Search in Open Innovation: How Does It Evolve with the Facilitation of Information Technology?

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Abstract. As a cornerstone of open innovations' success, the work of external search has been altered by the advancement in information technologies (ITs). This study depicts the IT-induced evolution of open search patterns in two case firms. While three patterns were observed in both firms, they took different trajectories of open search pattern change due to the different enabling roles of ITs. ITs were found to serve as an amplifier and a catalyst to induce different trajectories. This study contributes to the literature by unveiling the process of open search evolution including identifying different open search patterns and the roles of ITs. The managerial lessons learned from the two case firms can be applied by other firms.

Keywords: IT-induced Evolution, Open search, Case studies, Open innovation.

1   Open Innovation and IT-Induced Open Search

External search has played a very critical role in a firm's innovation process (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 remain competitive (Cohen and Levinthal 1990; Escribano et al. 2009). This external environment includes sources such as customers, suppliers, universities, research institutions, industry consortia, and even rival firms (Chesbrough 2003). It is noteworthy that conventional external search work is characterized by the use of a small number of individuals taking managerial positions in the R&D department to act as the firm's boundary spanners to scan the outside world through personal networks for knowledge, and process and disseminate them to the R&D employees (e.g., Allen 1984; Katz and Tushman 1981). However, 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 now source and share external knowledge with other employees with consummate ease and speed.

However, extant literature has paid scant attention to capture such a change. While prior literature provides valuable insights on conventional work of external search, there are some gaps limiting our understanding on how external search can be evolved from conventional pattern with the support of advanced ITs. Furthermore, despite IT tools serve as the key boundary objects to sustain the intense interaction and knowledge sharing across organizational boundaries for open innovations, there remains a paucity of research on how IT can facilitate the external search activities in open innovations.

Therefore, we employed two case studies to unveil the changing work process of "open search", which consists of sourcing external knowledge (i.e., technology or collaborator) and assimilating acquired knowledge into internal R&D employees' work. Two firms leading in open innovation were selected. Based on detailed field observations, documents and interviews with key stakeholders, we observed three different patterns of open search strategies: centralized, differentiated, and decentralized and explored the evolutionary processes of how ITs change the patterns of open search (e.g., ITs as an amplifier and a catalyst). As evident in two cases, the search work became more complex and dynamic with the inclusion of more and different boundary spanners and broadened search domains compared to the work identified in the literature.

More specifically, advances in ITs induced the evolution of open search pattern in two case firms, their impacts were different. In one case firm, ITs (e.g., data mining tools, data analytics, and open innovation platforms) served as the amplifier to enhance the speed and intensity of external sourcing and selection capabilities. When more powerful ITs were employed, managers have limited ability and time to employ them, which required the technological experts in sourcing, and led to the differentiated open search pattern. In contrast, for another case firm, intra- and inter-firm ITs (e.g., enterprise resources planning systems, supply chain management systems) served as the catalyst to accelerate knowledge access and sharing among R&D employees with value network partners (e.g., suppliers, customers). It stimulated R&D employees to discover innovation opportunities in the interconnected networks and resulted in the new decentralized open search pattern. IT indeed induced the work pattern change of open search in firms.

Through this study, we contribute to extant open innovation literature by providing a theoretically grounded exposition of different open search patterns and their evolution process. Additionally, this study explicates the differentiated roles of ITs in open search. ITs are found to serve as an amplifier and a catalyst to induce different trajectories of open search evolution. Our findings can also provide useful insights to firms' managers to design their innovation units and effectively use ITs to facilitate the evolution.

2   IT-Induced Evolution of Open Search Patterns

Two firms leading in open innovation were selected at this stage (see Table 1 for firms' details). Such a selection makes our findings more robust and generalizable than selecting single case (Eisenhardt and Graebner 2007). The qualitative data were collected through four sources: (1) interviews with key stakeholders, (2) onsite

observations of innovation products and work places, (3) follow-up emails and phone calls to track the innovation processes and clarify details, (4) archives including media and corporate materials. Such triangulation bolsters confidence in the accuracy of the findings. In total, 11 onsite interviews were conducted from two leading firms in open innovation (see Table 1). Each interview last 45-60 minutes, and was taped and transcribed. The interview questions largely focused on the evolution of work in conducting open search. Sample interview questions included "How does your firm conduct open search? Who and how to source external knowledge? How can the sourced knowledge be assimilated internally? Is there any change in terms of how your firm conducts open search? What factors drive the changes of open search work? What's the role of ITs in open search?"

Table 1. Details of firms and interviews

Firm*	Business description	Number of employees	Number of interviews	Interviewees' position
Pluto	A global top American multinational consumer goods company. Its products include pet foods, cleaning agents and personal care products.	7000 (China branch)	6	Senior technology manager, R&D director, R&D employee
Neptune	The largest and leading solar energy company in China. Its products range from solar water heaters, solar collectors to solar lights and PV lighting products.	4000	5	Chief executive officer, senior technology manager, R&D employee

To protect the confidentiality of participants' data, names of both firm have been replaced with pseudonyms.

We addressed potential informant bias in several ways. First, we triangulated data from multiple sources and informants for a firm. At least two evidences were used to support each finding (Klein and Myers 1999; Myers 1997). Second, we used "courtroom question" that focused on factual accounts of what informants knew (e.g., dates, meetings, participants) and avoided speculation (Huber and Power 1985). Third, we gave anonymity to our informants and their firms, which encourages candor. 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. This process ended when "theoretical saturation" was reached, where the incremental improvement on the research findings became minimum (Eisenhardt 1989).

2.1   Case Pluto

Episode 1: Centralized Open Search. Operating in a competitive market, Pluto envisioned new ideas and new products as its lifeblood and continuously searched for innovative ideas. As a leading firm in the consumer goods market, R&D managers in Pluto paid huge attention to assimilating state-of-the-art technologies into its product lines. Similar to the conventional external search pattern identified in Figure 1, the responsibility of open search fall upon the managers, who selected appropriate external knowledge (technologies or collaborators) from personal networks or reach potential ones through mutual acquaintances in personal networks. These technologies and collaborators were used for achieving long-term goals and gaining competitive advantage. However, ITs played prominent roles along the two stages of the open search process (i.e., external sourcing and internal assimilation). Since decision making is also a critical work responsibility and the stakeholders to perform it have changed, we include the discussion of it in the open search process. For managers, ITs had facilitated roles of broadening their networks, facilitated the decision making, and eased the internal knowledge assimilation process.

External sourcing: The work of external sourcing in Pluto was conducted by R&D managers. Besides existing network, managers also employed IT tools such as Internet to source potential external knowledge. After identifying potential targets, the possibility of collaboration was first negotiated mainly in the offline setting such as site visits and conference attendance. For example, the senior technology manager stated the following strategy to establish the network:

> *"Some top researchers at Chinese Academy of Sciences were invited to seminars and visits at our company a long time ago before our collaborative innovation projects started."*

Once the network was initiated, communication technologies such as emails, video conferencing and chat applications were used by managers to strengthen the relationships with external parties and build shared structures of interactions, cognition, and trust.

Decision making: We learnt from our informants that electronic reports available on the Internet were used by Pluto's managers to evaluate the potential collaborators. To ensure that the chosen external knowledge fit the firm, they also used executive information systems to monitor customer demands and competitors' movements before making the final selection.

Internal assimilation: After selecting the external collaborator, decision and the collaborator' information were passed downward from managers to lower level R&D employees, mainly through emails. This is referred to as top-down assimilation. R&D employees then planned the collaboration details with external partner together. Besides face-to-face meetings, communication ITs (e.g., emails, electronic noticeboards, newsletters, phone, fax) were used to facilitate interactions between the cooperating parties.

During this episode, Pluto had twelve innovation projects collaborating with two universities and one research institution. By sharing resources, leveraging ideas, and tapping the expertise, Pluto was able to create vibrant innovation ecosystems, multiply its efforts, and derive more strategic value for the firm.

Episode 2: Differentiated Open Search. To mark the completion of the first innovation episode, a specialized sourcing unit focusing on sourcing external knowledge was established in Pluto. We understood that the establishment of this unit was mainly due to two reasons. First, IT tools such as data mining applications, analytic techniques, and open innovation platforms significantly amplified the speed and intensity of external sourcing and selection capabilities. Under such circumstances, managers had limited ability and time to employ these IT tools. Second, the open mindset toward innovation had taken root in Pluto. Managers and R&D employees viewed external search not merely as a task but also as a way of building useful knowledge sources for future innovation projects.

External sourcing: The sourcing unit initially consisted of 11 employees, who were both IT experts and PhD holders in the areas relevant to Pluto's products. These employees in the sourcing unit not only handled requests for searching external knowledge from R&D unit, but also proactively probed cutting-edge external knowledge, mapping these emerging technologies to products and monitoring the technological capabilities of competitors. Employees in the sourcing unit were good at filtering, interpreting and synthesizing information from vast amount of web pages, scientific literature and patent databases using data mining and retrieval technologies.

In addition, employees in the sourcing unit also utilized open innovation portals to identify innovative external knowledge. First, they built a portal to post their needs and look for solutions from people all over the world. Second, they also utilized existing portals such as InnoCentive, NineSigma, and Alibaba to source for potential technologies, partners and monitor the development of new technologies. For instance, the R&D director mentioned that,

> *"Alibaba, [note: an online China manufacturer portal],linked our company to various manufacturers, suppliers, exporters, importers and buyers. For one innovation project, we searched for an important technology for two years, but did not find any satisfactory technology provider. With Alibaba, our sourcing unit managed to find one small company in China that met our requirements."*

Decision making and internal assimilation: After the new idea was identified by the employees in the sourcing unit, the knowledge was then assimilated throughout the R&D department. A down-top-down communication was used for knowledge assimilation. Managers of R&D department served as boundary spanners between the employees in the sourcing unit and R&D employees. As a supporting unit of the R&D department, the sourcing unit sourced external innovation solutions or potential technology or collaborators for the R&D department during their innovation projects. As we learnt from Pluto, R&D employees sent open search requests through managers of the R&D department to the employees in the sourcing unit. The acquired

external knowledge was also transmitted through managers. Although R&D employees participated in the decision making process, R&D managers still possessed more decision making power of deciding whether and which of the sourced external knowledge would be assimilated among R&D employees. For sourcing unit's proactive open search, they also disseminated new and innovative technologies they thought useful for R&D employees through managers to R&D employees. As illustrated by the R&D director,

> *"We had a structured and organized communication way between the sourcing unit and the rest of the R&D employees. The communication was bridged by the managers."*

Episode 3: Decentralized Open Search. As the benefits of external knowledge spread, more and more open search requests were requested by R&D employees. Only a small number of open search requests were handled by employees in the sourcing unit due to their limited capacities. Besides that, the communication and coordination costs involved in discussing open search requests and sourced knowledge with the sourcing unit were high. The R&D employees at Pluto started to search externally for their own innovation problems. They engaged in both external open search and traditional R&D work.

External sourcing: As the technology sourced by the sourcing unit benefits the entire R&D department, the objective of open search by R&D employees was to find solution to solve more specific innovation problems they encountered during their work. One R&D employee in Pluto indicated,

> *"Once during our innovation process, our bottle sealing technology failed to develop the new product. Since this needed technology may only be applied in this particular innovation project. Rather than sending request to the sourcing unit, we took the responsibility of open search. Finally my colleagues and I found the satisfactory technology in an exhibition in Hong Kong."*

Since open search was only a part of and not the focus of R&D employees' work, the search was not conducted systematically, but focused on finding a feasible solution for immediate practical use. They tapped closed proprietary networks (e.g., suppliers, retailers, competitors, and development and trade partners) and prior collaborative networks of firms available to the firm. They also looked for ideas and solutions in exhibitions, industrial associations, and organizational yellow pages. Various IT tools were also implemented by R&D employees to source external knowledge. We learnt through interviews that RSS technologies helped R&D employees in Pluto synthesize and share information from multiple sources; wikis and blogs had opened up new opportunities to integrate knowledge and ideas, accelerating knowledge discovery and innovation. R&D employees also actively participated in external communities of practice and Internet-based technology forums, which facilitated interactive and timely tacit knowledge acquisition. Therefore, ITs provided the means by which R&D employees engaged in their sourcing tasks with flexibility and agility.

Decision making and internal assimilation: If the sourcing R&D employees were also users of the acquired external knowledge, they would then made decisions about whether and which of the acquired external knowledge will be used in the innovation projects. If the sourced external knowledge would be used by all of the innovation project team members, the R&D managers also participated in the decision making process to select the right external knowledge. Since R&D employees knew very well who required the sourced external knowledge, they also took on the role of internal assimilator to disseminate the sourced the sourced external knowledge among the innovation project team members. Face-to-face meetings and discussions were used for internal assimilation. However, as a very large R&D department with around 550 R&D employees, the project team involved a large number of members, with some members who were distributed around the world. IT significantly enhanced interactions among individuals for knowledge assimilation in Pluto. A senior technology manager of Pluto said,

> "When some R&D employees identified the potential external knowledge, they uploaded it to a knowledge management system, called InnovationNet, and provided access to other innovation project team members to it. In addition, intranet and online communities also connect our R&D employees to facilitate their communication. "

Today, open innovation has permeated into each and every corner of Pluto's firm. All of its R&D employees actively search externally during the innovation process.

2.2   Case Neptune

Episode 1: Centralized Open Search. Neptune is the largest and leading solar energy firm in China. Its products range from solar water heaters, solar collectors to solar lights and PV lighting products. Neptune started its collaborative innovation journey as early as 2000. Similar to Pluto, in the early stage, the senior and R&D managers of Neptune undertook the work of open search through their personal networks.

External sourcing: Managers of Neptune, a Chinese firm, adopted a different approach from their Pluto counterparts by paying more attention to cultivate government ties in their social networks. Through attendance of association meetings and industrial development events, managers took opportunities to interact with government officers, which in turn brought them valuable connections to managers from other firms. The chief executive officer of Neptune recounted:

> "I know some government officers who are in charge of the technological development park. Our collaborative innovation project with the Institute of Electrical Engineering was brokered and supported by the municipal Science & Technology Commission."

In addition, as illustrated by our informants, managers of Neptune sourced in areas of the United States, Japan, and Europe for breakthrough research and many more for state-of-the-art development capabilities. Managers of Neptune purposefully attended

international fairs, exhibitions and visited foreign firms, with the deliberate aim of expanding the pool of potential partners. During their interactions with managers from foreign countries, they identified technologies and collaborators of great potential value to their own firm.

Decision making and internal assimilation: The sourcing managers played the same role of decision makers as managers in Pluto did in deciding on their collaboration partners. However, unlike the case of Pluto that applied the top-down assimilation of collaborative intentions with external partners, Neptune managers relied more on face-to-face meetings than on electronic communication. We learnt from our informants that they were various face-to-face communications among executive managers, middle level managers and R&D employees to create awareness and foster consensus on the innovation collaboration projects. Team briefings were also used to enable project managers to communicate and consult with R&D employees. Team briefings took place on a weekly basis or more frequently.

> *"Our CEO regularly delivered inspiring speeches to employees about the organizational strategic development. Senior managers also meet R&D employees regularly to communicate about the collaborative innovation projects."*

Episode 2: Decentralized Open Search. In this later stage, Neptune took a different trajectory of open search pattern change from Pluto. The change was due to two reasons. First, during this stage, Neptune hired some new engineers in the R&D department with new work practice and external knowledge. Second, the implementation of office automation systems, and supply chain management system in Neptune provided these new R&D employees access to external knowledge sources and consequently stimulated them to discover innovation opportunities in the interconnected networks.

External sourcing: The organizational informatization of intra-organizational and inter-organizational systems provided R&D employees access to codified knowledge in Neptune's knowledge base and enhanced interactions among individuals for knowledge transfer and sharing. It created a collaborative workplace, provided interconnected networks and systems for enhancing interactions for knowledge access and sharing externally across geographical regions, and value network partners (e.g., suppliers, customers). These technologies provided a window into the engine room of the innovation, where new innovative ideas may emerge.

Through the interconnected networks with external firms, these new employees in the R&D department discovered some innovation opportunities associated with external knowledge. This triggered an open search culture among R&D employees, a trend that was also encouraged by the R&D director in Neptune. For any innovation project, R&D employees first seek to find out if an external source already had a solution. Neptune also created a secure IT platform that allowed R&D employees to share technology briefs with its suppliers.

"If we are trying to find ways to improve our current technology or product, one of our suppliers may well have the solution. Since the creation of our supplier network system, we have had some innovation projects that are jointly staffed with Neptune and suppliers' researchers. In some cases, suppliers' researchers came to work in our labs, and in others, we worked in theirs."

Decision making and internal assimilation: Similar to Pluto, we also learnt from our informants that during the open search process, R&D employees were given more decision making power for selecting external knowledge. But unlike Pluto, Neptune had a R&D department with approximately 60 R&D professionals. To disseminate externally acquired knowledge, they relied more on regular face-to-face meetings and discussions. Meanwhile, ITs such as groupware systems were also instrumental in cultivating social interactions and connectedness among R&D employees. Electronic message software helped with communication and coordination.

Episode 3: Differentiated Open Search. Through the collaborative innovations with external partners, Neptune had accelerated innovation processes and improved products. However, in the meantime, they realized that there were significant overlaps in sourcing outcomes in their R&D employees' open search and their sourcing also tended to only focus on the current innovation projects. To achieve better innovation outcomes, it required early identification of innovative ideas and technological trends for the entire R&D department. Thus, to overcome these handicaps and to attain greater benefits through external knowledge, a specialized sourcing unit that focused on open sourcing and accumulating external knowledge to support the innovation development of Neptune was formed.

External sourcing: The major tasks of this sourcing unit were the same as Pluto's. But unlike Pluto, the employees in the sourcing unit did not have PhD degrees. They were assigned to the sourcing unit because they were good at using ITs compared to other R&D employees. Their sourcing activities were done mainly through the Internet and the sourced external knowledge was stored in custom-made knowledge management systems.

Decision making and internal assimilation: After a new idea was identified by the employees in the sourcing unit, the knowledge was assimilated throughout the R&D department. R&D managers were the key decision makers of selecting the sourced external knowledge. To disseminate the sourced external knowledge, the communication between the sourcing unit and R&D unit did not take a top-down knowledge assimilation path. In contrast, the two units directly communicated. As suggested by our informants, the sourcing employees were treated as just other R&D employees with different work.
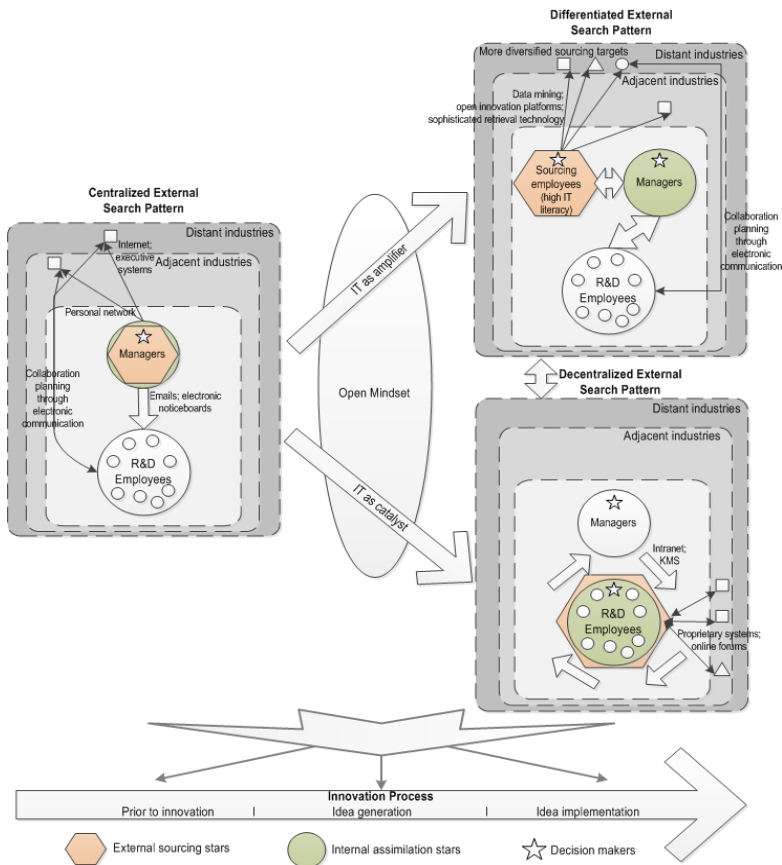
Fig. 1. Evolution of Three Emerging Open Search Patterns

3   A Cross-Case Discussion

3.1   Changing Work of Key Stakeholders

Three new work patterns in open search and their evolution in two firms are depicted in Fig.1. As evident in two cases, the search work became more complex and dynamic with the inclusion of more and different boundary spanners and broadened search domains compared to the work identified in the literature (see Fig.1). First, instead of occurring only at the idea generation stage of innovation process, open search could occur along the open innovation process due to different open search objectives. Second, not only managers, but R&D employees took roles of boundary spanners. Specifically, in centralized open search pattern, managers delegated part of the internal assimilation work to R&D employees. Compared to the external search patterns in prior literature that oral communication was the primary way to communicate with external partners, with communication ITs, R&D employees could work with distributed external partners together on collaborative innovation plan.

In differentiated open search pattern, external sourcing work supported by advanced ITs was assigned to employees in the sourcing unit. Managers took a new coordinating role between the employees in the sourcing unit and R&D employees. Managers and employees in the sourcing unit decided the selection of the sourced external knowledge together. In the decentralized open search pattern, the roles and work nature of R&D employees changed from being executor of the sourced external knowledge and conducting routine R&D work to being empowered to have work of external sourcing, decision making and internal assimilation of the sourced external knowledge. They also had more decision making power and autonomy on external sourcing work.

Table 2. Open search work of key stakeholders

Work pattern	R&D/senior managers	Employees in sourcing unit	R&D employees
Centralized open search	External sourcing; decision making; internal assimilation	N.A.	Internal assimilation (work with external partners on collaborative innovation plan)
Differentiated open search	Decision making (participative); internal assimilation	Decision making (participative); external sourcing	Internal assimilation (work with external partners)
Decentralized open search	Decision making (participative)	N.A.	External sourcing; decision making (participative); internal assimilation

3.2   Role of ITs

While advances in ITs induced the evolution of open search pattern in two case firms, their impacts were different. In Pluto, ITs (e.g., data mining tools, data analytics, and open innovation platforms) served as the amplifier to enhance the speed and intensity of external sourcing and selection capabilities. When IT became more powerful, managers had limited ability and time to employ them, which required the IT and technological experts in sourcing, and led to the differentiated open search pattern. In contrast, for Neptune, intra- and inter-firm ITs (e.g., enterprise resources planning systems, supply chain management systems) served as the catalyst to accelerate knowledge access and sharing among R&D employees with value network partners (e.g., suppliers, customers). It stimulated R&D employees to discover innovation opportunities in the interconnected networks and resulted in the new decentralized open search pattern. IT indeed induced the work pattern change of open search in firms.

4   Conclusion

While three patterns of open search were observed in both firms, they took different trajectories of open search pattern evolution, largely due to the different enabling roles of ITs. Firms' managers need to be mindful of the different roles that ITs can serve (e.g., as an amplifier and a catalyst). Appropriate ITs can then be employed to induce the suitable trajectory of open search evolution for the firm.

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