Innovation Through Boundary Spanning: The Role of IT in Enabling Knowledge Flows Across Technological and Geographical Boundaries

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Innovation Through Boundary Spanning:
The Role of IT in Enabling Knowledge Flows Across Technological and Geographical Boundaries

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ABSTRACT

Innovation is considered the engine for firm growth. Especially innovations, through recombining seemingly unrelated knowledge streams, can have groundbreaking impact and lead to sustained competitive advantage. To generate such innovation, firms often need to go beyond their existing technological or geographical boundaries to identify and integrate novel knowledge elements. This article refers to firms' knowledge activities of drawing upon distant knowledge (i.e., knowledge from dissimilar technological domains or distant geographical regions) to create novel technological solutions, as innovation through boundary spanning. Aiming to investigate the roles of information technology (IT) in facilitating innovation through boundary spanning, we collected data from the pharmaceutical industry over a six-year period to test the research model. The data analysis results indicate that IT supports boundary-spanning activities in firm innovation and different IT-enabled knowledge capabilities affect boundary-spanning innovation differently.

KEYWORDS

Absorptive Capacity, Distant Search, Firm Innovation, Information Technology, Pharmaceutical Industry

INTRODUCTION

Innovation is the engine of growth for most companies. This is especially true for pharmaceutical firms. Executive of Eli Lilly stated, "If we don't innovate, we go out of business."[1] However, research has shown that on average it takes about three thousand raw ideas to produce one significantly new successful commercial product (Schilling, 2006; Stevens & Burley, 1997). The odds of certain industries are even worse. For instance in pharmaceutical industry, one out of every five thousand compounds reach a pharmacists' shelf [2]. And, only one-third of those will be successful enough to recoup their R&D costs (Schilling 2006). Recently information technologies have been widely used in innovation activities to enhance the effectiveness of innovation. For instance, AstraZeneca, a major player in the pharmaceutical industry, is relying on its IT to redesign its innovation model, targeting technologies to "facilitate spontaneous conversations between stakeholders… to share huge data

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sets and images… to support collaboration both within the walls of the enterprise as well as with outside partners" (Hickins, 2012). Wyeth, a biotechnology and pharmaceutical company that was acquired by Pfizer, also invests significantly in IT to support its innovation activities (Mandviwalla & Palmer, 2008). These investments enable virtual teams from different business units around the world to collaborate in research and to develop new drugs (Carr, 2008).

Recent empirical studies also attest to the role of IT in facilitating innovation, showing that IT has a positive effect on technological discoveries (Kleis, Ramirez, & Cockburn, 2011; Ravichandran, Han, & Mithas, 2017), new product/services (Joshi, Chi, Datta, & Han, 2010; P. A. Pavlou & Sawy, 2006) and growth potential (Bardhan, Krishnan and Lin 2013). However, little attention has been paid to the effect of IT on specific type of innovation (Nambisan, Lyytinen, Majchrzak, & Song, 2017). We aim to investigate the effect of IT on the innovations that involve firms' drawing on distant knowledge (i.e., knowledge from unfamiliar technological domains or distant geographic regions), which we refer to as innovation through boundary spanning because firms need to go beyond their existing technological or geographic boundaries to create such innovations (Fleming, 2001; Schilling & Phelps, 2007; von Krogh, 2012).

Innovations through boundary spanning are likely to generate breakthrough impact (Ahuja & Katila, 2001) (Harhoff & Lakhani, 2016) and greater influence on the subsequent technological evolution (Rosenkopf & Nerkar, 2001). For instance, the major strength of Thomas Edison's laboratory lies in combining knowledge from disparate industries. Their inventions, such as the phonograph, light bulb, motion picture camera, and electric motor, all involved blending existing unconnected technologies used in telegraph, lighting, telephone and railway systems (A. B. Hargadon & Sutton, 1997). Innovation through boundary spanning also has the potential to speed up new product development and reduce the costs of innovation (Fleming, 2001; A. Hargadon, 2003). For instance, a European partner of Proctor & Gamble's (P&G) discovered a small Italian bakery that had invented an ink-jet method for printing edible images on food products. This partner shared the discovery with P&G by posting it on P&G's knowledge management system. The Italian bakery's invention was then quickly integrated into the development of Pringles potato chips. As a result, P&G created a whole new product line of Pringles Prints from concept to launch in less than a year, which might have otherwise taken much longer, and at a fraction of what it would have otherwise cost (Huston & Sakkab, 2006). In this example, P&G innovated through spanning its geographic boundaries and was able to reduce the costs of innovation and the time to market.

Despite the benefit of spanning boundaries, it is difficult and costly for firms to do due to bounded rationality and path dependency (Cohen & Levinthal, 1990). The existing cognitive map, organizational routines, and communication channels tend to make firms search for solutions in familiar areas (similar technology fields or geographic regions in proximity), leading to core rigidity (Leonard-Barton, 1992) or a familiarity trap (Ahuja & Lampert, 2001). Limited research, however, has paid attention to the capabilities that facilitate innovations through boundary spanning. For instance, Katila (2002) called for more research on the capabilities that facilitate the scanning of a knowledge space to generate innovation. This research aims to fill this void by examining the roles of IT in helping firms to span existing technological and geographic boundaries for the purposes of innovation.

Recently innovation through boundary spanning has been further fueled by the emerging of new ways of innovating, such as open innovation and online communities. Firms are increasingly looking for new ideas or technical solutions externally- in their alliances, offshore R&D centers, and online innovation communities (Chesbrough, 2003; Chesbrough, Vanhaverbeke, & West, 2006). Open innovation provides greater opportunities for firms to find and integrate knowledge from a different field or a distant region (Faraj, Krogh, Monteiro, & Lakhani, 2016; Trantopoulos, Krogh, Wallin, & Woerter, 2017). What we focus on in this paper is firms' searching for and integrating ideas from their alliance partners, which can be considered a form of open innovation. More importantly, however, we are examining the cases where firms not only cross firm boundary, but also the boundary of technological domain or geographical region. Such type of innovation is more challenging, but more rewarding at the same time. For instance, it is found that when a firm joins an open innovation network with greater heterogeneity, it is awarded with greater abnormal returns in the stock market (K. Han et al., 2012).

We conceptualize firms' IT capabilities by drawing upon Absorptive Capacity theory, which has been widely used to explain firms' abilities to acquire and utilize external knowledge (Zahra & George, 2002). In this paper, by invoking the theory of absorptive Capacity, we develop three fine-tuned categories of IT-enabled knowledge capabilities: IT-enabled potential, realized, and socializing knowledge capabilities. We posit IT-socializing knowledge capabilities as distinct and separate from the other two capabilities proposed by Zahra & George (Zahra & George, 2002) because of increasing use of Social Media and Web 2.0 tools and the potential effect they have on innovation activities.

In particular, we examine the boundary spanning of the focal firm in the context of alliances, focusing on how firms draw on distant knowledge from its alliance partners. Alliances are an appropriate context in which to study boundary-spanning activities because alliances are often formed as an efficient and effective way for firms to access new knowledge in the presence of hyper-competition. (Grant, 1996; McGill & Santoro, 2009). Thus, we examine how IT helps firms to identify and integrate distant (technologically or geographically) knowledge from their alliance partners. More specifically, we capture the extent to which firms span across existing technological or geographic boundaries by examining the citations from the focal firm to their alliance partners. If the focal firm cites patents from their partners that are very different from their existing technological base or that are invented at a distant geographic location, they are spanning across boundaries.

We test our model by collecting data from the pharmaceutical industry over a six-year period. The pharmaceutical industry provides an appropriate context for exploring innovation through boundary spanning for the following reasons. First, the discovery of new drugs requires input from an array of disciplines such as physiology, biochemistry, bioengineering, synthetic chemistry, molecular biology, and pharmacology, making it a natural context for studying boundary-spanning activities. Moreover, many of the world's large pharmaceutical companies have become increasingly dependent on a few blockbuster drugs, whose patents are up for expiration in a few years. Thus, a lot of pharmaceutical firms are now looking to shift their emphasis from blockbuster drugs to lower-volume specialty drugs. To get into such areas, they need to ally themselves with partners who know the requirement and the science behind those specialty conditions. An exemplar of such step could be pharmaceutical firm's increasing alliances with biotechnology firms (Cockburn, 2004) . Such alliances require a pharmaceutical firm to engage in boundary spanning activities to integrate diverse knowledge. Last, pharmaceutical industry relies heavily on patents to protect their innovation. Thus, we are more likely to capture the characteristics of their innovations by examining their patents and tracing their patent citations.

We collect patent and citation data from the PATSTAT database (Patent Statistical Database) published by European Patent Office and USPTO (United States Patent and Trademark Office) patent database and IT data from surveys conducted by Harte-Hanks. The findings of this study make multiple contributions. First, it contributes to the research stream in Information Systems that examines the relationship between IT and innovation by uncovering the role of IT in boundary-spanning innovation, which is an important and yet challenging one. Second, our findings provide a contingency view of IT's role in firm innovation by revealing the nuances and complexities embedded in this relationship. Our results suggest that the three IT-enabled knowledge capabilities influence boundary-spanning innovation differently. Furthermore, we find that geographic and technological boundary spanning requires different types of IT-enabled capabilities. This shows that IT is not monolithic and its effects on innovation are not uniform. Rather, IT's effects on innovation are not only contingent on the functionalities and capabilities embedded within it, but also depend on the innovation context. We believe that this research offers a starting point for investigating an important, yet under-explored, domain that calls for more studies of the aforementioned contingencies in order to better understand the role of IT in firm innovation. Lastly, the results from this study provide useful guidelines for companies, especially pharmaceutical companies, on the use of IT functionalities to enable innovation.

The rest of this paper is organized as follows. We first present the theoretical background. After that, we develop our research hypotheses, followed by a description of the research methodology. The next two sections present and discuss the research results. We then discuss our theoretical and practical contributions, followed by the conclusion of the paper.

BACKGROUND

In this section, we will discuss the theoretical background for innovation through boundary spanning and IT-enabled knowledge capabilities.

Innovation Through Boundary Spanning

Boundary spanning through technologically-dissimilar domains promotes cross-pollination of ideas and knowledge elements to create new and novel solutions. For example, it was through technological boundary spanning that the idea of a piano keyboard from the musical world was used to create early manual typewriters in the business world. Likewise, the computer industry created IBM punch cards by borrowing ideas from a punch-card system for weaving complex fabric patterns on a silk loom in the fabric manufacturing industry. Although cross-pollination can sometimes generate breakthrough innovations, firms tend to rely primarily on technical knowledge that is in close proximity to their own knowledge base to create future innovations. This is because it is cognitively easier for firms to search for and absorb knowledge that is technically similar to their existing knowledge (Cohen & Levinthal, 1990). In this study, we argue that firms' knowledge capabilities that are enabled and supported by IT (IT-enabled knowledge capabilities) can mitigate the aforementioned cognitive barriers to technological boundary spanning.

Boundary spanning through geographically distant regions allows harnessing of knowledge stocks for innovation that are dispersed across geographic boundaries. The extant literature has emphasized the importance of geographic proximity for one firm to access knowledge held by other firms for the purposes of innovation (Saxenian, 1990; Tallman & Phene, 2007). This literature argues that physical proximity allows for greater absorption of knowledge spillovers because diffusion of such spillovers across geographic distance is arduous. In this study, we argue that geographic barriers to knowledge flow can be lowered through IT-enabled knowledge capabilities.

IT-Enabled Knowledge Capabilities

In this study, we categorize IT into three fine-tuned sub-constructs, which we referred to as IT-enabled knowledge capabilities. This conceptualization is based on the absorptive capacity theory (Zahra & George, 2002) and Joshi et al.'s (Joshi et al., 2010) theorization. These IT-enabled knowledge capabilities include IT-enabled potential knowledge capability, IT-enabled realized knowledge capability, and IT-enabled socializing knowledge capability.

IT-Enabled Potential Knowledge Capability (IT-Potential)

Potential knowledge capability makes a firm receptive to acquiring and assimilating internal and external knowledge (Lane & Lubatkin, 1998; Zahra & George, 2002). Information technologies that help enable and support knowledge acquisition and assimilation are characterized as IT-enabled potential knowledge capability (Joshi et al., 2010).

Knowledge acquisition involves firms' ability to identify and obtain knowledge that is critical to their operations. There are several information technologies that can support and enhance firms' knowledge acquisition capabilities by amplifying the speed, intensity, and directionality of knowledge identification and selection. For instance, retrieval technology such as query software or search engines can help firms to locate relevant knowledge. Knowledge directories and expert finders help firms to locate experts with relevant knowledge. Various enterprise applications also support knowledge acquisition. For instance, CRM gathers and integrates customer-related data from different functions of marketing, sales and customer services, as well as diverse media sources (e.g., Web, email, call center, store outlet, mail) into a single, consistent view for better insight into customer behavior.

Knowledge assimilation capability involves a firm's ability to store acquired knowledge in its organizational memory and diffuse it among its organizational members. IT can enhance a firm's assimilating capability by creating organizational memory in the form of electronic repositories (Alavi & Leidner, 2001). IT can help firms with storing information in formats that are accessible to employees and enable them to interpret it in a consistent manner, thereby becoming a part of the entire firm's memory. There are several information technologies that can help enhance organizational memory. For instance, content management systems, databases, and data warehouses can help store various forms of data, information, and knowledge.

IT-Enabled Realized Knowledge Capability (IT-Realized)

Realized knowledge capability involves a firm's ability to transform knowledge to generate innovations (Zahra & George, 2002). Transformation capability synthesizes, develops and refines the existing and newly acquired and assimilated knowledge. Transformation can occur by adding, deleting or re-interpreting the absorbed knowledge in a different manner or for knowledge reuse. Transformation also allows organizations to view and develop knowledge through bisociation. This is achieved when knowledge from "two self-consistent but incompatible frames of reference" (Koestler, 1966, p. 35) is visualized and integrated to create new insights, to facilitate the recognition of opportunities, and to alter the way the firm sees itself and its competitive landscape. Information technologies that help enable and support knowledge transformation are characterized as IT-enabled realized knowledge capability (Joshi et al., 2010). Business intelligence tools such as data mining and analytical tools allow firms to transform existing data and knowledge to gain new insights and understanding. Visualization software can support bisociation by integrating and mapping disparate knowledge sets to uncover new knowledge.

IT-Enabled Socializing Knowledge Capability (IT-Socializing)

Socializing knowledge capability promotes connectedness, interactions, sharing, and cooperation among individuals and groups that build social capital (Zahra & George, 2002). Socializing capability has received increased attention lately. For instance, Nemanich et al. (Nemanich, Keller, Vera, & Chin, 2010) suggest that shared cognition capability is a dimension of absorptive capacity, in addition to the other three traditional dimensions (capabilities to evaluate, assimilate and apply knowledge). Information technologies that help enable and support social interactions to cultivate social capital are characterized as IT-enabled, socializing knowledge capabilities. For instance, e-mail, video-conferencing, and groupware systems are all instrumental in cultivating direct human interactions. Message boards and e-communities of practice help create a seamless network of people that share knowledge and develop shared discourse (Boland & Tenkasi, 1995; Hansen, 1999). IT can support both formal and informal social interactions. For instance, the use of video conferencing and groupware facilitates formal socialization, while tools such as e-community of practice, wikis, and blogs create opportunities for informal socialization (Shneiderman, 2007).

THEORETICAL MODEL

In this section, we present our research model that posits the role of three kinds of IT capabilities in innovation through boundary spanning. Figure 1 delineates the relationships of each IT capability with the innovation outcome. The absorptive capacity theory (Cohen & Levinthal, 1990; Zahra & George, 2002) forms the core theoretical foundation underlying this model. Below, we draw on the absorptive capacity literature to make our key argument that three particular IT-enabled absorptive capabilities can help lower the knowledge barriers created by cognitive and geographic boundaries in firm innovation activities.

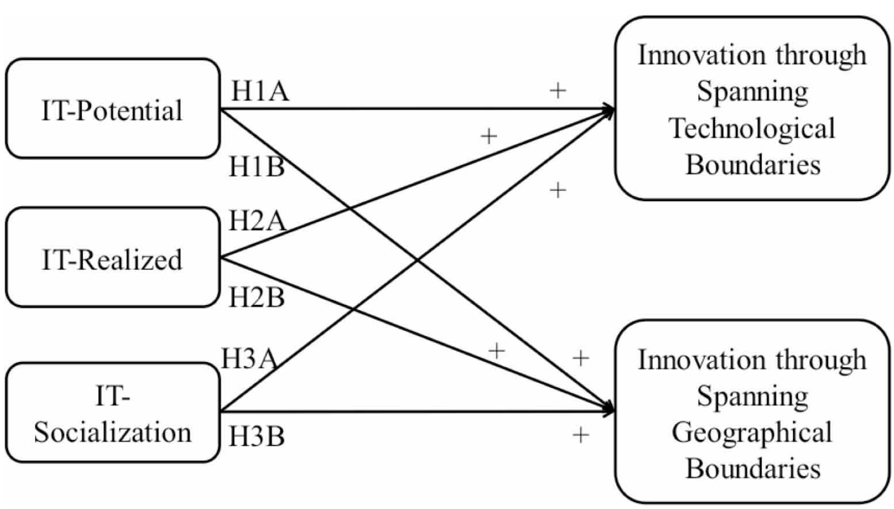
IT-Potential and Boundary-Spanning Innovation

Greater IT-enabled potential knowledge capability provides firms with a broad range of tools to acquire and assimilate a greater amount of technologically or geographically-distant knowledge from its alliance partners that otherwise may be costly or difficult to obtain.

IT-enabled knowledge acquisition capability enhances boundary spanning by two means. First, sophisticated retrieval technology such as query software, search engines, and knowledge maps can help identify, collect, and extract useful knowledge from a wide variety of knowledge resources within a firm's alliance partners with great speed and accuracy. Second, greater IT-Potential also enhances a firm's awareness of the relevant knowledge that may reside in its alliance partners through acquisition of meta-knowledge about its partners. It provides a firm with information about who possesses what knowledge, and who can solve what problems among its alliance partners (Cohen & Levinthal, 1990). Use of information technology, such as directory services and expert finder, can strengthen an organizational member's awareness of other members' knowledge and expertise. In addition, the inter-organizational systems, such as enterprise resource planning systems that facilitate the flow of knowledge resources across organizational boundaries, serve as a crucial infrastructure for acquisition of new knowledge.

Besides knowledge acquisition capability, IT-enabled knowledge assimilation capability can also facilitate boundary spanning. Cohen and Levinthal (1990) suggest that an organization's absorptive capacity depends on its ability to share knowledge among organizational members. As is often the case, knowledge from firms' alliances is first acquired by an individual or a unit within an organization and thus remains localized. The acquired knowledge may not be useful to the part of the organization

Figure 1. The relationship of each IT capability with the innovation outcome



that originally acquired it. It, however, could be valuable to a different part (e.g., function or division) of the organization. Therefore, the extent to which the localized knowledge can be embedded within an organization's memory will determine its value and utility. In the P&G example discussed at the beginning of the paper, the innovative use of the novel distant knowledge that was first acquired by P&G's foreign partner would not have materialized if this knowledge remained localized at its origin of discovery. P&G's organizational memory systems enabled the internalization and assimilation of the distant knowledge for future use. Organizational memory systems can increase the chance that the novel knowledge elements that are acquired from distant contexts, codified, and stored in the system, can be accessed throughout the firm and used later to generate new combinations of technological solutions.

Taken together, we propose the following:

HYPOTHESIS 1A: IT-Potential is positively associated with a firm's innovation through spanning technological boundaries.

HYPOTHESIS 1B: IT-Potential is positively associated with a firm's innovation through spanning geographic boundaries.

IT-Realized and Boundary-Spanning Innovation

IT-enabled realized capability offers a firm a wide range of tools for knowledge transformation, which greatly enhances its ability to conduct in-depth analyses of acquired and assimilated knowledge to gain a better understanding of how distal knowledge can be used innovatively. Information technologies, such as simulation and visualization tools, can greatly enhance bisociation capabilities of connecting and integrating knowledge from different contexts by merging, categorizing, reclassifying, and synthesizing it into forms that are meaningful to the focal firm. For instance, to discover the potential side effects of a drug that is already on the market, pharmaceutical companies need to integrate information from a diversity of sources, such as hospital records, patient journals, and insurance claims[3]. IT-Realized capability can help extracting insight by fusing, integrating and juxtaposing data from these disparate sources. Furthermore, the cognitive and physical limits of human brains can be augmented through IT tools such as business intelligence and visualization software that have the capability to mine, interpret and discover patterns and insights from large volume of data.

Knowledge, particularly distal knowledge, is often situated in specific contexts and is bounded by specific practices and value systems, making it difficult to transfer knowledge across boundaries. Analytical tools and simulation models that use a standard interface and common syntax (e.g. CAD-Computer Aided Design software) can help create a shared language; thus, facilitating coordination and greater innovation through boundary-spanning (Carlile, 2004). The models and prototypes developed using CAD can also serve as the boundary-objects between parties (Grant, 1996), which can ease the flow of new knowledge necessary for creating innovation.

Therefore, we propose the following:

HYPOTHESIS 2A: IT-Realized is positively associated with a firm's innovation through spanning technological boundaries.

HYPOTHESIS 2B: IT-Realized is positively associated with a firm's innovation through spanning geographic boundaries.

IT-Socializing and Boundary-Spanning Innovation

Knowledge from different contexts can be difficult to identify and integrate because of the dearth of social interaction among key agents that could create knowledge flows between the focal firm and its alliance partners. Moreover, when people are from different fields or geographical locations normally do not have an opportunity to meet face-to-face, communication visibility-who knows what and who knows whom, is especially low, which impedes knowledge flow. It has been found the enterprise socialization software can increase communication visibility via message transparency and network translucence, thus enhance knowledge sharing and innovation (Leonardi, 2014). Furthermore, IT-Socializing provides a broad spectrum of rich media and communication tools to facilitate the flow across diverse contexts by creating spontaneous, ad-hoc, and informal channels through which new knowledge can be shared. These informal channels, which are not supported by the formal communication and information exchange structures institutionalized by the organization are the wellsprings of innovation.

People coming from different contexts may have different assumptions, perceptions of reality, and understanding of issues. IT-Socializing is critical to the integration of knowledge acquired from a different context because it provides an infrastructure for various forms of social interactions that can help in establishing a common perspective for people from different technological backgrounds or geographic locations. Nemanich et al. (2010) suggests that external knowledge is shared among different members of an organization through social interpretation, which they referred to as shared cognition. One of the communication barriers for parties from different contexts is that they have different hidden assumptions. Having a space where members from different communities can share narratives or stories of their experiences can help with disclosing the implicit and unstated assumptions (Boland & Tenkasi, 1995; Santoro, 2006). In addition, the process through which the audience of the narratives "read into" the story enables them to open up to the perspective from another context, making it possible for them to see the world differently (Bruner, 1990). A firm's IT-Socializing tools (often referred to as Enterprise Social Software), such as e-community of practice, Wikis, social tagging/bookmarking can serve as seeding grounds for developing and sharing such narratives. Moreover, sharing of narratives through multimedia tools provided by IT-Socializing, such as videoconferencing, can provide the benefits of learning by experience (Boland & Tenkasi, 1995).

It is through social interactions between people from different contexts that existing knowledge from different contexts converges and gets re-combined, leading to the creation of new ideas (McGill & Santoro, 2009). Mobility of tacit knowledge across boundaries requires richer and more frequent communication (Santoro, 2006). IT –Socilizing tools, such as online communitites, give rise to repeated interaction among members (Faraj et al., 2016). Besides, IT-Socializing provides a range of media options that permits synchronous and spontaneous interactions, as well as use of non-verbal communication between individuals. By providing immediate feedback and rich information, these options foster the "moment of imaginary" when new ideas emerge (Gergen, McNamee, & Barrett, 2001; Vlaar, Fenema, & Tiwari, 2008). Furthermore, the demand for highly interactive, informal, and non-standardized coordination increases with the complexity and uncertainty of the task at hand (Vlaar et al., 2008). Innovation itself is characterized by a high level of ambiguity and uncertainty; and integration of knowledge from distant domains or regions, in particular, is shown to be risky (Dougherty, 1992). IT-Socializing, by offering a wide range of audio, video and multimedia tools, greatly enriches the information intensity and level of interactions among individuals. The media richness provided by IT-Socializing allows "wide ranging and deep interactions between individuals and, thus, permits the establishment of trust and development of common understanding" (Rosenkopf & Almeida, 2003), thus reducing the risks of uncertainty and ambiguity in developing new technological solutions.

Taken together, we propose the following:

HYPOTHESIS 3A: IT-Socializing is positively associated with a firm's innovation through spanning technological boundaries.

HYPOTHESIS 3B: IT-Socializing is positively associated with a firm's innovation through spanning geographic boundaries.

METHOD

In this section, we discuss our data collection procedure, variable measures, and data analysis method.

Data Collection

We collected data from the pharmaceutical industry to empirically test our research model for three major reasons. First, innovation is extremely important and costly for pharmaceutical companies. When the patent of a certain drug expires, pharmaceutical firms are faced with competition from low-priced generic substitutes. This forces them to compete by continually introducing new drugs. Second, the process of drug discovery is particularly long, costly and risky. A new drug can take 8 to 10 years and costs 0.8 to 1 billion dollars to develop. Third, drug development usually requires integration of knowledge from multiple disciplines, which makes boundary spanning critical for innovational success in the pharmaceutical industry. Finally, alliance formation is common in the pharmaceutical industry as a means to access external knowledge.

We first obtained a list of 272 public pharmaceutical companies based on the standard industry classification code (SIC 2834). By eliminating firms that had no alliances during the time window included in this study and matching the remaining companies with IT data, we ended up with an unbalanced panel of 123 observations of 31 unique pharmaceutical companies over a six-year period from 2000 to 2005.

To test our model, we collect secondary data about firms' IT-enabled knowledge capabilities and innovation outcomes from multiple secondary data sources. There is an increase in the use and acceptance of secondary data while modeling firm level effects of IT on firm performance (A. Bharadwaj, S., Bharadwaj, & Konsynski, 1999; A. S. Bharadwaj, 2000; Brynjolfsson & Hitt, 1996; Hitt & Brynjolfsson, 1996; Kraemer, Dedrick, & Yamashiro, 2000). This could be because the primary data is susceptible to common method bias. Primary data collections that are based on respondents' preferences, perceptions, and memory are relatively more subjective than secondary data (Devaraj and Kohli 2003; Joshi et al. 2010).

We collected patent citation data for our sample companies to capture innovation through boundary spanning at the firm level[4]. When a citation to a prior patent emerges on a new patent, it suggests that the inventor has both successfully acquired and built upon the knowledge underlying the earlier patent (Sorenson, Rivkin, & Fleming, 2006). We capture the extent to which firms span their technological boundary by examining the distance between their own patents portfolio and the collection of patents that they cite from their alliance partners. If the patents they cite are very different from their existing patents, they are spanning across their existing boundaries. The information of technological domain of the citing and cited patents is used to construct the measurement of innovation through technological boundary and the inventor location of the citing and cited patents is used to construct the measurement of innovation through geographic boundary spanning.

We collected patent citation data from the PATSTAT database (Patent Statistical Database) published by European Patent Office and USPTO (United States Patent and Trademark Office) patent database. Since our research context is bound by alliance partners, we collected a total of 80,250 patents from the 31 pharmaceutical companies, with 8,217 patent citations that were made by the pharmaceutical companies citing the patents of their alliance partners from 2000-2006. For firm citation data, we took one-year lag after the IT usage in a given year.

Variable Measures

Dependent Variable: Innovation Through Boundary Spanning

We followed Rosenkopf and Almeida's (Rosenkopf & Almeida, 2003) approach by using the technology classes defined by USPTO to reflect the technological domain of a knowledge element and by using the inventor location to reflect the geographic region of a knowledge element.

- **Innovation through Spanning Technological Boundaries:** The U.S. patent office assigns each granted patent a specific technological class. This classification system is developed and constantly updated by the U.S. Patent Office. We used the 2006 class system, which tabulates all the granted patents into six technological classes (Chemical, Computers & Communications, Drugs & Medical, Electrical & Electronic, Mechanical, and Others). We computed the technological boundary-spanning innovation as a distance measure based on the Euclidean distance between two profiles: one is comprised of the patents of the focal pharmaceutical firm, and the other is comprised of the patents that the focal firm cites from its alliance partners (Equation (1)):

$$Technological\ Distance = \sqrt{\sum_{i=1}^{6}\left(\frac{n_{1i}}{N_1} - \frac{n_{2i}}{N_2}\right)^2} \tag{1}$$

n_{1i}: Number of patents from a pharmaceutical firm 1 in class i.
N_1: Total number of patents from the firm 1.
n_{2i}: Number of patents that firm 1 cites from its alliance partners in class i.
N_2: Total number of patents that firm 1 cites from its alliance partners.

The measure of innovation through boundary spanning ranges from a MIN of 0 (which means the citing pharmaceutical firm has an identical technology profile to all the cited patents of its alliance partners) to a MAX of 1.4, which is the square root of 2, where both the pharmaceutical firm and its alliance partners concentrate 100% of their innovations on only one technology class, and each firm is active in a different class from others. We obtained technological boundary spanning for the 31 companies ranging from 0.06 to 1.28. A high score in technological boundary spanning between the pharmaceutical firm's patents and the patents it cites suggests that the pharmaceutical firm utilizes more knowledge elements outside its technological boundary to innovate.

- **Innovation through Spanning Geographic Boundaries:** The U.S. Patent Office records each patent inventor's geographic information. We use this information for a construct measure of geographic boundary spanning. Following Rosenkopf and Almeida (Rosenkopf & Almeida, 2003), for each citation from the focal firm to its alliance partners, we used a binary variable to indicate whether a pharmaceutical company is located in the same geographic region as the inventor of the cited patent (one if they are from different regions; zero if they are from the same one). We then summed up all of the binary values for each company as the measure for its geographic boundary spanning. Based on the US Census of Bureau classification, we divided the US into a total of nine geographic regions: New England, Mid Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, and Pacific. We classified regions outside of the US based on national boundaries. Altogether, the patent citations among the 31 pharmaceutical companies and their alliance partners involved a total of 30 regions within and outside of the US. A high score in geographic boundary spanning among the pharmaceutical firm's citing patents and cited patents suggests that the pharmaceutical firm utilized more knowledge elements outside of its geographic region.

Independent Variables: IT-Enabled Knowledge Capabilities

We collected IT data through the Harte-Hanks database. Harte-Hanks is a market intelligence company, which conducts surveys or on-site interviews about the IT usage of various hardware and software at selected corporate sites of major US companies each year. From Harte-Hanks, we obtained data for over 50 different IT applications used in our sample companies from the years 2000-2005, ranging from business intelligence, database, document management, content management, groupware, portal, and multimedia to various enterprise applications such as CRM, SCM, ERP and enterprise application integration such as Web services, and middleware.

We measured the three IT-enabled knowledge capabilities using the IT applications implemented in the pharmaceutical firms included in our sample. Joshi et al. (Joshi et al., 2010) developed a comprehensive categorization of IT-enabled knowledge capacities and methodology for measuring these capabilities using secondary data of IT applications. Harte-Hanks data provide site-level details about the revenue and various IT applications at each selected site of a pharmaceutical company. In order to obtain a firm-level measure, we first adjusted each site *s*'s IT applications by the total applications of all companies used in each year to account for the variation in IT applications from one year to another. Second, we weighted each site's revenue by the total of all selected sites of a company to account for different IT-enabled knowledge capabilities of different sites and then aggregated the weighted IT applications of all selected sites to represent a pharmaceutical company's, (*i*), IT-enabled knowledge capabilities in year *t*, $IT_{i,t}$ (Equation 2):

$$IT_{i,t} = \sum_{s=1}^{n_i} (w_{s,i,t} * IT_{s,i,t}) / IT_t \tag{2}$$

$IT_{s,i,t}$ = number of IT applications in each subcategory at site s of company i in year t
IT_t = total number of IT applications in year t
n_i = number of selected sites for company i

$$w_{s,i,t} = \frac{r_{s,i,t}}{\sum_{s=1}^{n_i} r_{s,i,t}}$$

$r_{s,i,t}$ = revenue at site s if company i and year t

IT-enabled knowledge capability has three sub-constructs: IT-Potential, IT-Realized, and IT-Socializing. IT-Potential capability is reflected in IT applications such as data reading or digital capture technology, search tools & directory services, databases (data warehouses), document management systems, content management systems, and enterprise applications (e.g., SCM, CRM, ERP). IT-Realized capability is reflected in IT applications including business intelligence, data analytics, data mining, visualization, simulation, decision support system, and CAD/CAM. IT-Socializing capability is reflected in IT applications including e-community of practice (e.g., blogs, wikis, BBS), messaging (e.g., email, instant messaging, VoIP, mobile messaging), conferencing (e.g., videoconferencing, multimedia), portals, groupware, and enterprise application integration (e.g., Web services, middleware, SOA). IT applications at each site were first counted and mapped to each of the three IT constructs by using the IT capability definition and characterization provided by Joshi et al (2010). Equation 2 was then used to calculate the three types of IT-enabled knowledge capabilities of a pharmaceutical company.

We control for firm size, its R&D efforts, and the number of citations a firm makes to cite patents from its alliance partners, as these three variables may significantly affect the extent to which firms draw upon knowledge that is outside its alliance partners' boundaries. Firm size is measured by number of employees. A firm's R&D effort is measured by the R & D spending of a pharmaceutical firm.

Data Analysis

Table 1 shows the descriptive statistics of our variable measures. From Table 1, we see the correlations among the three IT sub-constructs are relatively low, suggesting that these are distinct constructs. We examined two dependent variables: innovation through technological

Table 1. Descriptive statistics

Variables	Min	Max	Mean	SD	1	2	3	4	5	6	7
1. Technological Boundary-Spanning Innovation	0.06	1.28	0.26	0.17	-						
2. Geographic Boundary-Spanning Innovation	0.00	1156	187.88	280.33	-0.34***	-					
3. IT-Potential	0.04	0.73	0.26	0.12	-0.09	-0.05	-				
4. IT-Realized	0.00	0.54	0.05	0.11	-0.12	0.07	0.29***	-			
5. IT-Socializing	0.13	0.95	0.45	0.20	0.12	0.05	0.13	0.09	-		
6.Number of Employees (Millions)	0	0.12	0.05	0.03	-0.39***	0.37***	0.15	0.19*	-0.06	-	
7. Patent Citations Made to Cite Patents of Alliance Partners (Thousands)	0	1.23	0.24	0.34	-0.36***	0.97***	-0.06	0.09	0.04	0.41***	-
8. R & D spending ($ Billions)	0.07	9.09	2.44	1.84	-0.38***	0.32***	0.06	0.14	-0.18	0.84***	0.34***

N = 80; *p < 0.1; **p < 0.05; ***p < 0.01

boundary spanning and innovation through geographic boundary spanning. As our data was an unbalanced panel dataset, given the relatively small sample size, we used a firm random effect model, controlling for year effects. Results for technological boundary spanning innovation are presented in Table 2. Geographic boundary spanning is a count variable with over-dispersion (standard deviation (280.33) is larger than its mean (187.88)), so we used a negative binomial regression to accounts for the over-dispersion. Results for geographic boundary spanning innovation are presented in Table 3.

Table 2. Regression results (Dependent variable: Technological boundary-spanning innovation)

Variables	Coefficients
IT-Potential	-0.26
IT-Realized	0.06
IT-Socializing	0.25**
Employee number	-0.37
Patent Citations Made to Cite Patents of Alliance Partners	-0.13**
R&D Spending	-0.02
Year-Fixed Effects	Yes
Wald Chi-square	25.32***
N	80

*p < .10; ** p < .05; ***p < .01

Table 3. Negative binomial regression results (Dependent variable: Geographic boundary-spanning innovation)

Variables	Coefficients
IT-Potential	0.06
IT-Realized	0.77***
IT-Socializing	0.24
Employee number	1.55
Patent Citations Made to Cite Patents of Alliance Partners	1.56***
R&D Spending	0.14
Year-Fixed Effects	Yes
Wald Chi-square	271.18***
Log Likelihood	-351.48
N	80

*p < .10; ** p < .05; ***p< .01

RESULTS AND DISCUSSIONS

H1A proposes a positive relationship between IT-Potential and technological boundary-spanning innovation. Our result fails to support H1A and shows that the relationship is negative but not significant ($b = -0.26$, $p > 0.1$). H1B proposes a positive relationship between IT-Potential and geographic boundary spanning innovation. Our result fails to support H1B and shows that the relationship is positive but not significant ($b = 0.06$, $p > 0.1$).

H2A proposes a positive relationship between IT-Realized and technological boundary-spanning innovation. Our result shows that the relationship is positive but not significant ($b = 0.06$, $p > 0.1$), thus failing to support H2A. However, our result provides strong support for H2B, which proposes a positive relationship between IT-Realized and geographic boundary-spanning innovation ($b = 0.77$, $p < 0.01$).

Our result also provides good support for H3A, which proposes a positive relationship between IT-Socializing and technological boundary-spanning innovation ($b = 0.25$, $p < 0.05$). However, we failed to find support for H3B, which proposes a positive relationship between IT-Socializing and geographic distance ($b = 0.24$, $p > 0.1$).

Overall, our results suggest that IT can affect boundary-spanning innovation in the pharmaceutical industry, but the positive effects of IT on innovation are contingent upon the knowledge capabilities supported by the IT functionalities. The differential effects of IT capabilities on boundary-spanning innovation as indicated by a partial support of our posited model suggest that not all IT capabilities have a uniform or direct impact on firm innovation. This is an important finding, which, as discussed below, needs further investigation.

IT-Potential knowledge capability does not seem to play a statistically significant role in influencing innovation through boundary spanning. A possible explanation could be that IT-Potential might provide search and retrieval capabilities that enable fast access to diverse codified regulatory and scientific data from digital databases, but IT-Potential, by itself, may not be sufficient in locating or assimilating tacit knowledge required for innovations in the pharmaceutical industry. Tacit knowledge is embedded in human brains and a firm's work processes, and the process of converting tacit knowledge to explicit is critical for moving the knowledge across boundaries (Nonaka, 1994). Similarly, Boland and Tenkasi (Boland & Tenkasi, 1995) argued that for integration of knowledge to occur, the diverse knowledge held by individuals must be presented in an explicit way and made available for others to incorporate in their knowledge-intensive activities. Thus, the effect of IT-Potential may be limited before tacit knowledge is externalized. Another possible explanation is that firms may be incapable of comprehending the new and external knowledge identified through IT-Potential capability. This may constrain a firm's knowledge absorption. In other words, when IT-Potential capability helps locate a certain useful knowledge element that is from an unfamiliar field and therefore cognitively distant, the firm may not be able to recognize the value of this knowledge element because they lack the adequate prior knowledge necessary to assimilate the newly acquired knowledge.

Regarding spanning geographic boundaries, IT-Realized capability seems to play a significant role, but not IT-Socialization. This result indicates that IT-Realized capability facilitates the understanding and use of geographically dispersed knowledge among the alliance partners in the pharmaceutical industry. One of the reasons cited for the lengthy and expensive drug discovery process is that clinical-trial information is normally scattered in different systems and locations, which makes it difficult for clinicians to extract insight due to the fragmented view of the data[5]. The sophisticated analytical and visualization tools are important in mining, mapping and interpreting knowledge from different geographic locations to generate insights. Such results are consistent with prior findings that modularization and digitalization can help with the coordination between headquarter and offshore R&D centers for more analyzable tasks (Mani, Srikanth, & Bharadwaj, 2014). However, IT-Socializing does not affect innovation that is created through spanning the geographic boundaries. We reason that geographically-distant partners have different cultures, work practices, and time zones that could constrain knowledge flows even when the barriers to physical proximity are lowered. Sometimes synchronous and rich communications technologies that allow for immediate feedback such as video-conferencing may not be suitable for geographically-distant partners (e.g., German, Indian partners) who work in widely different time zones or have widely different work cultures (Clark, 1996). They may even have different norms regarding the use of these socialization tools. As such, in geographically-distant contexts and with increasing psychic distance, IT-Socializing capability may be limited by itself in creating new knowledge. Incentives and mechanisms that facilitate the understanding and familiarization of work practices and cultures of geographically-distant partners may be needed in order for IT-Socializing capability to be effective.

Regarding spanning technological boundaries, our results suggest that a host of rich information tools with varying functionalities, provided by IT-Socializing capability, can be effective. For instance, videoconferencing enables synchronous knowledge exchanges that not only allow immediate feedback but also convey subtle social cues, which enhance the understanding and processing of sticky knowledge (Dennis, Fuller, & Valacich, 2008). IT-Realized, however, falls short of contributing to spanning technological boundaries for innovation. Its inability to significantly affect innovation through spanning technological boundaries may be because the cognitive barriers to absorbing sticky and technologically distant knowledge in the pharmaceutical industry are particularly high. It is consistent with findings from prior research that when the nature of the task is less routinized and analyzable, which is typical for combining knowledge from different fields, digitalization and modularization are ineffective in coordinating distributed R&D works (Mani et al., 2014). Overcoming these barriers may also require a sufficient understanding of the knowledge context gained through the process of socialization. IT-Realized capability conceivably can be used in combination with IT-Socializing capability to effectively bridge technological boundaries in the pharmaceutical industry. Future research should investigate the interaction effects of these two capabilities.

IMPLICATIONS FOR RESEARCH AND PRACTICE

This study makes several important contributions. First, the paper contributes to IS research by examining the roles of IT in an important and unique value-adding context, i.e., innovation through boundary spanning. While prior IS research on the effects of IT on innovation has paid attention to the innovation output in general, for example, patent count (S. Han & Ravichandran, 2006; Kleis et al., 2011; Sabherwal & Sabherwal, 2005) and new product introduction (Joshi et al., 2010; P. Pavlou

& El Sawy, 2006), this research examines the type of innovation that draws upon knowledge sources across boundaries. We capture sources of knowledge elements through patent citations. This greater granularity in measuring innovation outputs enables us to examine the role of IT in a specific form of innovation, where firms search and integrate knowledge from unfamiliar technological areas or distant geographic regions. If we consider innovation through boundary spanning to be located at one end of the continuum of innovative activities, exploitation of the existing knowledge base rests at the other end (March, 1991). This paper highlights the role of IT in the explorative activities in firms' innovation pursuit, i.e., acquiring and combining knowledge across boundaries to continually reconfigure and refresh their knowledge bases for innovation. It would be interesting for future research to examine the use of IT and the trajectory of a firm's knowledge base.

Second, this research contributes to the literature by providing a more nuanced view of IT's roles in boundary–spanning innovation. We show that IT's effects on innovation through boundary spanning are contingent on IT's functionalities and the context within which these functionalities are being utilized. More specifically, our results highlight the differences among three distinct IT-enabled knowledge capabilities, i.e., IT-Potential, IT-Realized, and IT-Socialization. Despite advanced searching capabilities embedded in IT-Potential capability, if firms lack the related knowledge to apprehend the search results that are outside of their existing boundaries, they are not able to evaluate them or recognize their value. Besides related knowledge, other organizational factors may also influence the effects of IT-Potential on boundary spanning. Not-invented-here (NIH) syndrome, for instance, cannot be overcome by use of IT-enabled tools. When firms suffering from NIH syndrome encounter novel knowledge that is dissimilar to their existing knowledge base, they may disregard the knowledge or discount its value. On the other hand, once firms already recognize the value of the novel knowledge, IT-Realized and IT-Socializing capabilities can facilitate the integration of this knowledge through their capabilities of bisociation and creation of common knowledge, respectively.

Our findings also highlight the contingency effects of IT on the innovation context. More specifically, the results show that the types of IT-enabled knowledge capabilities required for innovation differ based on the nature of boundary spanning. Spanning technological and geographic boundaries may require different types of IT-enabled knowledge capabilities, as these two types of boundaries impose different kinds of knowledge-creation challenges. We find that for innovations through technological boundary spanning, IT-Socializing capability has a significant effect. When integrating knowledge from an unfamiliar technological area, the challenge mainly lies in the semantic boundary difference between technological domains and difficulties in communicating the contextual information, which can be bridged through the creation of shared meanings, frame of reference, and interpretive schemes (Carlile, 2004). Also, IT-Socializing capability facilitates the direct and interactive discussions and negotiations necessary to the creation of shared meaning and interests. With regard to the results on innovation through spanning geographic boundaries, we find that the effects of IT-Realized capability are significant. IT-Socializing may not work in the context of geographic boundary spanning because different regions may have different work practices in terms of IT use. For instance, past research found that Indian programmers tend to raise opposition through emails rather than conferencing (Krishna, Sahay, & Walsham, 2004). On the other hand, the analytical capabilities provided by IT-Realized helps with synthesizing massive data across regions and assessing the value embedded in remote knowledge sources.

Last, our paper contributes to research in boundary spanning. From the perspective of evolutionary economics, firms are inclined to search for solutions in the knowledge domains with which they are familiar (Nelson & Winter, 1982). Such path dependency, on one hand, can help with deepening firms' knowledge in certain domains. While on the other hand, it may create competency traps, core rigidities, or technology lockouts which impede firms from making new discoveries (Rosenkopf & Nerkar, 2001). Hence, to maintain sustained competitive advantage in a hypercompetitive environment, firms need to innovate by going beyond their technological or geographic boundaries. Past research has suggested some mechanisms that can facilitate boundary spanning innovation, such as formulating strategic alliances, structuring global research activities in an integrative manner, and cross-pollinating ideas through personnel mobility (Henderson & Cockburn, 1994; Rosenkopf & Almeida, 2003). However, to our knowledge, this is the first study to explore another important mechanism, i.e., the use of IT to innovate through boundary spanning. Findings from this study provide additional insights into mechanisms to boundary-spanning innovation.

This study provides practical guidelines for companies, especially pharmaceutical companies, to innovate by leveraging IT capabilities. In particular, results from our study suggest ways to design IT systems to support different types of boundary spanning in innovation activities, i.e., spanning technological boundaries and geographic boundaries. Our results suggest that IT-enabled socializing capability can be particularly important in facilitating a firm to innovate by integrating novel knowledge elements that are distant from its existing knowledge base. Integrating technologically-distant knowledge elements requires capability that supports rich and frequent communication to establish common knowledge, clarify hidden assumptions, and negotiate interests at stake. Companies may consider combining a wide range of utilities from rich media such as chatting and videoconferencing, which enable synchronous communication, and e-communities of practice, which facilitates the building and sharing of narratives, as well as email which provides asynchronous communication to allow for longer processing and thinking time. Our results also suggest that IT-enabled realized capability can facilitate a firm to integrate knowledge elements across different geographic locations. Companies may consider utilizing analytical tools such as CAD/CAM, visualization, simulation, and decision support tools to help leverage knowledge distributed across the globe.

CONCLUSION

In this paper, we explore IT's role in innovation in the pharmaceutical industry. The most general change in the pharmaceutical industry in recent years has been the change from a trial-and-error method of drug discovery to a rational drug-design approach. Traditionally, a new drug was typically found by looking for chemical compounds that caused a particular clinical reaction, a process that did not require the researcher to necessarily understand how the drug worked. A rational drug-design approach uses information about the structure of a drug receptor (a target molecule) or one of its natural ligands to identify or create candidate drugs and then to conduct large-scale screening experiments where potential drug targets are tested with thousands of different compounds to see if interactions take place. This industry change has resulted in an increasing effort by pharmaceutical companies to span across different technological and geographic boundaries for drug discovery. A number of studies of the pharmaceutical industry (Bierly & Chakrabarti, 1996; Henderson & Cockburn, 1994) have found that a firm's integration of technologically-distant knowledge from its alliance partners can be important for drug discovery.

In the aforementioned context, we examine how IT affects a firm's innovation through boundary spanning. We specifically study three types of IT-enabled knowledge capabilities: IT-enabled potential capability affords the ability to acquire, assimilate and store knowledge in the IT systems that may be retrieved and accessed for later use; IT-enabled realized capability affords the ability to analyze, generate, and use knowledge for new insights; IT-enabled socializing capability affords the ability to foster social interactions and build social capital. Our results suggest that IT-enabled socializing capability played a significant role in facilitating firm innovations through spanning technological boundaries, and IT-enabled realized capability helped firms go beyond their geographic boundaries, while our results suggest that pharmaceutical companies did not seem to use IT-enabled potential capability for facilitating the spanning of either technological or geographic boundaries. We interpret these results and highlight the significance of our work. We believe that this research offers a starting point for investigating an important, yet under-explored, domain that calls for more studies of the aforementioned context in order to better understand the role of IT in firm innovation.

REFERENCES

Ahuja, G., & Katila, R. (2001). Technological acquisitions and the innovation performance of acquiring firms: A longitudinal study. *Strategic Management Journal*, *22*(3), 197–220. doi:10.1002/smj.157

Ahuja, G., & Lampert, C. M. (2001). Entrepreneurship in the large corporation: A longitudinal study of how established firms create breakthrough inventions. *Strategic Management Journal*, *22*(6/7), 521–543. doi:10.1002/smj.176

Alavi, M., & Leidner, D. E. (2001). Knowledge management and knowledge management systems: Conceptual foundations and research issues. *Management Information Systems Quarterly*, *25*(1), 107–136. doi:10.2307/3250961

Bharadwaj, A. S. (2000). A resource-based perspective on information technology capability and firm performance: An empirical investigation. *Management Information Systems Quarterly*, *24*(1), 169–196. doi:10.2307/3250983

Bharadwaj, A. S., Bharadwaj, S. G., & Konsynski, B. R. (1999). Information Technology Effects on Firm Performance As Measured by Tobin's Q. *Management Science*, *45*(7), 1008–1024. doi:10.1287/mnsc.45.7.1008

Bierly, P., & Chakrabarti, A. (1996). Generic Knowledge Strategies in the U.S. Pharmaceutical Industry. *Strategic Management Journal*, *17*(S2), 123–135. doi:10.1002/smj.4250171111

Boland, R. Jr, & Tenkasi, R. (1995). Perspective Making and Perspective Taking in Communities of Knowing. *Organization Science*, *6*(4), 350–372. doi:10.1287/orsc.6.4.350

Bruner, J. (1990). *Acts of Meaning*. Cambridge, MA: Harvard Business Press.

Brynjolfsson, E., & Hitt, L. (1996). Paradox Lost? Firm-level Evidence on the Returns to Information Systems Spending. *Management Science*, *42*(4), 541–558. doi:10.1287/mnsc.42.4.541

Carlile, P. (2004). Transferring, Translating, and Transforming: An Integrative Framework for Managing Knowledge Across Boundaries. *Organization Science*, *15*(5), 555–568. doi:10.1287/orsc.1040.0094

Carr, D. (2008). Wyeth's Prescription for Business Process Management Success.

Chesbrough, H. (2003). *Open Innovation: The new imperative for creating and profiting form technology*. Boston, MA: Harvard Business School press.

Chesbrough, H., Vanhaverbeke, W., & West, J. (2006). *Open innovation: Researching a new paradign*. Oxford, UK: Oxford University press.

Clark, H. (1996). *Using Language*. Cambridge, UK: Cambridge University Press. doi:10.1017/CBO9780511620539

Cockburn, I. M. (2004). The Changing Structure Of The Pharmaceutical Industry. *Health Affairs (Project Hope)*, *23*(1), 10–22. doi:10.1377/hlthaff.23.1.10 PMID:15002624

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, *35*(1), 128–152. doi:10.2307/2393553

Dennis, A. R., Fuller, R. M., & Valacich, J. S. (2008). Media, tasks, and communication processes: A theory of media synchronicity. *Management Information Systems Quarterly*, *32*(3), 575–600. doi:10.2307/25148857

Dougherty, D. (1992). Interpretive Barriers to Successful Product Innovation in Large Firms. *Organization Science*, *3*(2), 179–202. doi:10.1287/orsc.3.2.179

Faraj, S., Krogh, G., Monteiro, E., & Lakhani, K. (2016). Online community as spece for knowledge flows. *Information Systems Research*, *27*(4), 668–684. doi:10.1287/isre.2016.0682

Fleming, L. (2001). Recombinant Uncertainty in Technological Search. *Management Science*, *47*(1), 117–132. doi:10.1287/mnsc.47.1.117.10671

Gergen, K. J., McNamee, S., & Barrett, F. J. (2001). Towards Transformative Dialogue. *International Journal of Public Administration*, *24*(7/8), 679–707. doi:10.1081/PAD-100104770

Grant, R. M. (1996). Towards a Knowledge-based theory of the firm. *Strategic Management Journal*, *17*(Winter), 109–122. doi:10.1002/smj.4250171110

Han, K., Oh, W., Im, K. S., Chang, R., Oh, H., & Pinsonneault, A. (2012). Value cocreation and wealth spillover in open innovation alliance. *Management Information Systems Quarterly*, *36*(1), 291–315.

Han, S., & Ravichandran, T. (2006). Does IT Impact Firm Innovativeness: An Empirical Examination of Complementary and Direct Effects. *Paper presented at the AMCIS*.

Hansen, M. T. (1999). The Search-Transfer Problem: The Role of Weak Ties in Sharing Knowledge across Organization Subunits. *Administrative Science Quarterly*, *44*(1), 82–111. doi:10.2307/2667032

Hargadon, A. (2003). *How breakthroughs Happen: The Surprising Truth about How Companies Innovate*. Harvard Business Press.

Hargadon, A. B., & Sutton, R. I. (1997). Technology Brokering and Innovation in a Product Development Firm. *Administrative Science Quarterly*, *42*(4), 716–749. doi:10.2307/2393655

Harhoff, D., & Lakhani, K. R. (2016). *Revolutionizing Innovation: Users, Communities, and Open Innovation*. Cambridge, MA: MIT Press.

Henderson, R., & Cockburn, I. (1994). Measuring competence? Exploring firm effects in pharmaceutical research. *Strategic Management Journal*, *15*(S1), 63–84. doi:10.1002/smj.4250150906

Hickins, M. (2012). IT takes charge at AstraZeneca. *Wall Street Journal Blog*. Retrieved from http://blogs.wsj.com/cio/2012/05/13/it-takes-charge-at-astrazeneca/

Hitt, L. M., & Brynjolfsson, E. (1996). Productivity, Business Profitability, and Consumer Surplus: Three Different Measures of Information Technology Value. *Management Information Systems Quarterly*, *20*(2), 121–142. doi:10.2307/249475

Huston, L., & Sakkab, N. (2006). Connect and Develop: Inside Procter & Gamble's New Model for Innovation. *Harvard Business Review*, *84*(3), 58–67.

Joshi, K. D., Chi, L., Datta, A., & Han, S. (2010). Changing the competitive landscape: Continuous innovation through IT-enabled knowledge capabilities. *Information Systems Research*, *21*(3), 472–495. doi:10.1287/isre.1100.0298

Katila, R. (2002). New Product Search over Time: Past Ideas in Their Prime? *Academy of Management Journal*, *45*(5), 995–1010. doi:10.2307/3069326

Kleis, L., Ramirez, R., & Cockburn, I. (2011). (forthcoming). Information Technology and Intangible Output: The Impact of IT Investment on Innovation Productivity. *Information Systems Research*.

Kraemer, K. L., Dedrick, J., & Yamashiro, S. (2000). Refining and extending the Business Model with information technology with IT: Dell Computer Corporation. *The Information Society*, *1*(1), 5–21.

Krishna, S., Sahay, S., & Walsham, G. (2004). Managing Cross Culture Issues in Global Software Outsourcing. *Communications of the ACM*, *47*(4), 62–66. doi:10.1145/975817.975818

Lane, P. J., & Lubatkin, M. (1998). Relative absorptive capacity and interorganizational learning. *Strategic Management Journal*, *19*(5), 461–477. doi:10.1002/(SICI)1097-0266(199805)19:5<461::AID-SMJ953>3.0.CO;2-L

Leonard-Barton, D. (1992). Core capabilities and core rigidities: A paradox in managing new product development. *Strategic Management Journal*, *13*(S1), 111–125. doi:10.1002/smj.4250131009

Leonardi, P. (2014). Social media, knowledge sharing, and innovation: Toward a theory of communication visibility. *Information Systems Research*, *25*(4), 896–816. doi:10.1287/isre.2014.0536

Mandviwalla, M., & Palmer, J. (2008). *The Globalization of Wyeth (Ivey Case 908M17)*. Ontario, Canada: Ivey Case Collection.

Mani, D., Srikanth, K., & Bharadwaj, A. (2014). Efficacy of R&D work in offshore captive centers: An empriical study of task characteristics, coordination mechanisms, and performance. *Information Systems Research*, *25*(4), 846–864. doi:10.1287/isre.2014.0552

March, J. G. (1991). Exploration and exploitation in organizational learning. *Organization Science*, *2*(1), 71–87. doi:10.1287/orsc.2.1.71

McGill, J., & Santoro, M. (2009). Alliance Portfolios and Patent Output: The Case of Biotechnology Alliances. *IEEE Transactions on Engineering Management*, *56*(3), 388–401. doi:10.1109/TEM.2009.2013835

Nambisan, S., Lyytinen, K., Majchrzak, A., & Song, M. (2017). Digital innovation management: Reinventing innovation management research in a digital world. *Management Information Systems Quarterly*, *41*(1), 223–238. doi:10.25300/MISQ/2017/41:1.03

Nelson, R., & Winter, S. (1982). *An Evolutionary Theory of Economic Change*. Cambridge, MA: Belknap Press.

Nemanich, L., Keller, R., Vera, D., & Chin, W. (2010). Absorptive Capacity in R&D Project Teams: A Conceptualization and Empirical Test. *IEEE Transactions on Engineering Management*, *57*(4), 674–688. doi:10.1109/TEM.2009.2037736

Nonaka, I. (1994). A Dynamic Theory of Organizational Knowledge Creation. *Organization Science*, *5*(1), 14–37. doi:10.1287/orsc.5.1.14

Pavlou, P., & El Sawy, O. (2006). From IT Leveraging Competence to Competitive Advantage in Turbulent Environment: The Case of New Product Development. *Information Systems Research*, *17*(3), 198–227. doi:10.1287/isre.1060.0094

Pavlou, P. A., & Sawy, O. A. E. (2006). From IT Leveraging Competence to Competitive Advantage in Turbulent Environments: The Case of New Product Development. *Information Systems Research*, *17*(3), 198–227. doi:10.1287/isre.1060.0094

Ravichandran, T., Han, S., & Mithas, S. (2017). Mitigating Diminishing Returns to R&D: The Role of Information Technology in Innovation. *Information Systems Research*, isre.2017.0717. doi:10.1287/isre.2017.0717

Rosenkopf, L., & Almeida, P. (2003). Overcoming Local Search through Alliances and Mobility. *Management Science*, *49*(6), 751–766. doi:10.1287/mnsc.49.6.751.16026

Rosenkopf, L., & Nerkar, A. (2001). Beyond Local Search: Boundary-Spanning, Exploration, and Impact in the Optical Disk Industry. *Strategic Management Journal*, *22*(4), 287–306. doi:10.1002/smj.160

Sabherwal, R., & Sabherwal, S. (2005). Knowledge Management Using Information Technology: Determinants of Short-Term Impact on Firm Value*. *Decision Sciences*, *36*(4), 531–567. doi:10.1111/j.1540-5414.2005.00102.x

Santoro, M., & Bierly, P. E. (2006). Facilitators of Knowledge Transfer in University-Industry Collaborations: A Knowledge-Based Perspective. *IEEE Transactions on Engineering Management*, *53*(4), 495–507. doi:10.1109/TEM.2006.883707

Saxenian, A. (1990). Regional Networks and the Resurgence of Silicon Valley. *California Management Review*, *33*(1), 89–112. doi:10.2307/41166640

Schilling, M. A. (2006). *Strategic Management of Technological Innovation*. New York: McGraw Hill Irwin.

Schilling, M. A., & Phelps, C. C. (2007). Interfirm Collaboration Networks: The Impact of Large-Scale Network Structure on Firm Innovation. *Management Science*, *53*(7), 1113–1126. doi:10.1287/mnsc.1060.0624

Shneiderman, B. (2007). Creativity support tools: Accelerating discovery and innovation. *Communications of the ACM*, *50*(12), 20–32. doi:10.1145/1323688.1323689

Sorenson, O., Rivkin, J. W., & Fleming, L. (2006). Complexity, networks and knowledge flow. *Research Policy*, *35*(7), 994–1017. doi:10.1016/j.respol.2006.05.002

Stevens, G. A., & Burley, J. (1997). 3,000 Raw Ideas = 1 Commercial Success! *Research Technology Management*, *40*(3), 16–27. doi:10.1080/08956308.1997.11671126

Tallman, S., & Phene, A. (2007). Leveraging Knowledge Across Geographic Boundaries. *Organization Science*, *18*(2), 252–260. doi:10.1287/orsc.1060.0227

Trantopoulos, K., Krogh, G., Wallin, M., & Woerter, M. (2017). External knowledge and information technology: Implications for process innovation performance. *Management Information Systems Quarterly*, *41*(1), 287–300. doi:10.25300/MISQ/2017/41.1.15

Vlaar, P., Fenema, P., & Tiwari, V. (2008). Cocreating Understanding and Value in Distributed Work: How Members of Onsite and Offshore Vendor Teams Give, Make, Demand, and Break Sense. *Management Information Systems Quarterly*, *32*(2), 227–255. doi:10.2307/25148839

von Krogh, G. (2012). How does social software change knowledge management? Toward a strategic research agenda. *The Journal of Strategic Information Systems*, *21*(2), 154–164. doi:10.1016/j.jsis.2012.04.003

Zahra, S. A., & George, G. (2002). Absorptive capacity: A review, reconceptualization, and extension. *Academy of Management Review*, *27*(2), 185–203.

ENDNOTES

[1] http://www.informationweek.com/informationweek-500-orion-builds-efficiency-into-eli-lillys-randd-system-/d/d-id/1071822?page_number=1

[2] Standard & Poor's Industry Survey: Pharmaceutical Industry, 2008

[3] http://www.informationweek.com/news/160900803

[4] Patents are the proxy for technological innovations and inventions, which are one step in the whole innovation process. However, we used patent here because patent citation provides us the opportunity to trace knowledge flows.

[5] http://www.informationweek.com/news/6508347

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