Understanding the Roles of IT in Product Innovation: Component Knowledge and Combinative Capabilities

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ABSTRACT

In this paper we draw from the knowledge-based view of the firm and dynamic capabilities theory to examine the effects of IT competencies on the innovation outcomes in firms. We argue that IT competencies impact product innovation by enhancing component knowledge such as technological and market knowledge of the firm. We are also posit that IT competencies allow firms to develop combinative capabilities that allow them to integrate component knowledge synergistically to meet competitive needs.

Keywords

Information technology, product innovation, combinative capabilities

INTRODUCTION

Innovation has been considered a critical source of competitive advantage (Teece, Pisano, and Shuen, 1997) and an important competence (Prahalad and Hamel, 1990) firms have to develop to be successful in today’s business environment (Linder, Jarvenpaa, and Davenport, 2003). Innovation has also been recognized as a primary means of corporate renewal (Dougherty, 1992; Bowen, et al. 1994), since the growth and development of a firm depend on its ability to introduce new products and processes over time (Dougherty and Hardy, 1996; Penrose, 1959). The importance of innovation is especially relevant in a rapidly-changing environment since organizations need to continuously renew themselves to survive and prosper in dynamic environments (Danneels, 2002). Furthermore, with a wide range of business processes, from manufacturing, back office operations to logistics and customer service, being outsourced, innovation has become the core of business of most large and small firms.

Information systems scholars have long been interested in the effects of IT on firm performance and have examined the relationship between IT stock and a myriad of firm performance indicators such as productivity, profitability, competitive advantage and consumer surplus. With innovation becoming the core mission of firms today, it is only appropriate that IS research expands in scope to include innovation as an indicator of firm performance. Firms in their endeavor to enhance their innovation capabilities have sought to use IT in every aspect of the innovation process. For instance, the chemistry industry is said to put product innovation a top priority for IT spending after years of pursuing operational excellence (Chemical Market Reporter, September 27, 2004). In pharmaceutical industry, pattern discovery and molecular modeling supported by advanced processing capacity of information technology have significantly accelerated the drug discovery process (Augen, 2002). Automakers, by leveraging 3-D virtual-reality modeling software, have dramatically cut the time it takes to build a car from 40 months to less than 18 months (InformationWeek, Sept. 22, 2003). While these anecdotes illustrate the growing use of IT to support product innovation processes in firms, limited systematic research has examined this phenomenon. This paper addresses this void by developing a theory based model of how IT impacts the product innovation capabilities and innovation outcomes in firms.

Product innovation occurs through an iterative interaction between market knowledge and technological knowledge (Day, 1994; Danneel, 2002; Nerkar and Roberts, 2004). Technological knowledge and market knowledge have been posited to be complementary (Dougherty, 1992; Penrose, 1959). Empirical studies have also found that interaction between them is positively related to product innovation success (Song, Droge, Hanvanich and Calantone, 2005). In this paper we propose...
that IT competencies contribute to product innovation by enhancing both technological knowledge and market knowledge of a firm.

Since any successful new product is a combination of technological knowledge and market knowledge (Dougherty, 1992), the means to integrate these two types of knowledge is also critical to new product development. Hauser and Clausing (1988) found that high performance in product development is associated with the use of organizational mechanisms that actively encourage the exchange of information across “component” boundaries within the firm. Matrix form of organizations (Allen, 1986), cross-function team (Dougherty, 1992), and heavy weight product team (Clark and Fujimoto, 1991) have been proposed to facilitate the integration. In this paper, we propose that IT allows firms to effectively recombine technological and market knowledge in a complementary manner to create synergistic bundles.

Through these two effects, we argue that IT competencies have an impact on the innovation outcome of a firm such as speed, variety and number of new product introductions. We draw from the knowledge-base view of firms and dynamic capabilities theory to develop the theoretical underpinning of our research model.

THEORETICAL BACKGROUND

The knowledge-based theory of the firm proposes that organizational capacity is created through integrating specialized knowledge. New product development is considered to require especially wide-ranging integration (Grant, 1996). In new product development literature, it has been proposed that product innovation by linking together market knowledge and technological knowledge (Day, 1994; Danneel, 2002; Nerkar and Roberts, 2004). Since these two types of knowledge usually reside in different specialists, departments, even organizations, there exist significant barriers for the integration to happen. Hence, various organizational forms, decision-making structure, coordination mechanisms have been proposed and applied, such as matrix form of organizations, cross-function team, heavy weight product team, and joint decision-making committee (Nonaka, 1990; Clark and Fujimoto, 1991; Wheelwright and Clark, 1992; Von Hippel, 1994). The ability for firm to synthesize and apply current and acquired knowledge has attracted researchers’ interest. Specially, it is called combinative capabilities by Kogut and Zander (1992), Nerkar and Roberts (2004), and Ven de Bosch, Volberda and Boer (1999). Similar concept has also been variously labeled as integrative capabilities (Henderson, 1994; Clark and Fujimoto, 1991), architecture competency (Henderson and Cockburn, 1994), and configuration competency (Henderson and Cockburn, 1990). Ven de Bosch, Volberda and Boer (1999) suggested that besides prior knowledge, combinative capabilities are another determinant of absorptive capacity, which is critical to the innovative capabilities of a firm (Cohen and Levinthal 1990). Henderson and Cockburn (1994) argued that “focusing on architectural or integrative characteristics of organizations can offer valuable insights into the source of enduring differences in firm performance”. Following them, we argue that success of new product development of a firm depends on both component knowledge (technological and market knowledge), and combinative capabilities.

Some strategy research (Barney, 1991; Levinthal, 1995; Montgomery, 1995) view firms as bundles of strategic assets that combine to produce and deliver an evolving set of products. They also define dynamic capabilities as the ability of firms to “integrate, build and reconfigure internal and external competences to address rapidly changing environments” (Teece et al., 1997: 516). The concept of combinative capabilities is closely associated with dynamic capabilities. In recent years the dynamic capabilities theory has evolved as an important theoretical lens through which the performance effects of IT has been examined. Recent studies have argued that IT enables firms to develop dynamic capabilities by providing them digital options to combine functional capabilities (Sambamurthy, Bharadwaj, and Grover, 2003). Digitized processes allow easier cross functional integration and also scale more effectively. An inherent aspect of this ability to reconfigure firm resources is learning. Scholars have argued that IT competencies enable firms to sense the environment effectively (Bharadwaj, 2000; El Sawy and Malhotra, 1999) and increase speed of response (Bharadwaj, 2000). More importantly, the ability to integrate knowledge resources both within and outside the firm can be enhanced by IT competencies (Alavi and Leidner, 2001). Thus, recent IS research has laid the foundation to theorize about how and why IT competencies enable firms to synergistically combine specialized knowledge to compete effectively in the market place.

We draw from this literature base to argue that IT competencies enable firms to enhance their product development capabilities in two ways 1) directly enhancing their technological and market knowledge and 2) enhancing their ability to combine technological and market capabilities synergistically, which we label combinative capabilities. Figure 1 depicts these two effects. The effects of technological and market knowledge and their interaction on product innovation performance has been studied in the literature (Danneel, 2002; Nerkar and Roberts, 2004; Song et al. 2005) and is not the focus of our theorizing here. Rather we restrict out focus on why and how IT competence enhance of both technological and market knowledge and how IT-enabled combinative capabilities moderates the relationship between technological and
market knowledge and product innovation performance, as is shown in the figure below. The four propositions are further elaborated in the remaining part of the paper.

Figure 1: Roles of IT in Product Innovation

**IT ENHANCING COMPONENT KNOWLEDGE**

There are two types of component knowledge which are essential in new product development: technological knowledge and marketing knowledge. We propose that information technology enhance both of them in a firm.

**Technological Knowledge**

We propose that IT competency enhances technological knowledge of a firm by supporting its internal R&D capabilities and enabling its innovation sourcing capabilities.

*Proposition 1: IT competency enhances a firm's technological knowledge.*

Technological knowledge of a firm is typically derived from its R&D activities (Teece, 1982). Information technology has been widely used in these activities due to its advanced computation capability and visual capability. R&D in biotech industry requires huge amount of computing and processing capabilities, which can be supported by IT. Sophisticated computing capabilities have enabled a radically new decoding process in pharmaceutical research, which accelerates the process of sequencing the human genome (Regalado, 2000). Automakers, by leveraging 3-D virtual-reality modeling software, have dramatically cut the time it takes to build a car from 40 months to less than 18 months (InformationWeek Sept. 22, 2003).

With the emerging of open innovation market, companies are no longer limited by ideas generated from internal R&D resources (Chesbrough, 2003). They are seeking to source innovation externally besides harnessing its internal R&D. Procter & Gamble Co. has created the position of director of external innovation and expects half of its new product ideas to be generated from outside by 2010, compared to 20% now (Business Week, Mar. 21, 2005). Use of advanced information technology enables organizations to leverage various external innovation sources such as virtual open innovation markets. First, IT reduces the searching cost in technology sourcing by connecting the focal firm to globally available technology resources. Eli Lilly and Co. has founded InnoCentive, which claims to be the “largest virtual laboratory in the world.” It is a
proprietary network of 70,000 registered “solvers” around the globe, helping Eli Lilly access almost all potential technological resources, no matter a Nobel laureate in Europe or a retired professor in China (Anthes, 2004). The virtual technology market relies mostly on the use of telecommunication network as an enabler. Secondly, cutting-edge search technologies are another enabler of the “connect and develop” approach, since success of virtual open technology market place depends on their ability to get high-quality responses, which in turn depends on their ability to identify the right problem solvers. Sophisticated search algorithms are used to build the right mailing list comprised of potential problem solvers. For instance, NineSigma Inc., another virtual innovation market, helps its 50 or so clients prepare technical briefs describing projects or problems they are trying to solve and then sends the briefs — without identifying the originating companies — to thousands of researchers around the world. NineSigma creates a unique database of potential respondents for every client request. The databases are said to be generated through a variety of searching techniques, some of which are proprietary.

Market Knowledge

Proposition2: IT competency enhances a firm’s market knowledge.

Market knowledge of a firm includes its knowledge of customer preferences, distribution channel and relevant regulatory organizations (Day, 1994). Information technology has been deployed to enhance all of them. First, information technology has been used to access customers and understand their preferences. Virtual customer community has involved customers in the whole period of product innovation, from generating idea, market testing, to distribution channel design. Actually, it has moved the role of product innovation toward customer side tremendously (Ozer, 2003). Secondly, storing mass amount of customer information requires storage function of IT. Analyzing that information requires processing capabilities that can also be provided by IT. Data mining function enabled by advanced computing ability has made it possible to analyze customers’ latent preferences conduct innovative market segmentation, and find niche market. Thirdly, IT has also help firms manage their relationship with regulatory organizations. In pharmaceutical industry, new product requires to obtain FDA approval before its launching. Use of IT has accelerated this process. For instance, Merck credits its knowledge management systems for the drastic reduction in the time it takes to get new products approved by Food and Drug Administration (Beierly and Chakrabarti, 1996; Ross et al., 1996). Construction material manufacturers have shared the updated industry guidelines and restrictions across geographically distributed development centers (Adhesives & Sealants Industry, September 2004). Hence, we propose:

IT ENHANCING COMBINATIVE CAPABILITIES

We propose that IT enhances combinative capabilities which synthesize existing and acquired knowledge responding to environments. Grant (1996) identify characteristics of knowledge integration which are pertinent to the creation and sustenance of competitive advantage: efficiency of knowledge integration and scope of knowledge integration. The efficiency of integration refers to how knowledge is integrated from a cost and economy of scale perspective. The scope of integration refers the breadth of specialized knowledge that combinative capabilities draw upon. We propose that advanced information technology enhance combinative capabilities by increasing both the efficiency and scope of knowledge integration.

Proposition3: IT competency enhances a firm's combinative capabilities.

Efficiency of Integration

One of the most significant influences of information technology is to facilitate communication and coordination (Allen, 1968; DeSanctis and Monge, 1999). Information technology improves coordination in two ways: by providing a common language and embedding organization routines into information systems.

Although both researchers and practitioners have been aware of the communication need in new product development activities, the real challenge resides in how to realize it. Cross-functional teams are not so difficult to set up, however, the challenge is for the team to access and integrate the knowledge of the team members (Grant, 1996). Demsetz (1991) identifies the prerequisite for communication between different specialists as the presence of common knowledge between them. The more common language shared between specialists, the more efficient the communication process. Virtual product design provided by computer-aided-design tools enables a common language when engineers from different fields communicate, more importantly, when engineers communicate with customers. Boeing benefits from its virtual product design platform by successfully integrating knowledge from electronics to new materials. Virtual product has become an important way to bring customers in the new product development process.
Technology can support coordination by embedding the organizational routines into information systems (Alavi and Leidner, 2001). Organizational routines refer to the development of task performance and coordination patterns, interaction protocols, and process specifications that allow individuals to apply and integrate their specialized knowledge without the need to articulate and communicate what they know to others (Alavi and Leidner 2001). Information systems can codify and automate organizational routines so that the need for communication and coordination is reduced. Some communication between specialists can be replaced by integration between information systems. For instance, in the R&D department of a construction materials manufacturer, the color formula was manually forwarded to the engineers. After systems integration between two design groups, the formula is automatically transferred and the process becomes more error-proof. The efficiency of coordination is improved by IT in this case because the need of communication is decreased. Secondly, although parallel processing or concurrent engineering has been called for in product innovation, its implementation is still problematic (Sethi, Smith, and Park, 2001). Sharing information about the project progress through centralized intranet keeps all the participants, like suppliers, marketing staff, manufacturing staff, scientists and engineers on the same page and they do not need to communicate in person since the information is updated through centralized database. The participants from different functions are even not necessarily from the same organization. For example, the involvement of supplier in product innovation has been proposed to improve product quality, cut manufacturing cost and decrease development cycle.

Scope of Integration

According to the social network theory, weak ties provide access to novel information by bridging otherwise disconnected groups and individuals in an organization. Weak ties are critical to knowledge integration, especially distant knowledge integration (Pickering and King, 1995). We propose that information technology enhances the scope of knowledge integration by increasing the number weak ties. Social ties are the links that bind individuals to other individuals, as manifested in the frequency and nature of communication among individuals. Granovetter (1973) differentiated between strong ties and weak ties on four dimensions: time, emotional intensity, mutual confidence and reciprocity. Weak ties are maintained through less frequent and less emotionally intense communication, in relationships that do not require or encourage sharing of confidences or establishment of strong reciprocities. Strong ties are generally in place for reasons not affected by marginal changes in communication costs. That is to say, strong ties will seldom be weakened by lack of communication technology access. On the contrary, the establishment of weak ties among people in the same organization or from different organization is greatly influenced by the ease and cost of communication and hence will be impacted by the use of information and communication technology, for instance, use of Intranet and bulletin broadcasting. P&G has used an internal website called “InnovationNet” that acts as the global “lunchroom” where researchers and marketing specialists throughout the world can trade information and make connections (Sakkab, 2002).

Integration between technological and market competencies across product lines is difficult but important for firm innovation. For instance, in consumer goods industry, sharing customer information between product lines, like hair care and skin care in P&G, is an important source of new product idea. P&G describes their innovation strength as linking the most impossible knowledge together (Sakkab, 2002). Nerkar and Roberts (2004) distinguishes between proximal and distal knowledge with respect to a focal new product. Proximal knowledge facilitates local search, while distal experience enables more global search. They further propose that not only proximal technological knowledge and proximal market knowledge are complements, but also proximal technological knowledge and distal market knowledge, proximal market knowledge and distal technological knowledge. Integration of proximal technological and distal market knowledge, integration of proximal market knowledge and distal technological knowledge, are extremely difficult, and mostly can only be enabled by weak tie connections in an organization.

CONCLUDING REMARKS AND FUTURE RESEARCH PLAN

Information systems scholars have long been interested in the effects of IT on firm performance and have examined the relationship between IT stock and a myriad of firm performance indicators such as productivity, profitability, competitive advantage and consumer surplus. With innovation becoming the core mission of firms today, this paper expands in scope to include innovation as an indicator of firm performance. Based on a synthesis of the product development, business strategy and IS research, we propose two roles of IT in new product development. First, IT enhances the component knowledge required in product innovation—technological knowledge and market knowledge. Secondly, IT enhances the combinative capabilities which enable the integration of technological knowledge and market knowledge. We do expect the results of this research to add to and further our understanding of how IT enables firms to compete in the market place.
This paper provides an overall picture for our future study. Our research plan includes empirically test the propositions put forth here and we are in the process of compiling data for this purpose. We will measure the impact of IT on technological knowledge using patent data, and measure the impact of IT on market knowledge using customer satisfaction data. Testing how IT impacts combinative capabilities will incur primary data collection. And finally, number and success of product introduction data will be collected from secondary data sources.

REFERENCES


