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Unleashing Inventions? How Do Firms Link Technologies to Applications in the Market for Technology

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Abstract
Innovation requires both the invention of new technologies and the commercialization of the technologies across diverse commercial applications. Increasingly, firms turn to the market for technology to link commercial applications to their technological inventions. We take an inventing-firm perspective and ask: how many commercial applications will a firm associate with a given technological invention? Proprietary data from an online marketplace allows us to investigate both technological-characteristics and organizational-attributes that affect the technology-application associations. We find that firms in general assign more applications to technologies, which have a broad impact on other technological fields but the relationship not always holds. While local search constrains a firm?s ability to associate a broad range of applications with a technology, slack poor firms associate more applications with their technologies.

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INTRODUCTION

Innovation requires both the invention of new technologies and the commercialization of the technologies across diverse and often nascent markets. While technologies are embedded in commercial products, technological inventions are distinct from commercial applications and a single technology may be used for different commercial purposes (Basalla, 1988; Penrose, 1959). Hence, the process of linking such "general" technologies with multiple commercial applications is an important challenge in the innovation process (Danneels, 2007; Shane, 2000) and requires evaluating both technical possibilities as well as commercial application opportunities (Freeman & Soete, 1997).

Researchers have suggested that markets for technology may be an important setting through which firms commercialize inventions, with a broad range of potential applications (Nelson, 1990). The benefits are twofold. Even without further development and deployment in the product market, the inventing firm may profit from its invention. Further, society benefits as an inventive technology is applied across a wider set of applications (Arora, Fosfuri, & Gambardella, 2001; Arora & Gambardella, 1994). We observe that the use of markets is not limited to entrepreneurs and nascent firms (Gans & Stern, 2003; Shane, 2000), but is increasingly used by established firms to commercialize their inventions. Yet, apart from an understanding of why established-firms participate in such markets in the first place (Fosfuri, 2006; Lichtenthaler, Ernst, & Hoegl, 2010; Palomeras, 2007), we know little about how firms link technologies and commercial application in such markets.

The purpose of this study is to fill this void and examine how established firms link commercial applications to technologies when they engage in the market for technology. Put differently, we take an inventing-firm perspective and ask: how many commercial applications will it associate with a given technological invention? Our research question is important given that established firms have a substantial cache of technological inventions (Rivette & Kline, 2000). Moreover, the market for technology as exemplified by licensing contracts has grown in importance over the last decades and has surpassed an annual contract volume of US$100 billion[1] (Arora & Gambardella, 2010).

Following prior literature (Danneels, 2007; Gruber, MacMillan, & Thompson, 2008; Maine & Garnsey, 2006; Shane, 2000), we identify both technological-characteristics and organizational-attributes that affect the way in which highly general technologies are matched with a range of commercial applications. We expect that established firms are first and foremost guided by the technology's generality[2], i.e., the potential of a technology to influence a wide range of technical fields and associate them with a broad range of commercial applications. However, established firms are also guided by established routines and predefined heuristic maps as to how technologies and commercial applications are linked (Danneels, 2007). Thus, if a firm has already commercialized a focal invention, it may limit the firm's ability to link the technology with a broad range of applications.

When examining organizational attributes, we explore the role of financial slack for innovation (Cyert & March, 1963; Nohria & Gulati, 1996). We reveal a counter-intuitive dynamic; it is the slack poor firms which benefit the most when commercializing highly general technologies. We postulate this pattern is due to the fact that these firms tap into the financial resources of others through the market for technology. Finally, we explore the effect of broad industry and market experience on the ability of firms to associate a broad range of applications

[1] This estimate is extrapolated from US data but only includes licensing of rights to use IP (Intellectual Property), protected as industrial property (Arora & Gambardella, 2009).
[2] We call such technologies short general technologies (Gambardella & Giarratana, 2009).

for their technologies. Consistent with prior research, we expect that such experience is fundamental to making new linkages between technologies and applications, and that the effect will be most pronounced for highly general technologies.

We test our hypothesis by examining 353 technologies listed on an online market for technology. In such a market, inventions discovered by one firm (technology sellers) may be utilized and commercialized by another firm (technology buyers). This setting enables us to gain important insights as to how sellers systematically attempt to apply their technologies in a broad range of applications. Moreover, studying a marketplace allows us to observe a firm's perspective on prospective applications, rather than being limited to consummated technology-application matches that may be driven by either sellers or buyers. In doing so, we fit into a stream of literature that undertakes the perspective of one partner in corporate transactions more deeply as exemplified by acquirees (Graebner & Eisenhardt, 2004) and investees (Hallen & Eisenhardt, 2011).

We find that firms engaged in the market for technology do indeed assign commercial applications based on the inherent potential of a technology to be used in multiple applications. As expected, however, this relationship is mediated by technology-characteristics and organizational-attributes. Prior commercialization experience with a given technology may result in local search and constrain a firm linking the technology with other commercial applications. We also find that slack-poor firms and slack-rich firms differ in their propensity to consider a broad range of commercial applications for their technologies. Finally, we do not find evidence that a firm's industry experience facilitates the matching process of technologies and commercial applications in the market for technology.

Technological Inventions, Commercial Applications, and the Market for Technologies

Inventions and Applications.

Technologies and commercial applications are distinct elements in the innovation process. While inventions are embedded in commercial products, the relationship between the two elements is not necessarily one to one.

Innovation entails both the discovery of inventions or technologies[3], as well as application, i.e., putting technologies into productive use (Kline & Rosenberg, 1986:162; Schumpeter, 1934). Both invention and application are necessary conditions for profitable innovation: failure to execute either one would likely lead to inferior performance. Invention builds the technical resources that a firm it can draw upon to solve problems (Ahuja & Morris Lampert, 2001). Conversely, application of technologies refers to the identification of promising commercialization opportunities (Dosi, 1988; Levinthal, 1998).

The distinction between a firm's technological resources (represented by its inventions) and its applications (represented by a firm's activity in product markets) is not new; researchers agree that technological resources lie upstream of commercial applications (Penrose, 1959; Prahalad & Hamel, 1990; Wernerfelt, 1984). Technologies are hence more than mere elements embedded in commercial products (Danneels, 2007). They have their own distinctive properties and while some properties may be specific to a particular commercial application, other properties may allow a technology to enable a wider set of applications (Gruber et al., 2008). As a result, the relationship between technologies and application is not necessarily one to one and

[3] Following (Tushman & Anderson, 1986:440), we define technologies as "those tools, devices and knowledge that mediate between input and outputs (process technology) and/or that create new products or services (product technology)."

can also change over time as the *"the first uses [of an invention] are not always the ones for which the invention will become best known"* (Basalla, 1988:141).

As an example, DuPont's Teflon (Polytetrafluoroethylene) has distinct technological properties as it is hydrophobic, heat resistant, and provides a a low coefficient of fricton.[4] Today, Teflon's market applications span a broad range of industries including automobiles (for paint), housing, and cookware, as well as photovoltaic energy products (DuPont, 2011).

To commercialize its technology, a firm has to match the technology to commercial applications (Maine & Garnsey, 2006). Increasingly, the match may take place not within a firm, but outside its boundaries, in what has become known as the market for technology, which we introduce next.

Market for Technology

Extant work observes that the process by which technologies are matched to commercial applications is no longer exclusively conducted within a firm (Arora, Fosfuri, & Gambardella, 2001). Rather, a market for technology enables one firm to discover a novel technology and for another firm to apply it commercially (Arora & Gambardella, 1994). Recently, more efficient forms of marketing technology have emerged across different industries and have grown substantially (Arora et al., 2001; Arora & Gambardella, 2010).

In the market for technology, inventions are traded unconditionally of their applications (Maine & Garnsey, 2006). That is, the assets traded are technologies that offer potential solutions to a wide set of commercial needs. The market connects and facilitates transactions between two pools of participants: on the one hand, it accommodates inventors and, on the other, it assists

[4] http://www2.dupont.com/Teflon_Industrial/en_US/products/selection_guides/properties.html

those who seek to commercialize the inventions. Specifically, we consider a marketplace for patents in which inventors and would-be commercializers interact and trade these inventions.

While the market for technology may allow the effective division of labor between inventors of new technologies and those commercializing new technologies (Arora & Gambardella, 1994), a growing stream of research, suggests that the initial matching of technologies and applications is far from trivial (Danneels, 2007; Gambardella, Giuri, & Luzzi, 2007; Shane, 2000). This is particularly relevant for technologies which have the potential to be applied in a broad set of applications, where difficulties in matching technologies and applications can stem from local search (Nelson & Winter, 1982; Rosenkopf & Nerkar, 2001), a lack of financial resources (Katila & Shane, 2005; Schoonhoven, Eisenhardt, & Lyman, 1990) and a lack of industry and market experience (Gans & Stern, 2003; Shane, 2000). In the next section we examine how firms try to commercialize inventions through the market of technology. We (a) hypothesize how the invention's technological-characteristics affect the range of commercial applications a firm considers, and (b) subsequently identify how this relationship is contingent on invention specific as well as firm-level attributes.

HYPOTHESES DEVELOPMENT

Technological Generality & Commercial Applications

Inventions differ in the extent to which they influence subsequent technological inventions. A greater technological generality indicates that an invention influences a diverse set of technology domains. It may also lead firms to associate these inventions with a broad set of commercial applications when engaging in the market for technology.

Technological inventions do not occur in isolation but rather are a result of an evolutionary process, which can be conceptualized as the recombination of existing inventions to form new solutions (Murray & O'Mahony, 2007; Nelson & Winter, 1982). An existing invention may influence other technological inventions in multiple ways. First, technologies which build on the focal invention may be from a narrow range of technology domains, so that the usefulness of the invention may be limited within that distinct technological domain (Fleming & Sorenson, 2004). Such technologies, for example, may facilitate specialization and incremental improvements within a given technological field. Alternatively, an invention may spur technologies across a broad set of technological domains. The original invention in such cases exerts influence on a large number of technological domains. The extent to which a technological invention influences subsequent inventions in a variety of technological fields has been labeled as an invention's breadth of impact (Argyres & Silverman, 2004) or the invention's technological generality or "general technologies" (Gambardella & Giarratana, 2009) . In sum, extant work indicates that technological inventions differ along a key characteristic, namely, the level of their technological generality.

Extant research has focused on the antecedents and consequences of technological generality such as inventor characteristics (Hicks & Hegde, 2005) and firm R&D structure (Argyres & Silverman, 2004). The level of an invention's technological generality reveals important characteristics as to its potential for commercial application, thus influencing a firm's decision to commercialize a technology in the first place (Arora et al., 2001; Palomeras, 2007). In other words, generality informs and shapes how technology and product market applications are matched.

Once a firm decides to commercialize a technology, it has to consider the commercial applications in which the technology can be of value. A characteristic of the invention (i.e., its technological generality) may inform its commercial potential. A general technology influences a large variety of other technological domains which, in turn, are associated with distinct sets of commercial applications (Silverman, 1999). It follows that an invention that affects a broad range of technological domains (i.e., an invention characterized by high level of technological generality) may be perceived as being associated with a broad set of commercial applications.

While firms have their own expert understanding of an invention's technological generality, they are also cognizant of the way in which their invention is subsequently used by external partners, competitors and entrepreneurs (Yang, Phelps, & Steensma, 2010). Over time, firms can observe how their invention influences other technological domains, which reveals to the firm if their technology can be successfully recombined with other technological fields. Such general inventions may be construed to have a greater potential for subsequent technological recombinations. Consider a firm that wants to commercialize a technology with a track record of technological recombination. The firm may consider that the invention has even greater potential to influence other technological fields. As a result, it will more likely associate this invention with a broader set of commercialization applications when commercializing the technology through a market. Taking both arguments in tandem, we propose:

> Hypothesis 1*: The greater the level of invention's technological generality, the greater* the number of commercial applications a firm will associate it with in the market for technology

While we expect technological generality to be associated with a broader range of commercial applications, the relationship may not always hold. Specifically, once firms have committed an invention towards distinct applications paths, they may fail to recognize alternative applications for the same technology due to the tendency to search locally (Danneels, 2007).

Furthermore, innovation is influenced by the firm's overall innovation context, including the availability of financial resources as well as the firm's experience in diverse markets and industries. Next, we examine how both local search at the invention level and financial slack and complementary assets at the firm level affect the relationship of technological generality and the number of commercial applications considered in the market for technology.

Local Search and Commercial Applications

Organizational routines shape firms' behaviors and activities, and often put them on a path of local search (March & Simon, 1958; Nelson & Winter, 1982; Rosenkopf & Nerkar, 2001). With respect to innovation activity, the implication is that firms often engage is local search when matching technologies and commercial applications (Danneels, 2007; Gambardella et al., 2007; Shane, 2000). As a result, a firm may only perceive a narrow set of commercial applications for its invention, even if the technology is of high technological generality.

In their search for potential applications firms are guided by organizational routines such as local search (March & Simon, 1958), which guide firms to search for solutions in the neighborhood of the firm's current expertise. Extant research has examined local search predominantly in the domain of inventions and discovery, where local search describes a firm's efforts to focus on similar technologies, thus leading to incremental and specialized inventions (Rosenkopf & Nerkar, 2001; Stuart & Podolny, 1996).

Organizational routines also impact the process of matching technologies and applications (Reitzig & Puranam, 2009; Shane, 2000). Hence, local search equally applies to the phase in which a firm moves an invention towards commercialization, the phase in which firms decide to which commercial applications their technology can be linked to (Gruber et al., 2008).

The local search effect is particularly strong for a technology that was already internally commercialized by a firm (Danneels, 2007; Shane, 2000). For a focal invention, the presence of prior commercial application will likely affect subsequent attempts to commercialize the technology through the market for technology. In other words, the commercialization of an invention shapes the number and type of future applications a firm may envision for that technology. The 'prior commercialization local search' effect arises for the following reasons. First, prior commercialization provides a firm with valuable information as to in what commercial applications do or don't work for a given technology. Second, prior commercialization entails the emergence of organizational routines, codification and translation of an invention for a particular use. The presence of such routines may shape (and potentially limit) a firm's vision as to other linkages between the technology and new applications (Danneels, 2007; Winter, 2000). It follows that prior commercialization gives rise to local search and leads to further specialization of a technology in commercial applications related to the existing commercial application.

While local search allows specialization, it may also have side-effects, (Levinthal and March, 1993; March, 1991) which may be particularly salient when firms try to commercialize inventions with high technological generality. Christensen and Rosenbloom (1995) indicated early that firms may become locked into technology-application paths by customers, which may prevent firms from commercializing a new technology. In a similar vein, Lichtenthaler, Ernst and Hoegl (2010) suggest that firms may refrain from commercializing a technology through external market altogether if faced with an attitude of "not sold here" within the organization.

Similar issues are significant when matching commercial applications to technologies characterized by high level of generality (Freeman & Soete, 1997). An invention with high technological generality has the potential to be utilized in a broad number of commercial applications. Recognizing these commercial applications requires firms to experiment, i.e., redefine their heuristics as to how technologies and application are interconnected (Itami & Roehl, 1991; Lei, Hitt, & Bettis, 1996). However, de-linking technologies and applications is difficult once a firm has internally commercialized the technology. In such cases, firms tend to exhibit local search, focusing on existing technology-applications paths and failing to uncover the full set of commercial potential of their inventions (Danneels, 2002). While local search is generally effective in the realm of existing applications, making distant or "long jumps" in uncovering commercial applications unrelated to existing applications is ineffective (Danneels, 2007; Levinthal, 1997).

In summary, we suggest that prior internal commercialization gives rise to local search, therefore limiting a firm's ability to uncover the full set of commercial applications for a technology with high technological generality. We propose:

> Hypothesis 2: Prior commercialization of a technology negatively moderates the effect of technological generality on the number of commercial applications a firm will associate it with in the market for technology

Extant research indicates that it is not only technological characteristics that affect a firm's innovation attempts, but that it is also important to consider the firm's overall innovation context, including its access to financial slack and its experience across industries and markets (Danneels, 2002; Gans & Stern, 2003; Nohria & Gulati, 1996; Voss, Sirdeshmukh, & Voss, 2008). We next explore how these firm-level factors affect the relationship between technological generality and applications considered in the market for technology.

Financial Slack & Commercial Applications

Deploying an invention towards a new commercial application often requires upfront investment. It follows that firms require financial slack to invent and innovate internally (Greve, 2003; Nohria & Gulati, 1996). However, a firm need not commercialize its inventions internally. Through the market for technology, a firm may tap the financial resources of other firms. That is, a firm with limited financial resources may choose to advertise the potential application of its high technological generality inventions.

Cyert and March (1963:189) early explained the fundamental role of slack for innovation as it "provides a source of funds for innovations that would not be approved in the face of scarcity."[5] One key category of slack if financial slack (Voss et al., 2008), which is composed of excess liquid resources beyond what is needed to operate the firm in the short term (Singh, 1986). Financial slack supports the matching of technologies and applications in two ways. First, financial slack provides excess resources (Cyert & March, 1992), which a firm can deploy for the exploration, discovery and pursuit of a broad range of applications. Second, financial slack affects a firm's decision-making environment by relaxing its internal monitoring and controls (Bourgeois III, 1981). It therefore provides a buffer in the event of failure (Cyert & March, 1992:43) and encourages experimentation with additional technology-application combinations. Financial slack is particularly important to inventions with high technological generality, wherein there are substantial costs to applying a technology in multiple domains (Chesbrough & Rosenbloom, 2002; Maine & Garnsey, 2006; Shane, 2000). It follows that a financially

[5] Although slack may take many different forms, researchers have predominantly focused on financial slack in the form of financial reserves as an important resource influencing innovation (Nohria & Gulati, 1996)

constrained firm is limited in its internal commercialization efforts: it must focus on a subset of feasible applications and forego the others.

Engaging in a market for technology removes resource-constraints considerations because an innovative firm need not commercialize the invention itself. An important characteristic of the market for technology is that it allows firms to tap and leverage financial slack from other firms. As a result, commercializing a technology through a market generally requires utilization of fewer financial resources of the inventing firm. Not only does a firm share the cost of discovery and commercialization with others (Eisenhardt & Schoonhoven, 1996; Sakakibara, 1997), but it also can defer or avoid altogether the need to make costly upfront investments in commercialization. Indeed, prior work shows that a key incentive to engage in the market for technology stems from the ability to save costs through sharing resources in the innovation process (Hagedoorn, 2002; Sakakibara, 1997).

Overall, a slack-poor firm participating in a market for technology can consider a broader range of applications for an invention of high technological generality, once it realizes that internal financial resources need not be the sole source for enabling commercialization. Consider an invention with an inherently broad-application space, as exemplified by DuPont's Teflon. While a slack rich firm can commercialize the technology in multiple applications a slack poor firm is limited in tis commercialization efforts: it must focus on a subset of feasible applications and forego the others. In the presence of an active marketplace, other resource-rich firms can sponsor the development of multiple applications for technologies concomitantly (Gambardella et al., 2007).

It stands to reason that it is slack-poor firms that will enjoy advantages when commercializing a technology with high generality through the market. Namely, we expect the positive relationship between technological generality and commercial applications to only hold for firms with low financial slack.

> Hypothesis 3: Financial Slack negatively moderates the effect of technological generality on the number of commercial applications a firm will associate it with in the market for technology

Breadth of Industry Experience & Commercial Applications

The application of invention requires firms to match their inventions with other, complementary assets, including manufacturing, marketing and other resources (Teece, 1986). Drawing on its industry experience, each firm generates new linkages between inventions and commercial applications. In the absence of a broad industry experience, firms may forego applications because they cannot adequately connect their technology with potential commercial applications.

A second important firm-level resource facilitating the matching of technologies and application is the extent to which firms have experience with a broad range of commercial applications (Gruber et al., 2008; Shane, 2000). Prior work indicates that commercial applications co-evolve with a firm’s experience in markets and industries (Shane, 2000; Venkataraman, 1997). Firms that are active across multiple industries have the advantage of recombining their knowledge about commercial applications with new technologies (Kogut & Zander, 1992; Kogut & Zander, 1993). Conversely, firms lacking exposure to diverse markets and industries are likely to possess limited industry knowledge and may also lack complementary assets, which is why they may opt to apply their technologies narrowly (Maine & Garnsey, 2006). This may limit the commercialization potential of high-generality technologies, which would require recombination of technologies and commercial applications to identify a broad set of potential commercial applications.

An active marketplace may have immediate implications for this issue as market participants have heterogeneous resource profiles which are often complementary to that of the technology selling firm (Arora & Gambardella, 1990; Rothaermel & Boeker, 2008). It may allow an inventing firm to tap into industry and market experience, including their complementary assets from commercial partners (Gans & Stern, 2003; Rothaermel, 2001).

However, it is doubtful that a lack of industry and market knowledge may be easily overcome when listing an invention on the market for technology. Industry and market experience constitute deep and quite often tacit knowledge on the needs of customers and what technologies may be effective in solving problems (Von Hippel, 1988). A firm with no broad diversification experience may hence be unaware of industry and market needs for which their technologies may be useful. As such, the firm would first need to interact with other partners in the market to learn about distinct markets and opportunities (Maine & Garnsey, 2006), which may take substantial time (Dierickx & Cool, 1989). Lacking diverse experience may prevent a firm from applying their technologies in a broad set of applications in the initial stages of commercializing the technology through a market. This is most salient for highly general technologies, for which numerous technology-commercial applications matches are feasible.

Whereas Hypothesis 2 focuses on a focal invention and whether it has been previously commercialized by the firm internally, Hypothesis 4 suggests that a firm's overall breadth of industry experience matters when matching technologies and commercial applications for highly general technologies. In such cases, firms having a diverse set of industry and market experience are best positioned to match technologies and commercial applications for technologies with a broad potential of applications.

> Hypothesis 4: A lack of broad industry and market experience positively moderates the effect of technological generality on the number of commercial applications a firm will associate it with in the market for technology

RESEARCH SETTING

Online Marketplaces.

This study utilizes detailed data from a leading market for technology, www.Yet2.com (hereafter Yet2). The marketplace operates as an online platform that allows "sellers" to post their inventions for a fee, while "buyers" can register free of cost, search the listed inventions and engage in an exchange. Charging a fee to the seller is common practice among online markets for technology and ensures that only high-quality sellers will list their inventions in the marketplace (Dushnitsky & Klueter, 2010). The inventions listed on Yet2 include major inventions such as the Oncomouse by Du Pont (Murray, Aghion, Dewatripont, Kolev, & Stern, 2009). Indeed, prior work has recognized Yet2 as an important knowledge intermediary (Gambardella et al., 2007; Palomeras & Madrid, 2007).

On the sellers' side, Yet2 is used by a multitude of participants including industrial firms (e.g., DuPont and Honeywell), entrepreneurial ventures, research universities and individual inventors. These sellers use the marketplace to license, sell, or initiate collaborative agreements for their inventions. We identified more than 71 multinational companies, individual inventors, research institutes and brokers who list their inventions on Yet2. On the buyers' side, barriers to entry are low since buyers can search the Yet2 free of charge. Two years after its launch, Yet2 had over 15,000 registered buyers; roughly 100,000 users were registered with Yet2 in 2008 (Yet2.com, 2009).

We chose this research setting because it allows us to overcome the critical challenges faced by prior empirical studies of the market for technology. Yet2 closely resembles a two-sided marketplace for technology, where inventors list their technologies unconditionally of the application needs of the participants (i.e., the needs of the 'buyers' do not dictate which inventions are listed by the sellers who are our focus. Of course, buyers' needs will determine which exchanges are consummated, which is not the focus of this study). In this setting, participants are most likely outside the selling firm's social circle. Based on our theory, we expect that, in such a setting, firms attempt to apply their technologies broadly.

Most importantly, as a research setting, Yet2 allows us to capture the full 'risk set' – we can observe all potential commercial uses in which an invention is at risk of being applied. A study of the market for technology seeks to understand which feasible applications are there for all existing inventions, requiring researchers to observe all prospective invention-application matches. As indicated, realized transactions can make up a small portion of the actual risk set within the market for technologies. Moreover, only considering realized transactions is not representative of the underlying risk set. Put differently, our research question necessitates observation of all inventions in the marketplace, including those that were or were not a subject of an exchange. Yet2 allows us to capture all the technologies at risk of being traded, not only those consummated at a particular point in time, which overcomes these problems.

Overall, Yet2 has characteristics of a two-sided marketplace from which we can gain important insights into what constitutes the risk set of the market for technology and what technologies and product market applications are facilitated by this market.

EMPIRICAL ANALYSIS

Sample

In Yet2, inventors and technology owners fill in a pre-specified technology listing.[6] The listing gives a brief functional overview of the technology and the underlying intellectual property in form of patents. We took two points in time at which inventions were listed on Yet2.com - February 2009 and added Techpacks, which entered the marketplace up to February 2010. Overall, Yet2 featured 1537 searchable technology listings, but, for the following reasons, only a subset is used for our analysis: First, about 31% of the listings did not include sufficient patent information.[7] Second, we make technologies as comparable as possible by focusing on patents filed in the US, leaving 843 usable listings. Given our independent variables, we also require inventions to have received citations to measure their technological generality; this further reduced the sample to 630. Another 200 technologies were dropped due to missing data on commercialization experience. Finally, our research question dictates that we find valid proxies for a firm's financial resources, which is the reason that we focus on a sample of technology of 353 listings of 22 listed firms, for which this is possible.

Variables

Dependent variable. It is the sellers in Yet2 who provide all relevant information for listing a technology on the marketplace. Specifically, they assign each technology to potential

[6] The use of standardized listings ensures that the technologies on the marketplace conform to some minimum quality. In addition, sellers pay a fee to list on Yet2, which reduces information asymmetries between market participants by discouraging technology owners with useless inventions.

[7] Most sellers indicate that patents related to their inventions are still in the application process. Other sellers did not provide a valid patent number, which could be retrieved from the USPTO website.

application categories. The categories cover a wide range of product markets applications such as automotive vehicle engines, chemistry refrigerants or test and measurement instrumentation. In 2008, Yet2 included 28 major application categories (listed in Appendix 1), which capture distinct industries. When a technology owner submits an invention, s/he assigns it to application categories. The quote below explains the role of application categories in Yet2:

> *"Categories are important! They help searchers find your technology* – even when *searchers don't know precisely what they are looking for, and* they help Yet2 promote your technology appropriately. Think about categories outside the normal application of the technology: radar for machine tool alignment or color-changing paint to measure *airflow"*(Yet2 website).

For each technology listing on Yet2, we capture the number of unique applications to which it may be applied. When listing a technology, the technology owners indicate in which of the 28 Yet2 application categories the technology may be useful. The 28 categories represent a comprehensive set of industry categories, from automotives to medical equipment. Namely, each of the categories represents a broad domain of application. Thus, observing that a technology is assigned to more than one application domain implies that the technology has a truly diverse application potential. The variable Commercial Applications is the count of the number of unique categories to which the focal invention has been assigned by the technology seller. Multiple applications for a given technology are possible and, in 66% of all cases, sellers assign more than one application category.

Independent variables.

Technological Generality: We follow prior research and employ a measure of technological generality proposed by Hall et al. (Argyres & Silverman, 2004; Hall, Jaffe, & Trajtenberg, 2001; Hall & Trajtenberg, 2004). It is based on US patent classes and equals 1 minus the Herfindahl index of the forward citations to the patent. In detail (Hall et al., 2001:45):

$$G_i = 1 - \sum_{j=1}^{J} (\frac{N_{ij}}{N_i})^2$$

Where N_i denotes the number of forward citations to a patent, and N_{ij} is the number received from patents in class j. A higher value of G_i indicates that the focal patent is cited across a broad range of patent classes, indicating that the technology has greater technological generality. Given that, for technologies with a small number of citations, G_i is a biased estimate of the true measure, we follow Hall & Trajtenberg and apply the following correction to derive an unbiased estimate $\overline{y}$ [8].

$$\overline{y} = \frac{N_i}{N_i - 1} * G_i$$

Accordingly, the first independent variable, Generality, follows the measure of generality of a technology as developed by Hall et al. (2001).[9]

Next, we develop measures of prior commercialization experience, financial slack and complementary assets that characterize the technology sellers. Recall that Hypotheses 2, 3 and 4 theorize about the moderating effect of invention and inventing-firm characteristics on the relationship between the generality of a technology and applications considered.

Firms in Yet2 indicate if they have already commercialized a listed technology. We set the variable "Applied Commercially" to one if firms indicate that the technology is already commercialized internally, which is our proxy for the firms' prior application experience for a

[8] We follow Hall et al. and consider patents with at least two forward citations.

[9] The number of claims on a patent has been suggested as an alternative measure for the general nature of an invention as it directly captures areas of applications (Lerner, 1994). However, as firms could artificially augment their number of claims, this measure can be noisy (Gambardella & Giarratana, 2009), and we only use it as a control.

given technology. The variable is set to zero if the firm does not indicate if the technology was already commercialized internally.

We follow prior literature and proxy of financial slack by the current ratio of the inventing firm (Bourgeois III, 1981; Singh, 1986). Namely, for each technology, we identify the inventing firm and obtain its current ratio. Firms with a low current ratio are resource-constrained as their current liabilities outweigh their current assets. The variable, Current, is equal to firms' current ratio as of 2008,[10] as reported in Compustat.

As a proxy of industry experience assets, we focus on the number of different business domains in which the firm is active. Engaging in multiple business domains requires firms to build complementary assets and develop experience in diverse industries (Silverman, 1999; Teece, Rumelt, Dosi, & Winter, 1994). To the extent that a broad set of resources is necessary to serve different markets, it follows that the greater the number of markets in which a firm is active, the broader its set of resources. Conversely, a firm that is active in few markets likely possesses limited, complementary assets. Accordingly, for each technology, we identify the inventing firm and search its Hoovers' entry to obtain the number of unique business domains (i.e., SIC codes) in which it is active. The variable, Diversification, is a count of the number of unique (3 digit) SICs in which the inventing firm operates.

Controls. We control for a host of invention and firm characteristics that may affect the number of applications identified for a focal technology. For invention characteristics, we use the USPTO database to construct several variables. Extant research has shown that the age and scope, i.e., how well the invention is protected, affect the likelihood of commercialization (Nerkar & Shane, 2007). Accordingly, we use the variable AppYear as the application year

[10] Results are robust using an average of the years 2006-2008 or the year 2007 only. For Techpacks added in 2010, we used the same variable but in the years 2007-2009 and 2008 respectively.

reported in USPTO to capture the age of the technology. Claims counts the number of claims for a listed invention, which is an indication of how well the invention is protected. We further control for the underlying value of an invention by including the number of forward citations that an invention has received (Griliches, 1990; Harhoff, Narin, Scherer, & Vopel, 1999). The variable Citations is the number of citations to a given technology. An additional control, Inventor, counts the number of inventors for the patent of an invention as recorded by the USPTO database. Finally, we control if firms are willing to commit their own Personnel in facilitating the transfer of the technology to potential licensees, which is indicated on the technology listings.

Empirical specification.

As application categories assigned by technology owners are integer counts that take only positive values, we employ a negative binomial specification. Models with dependent count variables may be misspecified using OLS regression, and Poisson regressions are restrictive as they require the mean and variance of the dependent variable to be equal (Long & Freese, 2006). The distribution of observations y_i of application categories follows the following Poisson distribution:

$$\Pr(y_i|x_i, \delta_i) = \frac{e^{-\mu_i}{\mu_i}^{y_i}}{y_i!}$$

In this model, δ_i corrects for the overdispersion and μ represents the mean count of application categories (Cameron & Trivedi, 1998). It is estimated by

$$\mu_i = \exp(x_i\beta)$$

where x_i contains our independent variables including technological characteristics, financial resources and complementary assets. We also correct the standard error by clustering by firm. We control firm fixed effects by entering firm dummies into all regression.

Analysis. Table 1 and Table 2 report the correlation matrix and descriptive statistics. In our sample, the average number of applications associated with a technology is 2.6. Also noteworthy are the technology age and citation counts, which indicate that the technologies listed on the market are of age and highly cited (which is also reflected in a high average generality score). Our key independent variables show little correlation allowing us to interact them in the empirical analysis.

== Insert Tables 1 and 2 about here ==

Table 3 reports the tests of hypotheses. Model 1 reports the baseline specification including all control variables. Interestingly, the main effect of age demonstrates that the younger the technology the more commercial applications are considered in the market for technology. We note, however, that the youngest technology in our sample is from 2005. Not surprisingly, the main effect of "Applied Commercially" is positive (and marginally significant). We indicated that firms which have already commercialized the technology may already have established technology-application combination with which they are familiar. Finally, the number of claims of a listed technology is associated with a lower number of commercial applications as well as technologies, which were discovered by a large number of inventors.

Model 2 adds technological generality and supports Hypothesis 1: the number of applications considered by a firm is larger the higher the invention's technological generality. The effect of Generality is meaningful: a standard deviation around them means an increase in generality, holding all other variables fixed at their mean, increasing the number of applications by 19%.

Next, we investigate how the relationship of Generality and Commercial Applications may be moderated by the indicator Applied Commercially as well as Financial Slack and

Diversification. In Model 3 we interact[11] Generality with the Applied Commercially indicator. The result is consistent with Hypothesis 2: the interaction reveals a negative and significant effect. This suggests, that once a technology has been commercialized internally, the selling firm considers a smaller number of applications for it in the market for technology, even if the technological itself has a high potential to be applied broadly.

== Insert Table 3 about here ==

To demonstrate the effect, we visualize the interaction plotting the Generality-Commercial Applications relationship for technologies, already internally commercialized versus not already internally commercialized. Figure 1 shows that, while the number of applications is quite similar for technologies with and without internal commercialization at lower level of technological generality, at higher levels, there are substantial differences. Namely, a technology, which already was already commercialized, is assigned fewer applications at higher levels of technological generality.

Model 4 examines the moderating role of financial slack on the Generality – Applications relationship. The main effect of financial slack is positive: a firm endowed with financial slack generally assigns more applications. The interaction term uncovers an interesting effect, however. It is the resource poor firms that consider a broader range of application for technological with high technological generality, consistent with Hypothesis 3. The results indicate that resource poor firms are more effective realizing the generality-commercial applications relationships, while resource rich firms consider a broader range of applications for all their technologies.

[11] Wherever necessary, we center the independent variables to avoid problems of multicollinearity when interacting terms (Aiken & West, 1991).

We demonstrate the effect again graphically in Figure 2. We consider low, high (defined as 2 standard deviations below and above the mean value of the Current Ratio) and medium (average) slack firms in the graph. In line with Hypotheses 3, the figure reveals that slack poor firms assign a higher number of applications to more general technologies. The relationship does not hold for slack rich firms.

== Insert Figure 2 about here ==

Model 5 examines the effect of Diversification on the number of applications considered by technology owners by interacting the variable with Generality. Hypothesis 4 predicts that those firms possessing experience in a wide range of industries may be better able to identify a broader range of applications for their technologies of high generality. However, while the coefficient is positive, we do not find a significant effect of the Diversificatio-Generality interaction on the number of applications. Hence, we reject Hypothesis 4.

Robustness Tests: We ran several robustness tests to further support our analysis. First we employed a zero truncated negative binomial model given that firms at least assign one application. The analysis gave very similar results to the one reported above. We further excluded three of the 22 firms' listed technologies (Honeywell, DuPont and Aga) as they were the most active posters but find the same results with the subset of remaining firms. We expanded our analysis for Hypothesis 3 and 4 to include those Techpacks for which we did not have a commercialization flag and found that the results were supported. Finally, we adjusted the financial slack measure using different lag structures and averages (over three years) and found our results supported.

CONCLUSIONS

The challenge associated with inventing a technology and subsequently matching it with commercial applications has been studied by a range of scholars in the fields of entrepreneurship, strategy and economics (Gruber et al., 2008; Maine & Garnsey, 2006; Shane, 2000; Tripsas & Gavetti, 2000). These challenges are particularly salient when the underlying invention is inherently general, i.e., it influences many technological fields, which is an indication of the potential to commercialize a technology in a broad range of applications. (Basalla, 1988; Chesbrough & Rosenbloom, 2002; Freeman & Soete, 1997; Giuri et al., 2007; Rosenberg, 1976). For such inventions, linking technologies and applications is highly important as applying them too narrowly would preclude an inventing-firm from reaping the true benefits of its innovative efforts (DiMasi, Hansen, & Grabowski, 2003; Ganuza, Llobet, & Dominguez, 2009). This paper examines the process by which inventing-firms identify a range of commercial applications for their technologies.

We examine an online knowledge market, which is a virtual marketplace that facilitate the listing, search and exchange of knowledge assets (Bakos, 1998; Dushnitsky & Klueter, 2010). These markets bring together strangers, thus constituting a sharp departure from accepted practices wherein transactions tend to materialize in one's geographic area (e.g. Dushnitsky & Klueter, 2010; Giuri & Mariani, 2009) and social circle (Kirsch, Goldfarb, & Gera, 2009; Shane & Cable, 2002).

Our analysis of 353 patented inventions listed on Yet2, one of the largest online technology marketplaces, offers important insights. We confirm prior studies that focus on the role of technological characteristics in the market for technology (e.g. Gambardella & McGahan, 2010; Nerkar & Shane, 2007): our evidence suggests that technologies with high technological generality are indeed associated with a broader set of applications considered by the listing firms. However, supporting the idea of local search, this relationship does not hold once a firm has already commercialized the technology internally. This suggests that even in the market for technology, local search is an important force, which may limit a firm in identifying an adequate set of commercial applications for its technology.

We further find that organizational characteristics shape a firm's behaviour in the market for technology. Specifically, slack poor firms consider a broader range of applications for inherently general technologies. This suggests that financial slack internal to the firm plays only a limited role as slack poor firms can tap into the resources of other firms engaging in the market. Moreover, our finding suggests that the idea that firms can innovate while facing scarcity (Katila & Shane, 2005; Mishina, Pollock, & Porac, 2004) also applies to attempts at linking technologies with commercial applications.

Contrary to our predictions, we do not find results for another firm characteristic: the breadth of industry and market experience affecting the range of commercial applications. One reason for the non-significance may stem from the fact that those firms with a breadth of industries may opt to commercialize their inventions internally through the various industries they already serve. Prior literature has indicated that firms with a large range of industries are more likely to entirely forgo the opportunity to use the market for technology (Lichtenthaler et al., 2010).

Our study makes several other contributions. First we contribute to the literature examining how entrepreneurs and new firms link their technologies to commercial applications (Gruber et al., 2008; Maine & Garnsey, 2006; Shane, 2000). We add the perspective of an established firm that attempts to commercialize some of their available patented technologies. While, in an entrepreneurial setting, invention and commercialization tend to occur at the same time, our firms try to commercialize older technologies, for which they may have a better understanding of the inherent potential to apply the technology in a range of applications.

We also contribute to the literature on the challenges associated with linking technologies to commercial applications (Danneels, 2007). Namely, prior commercialization experience may constrain firms in their subsequent commercialization efforts, which can substantially limit the applications considered even if the technology itself has a much higher commercialization potential. .

Our study also fits into a growing literature, which examines the role of online intermediaries and online markets for firm innovation processes (e.g. Lopez-Vega & Vanhaverbeke, 2010; Verona, Prandelli, & Sawhney, 2006; Zhang & Li, 2010). Future studies could examine if there are distinct types of intermediates, which differently affect the ability of firms to broadly apply technologies.

Despite uncertain performance consequences, markets for technology and, in particular, online markets for technology are an emerging setting, through which firms can experiment and learn about their own technologies. Firms can use this setting to gain important insights into the potential applications and, ultimately, the value of existing technologies. The next years will tell if firms are indeed able to "unleash" their "hidden gems" (Rivette & Kline, 2000) through the application of inventions through market mechanisms.

Table 1: Summary Statistics

	mean	sd	min	max
Commercial Applications	2.65	1.70	1	9
Inventors	2.74	1.77	1	16
Citations	17.77	22.74	2	137
Application Year	1995.85	4.73	1983	2006
No. Claims	19.77	14.89	1	99
IPCs	5.86	3.44	1	20
Personnel	0.49	0.50	0	1
Financial Slack	1.32	0.33	0.1	2.96
Applied Commercially	0.23	0.42	0	1
Diversification	8.59	4.29	1	14
Generality	0.49	0.22	0	0.91
N	353			

Table 2: Correlation Matrix

		1	2	3	4	5	6	7	8	9	10	11
1	Commercial Applications	1										
2	Inventors	0.06	1									
3	Citations	0.07	0.14	1								
4	Application Year	0.26	0.3	-0.12	1							
5	No. Claims	0.02	0.23	0.25	0.18	1						
6	IPCs	-0.03	0.15	0.17	0.01	0.15	1					
7	Personnel	0.29	0.07	-0.12	0.32	0.03	0.06	1				
8	Financial Slack	0.17	0.00	-0.25	0.24	-0.11	-0.06	0.4	1			
9	Applied Commercially	0.12	0.06	0.17	0.07	0.13	0.08	0.27	0.12	1		
10	Diversification	-0.19	-0.07	0.07	-0.35	-0.07	-0.06	-0.3	-0.22	-0.15	1	
11	Generality	0.12	0.11	0.31	-0.08	0.13	0.15	0.04	-0.11	0.1	0.09	1

Table 3: Results: Negative Binomial Model (including firm effects)

DV: Count of Commercial Applications	Model 1		Model 2 – H1		Model 3- H2		Model 4 – H3	
	b	se	b	se	b	se	b	se
Firm Effects Included	Y		Y		Y		Y	
Inventors	-0.022+	[0.0116]	-0.026*	[0.0116]	-0.029**	[0.0105]	-0.024*	[0.0111]
Citations	0.003	[0.0022]	0.002	[0.0022]	0.003	[0.0021]	0.002	[0.0022]
Application Year	0.024**	[0.0042]	0.025**	[0.0042]	0.026**	[0.0046]	0.022**	[0.0044]
No. Claims	-0.003*	[0.0013]	-0.003*	[0.0013]	-0.003+	[0.0014]	-0.003*	[0.0012]
IPCs	-0.008	[0.0102]	-0.010	[0.0102]	-0.009	[0.0108]	-0.010	[0.0099]
Personnel	0.253	[0.2040]	0.236	[0.2040]	0.228	[0.2062]	0.244	[0.2015]
Applied Commercially	0.152+	[0.0746]	0.148*	[0.0746]	0.168**	[0.0572]	0.168*	[0.0690]
Financial Slack	0.398	[0.3050]	0.449	[0.3050]	0.460	[0.3014]	0.708**	[0.2712]
Diversification	0.044	[0.0386]	0.047	[0.0386]	0.045	[0.0384]	0.056+	[0.0334]
Technological Generality		[0.0650]	0.339**	[0.0650]	0.527**	[0.1010]	0.548**	[0.1430]
Generality X Ap. Commercially					-0.724*	[0.3063]		
Generality X Current							-1.294**	[0.3422]
Generality X Diversified								
Constant	-46.231**	[8.3769]	-49.915**	[8.3769]	-50.910**	[9.2826]	-43.857**	[8.8385]
Log Likelihood	-607.29		-605.36		-603.40		-603.54	
N	353		353		353		353	

+ p<.10, * p<.05, ** p<.01

Negative Binomial Regressions - Dependent Variable: Count of Applications using clustered standard errors.

Table 4: Results continued

DV: Count of Commercial Applications	Model 5 – H3		Model 6 – Full Model		Model 7 – All Interactions	
	b	se	b	se	b	se
Firm Fixed Effects included	Y		Y		Y	
Inventors	-0.025*	[0.0114]	-0.028**	[0.0102]	-0.029**	[0.0098]
Citations	0.002	[0.0022]	0.003	[0.0021]	0.003	[0.0021]
Application Year	0.024**	[0.0048]	0.024**	[0.0049]	0.025**	[0.0049]
No. Claims	-0.003*	[0.0013]	-0.003*	[0.0012]	-0.003*	[0.0013]
IPCs	-0.010	[0.0102]	-0.009	[0.0105]	-0.008	[0.0106]
Personnel	0.236	[0.2042]	0.236	[0.2032]	0.239	[0.2029]
Commercialized	0.150*	[0.0725]	0.182**	[0.0573]	0.184**	[0.0577]
Financial Slack	0.493	[0.3107]	0.668*	[0.2692]	0.661*	[0.2663]
Diversification	0.047	[0.0383]	0.053	[0.0333]	0.054	[0.0331]
Technological Generality	0.386**	[0.0632]	0.676**	[0.1377]	0.653**	[0.0932]
Generality X Ap. Commercially			-0.614*	[0.2769]	-0.634*	[0.2891]
Generality X Current			-1.096**	[0.3460]	-1.418*	[0.5789]
Generality X Diversified	0.024	[0.0253]			-0.040	[0.0291]
Constant	-48.158**	[9.5278]	-47.256**	[9.7112]	-48.675**	[9.7435]
Log Likelihood	-605.21		-601.60		-601.50	
N	353		353		353	

+ p<.10, * p<.05, ** p<.01

Negative Binomial Regressions - Dependent Variable: Count of Applications using clustered standard errors.

Figure 1 Moderating effect of “Applied Commercially”

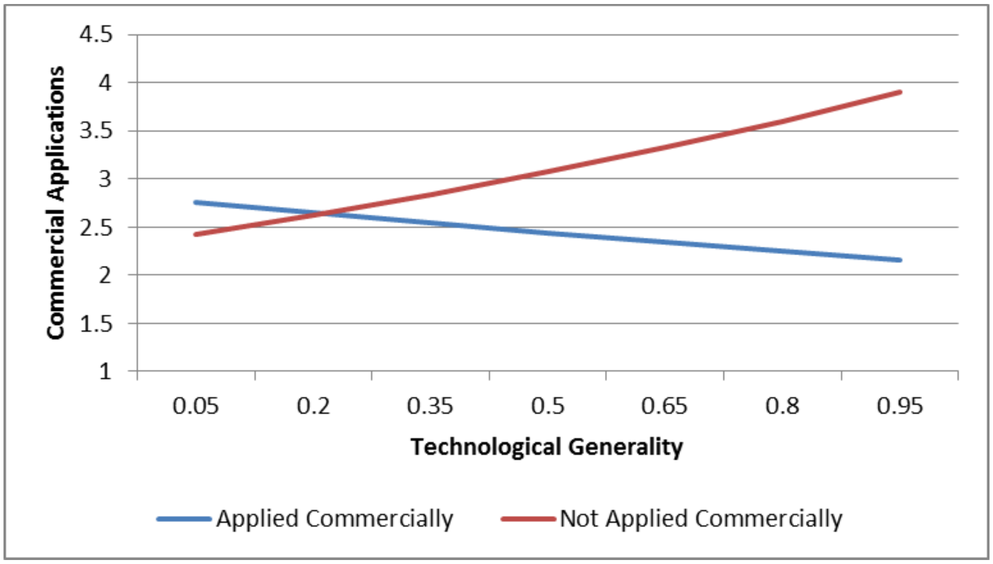
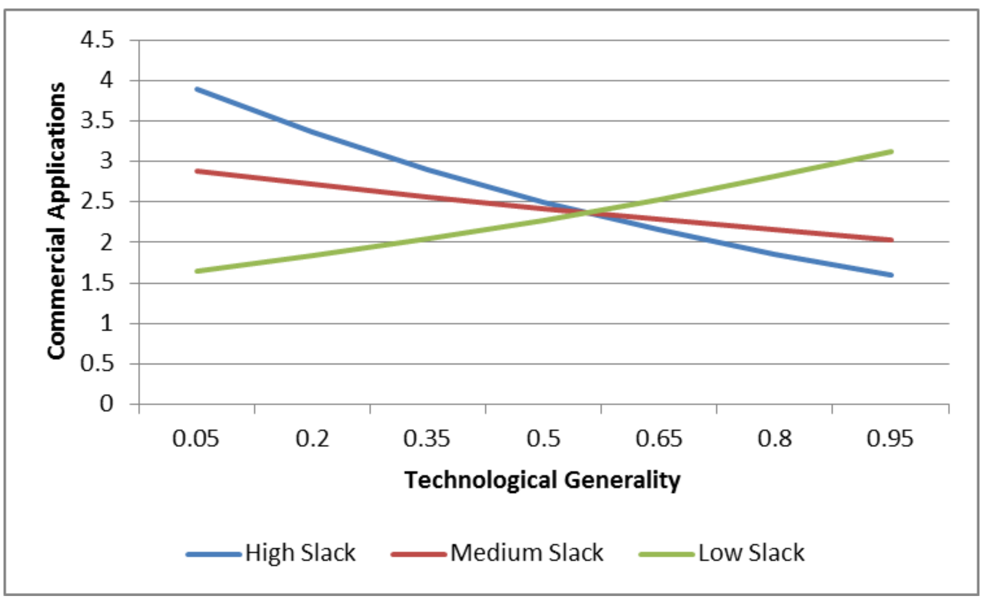


Figure 2 Moderating effect of “Financial slack” (current ratio)



Appendix

Appendix 1: Yet2 Application Categories

Aerospace	Geology
Agriculture	Health, Wellness, Personal Care
Automotive	Instrumentation
Biological Sciences	IP Professionals
Chemistry*	Manufacturing
Communications	Materials
Education	Mechanical
Electronic Data Processing	Medical
Electronics	Optics
Energy	Physics Computer Applications
Environmental	Public Administration
Finance	Techniques
Foods	Transportation
Fuels	

* contains for example refrigerants, cleaning agents….

Bibliography

Ahuja, G., & Morris Lampert, C. 2001. Entrepreneurship in the large corporation: A longitudinal study of how established firms create breakthrough inventions. **Strategic Management Journal**, 22(6 7): 521-543.

Aiken, L. S., & West, S. G. 1991. **Multiple regression: Testing and interpreting interactions**. Thousand Oaks, California: Sage Publications.

Argyres, N., & Silverman, B. 2004. R&D, organization structure, and the development of corporate technological knowledge. **Strategic Management Journal**, 25(8/9): 929.

Arora, A., Fosfuri, A., & Gambardella, A. 2001. **Markets for technology: The economics of innovation and corporate strategy**. Cambridge: MIT Press.

Arora, A., & Gambardella, A. 1990. Complementarity and external linkages: the strategies of the large firms in biotechnology. **The Journal of Industrial Economics**: 361-379.

Arora, A., & Gambardella, A. 1994. The changing technology of technological change: general and abstract knowledge and the division of innovative labour. **Research Policy**, 23(5): 523-532.

Arora, A., & Gambardella, A. 2010. Ideas for rent: an overview of markets for technology. **Industrial and Corporate Change**, 19(3): 775-803.

Bakos, Y. 1998. The emerging role of electronic marketplaces on the Internet. **Communications of the Acm**, 41(8): 35-42.

Basalla, G. 1988. **The evolution of technology**: Cambridge Univ Press.

Bourgeois III, L. 1981. On the measurement of organizational slack. **The Academy of Management Review**, 6(1): 29-39.

Cameron, A., & Trivedi, P. 1998. **Regression analysis of count data**: Cambridge Univ Pr.

Chesbrough, H., & Rosenbloom, R. S. 2002. The role of the business model in capturing value from innovation: evidence from Xerox Corporation’s technology spin-off companies. **Industrial and Corporate Change**, 11(3): 529-555.

Christensen, C. M., & Rosenbloom, R. S. 1995. Explaining the attacker's advantage: technological paradigms, organizational dynamics, and the value network. **Research Policy**, 24: 233-257.

Cyert, R., & March, J. 1992. **Behavioral theory of the firm**: 2nd edition, Blackwell Publishing.

Cyert, R. M., & March, J. G. 1963. **Behavioral theory of the firm**. New Jersey: Prentice Hall Inc., Englewood Cliffs.

Danneels, E. 2002. The dynamics of product innovation and firm competences. **Strategic Management Journal**, 23(12): 1095-1121.

Danneels, E. 2007. The process of technological competence leveraging. **Strategic Management Journal**, 28(5): 511.

Dierickx, I., & Cool, K. 1989. Assets Accumulation and Sustainability of Competition Advantage. **Management Science**, 35(12): 1504-1514.

DiMasi, J., Hansen, R., & Grabowski, H. 2003. The price of innovation: new estimates of drug development costs. **Journal of Health Economics**, 22(2): 151-185.

Dosi, G. 1988. Sources, procedures and microeconomics effects of innovation. **Journal of Economic Literature**, 26: 1120-1171.

DuPont. 2011. Du Pont Telfon, Vol. 2011.

Dushnitsky, G., & Klueter, T. 2010. Is there an ebay for ideas? insights from online knowledge marketplaces. **European Management Review**.

Eisenhardt, K., & Schoonhoven, C. 1996. Resource-based view of strategic alliance formation: Strategic and social effects in entrepreneurial firms. **Organization Science**, 7(2): 136-150.

Fleming, L., & Sorenson, O. 2004. Science as a map in technological search. **Strategic Management Journal**, 25(8-9): 909-928.

Fosfuri, A. 2006. The licensing dilemma: understanding the determinants of the rate of technology licensing. **Strategic Management Journal**, 27(12): 1141.

Freeman, C., & Soete, L. 1997. **The economics of industrial innovation** (3rd ed. ed.): Pinter Press, London, UK.

Gambardella, A., & Giarratana, M. 2009. General technologies, product market fragmentation, and markets for technology: evidence from the software security industry. **draft, Bocconi University**.

Gambardella, A., Giuri, P., & Luzzi, A. 2007. The market for patents in Europe. **Research Policy**, 36(8): 1163-1183.

Gambardella, A., & McGahan, A. M. 2010. Business-model innovation: General purpose technologies and their implications for industry structure. **Long Range Planning**, 43(2-3): 262-271.

Gans, J. S., & Stern, S. 2003. The product market and the market for "ideas": commercialization strategies for technology entrepreneurs. **Research Policy**, 32(2): 333-350.

Ganuza, J.-J., Llobet, G., & Dominguez, B. 2009. R&D in the Pharmaceutical Industry: A World of Small Innovations. **Management Science**: mnsc.1080.0959.

Giuri, P., & Mariani, M. 2009. When distance does not matter: Inventors, education, and the locus of knowledge spillovers **working paper**.

Giuri, P., Mariani, M., Brusoni, S., Crespi, G., Francoz, D., Gambardella, A., Garcia-Fontes, W., Geuna, A., Gonzales, R., & Harhoff, D. 2007. Inventors and invention processes in Europe: Results from the PatVal-EU survey. **Research Policy**, 36(8): 1107-1127.

Graebner, M. E., & Eisenhardt, K. M. 2004. The seller's side of the story: Acquisition as courtship and governance as syndicate in entrepreneurial firms. **Administrative Science Quarterly**: 366-403.

Greve, H. 2003. A behavioral theory of R&D expenditures and innovations: Evidence from shipbuilding. **The Academy of Management Journal**, 46(6): 685-702.

Griliches, Z. 1990. Patent statistics as economic indicators: a survey. **Journal of economic literature**, 28(4): 1661-1707.

Gruber, M., MacMillan, I. C., & Thompson, J. D. 2008. Look before you leap: Market opportunity identification in emerging technology firms. **Management science**, 54(9): 1652-1665.

Hagedoorn, J. 2002. Inter-firm R&D partnerships: an overview of major trends and patterns since 1960. **Research Policy**, 31(4): 477-492.

Hall, B., Jaffe, A., & Trajtenberg, M. 2001. The NBER patent citations data file: lessons, insights and methodological tools.

Hall, B. H., & Trajtenberg, M. 2004. Uncovering GPTs with patent data: National Bureau of Economic Research.

Hallen, B. L., & Eisenhardt, K. M. 2011. Catalyzing Strategies: How Entrepreneurs Accelerate Inter-Organizational Relationship Formation to Secure Professional Investments. **Academy of Management Journal**: , forthcoming.

Harhoff, D., Narin, F., Scherer, F. M., & Vopel, K. 1999. Citation Frequency and the Value of Patented Inventions. **Review of Economics & Statistics**, 81(3): 511-515.

Hicks, D., & Hegde, D. 2005. Highly innovative small firms in the markets for technology. **Research Policy**, 34(5): 703-716.

Itami, H., & Roehl, T. W. 1991. **Mobilizing invisible assets**: Harvard Univ Pr.

Katila, R., & Shane, S. 2005. When does lack of resources make new firms innovative? **The Academy of Management Journal**, 48(5): 814-829.

Kirsch, D., Goldfarb, B., & Gera, A. 2009. Form or substance: the role of business plans in venture capital decision making. **Strategic Management Journal**, 30(5): 487-515.

Kline, S., & Rosenberg, N. 1986. An overview of innovation. **The positive sum strategy: Harnessing technology for economic growth**: 275-305.

Kogut, B., & Zander, U. 1992. Knowledge of the firm, combinative capabilities and the replication of technology. **Organization Science**, 3(3): 383-397.

Kogut, B., & Zander, U. 1993. Knowledge of the firm and the evolutionary theory of the multinational enterprise. **Journal of international business studies**, 24(4): 625-645.

Lei, D., Hitt, M. A., & Bettis, R. 1996. Dynamic core competences through meta-learning and strategic context. **Journal of management**, 22(4): 549.

Levinthal, D. 1998. The slow pace of rapid technological change: gradualism and punctuation in technological change. **Industrial and Corporate Change**, 7(2): 217.

Levinthal, D. A. 1997. Adaptation on rugged landscapes. **Management Science**, 43(7): 934-950.

Lichtenthaler, U., Ernst, H., & Hoegl, M. 2010. Not-Sold-Here: How attitudes influence external knowledge exploitation. **Organization Science**, 21(5): 1054-1071.

Long, J. S., & Freese, J. 2006. **Regression models for categorical dependent variables using Stata. 2nd edition**. College Park, TX: Stata Press.

Lopez-Vega, H., & Vanhaverbeke, W. 2010. How innovation intermediaries are shaping the technology market?

An analysis of their business model **working paper**.

Maine, E., & Garnsey, E. 2006. Commercializing generic technology: The case of advanced materials ventures. **Research Policy**, 35(3): 375-393.

March, J., & Simon, H. 1958. Organizations.

Mishina, Y., Pollock, T. G., & Porac, J. F. 2004. Are more resources always better for growth? Resource stickiness in market and product expansion. **Strategic Management Journal**, 25(12): 1179-1197.

Murray, F., Aghion, P., Dewatripont, M., Kolev, J., & Stern, S. 2009. Of Mice and Academics: Examining the Effect of Openness on Innovation. **National Bureau of Economic Research Working Paper Series**, No. 14819.

Murray, F., & O'Mahony, S. 2007. Exploring the foundations of cumulative innovation: Implications for organization science. **Organization Science**, 18(6): 1006-1021.

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

Nelson, R. R. 1990. Capitalism as an engine of progress. **Research Policy**, 19(3): 193-214.

Nerkar, A., & Shane, S. 2007. Determinants of invention commercialization: An empirical examination of academically sourced inventions. **Strategic Management Journal**, 28(11): 1155-1166.

Nohria, N., & Gulati, R. 1996. Is slack good or bad for innovation? **The Academy of Management Journal**, 39(5): 1245-1264.

Palomeras, N. 2007. An analysis of pure-revenue technology licensing. **Journal of Economics & Management Strategy**, 16(4): 971-994.

Palomeras, N., & Madrid, C. 2007. An analysis of pure-revenue technology licensing. **Journal of Economics & Management Strategy**, 16(4): 971-994.

Penrose, E. 1959. **The Theory of the Growth of the Firm**: Oxford University Press.

Prahalad, C. K., & Hamel, G. 1990. The core competence of the corporation. **Harvard Business Review**, May-June: 79-91.

Reitzig, M., & Puranam, P. 2009. Value appropriation as an organizational capability: The case of IP protection through patents. **Strategic Management Journal**, 30(7): 765-789.

Rivette, K., & Kline, D. 2000. Discovering new value in intellectual property. **Harvard Business Review**, 78(1): 54-146.

Rosenberg, N. 1976. Technological change in the machine tool industry, 1840-1910. In N. Rosenberg (Ed.), **Perspectives on Technology**, Vol. 23: 11-31. Cambridge Cambridge University Press.

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

Rothaermel, F., & Boeker, W. 2008. Old technology meets new technology: complementarities, similarities, and alliance formation. **Strategic Management Journal**, 29(1): 47.

Rothaermel, F. T. 2001. Incumbent's advantage through exploiting complementary assets via interfirm cooperation. **Strategic Management Journal**, 22(6-7): 687-699.

Sakakibara, M. 1997. Heterogeneity of firm capabilities and cooperative research and development: An empirical examination of motives. **Strategic Management Journal**, 18: 143-164.

Schoonhoven, C., Eisenhardt, K., & Lyman, K. 1990. Speeding products to market: Waiting time to first product introduction in new firms. **Administrative Science Quarterly**, 35(1).

Schumpeter, J. 1934. **The Theory of Economic Development: An Inquiry Into Profits, Capital, Credit, Interest, and the Business Cycle**: Harvard University Press, Cambridge, MA (originally published 1911).

Shane, S. 2000. Prior knowledge and the discovery of entrepreneurial opportunities. **Organization Science**: 448-469.

Shane, S., & Cable, D. 2002. Network ties, reputation, and the financing of new ventures. **Management Science**: 364-381.

Silverman, B. 1999. Technological resources and the direction of corporate diversification: Toward an integration of the resource-based view and transaction cost economics. **Management Science**: 1109-1124.

Singh, J. 1986. Performance, slack, and risk taking in organizational decision making. **The Academy of Management Journal**, 29(3): 562-585.

Stuart, T. E., & Podolny, J. M. 1996. Local search and the evolution of technological capabilities. **Strategic Management Journal**, 17 Issue Summer: 21-38.

Teece, D. J. 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. **Research Policy**, 15(6): 285-305.

Teece, D. J., Rumelt, R. P., Dosi, G., & Winter, S. G. 1994. Understanding corporate coherence. **Journal of Economic Behavior and Organization**, 23(1): 1-30.

Tripsas, M., & Gavetti, G. 2000. Capabilities, cognition and inertia: evidence from digital imaging. **Strategic Management Journal**, 21: 1147-1161.

Tushman, M. L., & Anderson, P. 1986. Technological discontinuities and organizational environments. **Administrative Science Quarterly**, 31(3): 436-465.

Venkataraman, S. 1997. The distinctive domain of entrepreneurship research. **Advances in entrepreneurship, firm emergence and growth**, 3(1): 119–138.

Verona, G., Prandelli, E., & Sawhney, M. 2006. Innovation and virtual environments: Towards virtual knowledge brokers. **Organization studies**, 27(6): 765-788.

Von Hippel, E. 1988. **The sources of innovation**. New York: Oxford University Press

Voss, G. B., Sirdeshmukh, D., & Voss, Z. G. 2008. The effects of slack resources and environmental threat on product exploration and exploitation. **The Academy of Management Journal (AMJ)**, 51(1): 147-164.

Wernerfelt, B. 1984. A resource-based view of the firm. **Strategic Management Journal**, 5(2): 171-174.

Winter, S. G. 2000. Appropriating the gains from innovation. In G. Day, & P. J. H. Schoemaker (Eds.), **Wharton on managing emerging technologies**. New York: Wiley.

Yang, H., Phelps, C., & Steensma, H. K. 2010. Learning from what others have learned from you: the effects of knowledge spillovers on originating firms. **The Academy of Management Journal (AMJ)**, 53(2): 371-389.

Yet2.com. 2009. Yet2.com Executive Overview, Vol. 2009.

Zhang, Y., & Li, H. 2010. Innovation search of new ventures in a technology cluster: the role of ties with service intermediaries. **Strategic Management Journal**, 31(1): 88-109.