pharmacology—subsequently served as a platform for a new set of innovations featuring stents with therapeutic properties, helping in thinning blood over and above mechanically keeping the arteries dilated.

While these arguments based on exploratory search help us understand how firms can generate greater technical value, they tell us little about how such value can be appropriated by an innovator. Even when an organization's exploratory search efforts generate technically valuable innovations that spark subsequent innovations, it does not necessarily follow that this same organization is alone in generating those subsequent innovations. They may well be generated by other organizations. In fact, exploratory search may even present a potential problem for organizations, as by generating more technical value it could further expose its own new creation of knowledge to outsiders and attract greater competitive attention (Ndofor & Levitas, 2004).

To overcome these limitations and to understand how firms can ensure that the locus of subsequent innovations from the underlying knowledge remains with the innovator, we consider studies on complementary assets. *Complementary assets* are assets that complement the more primary capabilities of innovation (Teece, 1986). Examples include prowess and capacities for marketing, manufacturing, and after-sales support, which are known to complement more fundamental aspects of innovation such as technical/science know-how, and thereby enhance the ability of a firm to appropriate market returns from an innovation (Parmigiani & Mitchell, 2009). While most studies on complementary assets focus on physical assets that are more suited to appropriate, more immediate commercial value of an innovation, our interest is in a different dimension—namely, *complementary knowledge assets* (Teece, 1998).

Complementary knowledge assets allow organizations to identify, filter, and frame relevant information to extend an innovation's underlying knowledge into other potential domains (Thomas, Sussman, & Henderson, 2001). More specifically, it is expertise in those potential domains that provides avenues for an innovation's underlying knowledge to be extended for subsequent innovations (Dougherty & Borrelli, 2000). In other words, complementary knowledge assets provide a firm with greater absorptive capacity to extend an innovation into new opportunity trajectories (Cohen & Levinthal, 1990). For example, identifying the therapeutic opportunities embedded within mechanical stents becomes easier for *Medtronics* if it also has expertise in pharmacology and biochemistry, not just material science. If it does not have that expertise, it may either not notice those extension possibilities or be preempted by a competitor that does (e.g., *Johnson & Johnson*). Thus, expertise in the domains explored for an innovation can become the requisite complementary knowledge assets enabling innovators subsequently to identify and make sense of the new opportunities embedded in their innovations, and thus help appropriate them.

However, organizations do not necessarily explore in domains in which they have *a priori* expertise. In fact, by exploring only in domains where the innovator has prior expertise may unnecessarily constrain the breadth of their search, restrict the seeds of knowledge sowed in their innovations, and thereby limit their potential technical value (Holmqvist, 2004). Thus, to increase the potential technical value in their innovations, innovators may stray into domains in which they do not have expertise. An important question stemming from this quandary is, are there aspects of exploratory search that could embed a wide range of knowledge kernels yet also help an innovator subsequently interpret and make sense of the opportunities implanted in those kernels for future innovations? That is, can innovators direct their exploratory search such that it increases their chances of possessing requisite complementary knowledge assets to better appropriate the technical value of their innovations?

One such aspect of exploratory search entails the degree to which innovators explore domains with *situated* as opposed to *non-situated* knowledge. Situated knowledge, as Tyre and von Hippel (1997, p. 71) put it, "is not absolute, but rather can only be defined in relation to a specific situation or context." As a consequence, absorbing situated knowledge and further extending it by interpreting and making sense of its ensuing opportunities requires not just an understanding of the relevant technological knowledge in an isolated form but also the context from which the knowledge originates (Lam, 1997). This contextual understanding is generally more difficult to obtain. In comparison, absorbing, interpreting, and making sense of innovation extension opportunities offered by non-situated knowledge do not require such added contextual knowledge. Hence, when unfamiliar domains explored for a focal innovation comprise non-situated knowledge, an innovator may subsequently find it easier to extend that knowledge into new opportunities. That is, innovators may find it easier to possess requisite complementary knowledge assets in domains with non-situated, isolated strands of know-how as opposed to domains with situated know-how embedded within idiosyncratic contexts. Put another way, innovators are more likely to possess a greater absorptive capacity (Cohen & Levinthal, 1990) to discern and perceive new innovation ideas when a focal innovation generates its technical value from non-situated knowledge rather than situated knowledge.

2.2. Hypotheses development

Distinctions in the extent of situated and non-situated knowledge that innovators encounter become particularly evident when the areas they explore span different technical and industry domains (Tyre & von Hippel, 1997). When innovators explore different technical domains they are usually seeking new inputs and ideas that are fundamental and technical, not specialized for any particular context, and hence relatively non-situated. In inkjet printers, for example, firms may explore technical domains such as adhesive bonding, electrical resistance, or thermal engineering. In doing so, innovators may seek inputs that are relatively non-situated, fundamental applications of sciences such as physics and chemistry (Tyre & von Hippel, 1997). On the other hand, inkjet printing firms can also explore across industry domains—such as petroleum, textile, glassware, or photographic equipment (Tsuji, 2001). Here the explored inputs will contain many elements of situated knowledge because of the unique settings of those applications.

Thus, the manner in which innovators direct their exploratory search across technical or industry domains influences the extent to which they acquire situated or non-situated knowledge (Bierly, Damanpour, & Santoro, 2009). Also, it is from these domains that the innovator draws seeds of new knowledge that ultimately become the platforms for ensuing new knowledge trajectories and innovations—or, technical value. If these knowledge seeds are based on non-situated knowledge—such as that of the more pure and fundamental sources of science in technical domains—the innovator is likely to absorb them more easily (Zahra & George, 2002) comprehend them, and find more ways to extend them for new innovation opportunities (Dougherty & Borrelli, 2000). In other words, the kernels of non-situated knowledge arising from exploratory search across technical domains may provide the innovator with greater complementary knowledge assets (Teece, 1998). Consequently, the innovator is also more likely to appropriate the technical value of these innovations. Hence:

Hypothesis 1a. Exploring across technical domains will positively influence the appropriation of an innovation's technical value.

In contrast, when exploring across industry domains, innovators will instill more situated knowledge kernels in their innovations. Compared to non-situated knowledge inputs, situated knowledge is more difficult to understand fully because the innovator needs an appreciation of the contexts from which these inputs are drawn (Tyre & von Hippel, 1997). To begin with, exploratory search in itself draws innovators into new, unfamiliar domains (Gupta, 2006). The unfamiliar contexts hence become an additional impediment. As a consequence, when a focal innovation is built on situated knowledge inputs drawn from exploratory search, the innovator may find it much harder to perceive or interpret new opportunities for future innovations emerging from that knowledge base. That is, when exploring across industry domains innovators are less likely to possess the requisite complementary knowledge assets in those domains (Lichtenthaler, 2009).

In addition, by broadening the range of industries explored, innovators are also likely to encounter a greater number of rival organizations established in each of those contexts (Yu, Subramaniam, & Cannella, 2009). Some rivals may be more familiar with those contexts than the innovator. These rivals may correspondingly have an edge in better absorbing, interpreting, and making sense of the situated knowledge embedded in those domains (Kostopoulos et al., 2011). Exploring across industry domains may consequently raise the threshold of expertise required for innovators to prevent rivals from preempting them in identifying new ways to extend an innovation's trajectory. Also, knowledge procured by exploring across industry domains may be available to all firms and hence more difficult for any one firm to interpret in novel ways. Therefore, the likelihood of innovators possessing pertinent complementary knowledge assets to appropriate their innovation's technical value is diminished when exploring across industry domains. Hence:

Hypothesis 1b. Exploring across industry domains will negatively influence the appropriation of an innovation's technical value.

On average, knowledge diffuses across a greater cross-section of organizations with increasing age and thereby gets more widely accepted and established (Nerkar, 2003). New knowledge, on the other hand, tends to be isolated, restricted to, and contained within the boundaries of its source (Schulz, 2001; Simonin, 1999). This distinction in the containment and commonness of knowledge associated with its age assumes particular significance when considering how it can influence the likelihood of innovators possessing requisite complementary knowledge assets to appropriate innovations' technical value.

As we reasoned earlier, exploring technical domains facilitates the possession of relevant complementary knowledge assets because innovators find it easier to assimilate, interpret, and make sense of new opportunities in these relatively non-situated domains (Reagans & McEvily, 2003). This ease, however, should be accentuated when the knowledge explored is old rather than new. As older knowledge is more established, we can expect innovators using such knowledge more clearly to understand, assimilate, and interpret its implications and ramifications for further extensions (Katila, 2002). Thus, exploring older knowledge in these domains is likely additionally to strengthen innovators' complementary knowledge assets and thereby further enhance the extent to which the technical value of innovations is appropriated. Hence:

Hypothesis 2a. The positive relationship between exploring technical domains and appropriated technical value is further pronounced for innovations incorporating older as opposed to newer knowledge.

Conversely, exploring across industry domains hampers the possession of relevant complementary knowledge assets as innovators find it hard to assimilate, interpret, and make sense of new opportunities in these relatively more situated domains (Bierly et al., 2009). This difficulty, in turn, should be even more accentuated when the explored knowledge is new, given that newer knowledge is more isolated, contained, and intelligible only to a few organizations that are closely linked to its source (Brown & Duguid, 2002). Thus, exploring newer as opposed to older knowledge in these domains is likely additionally to weaken innovators' complementary knowledge assets and thereby further diminish the extent to which the technical value of innovations is appropriated. Hence:

Hypothesis 2b. The negative relationship between exploring industry domains and appropriated technical value is further pronounced for innovations incorporating newer as compared to older knowledge.

Clearly, the more an innovator appropriates the technical value of its innovation, the greater it should benefit from that innovation (Ceccagnoli, 2009). This benefit is a logical outcome of a more efficient utilization of its knowledge advancements. Moreover, in cornering a greater share of the subsequent innovations that are spawned by its knowledge advancement, the innovator is more likely to proliferate its market with an ongoing stream of innovations (Kafouros, 2008). Appropriation of technical value thus enhances the likelihood of firms being able to dominate their markets. This should be reflected in their long-run market share. Hence we expect:

Hypothesis 3. The greater the appropriated technical value, the higher the organization's long-run market share.

3. Methodology

We use patent data to classify exploration and examine the conditions under which it influences the appropriation of an innovation's technical value. Our unit of analysis is the individual patent—which we refer to as the "focal patent"—and its associated content. By referring to or citing any other patent, an innovation taps into and thereby *explores* the knowledge embodied in those antecedent patents. Likewise, if an innovation is cited by a progeny patent, its knowledge has been tapped into by, and thus provided technical value to, that subsequent innovation.

The information we use to track exploration in this study is related to the technical subclasses assigned to each antecedent patent, the Standard Industrial Classification (SIC) codes assigned to the innovating organization behind the antecedent inventions, and the relative age of the antecedent patents (i.e., knowledge) upon which each focal patent builds. To measure appropriated technical value, we use information contained in the progeny patents that subsequently cite each focal patent—in particular, the identities of the organizations behind those ensuing innovations.

3.1. Sample

Following Rosenkopf and Nerkar (2001), we limited our sample to a single industry. We chose this approach to ensure an industry-based consistency in the distinctions across exploratory search and their implications to associated complementary knowledge assets and appropriated technical value. We specifically chose the inkjet printing industry because of its dynamism and the proclivity of its innovators for patenting their innovations. Six inkjet printing patent subclasses (i.e., focal technical domains) were identified through a search of the United States Patent and Trademark Office (USPTO) manual of patent classification and verified through consultation of prior studies of inkjet technology (Tsuji, 2001). More than 1400 patents were granted in the designated inkjet printing subclasses between 1980 and 2000. 10 firms account for 772, or approximately 55% of these inkjet patents. We concentrate our analysis on these 10 firms and their 772 inkjet patents, as the remaining inkjet patents are spread out over dozens of firms, each of which holds fewer than nine inkjet patents and no measurable inkjet market share over the 20-year period in question. These 772 focal patents each contain references to antecedent patents, providing a record of the exploration conducted and knowledge built upon by the inventors. In addition, these focal patents also contain information on progeny patents granted to organizations that subsequently cite each focal patent, permitting the construction of our appropriated technical value measure.

3.2. Measures

We define appropriated technical value as the extent to which the locus of subsequent innovations stimulated by any innovation is retained within the organization initiating that innovation. Accordingly, we measure it as the number of times a focal patent is subsequently cited by that patent's originator as a proportion of the total number of times it is cited. In other words, to calculate this variable we divide the number of times a focal patent is cited by the innovating organization by the number of times that patent is cited overall. Following the suggestion of Albert, Avery, Narin, and McAllister (1991, p. 255) to "insure a reasonable accumulation of patent citations", only patents in existence for at least three years at the time of the data collection (i.e., 2000 and earlier) are included in the analysis.

Consistent with Rosenkopf and Nerkar (2001) we measure exploration across technical domains as the number of unique patent subclasses covered by the focal patent's references. We measure exploration across industry domains as the number of unique SIC codes assigned to the organizations from which each focal patent references prior patents (e.g., Clarke, 1989; Zajac, 1988). Following Sorensen and Stuart (2000) and Nerkar (2003), we use the time elapsed since the application filing date of each cited patent and then arrive at an average age of the knowledge built upon at the time it was used (cf. Ahuja & Katila, 2001). Since this study is technology-specific (i.e., the inkjet printer), we use the percentage of total U.S. inkjet printer sales captured by an organization as our performance measure. In addition, we use the average inkjet market share of the innovating organization three, four, and five years following the application date of the patent behind each innovation to measure the impact of appropriated technical value on market performance (e.g., a patent applied for in 1998 is matched with the average market share for the innovating organization in inkjet printers for 2001, 2002, and 2003).

We incorporate a number of control variables in our analysis. We include two sets of dummy variables to account for *firm* and *year fixed effects* of the 10 separate firms and 21 years covered in our dataset. Next, we include *organization size* (e.g., Laforet, 2008) measured by the natural log of the number of individuals employed by the innovating firm during the year prior to the focal patent's application date. This variable has proven alternately to enhance innovation through the scope and scale advantages of larger organizations or hinder innovation via lowered incentives and reduced inventor productivity that come with increased size. We also include *prior organizational performance* as measured by the innovating firm's average earnings per share (EPS) for the three years prior to the focal patent's application date. This variable also has been shown either to foster innovation through an increase in the slack resources available or hamper innovation as organizations rest on their past successes (Subramaniam & Youndt, 2005). We include *prevailing organizational knowledge* as measured by the number of patents the focal firm already held in the inkjet printing domain at the time of the focal patent's application date (Yayavaram & Ahuja, 2008). One of the most common and directly relevant innovation study control variables is *R&D intensity* (e.g., Ettlie, 1998), as measured by the ratio of the innovating firm's research and development expenses to sales during the year prior to the focal patent's application date, and serves as a proxy for an organization's resource commitment to the innovation process (Cohen & Levinthal, 1990). Also included in all analyses is a dummy variable labeled *United States* to represent the innovating firm's geographical region (i.e., United States = 1; otherwise = 0).

4. Analyses

Our dependent variables—both appropriated technical value and market share—are bounded by zero and one and thus limited to non-negative values. As a result, the residual error terms are also limited and cannot be independently distributed. Moreover, a large number of our observations are "zero"—either because of patents that are not cited by the innovator (i.e., no appropriated technical value) or firms that have patented in the inkjet field but have not claimed any market share. In light of these data characteristics, we use the Tobit regression method of maximum likelihood for our analysis (Kitchen & Dalton, 1990). As a non-parametric alternative to ordinary least squares (OLS) regression analysis, Tobit is often used when the dependent variable is censored, skewed, or otherwise fails to meet parametric assumptions (e.g., Sanders & Carpenter, 2003).

5. Results

The means and standard deviations of, along with the bivariate correlations among, the study's variables are summarized in Table 1. The results of the Tobit analyses testing our hypotheses are presented in Table 2.

Model 1 in Table 2 presents the influence of all control variables on appropriated technical value. We find that organization size

Table 1
Means, standard deviations, and correlations [a].

	Mean	S.D.	1	2	3	4	5	6	7	8	9
1. Appropriated technical value	0.31	0.36									
2. Organization size [b]	10.76	1.26	0.11								
3. Prior organizational performance (EPS)	0.97	1.14	−0.01	0.29							
4. Prevailing organizational knowledge	101.65	98.20	0.04	0.05	0.01						
5. R&D intensity	0.08	0.39	−0.03	0.01	−0.04	−0.06					
6. United States	0.39	0.49	0.00	0.35	0.51	0.15	−0.03				
7. Exploration across technical domains	8.47	7.82	0.12	0.15	0.10	0.07	−0.03	0.17			
8. Exploration across industry domains	9.24	8.70	0.01	0.05	0.08	−0.06	−0.04	0.14	0.60		
9. Knowledge age	7.70	4.30	0.01	0.13	0.12	0.09	0.02	0.09	0.24	0.14	
10. Market share	0.19	0.18	0.11	0.17	0.34	0.01	−0.01	0.14	0.00	−0.03	−0.03

[a] $n = 772$. Correlations greater than 0.07 are significant at $p < 0.05$.
[b] Logarithm.

($b = -0.0009$; $p < 0.01$) and prior organizational performance ($b = -0.0871$; $p < 0.01$) both have negative significant effects on appropriated technical value. In addition, R&D intensity ($b = 2.2203$; $p < 0.001$) and a United States headquarters location ($b = 0.1659$; $p < 0.05$) both have positive significant effects on appropriated technical values.

Model 2 in Table 2 reports the direct effects of the two different approaches for exploratory search on appropriated technical value. We find the coefficient for exploratory search across technical domains to be positive and significant ($b = 0.0292$; $p < 0.001$), whereas the coefficient for exploratory search across industry domains is negative and significant ($b = -0.0143$; $p < 0.001$). These results strongly support Hypotheses 1a and 1b.

Model 2 in Table 2 also reports the moderating effects of knowledge age. We find that the interaction effect of exploratory search across technical domains and knowledge age is negative and significant ($b = -0.0019$; $p < 0.001$). This indicates that the positive influence of exploratory search across technical domains on appropriated technical value is reversed as the age of the knowledge being used increases. This result does not support Hypothesis 2a. On the other hand we find that the interaction effect of exploratory search across industry domains and knowledge age is positive and significant ($b = 0.0013$; $p < 0.01$). This indicates that the otherwise negative influence of exploratory search across industry domains is weakened and in fact reversed as the knowledge being used ages, consistent with and supporting Hypothesis 2b. Both of these interaction effects are illustrated in Fig. 1.

Finally, Model 3 in Table 2 reports the influence of appropriated technical value on the long run market share of the innovator. Here we find that the coefficient is positive and significant ($b = 0.0681$; $p < 0.05$), thus supporting Hypothesis 3. In summary, we find strong support for all but one of our hypotheses.

6. Discussion

Generating innovations with high technical value is clearly an important and desired goal for organizations. Such innovations initiate new trajectories for subsequent innovations and maintain the organizations' vitality. In generating such innovations, however, there is always a risk of their benefits spilling over to rivals. While prior research provides important insights into how such technically valuable innovations can be generated, it does not inform us about how the benefits of such innovations can be retained and appropriated by the innovator.

Table 2
Tobit models predicting appropriated technical value and market share.

Dependent variable	Appropriated technical value		Market share
	Model 1	Model 2	Model 3
Control variables			
Nine dummy variables for ten companies	(Not reported[a])	(Not reported)	(Not reported)
Twenty dummy variables for twenty-one years	(Not reported)	(Not reported)	(Not reported)
Organization size	−0.0009 **	−0.0009 **	−0.0004 ***
Prior organizational performance (EPS)	−0.0871 **	−0.0799 **	−0.1307 ***
Prevailing organizational knowledge	0.0002	0.0001	0.0018 ***
R&D intensity	2.2203 ***	2.599 ***	4.0858 ***
United States	0.1659 *	0.1330 *	0.3332 ***
Independent variables			
Exploration across technical domains		0.02920 *** (Hypothesis 1a)	
Exploration across industry domains		−0.01428 *** (Hypothesis 1b)	
Knowledge age		−0.0009	
Exploration across technical domains X knowledge age		−0.0019 *** (Hypothesis 2a)	
Exploration across industry domains X Knowledge age		0.0013 ** (Hypothesis 2b)	
Appropriated technical value			0.0681 * (Hypothesis 3)
Intercept	−0.0596	−0.1426 **	−0.3800 ***
Model statistics			
Wald test of joint significance	705.80 ***	693.92 ***	406.18 ***

[a] The beta coefficients of the dummy variables are not reported for the sake of brevity.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

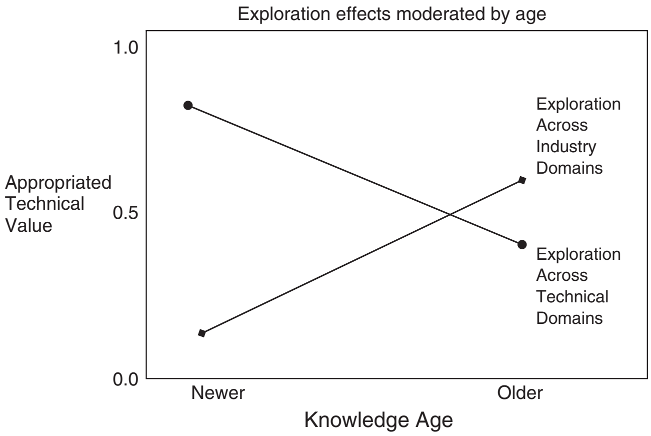

Fig. 1. Exploration effects moderated by age.

Our findings suggest that for appropriating an innovation's technical value, innovators are better off exploring across technical rather than industry domains. Broadening the scope of industries for exploratory search hampers the appropriation of innovations' technical value. Our rationale for these observed effects is based on the notion of complementary knowledge assets. Just as complementary *physical* assets (Teece, 1986) are necessary to appropriate the commercial value of an innovation, we contend that appropriating technical value requires complementary *knowledge* assets, or relevant skills at interpreting, framing, and making sense of the ensuing extension opportunities that the new knowledge underlying an innovation offers (Thomas et al., 2001). Possessing such complementary knowledge assets, on average, is easier for innovators when they explore across technical domains; it is harder when they explore across industry domains. Consequently, we see different effects of these exploratory search approaches on the appropriation of innovations' technical value.

Our findings on the moderating effects of knowledge age prompt us to modify somewhat our original theoretical rationale. We had expected older knowledge to be easier to interpret, assimilate, and make sense of, given that such knowledge is more established and widely diffused. Accordingly, we had expected that exploring across older and more established technical domains should make it even easier for innovators to possess pertinent complementary knowledge assets. We find the reverse effect is true; that is, older knowledge negates the benefits of exploring technical domains for appropriating the technical value of innovations. Interestingly, however (as hypothesized), older knowledge improves the benefits of exploring industry domains for appropriating the technical value of innovations.

It appears that as knowledge ages, it negates any of the differential advantage it may have initially provided to its users. When exploring technical domains, it is the innovator that has an advantage for appropriating an innovation's technical value. That's because innovators find it easier to possess non-situated complementary knowledge assets in those domains. However, with aging knowledge this ease may be apparent to other firms, too. Put another way, competing firms are as likely to possess comparable complementary knowledge assets in older technical domains, hence eroding the innovator's advantage. Similarly, when exploring across industry domains, other firms competing across industries have a differential advantage in possessing relevant complementary knowledge assets because of the more situated and context-specific nature of the underlying knowledge. But this differential advantage also appears to dissipate with aging knowledge, giving the innovator greater parity in possessing the relevant complementary knowledge assets and hence improving its chances at appropriating the technical value of its innovations. In essence, newer knowledge reinforces an existing advantage; older knowledge erodes it.

In addition, we find a strong and positive influence of the appropriation of innovations' technical value on the innovators' long-run market share. While not surprising, this finding underscores the competitive significance of appropriating technical value for innovators. This emphasis is particularly telling considering that we also found (although it was not hypothesized) the relationship between overall technical value and market share to be not significant. It appears thus that it is more important for innovators to pay attention to appropriating their innovations' technical value rather than merely trying to generate innovations with high technical value or impact.

6.1. Theoretical and managerial contributions

Our study offers several theoretical contributions and important managerial implications. From a theoretical point of view, our study interweaves three distinct streams of research to offer a novel concept of technical value and the factors influencing its appropriation. Prior research has largely treated these three streams of research—those of exploratory search, appropriation/complementary assets, and situated knowledge—independently and advanced them in separate trajectories. Our study is one of the first that integrates them and conceptually extends them in new and distinct ways.

We extend the research on exploratory search by highlighting two new dimensions of search—namely, search across technical domains and industry domains. In highlighting this distinction we are able to theorize and empirically demonstrate that search differentiated by these dimensions can influence the extent to which a firm can appropriate the technical value of its innovation. We could identify these dimensions of search and discover their implications to the appropriation of technical value by using and extending insights on complementary assets and situated knowledge. Much of the research on complementary assets has focused on physical complementary assets such as distribution channels or brand image (Teece, 1986). We extend this research by highlighting the significance of complementary *knowledge* assets and how they can help innovators select the domains they explore to enhance their odds of appropriating their technical value. Similarly, we also extend the concept of situated knowledge by establishing its importance in further refining the domains of search for innovators. In doing so, our theoretical framework and findings imply that when exploratory search draws on non-situated knowledge, it can provide innovators not only with greater technical value but also with greater complementary knowledge assets to better appropriate that technical value.

From a managerial perspective, our findings help innovators take a longer-term perspective on their innovation investment decisions. An innovation's value can far exceed normal projected life cycles if its potential technical value is properly understood. Also, if exploratory search is appropriately conducted in the development stage, this value can also be better appropriated, providing much greater returns to investments than previously thought. In hyper-competitive industries like the inkjet printing industry, such insights can help firms better manage their competitive positions through more proactive control over their innovation strategies.

As to some limitations of this study, we should point out that the validity and reliability of our patent data are based in large part on patent law and its enforcement. We have tried to circumvent such possible limitations by validating our dependent variable (patent based) measure with independent archival data on market share. Also, by focusing on a single industry in order to make a clear demarcation of business boundaries and collect data pertinent to the focal business, we may have lost on generalizability. We need to replicate this study over diverse industries to determine how widely these results hold true.

To conclude, our study examines how different approaches to exploratory search can enhance or thwart innovators' ability to appropriate the technical value of their own innovations. Our study thus helps to understand different search strategies and appreciate how their implementation impacts the appropriation of innovation's value.

References

Ahuja, G., & Katila, R. (2001). Technological acquisitions and the innovation performance of acquiring firms: A longitudinal study. *Strategic Management Journal*, *22*, 197–220.

Albert, M. B., Avery, D., Narin, F., & McAllister, P. (1991). Direct validation of citation counts as indicators of industrially important patents. *Research Policy*, *20*, 251–259.

Bierly, P. E., Damanpour, F., & Santoro, M. D. (2009). The application of external knowledge: Organizational conditions for exploration and exploitation. *Journal of Management Study*, *46*, 481–509.

Bowen, F. E., Rostami, M., & Steel, P. (2010). Timing is everything: A meta-analysis of the relationships between organizational performance and innovation. *Journal of Business Research*, *63*, 1179–1185.

Brown, J. S., & Duguid, P. (2002). Local knowledge: Innovation in the networked age. *Management Learning*, *33*, 427–437.

Brown, S. L., & Eisenhardt, K. M. (1995). Product development: Past research, present findings, and future directions. *Academy of Management Review*, *20*, 343–378.

Ceccagnoli, M. (2009). Appropriability, preemption, and firm performance. *Strategic Management Journal*, *30*, 81–98.

Clarke, R. N. (1989). SICs as delineators of economic markets. *Journal of Business*, *62*(1), 17–31.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, *35*, 128–152.

Dougherty, D., & Borrelli, L. (2000). Systems of organizational sensemaking for sustained product innovation. *Journal of Engineering and Technology Management*, *17*, 321–355.

Ettlie, J. E. (1998). R&D and global manufacturing performance. *Management Sciences*, *44*, 1–11.

Gupta, A. K. (2006). The interplay between exploration and exploitation. *Academy of Management Journal*, *49*, 693–706.

Holmqvist, M. (2004). Experiential learning processes of exploitation and exploration within and between organizations: An empirical study of product development. *Organization Science*, *15*, 70–81.

Jimenez-Jimenez, D., & Sanz-Valle, R. (2011). Innovation, organizational learning, and performance. *Journal of Business Research*, *64*, 408–417.

Julian, D. G., Chamberlain, D. A., & Pocock, S. J. (1996). A comparison of aspirin and anticoagulation following thrombolysis for myocardial infarction (the AFTER study): A multicentre unblinded randomised clinical trial. *British Medical Journal*, *313*, 1429–1431.

Kafouros, M. I. (2008). Economic returns to industrial research. *Journal of Business Research*, *61*, 868–876.

Katila, R. (2002). New product search over time: Past ideas in their prime? *Academy of Management Journal*, *45*, 995–1010.

Kitchen, H., & Dalton, R. (1990). Determinants of charitable donations by families in Canada: A regional analysis. *Applied Economics*, *22*, 285–299.

Kostopoulos, K., Papalexandris, A., Papachroni, M., & Ioannou, G. (2011). Absorptive capacity, innovation, and financial performance. *Journal of Business Research*, *64*, 1335–1343.

Laforet, S. (2008). Size, strategic, and market orientation affects on innovation. *Journal of Business Research*, *61*, 753–764.

Lam, A. (1997). Embedded firms, embedded knowledge: Problems of collaboration and knowledge transfer in global cooperative ventures. *Organization Studies*, *18*, 973–996.

Lichtenthaler, U. (2009). Absorptive capacity, environmental turbulence, and the complementarity of organizational learning processes. *Academy of Management Journal*, *52*, 822–846.

March, J. G. (1991). Exploration and exploitation in organizational learning. *Organization Science*, *2*, 71–87.

Miner, A. S., Bassoff, P., & Moorman, C. (2001). Organizational improvisation and learning: A field study. *Administrative Science Quarterly*, *46*, 304–337.

Ndofor, H., & Levitas, E. (2004). Signaling the strategic value of knowledge. *Journal of Management*, *30*, 685–702.

Nelson, R., & Winter, S. (1982). *An evolutionary theory of economic change.* Cambridge, Massachusetts: Belknap Press.

Nerkar, A. (2003). Old is gold? The value of temporal exploration in the creation of new knowledge. *Management Sciences*, *49*, 211–229.

Parmigiani, A., & Mitchell, W. (2009). Complementarity, capabilities, and the boundaries of the firm: The impact of within-firm and interfirm expertise on concurrent sourcing of complementary components. *Strategic Management Journal*, *30*, 1065–1091.

Randall, M. D., & Neil, K. E. (2004). *Disease management.* London: Pharmaceutical Press.

Reagans, R., & McEvily, B. (2003). Network structure and knowledge transfer: The effects of cohesion and range. *Administrative Science Quarterly*, *48*, 240–267.

Rosenkopf, L., & Nerkar, A. (2001). Beyond local search: Boundary-spanning, and impact in the optical disk industry. *Strategic Management Journal*, *22*, 287–306.

Sanders, W. G., & Carpenter, M. A. (2003). Strategic satisficing? A behavioral-agency theory perspective on stock repurchase program announcements. *Academy of Management Journal*, *46*, 160–178.

Schulz, M. (2001). The uncertain relevance of newness: Organizational learning and knowledge flows. *Academy of Management Journal*, *44*, 661–681.

Sherwood, A., & Covin, J. G. (2008). Knowledge acquisition in university–industry alliances: An empirical investigation from a learning theory perspective. *Journal of Production Innovations Management*, *25*, 162–179.

Simonin, B. L. (1999). Ambiguity and the process of knowledge transfer in strategic alliances. *Strategic Management Journal*, *20*, 595–623.

Sneader, W. (2000). The discovery of aspirin: A reappraisal. *British Medical Journal*, *321*, 1591–1594.

Sorensen, J. B., & Stuart, T. E. (2000). Aging, obsolescence, and organizational innovation. *Administrative Science Quarterly*, *45*, 81–112.

Subramaniam, M., & Youndt, M. A. (2005). The influence of intellectual capital on the types of innovative capabilities. *Academy of Management Journal*, *48*, 450–463.

Teece, D. J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy*, *15*, 285–305.

Teece, D. J. (1998). Capturing value from knowledge assets: The new economy, markets for know-how, and intangible assets. *California Management Review*, *40*(3), 55–79.

Thomas, J. B., Sussman, S. W., & Henderson, J. C. (2001). Understanding "strategic learning": Linking organizational learning, knowledge management, and sensemaking. *Organization Science*, *12*, 331–345.

Tsuji, Y. S. (2001). Product development in the Japanese and U.S. printer industries. *Technovation*, *21*, 325–332.

Tyre, M. J., & von Hippel, E. (1997). The situated nature of adapted learning in organizations. *Organization Science*, *8*, 71–83.

Yayavaram, S., & Ahuja, G. (2008). Decomposability in knowledge structures and its impact on the usefulness of inventions and knowledge-base malleability. *Administrative Science Quarterly*, *53*, 333–362.

Yu, T., Subramaniam, M., & Cannella, A. (2009). Rivalry deterrence in global markets: Contingencies governing the mutual forbearance hypotheses. *Academy of Management Journal*, *52*(1), 127–147.

Zahra, S. A., & George, G. (2002). Absorptive capacity: A review, reconceptualization, and extension. *Academy of Management Review*, *27*, 185–203.

Zajac, E. J. (1988). Interlocking directorates as an interorganizational strategy: A test of critical assumptions. *Academy of Management Journal*, *31*, 428–438.