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Abstract

External search has played a very critical role in a firm's innovation process. As a cornerstone of open innovations' success, the work of external search has been altered by the advancement in information technologies (ITs). Employees at different organizational levels can source external knowledge and share them with other employees with consummate ease and speed. However, the inclusion of more and different boundary spanners and broadened search domains pose new challenges to firms in managing their open search process. In this study, we attempt to address this under-studied phenomenon by conducting multiple case studies to build a deep understanding of the open search work. Drawing on the perspectives of upper echelon theory and organic/mechanistic organizational forms, we developed a theoretical exposition of open search work by 1) evaluating the impact of each open search pattern on efficient search outcomes; 2) understanding appropriate IT mechanisms for each identified pattern; and 3) unveiling the relationships of three open search patterns by considering the uncertainty as a unique trait of open innovation. Through this study, we seek to contribute to building a middle-range theory of open search by shedding light on the different patterns of open search and their varying impact on search outcomes. Our findings can also provide useful insights to firms' managers to design their innovation units effectively to achieve optimal results.

Keywords IT-induced open search patterns, Case studies, Open innovation, Uncertainty

1   Introduction

The ability to acquire, absorb, and exploit knowledge from external sources is an increasingly necessary condition for organizations to innovate (Laursen and Salter 2006). Many organizations are consequently developing these open search capabilities in order to ensure survival or growth (e.g., Berchicci 2012). Past studies have shown that firms must acquire and exploit new scientific knowledge and technological developments from the external environment in order to innovate and compete (Escribano et al. 2009). This external environment includes sources such as customers, suppliers, universities, research institutions, industry consortia, and even rival firms (Chesbrough 2003).

The advancement in information technologies (ITs) has transformed the practices and strategies of organizational open search. ITs such as search engines, electronic communication tools and intra and inter-organizational systems have become obligatory passage points for most R&D employees at different hierarchical levels who are seeking to source external knowledge and disseminate it to other employees within their organization (Teigland and Wasko 2003). In addition, the utilization of some newly developed IT tools (e.g., data and text mining techniques) in external search has transformed external search practices. The open source communities and crowdsourcing platforms have broadened the scope and the distance of external search.

The inclusion of more and different boundary spanners and broadened search domains pose new challenges to firms in managing their open search process. First, searching knowledge from a wide range of less known external sources may generate significant risk to the innovation project. "Settling" for less satisfied technologies or partners usually yields poorer resources and threatens the attainment of effective innovation outcomes. For instance, inappropriate external knowledge source was deemed as a main reason causing the failure of Boeing's Dreamliner 787 project (Forbes 2011). A survey results show that 43% managers are concerned with the difficulty of finding the right partner in open innovations (Enkel et al. 2009). Second, without building sufficient knowledge in this new work arrangement and a suitable organizational design, firms can suffer from unnecessary resources wastage, chaos in R&D employees' open search, and delayed completion of the innovation project. These challenges therefore call for a more insightful understanding.

In this study, we attempt to address this under-studied phenomenon by conducting multiple case studies to build a deep understanding of the open search work. Drawing on the perspectives of upper echelon theory (Hambrick 2007; Hambrick and Mason 1984) and organic/mechanistic organizational forms (Burns and Stalker 1961), we identified three patterns of open search - centralized, differentiated, and decentralized. We also developed a theoretical exposition of open search work by 1) evaluating the impact of each open search pattern on efficient search outcomes; 2) understanding appropriate IT mechanisms for each identified pattern; and 3) unveiling the efficiency of the three open search patterns by considering the uncertainty of involving external knowledge along the innovation process. Through this study, we seek to contribute to building a middle-range theory of open search by shedding light on the different patterns of open search and their varying impact on search outcomes. Our findings can also provide useful insights to top management to design their innovation units effectively to achieve optimal results.

2   Theoretical Foundation

2.1   Work Patterns of Organizational Open Search

The work arrangement of the three open search patterns can be traced to three schools of management thought: upper echelons theory and the mechanistic versus organic organization design structure. These serve as the foundation to guide our investigation of the open search.

In the *centralized open search pattern,* managers take full control of the search process. This is in line with *upper echelons theory*, which suggests that the firm is a reflection of its management team (Hambrick 2007; Hambrick and Mason 1984). The managers' experiences and values greatly influence their interpretations and, these in turn affect their choices. Consistent with this perspective, external search is originally viewed as an informal, unstructured activity with executive managers acquiring information in the course of their daily activities (e.g., Aguilar 1967). Additionally, managers' social capital with other firms (e.g., suppliers, buyers, and competitors), political leaders and civil servants, and community leaders is critical to enhancing organizational performance (Acquaah 2007).

Differentiated and decentralized open search patterns are related to the ongoing debate on designing mechanistic or organic organizational structure (Burns and Stalker 1961). Proponents of *mechanistic organizational form* argue that the bureaucratic firm, with clear-cut division of activities, and

assignment of roles, is "technically superior to all other forms of firm" (Weber 1947: 196). Functional specialization reduces work ambiguity, enables individual focus, learning, and decision making, decrease the cost of coordination, and increase efficiency. Therefore, employees can concentrate on the execution of specified and narrowly defined tasks to accumulate task-related knowledge, and enhance information-processing capabilities (Thompson, 1967).

In contrast, *organic organizational form*, characterized by a lack of formally defined tasks argues that firms with loosely coupled networks of workers, can better adapt to dynamic environments (Burns and Stalker 1961). An organic firm is a fluid and flexible network of multi-talented individuals who perform a variety of tasks. It takes into consideration the ideas of the employees, opening the doors to teamwork among employees, instead of competition or a feeling of powerlessness. This work arrangement is thought to provide incentive to employees to perform to the best of their abilities.

2.2   IT and Open Search

Prior studies have highlighted the role of IT in vastly increasing the ability of firms to work across different geographic and organizational boundaries (Pavitt, 2003). Innovations in IT improve the way knowledge is stored and retrieved. IT, by lowering the cost of communication, also provides increased access to the codified knowledge of others. To put it in terms of our search landscape, IT enables a broader coverage of the search space by effectively reaching more firms or individuals whose expertise the focal firm potentially lacks, and who may be located on distant peaks, and it improves the ability of these firms or individuals to solve problems.

The Internet and other advancements in IT have changed the workplace (e.g., Dewan and Kraemer 2000). Employees at all levels are equipped with various IT tools, such as environmental scanning tools IT tools (e.g., data mining tools, data analytics, and open innovation platforms) and intra/inter-organizational enterprise systems (e.g., office automation systems, electronic collaborative workplace, and supply chain management systems). The impact of IT arguably plays a particularly important role in the production of knowledge. In doing so, the use of these technologies has helped to support the shift towards more open, collaborative and network-cantered innovation practices (Christensen and Maskell, 2003).

3   Research Methodology

As part of a large-scaled project, we have collaborations with an innovation and development government agency and we used the three schools of thoughts on work arrangement to guide our selection of firms from a list of high-tech enterprises to explore the different search patterns. After paying site visits and calling on the senior management of more than 20 firms, we settled on seven firms that agreed to participate, satisfied our theoretical sampling criteria and covered a good variety in terms of size and industries (To protect the confidentiality of participants' data, all company names have been replaced with pseudonyms). The chosen firms had active open search practice so that the researchers could have rich data for analysis and had high within-firm and across-firm variation. It is useful for our aim of building accurate, parsimonious, and generalizable theory.

The data collection process included four sources: (1) interviews with key stakeholders, (2) onsite observations of innovation products and work places, (3) follow-up e-mails and phone calls to track the innovation processes and clarify details, (4) archives including media and corporate materials. In each firm, we first interviewed the manager(s) in charge of the R&D area. We conducted interviews with key stakeholders for recently completed open search activities with emphasis on objectives of open search, patterns of search, interactions with potential technologies/partners, and open search outcomes. This practice reduces recall bias and enhances accuracy (Golden 1992). In total, 21 open innovation projects were identified and analysed in this study. The transcribed field notes and interviews were coded by three researchers, who then met to discuss the codes to ensure the interpretation consistency. An initial set of coding themes was derived based on our objective to understand the open search work and its evolution. The findings were moved back and forth between empirical data and conceptual themes. The collected data was analysed within each case as well as across the different cases.

4   Research Findings

As a research in progress, our preliminary research findings are summarized in this session.

4.1 Centralized Open Search

Consistent with upper echelons theory, we found the objective of managers' open search involvement is to meet is the firm's long-term innovation goals. When managers felt uncertain of the firm's current prospects or wished to achieve long-term strategic goals, they would look for potential partners to initiate collaborative innovation relationships that were beneficial to the firm.

Open search efficiency and impact: Among the identified open innovation projects by our interviewees, centralized open search patterns were completed with high efficiency. Managers usually approached potential partners whom they knew (i.e., direct ties) or to whom they were introduced by mutual acquaintances (i.e., indirect ties). They may also interact with managers from other firms in conferences and social events to explore collaborative innovation opportunities. Although it took some time to reach mutual collaborative intentions, the sourcing efficiency is relatively high, especially when the managers possessed direct or indirect ties to the targeted partners.

The collaborative relationships brought not only technological resources benefits, but also allowed the focal firm to benefit from its partner's reputation and market resources. For instance, the senior technology manager of Company Saturn expressed that *"we are relatively new to the Chinese market and has a higher product price than Chinese native brands. Collaborating with the famous Chinese local company provided us an opportunity to increase our brand awareness in Chinese market."* Through collaboration, firms were either able to create new market segments for their mutual product, or as one partner gained access to a new market, the other had the opportunity to become a value-added supplier. Similarly, Company Venus is a start-up with ongoing collaborative innovation relationships with several famous research institutions. Its CEO stated that *"working with experienced scientists and engineers from large research institutions gave us credibility and legitimacy for our products and industrial recognition of our firm, which is what we wanted through open innovation".* However, this kind of open search impact has potential risk when skills are not compatible on both sides. The unpleasant open innovation project of IT firm Mars is an example. Its technical director illustrated one unsuccessful open innovation project with one famous firm in the IT industry: *"we initially considered our collaboration as a potent combination, but we encountered technical conflicts in our development and engineers from two firms took a long time to solve these problems. The project has been significantly delayed."*

Role of IT: For the centralized open search pattern, IT facilitates the managers to obtain information about external resources and supports managers' inter-organizational relationship and personal network building. As mentioned by the chief technical officer of Company Mercury, *"I used to rely on newspapers and magazines to keep abreast of industry development and the movements of our competitors. Now with Internet and search engines, I can take the initiative to search for information, rather than passively receive information. And it is more efficient in finding what I want to know."* Our informants also indicated that potential partners could be tapped using electronic mails, video conferencing or chat applications. ITs facilitate interactions by enabling a variety of strong and loose ties among managers from different firms.

4.2 Differentiated Open Search

As indicated by the mechanistic organizational form view that highlights the functional specification in task allocation, a group of specialized employees were assigned to the sourcing unit to take responsibility of sourcing external knowledge in these firms.

Open search efficiency and impact: As we learnt from our informants, open search projects using differentiated open search pattern were considered to have a high level of time and effort to attain desirable outcomes. As employees in the sourcing unit's specialized and concentrate on tasks of external sourcing, they tend to adopt a systematic approach to sourcing by using multiple search channels and searching widely to identify the best solution, technology or collaborator. Hence, it took employees in the sourcing unit a long time and great effort to complete sourcing tasks, resulting in relatively low sourcing efficiency. For example, as an employee in the sourcing unit in Company Pluto described: *"For the project of a deodorization technology, we evaluated more than ten companies and the whole process took more than two years."* We also observed the same in other case firms. For instance, Company Mars used innovation idea competition to identify a large pool of potential technologies to select a few suitable ones. It expended a great deal of efforts in identifying, collating and evaluating and it took nearly a year.

We gathered from our informants that despite the low efficiency in sourcing, the sourced technology was highly satisfactory and beneficial. Employees in the sourcing unit looked at areas that are usually

ignored by the managers and R&D employees. It included some start-ups, small and medium enterprises and even pioneering individual innovators. For example, as a large Chinese leading digital media company, Earth had initiated open innovation projects with several innovative start-ups. Neptune once identified and sourced technology from an individual innovator in Australia. As suggested by the technology director of Neptune, *"our sourcing unit once found a advanced heat storage technology in Australia. We used it in one of our new products, which was absolutely new to the Chinese market"*. Moreover, employees in the sourcing unit were able to target technology that was located in firms from unfamiliar domains. For instance, Jupiter in the railway electric industry sourced technology from an automobile company and developed a new, revolutionary product for the railway electric industry. The external knowledge, sourced from a wide range of and distant unfamiliar domains, conferred on the focal firm tremendous ability to develop new and radical products, not only from the firm's perspective but also the market's perspective.

Role of IT: We learnt from our informants that ITs supported and enhanced the sourcing unit's external knowledge sourcing capability by enhancing the speed, intensity, and directionality of knowledge identification and selection. Besides the ITs identified in Phase 1, the intelligent mechanisms built into search and retrieval technologies, together with the sophisticated data structuring, indexing, and tagging techniques, helped navigate the knowledge acquisition process in the right direction quickly. The intelligent data-mining tools included automated search mechanisms to find useful knowledge in public databases, publication and patent analyses as well as trending curves. IT also supported the sourcing unit to organize and store the acquired knowledge properly to facilitate future retrieval and usage. For instance, informants mentioned the use of organizational memory systems, multi-dimensional databases, and data warehouses to store various forms of data, information, and knowledge. ITs also bridged the gap between the sourcing unit and the R&D department by reducing the coordination and communication costs. For example, in some case firms, a visualization suite was used to test representations of product designs; a 3D computer-aided design (CAD) system which can simulate and model prototypes helped build understanding between employees in the sourcing unit and the R&D employees. According to a senior engineer of Compnay Jupiter, *"We have a better idea of R&D unit's requirements with the illustration of a CAD design of the new product, even when their requirements are changing quickly. The CAD drawing can be altered accordingly and be demonstrated to us to facilitate our sourcing task."*

4.3 Decentralized Open Search

For decentralized open search pattern in our case firms, the R&D employees also engaged in the open search activities besides their traditional R&D work. This work pattern is consistent with the organic organizational form (Burns and Stalker 1961), which emphasizes role flexibility and lack of formally defined tasks.

Open search efficiency and impact: The open search projects by R&D employees were completed with high efficiency in our case firms. As suggested by our interviewees, the objective of open search in this pattern was to find solution for more specific needs or specific problems during the idea generation and implementation stages in the innovation process. Considering that the R&D employees, as implementer of innovation projects, knew the problem well and the technology or partner required, time and effort was not required of them to communicate the open search request with different units. As the R&D employees were not specialists of external sourcing, they usually did not perform systematic or extensive sourcing; rather they often sourced for a practical and feasible solution within familiar domains in limited range. Hence, it took less time and effort to identify the desirable technology or collaborator, resulting in high sourcing efficiency. As expressed proudly by a project manager of the Company Uranus, *"for one particular innovation problem, our R&D employees used only one week to find a solution."*

Our interviewees illustrated that decentralized open search pattern bring complementary knowledge to the organizational internal knowledge with speed and flexibility, hence, accelerated time to market of the new product. As expressed by a project manager of the Company Jupiter, *"When we were developing a new product, we found our old cooling technology did not meet the requirement. One of our R&D employee found a firm with relevant technology from directory of the Railway Industrial Association, which quickly solved our difficulty."*

Role of IT: ITs provided employees with interconnected networks and systems to enhance interactions, gain knowledge access and share knowledge both internally and externally. For instance, Mars used electronic networks of alliances and collaborators to support and cultivate inter-firm knowledge synergies. Our case firms also used ITs to capture knowledge about customers, business partners, inter-firm operational processes and other significant sources of organizational intelligence.

For instance, the supply chain management system and the customer relationship management system facilitated information flows across geographical regions and value network partners (e.g., suppliers, customers). RSS technologies also helped employees synthesize and share information from multiple sources while wikis and blogs opened up new opportunities to integrate knowledge and ideas coherently, accelerating knowledge discovery and innovation. We also learnt from our interviewees that internal e-community of practice, Web conferencing, and groupware systems were instrumental in cultivating social interactions and connectedness among R&D employees. Intranets, message boards, electronic message software, and chat rooms helped with communication and coordination. Enterprise resource planning and knowledge management systems helped build an internal expertise map and enhanced the firm's ability to accomplish internal assimilation.

5 A Cross-Case Analysis of Three Open Search Patterns

While each organizational design perspective adds to our understanding of open search process, it also limits in the explanations it can provide as illustrated by our cases. We argue that the use of alternative perspectives can help provide a better explanation by supplementing a given perspective's limits. In this section, we propose a process theory of open search, which contributes to a richer understanding of relationships between three open search patterns. The relationships are explained under different levels of uncertainty, which captures the unique trait of open innovation.

The development of innovations can be seen as a process composed of two phases: 1) idea generation and 2) idea implementation (Eisenhardt 1980). Since firms constantly open search for collaborative innovation opportunities and the sourced external technology or partner may initiate the innovation project, we also consider the phase of "prior to innovation" before the idea generation and idea implementation phase. Considering the nature of open innovation with the use of purposive inflows and outflows of knowledge during the entire innovation process (Chesbrough 2003), each phase is characterized by different objectives of open search as well as by different uncertainty concerns of knowledge flows. Therefore, in addition to taking into account the three open search patterns, our theory (illustrated in Figure 1) includes uncertainty as well as a temporal dimension. A core concept of the theory is that only one or two open search patterns occur at each phase during innovation process due to their open search objectives. At each phase, if high degree of uncertainty is involved in the innovation project, some search pattern become inefficient.
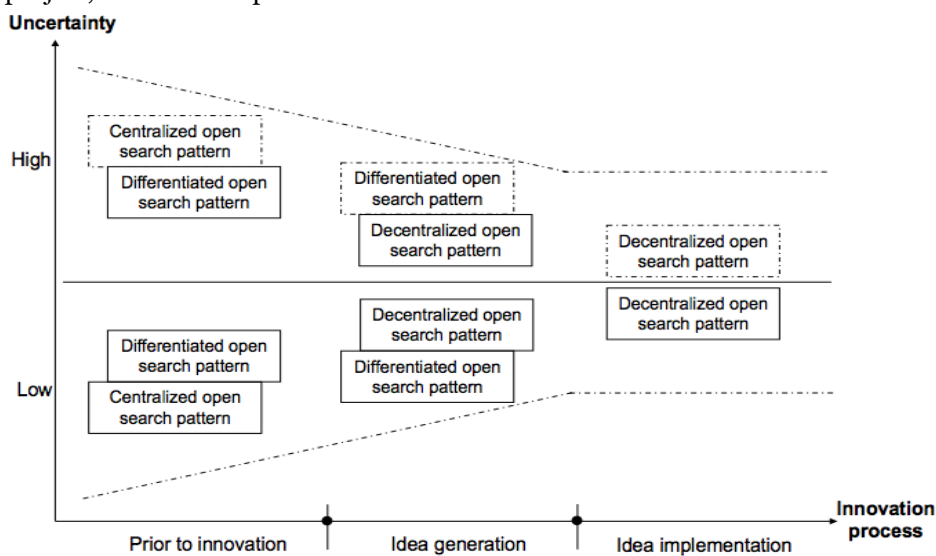

Figure 1: A Process Theory of Open Search

5.1 Prior to Innovation

The innovation process begins with the first phase "prior to innovation". Open search in this phase is characterized as proactively exploring for collaborative innovation opportunities without specific innovation plan. Our findings posit that centralized and differentiated open search patterns take a prominent position in this phase. Managers constantly open search when they perceive strategic needs such as exploring other technological areas. Besides, a major work for sourcing employees is also to proactively search for external innovative knowledge. In contrast, decentralized open search is unlikely

to be a prominent search pattern in this phase. This is because ordinary R&D employees tend to focus on their assigned innovation projects without a holistic view of the firm's overall strategies.

In this first phase, without specific collaboration direction, the evaluation of external partner may not be very concrete. Furthermore, given that a time-lag is likely to occur between the search of external collaborators and commencement of the collaboration project, uncertainties can occur as the focal firm or its external collaborator may go through changes in terms of firm's strategy, products or internal structure. For instance, as mentioned in our Phase 2 case analysis, the open innovation project in Mars, which belongs to the IT industry, delayed due to technological resource conflicts in the idea implementation phase. IT industry is a volatile industry with fast changing user demands and competitor movements. Hence, the uncertainty of searching external knowledge prior to innovation becomes high. When the uncertainty is high, limitation of centralized open search pattern (i.e., managers may evaluate the external partner and its knowledge at the high level without sufficient details) can be magnified. Our theory suggests that the differentiated open search pattern is more efficient than centralized open search pattern under condition of high uncertainty in evaluating collaboration partners in this stage. With the advance ITs, employees in the sourcing unit are able to collect and analyse a large amount of information. Also, in this pattern, managers and R&D employees need to participate in the decision-making and internal assimilation process to evaluate the external partner. Hence, the potential risk of conflicts can be further weakened.

5.2 Idea Generation

During the idea generation phase, the innovation project has commenced and external sourcing stars look for external knowledge to supplement the knowledge gaps or enhance the innovativeness of the project. Our data find that in general, differentiated and decentralized open search patterns take a prominent position in this phase. The uncertainty in this phase is likely to be associated with the direction of the innovation project: requirement of new product innovativeness and speed to market, It is suggested by our theory that differentiated pattern outperforms decentralized open search pattern when innovativeness is emphasized while decentralized open search pattern is more efficient when speed to market is needed. On one hand, an organic structure has been identified as a suitable organizational design for innovation in dynamic changing environment (Hatum and Pettigrew, 2006). A low level of functional specialization leads to increased flexibility in open search (Burns and Stalker, 1961). It fosters rapid decision-making, a horizontal interaction between diverse perspectives and a range of possible solutions to problems among R&D employees. Hence, decentralized open search pattern accelerates the speed to market. On the other hand, a mechanistic structure allows employees in the sourcing unit to concentrate on the execution of specified sourcing tasks and to accumulate sourcing task-related knowledge, and thus it enhances information-processing capabilities (Burns and Stalker, 1961; Thompson, 1967). With the supports of ITs, employees in the sourcing unit are able to perform systematic sourcing in a large amount of information with high reach in distant technological areas. Thus, cutting-edge innovative external knowledge for the innovation project is likely to be identified with differentiated open search pattern.

5.3 Idea Implementation

The idea implementation phase is characterized as more focused problem solving requiring deep understanding of knowledge internally possessed for the innovation project. During this phase of innovation process, innovation idea has been generated and knowledge has been accumulated about the innovation. So the level of uncertainty is relatively low in this phase. In line with the case findings, our theory posits that decentralized open search is the major open search pattern in this phase. Since R&D employees are the implementers of the innovation project, they know well about the innovation problem and the required solution or technology. The open search targets at short-term collaboration with limited outflow of internal knowledge such as technology licensing and consultation.

6 Discussion

6.1 Theoretical Implications

This study constitutes one of the first studies to build a deep understanding of the changing work of external search. First, we add to the literature by unveiling three IT-induced patterns of open search: centralized, differentiated, and decentralized. Comparing with conventional search patterns, these three patterns differ in terms of work arrangement, employment of IT applications, as well as search efficiency and impact. A middle-range theory is proposed to elucidate desirable patterns along the

open innovation process, which provides a foundation to invoke future research on dynamics of search work, especially given the rise of "open" behaviours.

Second, this study explicates the differentiated roles of IT in open search. On the one hand, IT is found to serve as an amplifier and a catalyst to induce different trajectories of open search evolution. On the other hand, we propose that IT mechanisms can be categorized into multiple groups: informative ITs, communication ITs, scouting ITs, visualization ITs and knowledge sharing ITs. While the specific mechanisms may not be excusive to one open search pattern, the categorization is based on the utility of these mechanisms and can foster the understanding of how these groups exhibit varied impacts on facilitating/inhibiting efficiency of open search.

6.2 Practical Implications

The findings of this study provide managers with the conceptual clarity to open search patterns, enable them to mindfully select appropriate work arrangement so as to achieve desirable open search outcomes. First, firms' managers need to be aware that three open search patterns (i.e., centralized, differentiated and decentralized) can offer different impacts on open innovation projects. Hence, the selection of open search could be based on the desirable expectation of external knowledge. For instance, with the objective to explore innovative and distant technological areas, differentiated open search with systematic sourcing in a large range can be considered for idea generation. In order to achieve high flexibility and speed in solving problems during the middle of the innovation process, decentralized open search conducted by R&D employees is suitable to access external knowledge

Second, given the different roles of ITs in influencing open search, this research offers important insights for managers to make a wise investment on IT applications. For instance, for firms keen on revolutionary or radical innovation, managers may consider investing in data mining techniques, data analytics, or open innovation portals to support differentiated open search. IT applications significantly enhance information processing capability to reach a large range of sourcing area for innovative and new technology. For firms want to cultivate collaborative innovation opportunities in peripheral networks with suppliers or customers, the investment in intra-firm and inter-firm systems would be a beneficial choice. Enterprise resource planning systems and supplier chain management systems supporting an interconnected network both internally and externally provide firms with flexibility and efficiency to reach and incorporate complementary external knowledge.

7 Conclusion

Open innovation is a major feature of the increasingly competitive and fast-paced global business environment precipitated by new technological developments. In this context, open search is becoming a fundamental activity that each firm engages in on a daily basis and across all innovation projects. Our study took a deep and contextual look into how firms navigate the different search patterns in their open search projects and how these patterns impact the search outcomes. Based on these analyses, we proposed a conceptual framework of open search and highlighted key implications for the open search and the organizational design literatures. Practical implications on when and how different open search patterns might be used were also highlighted. Our study is a first step towards developing a theoretical conceptualization of the fundamental transformations in open search work induced by the substantial increase in IT-supported search techniques.

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