

# How networks influence radical innovation: the effects of heterogeneity of network ties and crowding out

## **Abstract**

**Purpose** – This paper aims to offer a novel set of insights to understand the role of network ties in pursuit of radical innovation. In this sense, the purpose of the study is to analyze how the heterogeneity in the content of network ties affects radical innovation.

**Design/methodology/approach** – Based on a comprehensive review of existing literature, this paper conceptualizes how different types of network ties affect radical innovation by deriving five research propositions.

**Findings** – Both buyer-supplier ties and peer collaboration ties are positively related to radical innovation, whilst the peer collaboration ties may be further affected by partner similarity. Compared to the two other types of network ties, equity ties have more of a moderating role on spurring radical innovation. Crowding out between network ties prevents firms from knowledge searching within an extensive network scope, reducing the opportunities of mixing-and-matching different types of knowledge required for radical innovation.

**Research limitation/implications** – The study suggests a different way of launching marketing strategy by selectively integrating different sources of knowledge (market, supplier, or technology) needed for commercializing radical technologies, highlighting the importance of partner selection for radical innovation among different types of firms surrounding the current market. For managers, it is necessary to identify and select network ties that can be helpful for long-term business and strategic interests.

**Originality/value** – This paper makes two main contributions. First, it addresses the question of how networks influence radical innovation by identifying three types of network ties and their effects —individually and in combination — on extension of the depth and breadth of knowledge and development of disruptive ideas. Second, it develops the existing

literature by demonstrating the crowding out effect of network ties.

**Keywords** Network tie heterogeneity, Interfirm network, Radical innovation, Crowding out, Knowledge acquisition

**Paper type** Conceptual paper

## Introduction

The origins of radical innovation in organizations have long been of great concern for marketing and strategic management. A vast amount of research has been devoted to identifying the individual and structural determinants and consequences of knowledge or capability acquisition for radical innovation (Duchesneau *et al.*, 1979; Hannan and Freeman, 1984; Cusumano and Nobeoka, 1998; Rice *et al.*, 2001; Sorescu *et al.*, 2003; Govindarajan and Trimble, 2005; Linton, 2009; Yanadori and Cui, 2013; Mudambi and Swift, 2014). More recently, the manifest potential for new theoretical insights into these issues has been accentuated through introducing the role of networks and relationships (e.g., Story *et al.*, 2008; Story *et al.*, 2009; Möller, 2010; Karamanos, 2011; Yang *et al.*, 2014).

Existing research has discussed a number of reasons why networks and relationships are important to radical innovation, such as specialized competence development (Story *et al.*, 2009), heterogeneous knowledge acquisition (Phelps, 2010; Karamanos, 2011), and comparative synergistic benefits (Zhou, 2011), highlighting the role of network ties through which firms co-create value with their partners (Han *et al.*, 2012). The network of interfirm ties serves as relational exchange with peers (competitors), customers and suppliers, which can be a critical source of knowledge leading to radical innovation (von Hippel, 1988; Bao *et al.*, 2012). However, this stream of work sheds significant light on how firms acquire knowledge for radical innovation through network ties, whereas the potential influence of the heterogeneity of network ties in such relationships is yet to be discussed. We argue that different types of network ties may perform differently when providing access to particular knowledge sets. Whilst buyer-supplier ties mostly provide access to marketing and/or component production knowledge, network ties with competitors transfer knowledge about product architecture or specialized modules. Such differences highlight the notion that the choice of network ties has radical innovation effects determined by the nature of the structural attributes of different networks (Burt, 1982; Human and Provan, 1997), suggesting

the need for a deeper understanding of the mechanisms of network ties influencing radical innovation as the type of network ties varies.

Moreover, the amount of knowledge a firm may acquire from its partners depends significantly on what the firm could provide with the partners (Homans, 1958), implying that a firm could not build network ties boundlessly and a new network tie may have to be developed at the expense of terminating an old network tie. Then, the questions arise: how network ties affect each other, and what are the effects that the interaction of network ties may exert on radical innovation?

In this paper we aim to fill in the research gaps and contribute to this special issue by improving understanding of the heterogeneity of network ties, and how they may affect knowledge acquisition and radical innovation. We do this by identifying three kinds of network ties in interfirm network contexts (Belderbos *et al.*, 2004; Mahmood *et al.*, 2011): (1) buyer-supplier ties, when firms within networks involve in buyer-supplier relations, (2) peer collaboration ties, when firms build collaborative relationships with competitors, and (3) equity ties, when collaborative partners hold each other's equity stakes. We strive to integrate some of the existing research and develop a preliminary framework of radical innovation within interfirm network contexts, trying to provide a detailed exploration of the mechanism in which network ties facilitate and/or hamper knowledge acquisition and disruptive idea development. We conduct research by launching a conceptual analysis, as the issue we are focusing on needs much exploratory work. Articles for inclusion in the present study were firstly identified by selecting key references from known authorities on the subject, which were extended through references and a preliminary search of recent publications in marketing, strategy, innovation and other related studies. Thereafter, three databases were used, EBSCO, JSTOR and ABI Inform, to conduct a systematic search for literature. Different terms were used for search, including the concepts that reflect radical innovation, such as knowledge exploration, disruptive innovation, discontinuous innovation and exploratory innovation, and the key words that relate to network ties, such as ties, relationship, collaboration, interfirm etc. We refined the search results by reading the titles and abstracts.

In the following sections, we first review relevant literature to explain the existing research and the gaps, followed by investigating how different types of ties — individual and in combination — will have different effects on radical innovation. Then,

we discuss the situation in which network ties crowd out each other and their impact on radical innovation. We conclude by discussing the implications and outlining several suggestions for future research.

### **Radical innovation: from within-firm to inter-firm**

Radical innovation can be traced back to Joseph Schumpeter's entrepreneurship which was considered as a breakthrough innovator, involving the "carrying out of new combinations" (Schumpeter, 1934). One main factor to identify radical innovation is whether or not the innovation incorporates technology which is a clearly risky departure from existing practice (Duchesneau *et al.*, 1979; Hage, 1980). By mentioning this, a radical innovation represents disruption of an existing technological trajectory (Dosi, 1982). For Chandy and Tellis (1998), a radical innovation not only refers to the extent to which the product incorporates a new technology, but also concerns fulfilling customer needs better than existing products. Linton (2009) also identifies radical innovation using two dimensions: a technical dimension (significant leap in technological development), and a social dimension (potential for new features and improvement), which involves 'a substantially different technology while offering a substantial increase in customer benefits' (Sorescu *et al.*, 2003, p. 84). Hence, markets with radical innovations would be restructured, and current products are supposed to be replaced by entirely new product categories (Rice *et al.*, 2001). For instance, the emergence of new communication software developed for mobile phones, such as WeChat, iMessage, Talkbox, and Whats App, provides services including text message, talkback, video sending, and geographical friends searching, thus substituting traditional telecommunication services such as phone calls and voice-mall as well as traditional email based services (e.g., yahoo and hotmail MSN).

Most of the studies on radical innovation were conducted at the within-firm level, focusing on how and under what conditions a firm could spur a radical innovation and the consequences of it. According to Ettlie *et al.* (1984), radical process can be significantly promoted by an aggressive technology policy and concentration of technical specialists. Since the degree of radicalness is fundamentally based on the relation with the firm's existing capabilities (Cusumano and Nobeoka, 1998), prior innovations seem to be valuable in developing a disruptive technological breakthrough (Golder *et al.*, 2009), and helping consumers comprehend,

evaluate, and adopt radical innovations (Reinders *et al.*, 2010).

It is demonstrated that separate firms deal with potential radical innovations by initiating dedicated project teams (O'Reilly and Tushman, 2004; Govindarajan and Trimble, 2005), developing cross-functional integration (Brettel *et al.*, 2011), introducing corporate venturing (Zahra, 1991; Maine, 2008), etc. However, keeping all innovation activities in-house may impede focal firms from recognizing, planning, and experimenting in radical innovations (Chang *et al.*, 2012). This is because, firstly, existing structure and organizational routines could be inhibitors of radical innovation. The existing structure and routines are historically formed and organized by former incremental change (Birkinshaw *et al.*, 2007), and may only support small changes within the present framework, which is recognized as “core rigidities” in disruptive competence development (Leonard-Barton, 1992). Radical changes in organizations, therefore, may be faced with resistance from affected members (Hannan and Freeman, 1984; Stringer, 2000; Junarsin, 2009).

Secondly, the existing knowledge base of focal firms may not support a discontinuous breakthrough. In order to spur radical innovation, focal firms emphasize not only analyzing and planning existing knowledge, but also experimenting and utilizing other knowledge types (Forsman, 2009) which are in excess of the current knowledge base. Since most focal firms serve their mainstream markets, their core knowledge has been embedded into the systems architecture of existing products or services (Henderson and Clark, 1990). Very few firms have the know-how and capabilities to develop all radical innovation competences by themselves (Story *et al.*, 2009). As a result, many companies grasp how to maintain the present systems architecture, but find it difficult to develop disruptive ideas for it (Christensen, 1997; Story *et al.*, 2008).

From the inter-firm or network perspective, over reliance on existing organizational routines and a limited knowledge base could be improved by being involved in long-term relationships (Birkinshaw *et al.*, 2007; Phelps, 2010; Zhou and Li, 2012). Since knowledge and resource is widely distributed (von Hayek, 1945), firms develop mutual relationships to absorb it from outside of their boundaries (Cohen and Levinthal, 1990). By engaging in interfirm relationships, firms can get access to partners' intangible resources such as knowledge, information, and technical know-how (Belderbos *et al.*, 2004). As pointed out by Powell *et al.* (1996),

inter-firm learning in networks plays a crucial role in reducing the inherent uncertainties associated with new product development. Bao et al. (2012) also considered external learning as an important determinant of radical innovation. External learning and internal knowledge sharing jointly interact with the existing knowledge base, which consequently changes firms' knowledge depth and breadth and promotes radical innovation (Zhou and Li, 2012). Repeated interaction and learning leads firms to acquire, assimilate, transform, and exploit knowledge (Zahra and George, 2002), and adjust their organizational routines and technological trajectory in correspondence with market dynamics.

According to social network theory, interfirm relationships embed into specific networks. A network tie is a means of access to resource within the network (Granovetter, 1973). In contrast to a dyadic partnership, a focal firm involved in a network obtains access to diverse resources through different network ties. For example, McEvily and Marcus (2005) argued that joint problem-solving arrangements with suppliers are associated with capability acquisition; Greer and Lei's (2012) recent review showed that ties with customers contribute to the development of innovative products or services. A more integrated study conducted by Mahmood *et al.* (2011) identified three different ties through which firms acquire capabilities within a group network: buyer-supplier ties, equity ties, and director ties. Those network ties are supposed to benefit capability acquisition, but in rather different ways. This is consistent with Belderbos *et al.* (2004) who argued that different types of partners (customers, suppliers, competitors, and universities and research institutes) lead to different levels of innovativeness of joint product development. Such differences can be especially significant because radical innovation calls for considerable change in knowledge configuration. This highlights the theoretical value of exploring how different types of network ties can affect radical innovation.

To summarize, given the knowledge and capability requirements of a radical innovation, it is clear that a switch of analytical paradigm from within-firm to interfirm is important. Networks and relationships create an advantageous path, from which firms acquire extensive intangible resources and build radical innovation competences. However, as the managerial and organizational competences required for radical innovation may be different from those required for incremental innovation (i.e., minor improvements or simple adjustments in current technology) (Veryzer, 1998), it is still unclear how different types of network ties

could enhance radical innovation. Moreover, existing network and interfirm relationship theory sheds significant light on how firms acquire resources through network ties, whilst the mechanism of network ties affecting each other is yet to be discussed.

## **Constructing network ties to drive radical innovation**

Firms within a network are equipped with a variety of network ties, through which they acquire knowledge and information from their partners and enhance R&D capabilities and innovation performance. As different types of network ties function differently and exert diversified impact on radical innovation (Mahmood *et al.*, 2011), here we identify three kinds of network ties: buyer-supplier ties, peer-collaboration ties and equity ties. In this section, we develop propositions on how network ties may spur radical innovation.

### **Buyer-supplier ties in radical innovation**

Firms aiming to develop radical innovation require access to dissimilar knowledge (Greve, 2007), including architecture knowledge of a product, as well as the knowledge about how each component works and the ways they interact with each other. In other words, firms need to know more than they make (Brusoni *et al.*, 2001). We propose that buyer-supplier ties can be particularly useful in providing firms with access to novel knowledge for the following three reasons: (1) buyer-supplier ties can be effective access to diverse technological knowledge; (2) administrative learning from buyer-supplier ties could be useful in adapting focal firms' organizational routines to new technologies; and (3) repeated interaction with customers and supplier fosters reciprocity which is helpful to technological and administrative knowledge absorption.

As pointed out by Phelps (2010), technological diversity plays a vital role in radical innovation. Buyer-supplier ties provide focal firms with significant access to diverse technologies (Belderbos *et al.*, 2004; Mahmood *et al.*, 2011). For example, IBM launched an innovation Jam, a 72-hour web-based discussion forum, to integrate employees, customers, and suppliers for exploring emerging market opportunities, resulting in 31 follow-up projects in various parts of IBM (Birkinshaw *et al.*, 2007). A buyer or

supplier probably has opportunities to leverage its partner's complementary resources especially when they locate in the same supply chain (Mahmood *et al.*, 2011). Generally, suppliers have technological advantage and greater expertise in specific parts or components. Such comprehensive knowledge is critical to re-configuration of product architecture (Henderson and Clark, 1990) and creation of new solutions for highly novel improvements (Song and Thieme, 2009; Tsai, 2009). Tight collaboration with suppliers contributes towards rapid development in a context of limited resources (Pohl and Elmquist, 2010). Similarly, customers serve as another knowledge source for radical innovation (Franke *et al.*, 2006; Ojanen and Hallikas, 2009), since collaboration with customers facilitates the focal firm's knowledge exploration, retention, and exploitation outside its boundary throughout the innovation process (Lichtenthaler, 2011). Suppliers and customers are normally involved in a variety of interfirm relationships, from which they obtain knowledge about potential market change and technological dynamics. By engaging in buyer-supplier ties, focal firms may gain access to not only the supplier or customer's knowledge, but also the knowledge that the supplier or customer acquires from its own ties. Extensive involvement in buyer-supplier ties expands focal firms' scope of knowledge searching, both locally and distantly (March, 1991). Distant search involves recombination of novel and unfamiliar knowledge (Phelps, 2010), and boosts the process of exploration. Even though local search is more of an exploitative behavior (March, 1991), it can be helpful in enhancing technological diversity. In the course of knowledge searching, a firm could build new buyer-supplier ties with new partners. By searching diverse and novel domains, firms can integrate their existing knowledge base with new technological solutions, and develop novel ideas for existing problems or apply one solution into another R&D domain (Hargadon and Sutton, 1997). Moreover, diverse technological knowledge provides a firm with a variety of combinations for knowledge integration, thus promoting the process of mixing and matching within totally new product architecture to fulfill novel product functions (see, Henderson and Clark, 1990). Also, customers and suppliers could participate in commercializing disruptive ideas.

Since technological knowledge embeds in organizational routines (Nelson and Winter, 1982), a radical innovation requires that a firm makes radical changes in its current organizational routines (Bao, 2009). Administrative learning from buyer-supplier relationships benefits focal firms with respect to how to adapt their organizational routines to novel technologies (Bao *et al.*, 2012).

Focal firms obtain knowledge from buyer-supplier ties and draw lessons about partners' administrative experiences so as to change their own assumptions and refresh their mindsets for developing new organizational routines (Baker and Sinkula, 1999; Birkinshaw and Mol, 2006). As the development of new organizational routines refers to plenty of administrative affairs which call for acquisition of extensive administrative knowledge, a more central position (i.e., a higher position in a status hierarchy (Ibarra, 1993)) in a buyer-supplier network can be helpful in reconfiguring and restructuring existing routines (Brown and Eisenhardt, 1995).

Different from other network ties, ties with customers and suppliers are built based on existing relationships, making it much easier for focal firms to develop reciprocity with partners. According to Dyer and Singh (1998), reciprocity serves as an effective mechanism promoting interfirm knowledge acquisition. Durable reciprocity with customers and suppliers strengthens network ties and, correspondingly, facilitates long-term knowledge sharing and integration (Ring and Van de Ven, 1994; Lövblad *et al.*, 2012). Intel's collaboration with Imoko Composites of Japan in developing organic/4C packaging technology provides a good example of this situation (see Perrons, 2009). In order to develop the organic/4C packaging technology for Pentium II system, Intel built a collaborative R&D relationship with Imoko based on "trust and a relatively benevolent form of power that is exemplified by the company's 'open kimono principle'" (Perrons, 2009, p.1300), which promoted the sharing of financial data and highly proprietary technology information. As long as suppliers and customers are involved in each other's R&D process and other technical issues (Ring and Van de Ven, 1992), trust and mutual dependence could then be developed to promote successful recombination of each other's knowledge base (Dyer and Singh, 1998). During a repeated interaction process, joint problem-solving arrangements within buyer-supplier relationships may be formed and used as a platform for the transfer of complex and tacit knowledge (McEvily and Marcus, 2005). As a result, buyer-supplier ties become an enduring and stable source of novel knowledge for developing disruptive ideas.

In summary, the more buyer-supplier ties a firm can develop, the more likely it will be to acquire knowledge and come up with novel concepts. Therefore, we propose:

*Proposition 1: Buyer-supplier ties are positively related to radical innovation.*

**Peer collaboration ties in radical innovation**

While firms compete with peers in specific markets, they may also acquire knowledge and spur radical innovation from peer collaboration ties (Inkpen and Pien, 2006; Tsai, 2009). Peer collaboration represents an enduring and reciprocal relationship between competitors which may be helpful for their long-term strategies, such as joint R&D. Peers generally have a similar knowledge base in the aspect of breadth, but different in the aspect of depth (Zhou and Li, 2012). Although partnership between peers has a limited complementary capacity because of a lack of essential structural diversities in terms of resources, skills, and capabilities (Balakrishnan and Koza, 1993; Han *et al.*, 2012), it may still be helpful in integrating in-depth knowledge and developing discontinuous ideas (Zhou and Li, 2012). The differences between specific knowledge depth constitute their own advantageous technology modules respectively, and thus the combination of such advantages may greatly influence the knowledge base of new product development. Since more depth in knowledge base stimulates intensive experimentation and exploration, firms can identify potentially useful elements of technological knowledge, combine these elements fruitfully, and effectively access and assimilate this knowledge (Galunic and Rodan, 1998). As a result, involvement in peer collaboration ties help to rebuild highly novel configuration of existing elements (Siedel, 2007). Disruptive ideas, which are difficult for single firm, may then be developed. With the focal firm moving towards an increasingly central position, more and more peer collaboration ties can be developed, thus facilitating configuration of existing elements and technology architecture.

According to O'Connor and DeMartino (2006) and Story *et al.* (2009), discovery, incubation, acceleration, and commercialization are the four competences necessary to capture the requirements for success in radical innovation resulting from external collaboration. Peer collaboration ties provide firms with access to capability development in terms of time and risk reduction (Belderbos *et al.*, 2004) and know-how exploitation (Gemünden *et al.*, 2007). Partners locating in the same industry can develop strategic and organizational compatibility through relationships with much less effort and cost than partners operating in different industries (Koh and Venkatraman 1991). Consequently, collaborative partners from the same industry can easily identify, understand,

and learn from each other. This can be explained by the fact that automobile enterprises have been collaborating with each other to explore novel technologies or develop new market domains, such as General Motor (GM) and FIAT in 2000 and Daimler and Renault in 2010. A firm with a more developed absorptive capacity, i.e., the capacity to acquire, assimilate, transform, and exploit knowledge (Zahra and George, 2002), extends the reach (both in distance and scope) of the firm's cooperative potential (Freel, 2003) and enhances its innovation capabilities (Assink, 2006). As Herrmann *et al.* (2007) have pointed out, relying only on existing customers and their needs is not sufficient in promoting radical innovation. In case that partners are equipped with different core competences and serve in different segment markets, a firm may absorb different customer information from peer collaboration ties and help to seize opportunities to develop radical ideas. The more ties a focal firm occupies, the more customer information it may obtain from its peer collaboration network. Therefore, we can expect that a firm's peer collaboration ties are positively related to its radical innovation.

However, if a firm is involved in too much collaboration with partners from similar segment markets, it may find it difficult to obtain knowledge diversity from other ties (Luo and Deng, 2009). In such cases, a firm benefits more in terms of incremental innovation than radical innovation from peer collaboration ties (Belderbos *et al.*, 2004). For example, Darr and Kurtzberg (2000) have pointed out that since similar partners possess similar identities and routines, they can transfer knowledge and coordinate with each other more easily, thereby facilitating knowledge co-creation for incremental innovation (Kraatz, 1998). Nevertheless, knowledge sharing with similar partners may not meet the requirements of discontinuous product change as such peer organizations are less likely to complement the needs of each other and offer new knowledge for the other party to learn (Harrison *et al.*, 2001; Stieglitz and Heine, 2007). According to Luo and Deng (2009), similar partners within an interfirm collaboration network contribute to the focal firm's innovation up to a threshold, beyond which additional similar partners can lead to a decrease in innovation. Uzzi (1997) also pointed out that benefits of ties with close partners rise up to a threshold. When a firm builds peer collaboration ties with similar partners, the extension of knowledge base may be greatly restricted by similar elements and routines, thereby setting an intrinsic limit to the innovation-producing knowledge trajectory (Luo and Deng, 2009). Consequently, a firm may fail to obtain as

many radically new elements and ideas from similar partners as from dissimilar partners. Even though the firm occupies a central position in the peer collaboration network, it is likely that it will not be able to significantly change the effect of peer collaboration ties (with high similarity) on radical innovation. Therefore, we can expect that partner similarity negatively moderates the relationship between peer collaboration ties and radical innovation.

*Proposition 2: Peer collaboration ties are positively related to radical innovation, and the relationships are more significant when partner similarity is low than when it is high.*

### **Equity ties in radical innovation**

Buyer-supplier ties and peer collaboration ties are perceived to be critical elements of radical innovation, enabling knowledge to flow between partners. Equity ties, then, can be seen as boosters of such knowledge flow (Mahmood *et al.*, 2011). According to Kogut (1988), equity ties are good vehicles by which tacit or organizationally embedded knowledge can be transferred. Equity ties exist in buyer-supplier or peer collaboration networks, in which buyers and suppliers, or competitors hold each other's equity. Generally, equity ties reinforce the relationship between buyer-supplier ties and radical innovation through two paths: (1) equity ties provide firms with financial support for further knowledge exploration through buyer-supplier ties; (2) equity ties act as formal contracts between customers and suppliers in the knowledge sharing processes, through which partners make further commitment to each other to guarantee mutual trust and enduring collaboration.

In general, financial support stems from partners aiming to acquire new technologies or obtain investment returns (Benson and Ziedonis, 2009; Hochberg *et al.*, 2007). For example, corporate venture capital investment from established firms helps them to renew and extend their internal capabilities and resources by acquiring and redeploying external technologies from start-up firms (Agarwal and Helfat, 2009). On the other hand, firms that obtain financial capital also benefit from it in terms of R&D investment. Within an equity network (i.e., a network within which firms hold or share each other's equity), firms are able to obtain continuous investment and then update organizational skills, routines and systems (Mahmood *et al.*, 2011). They also benefit from equity ties by

using the ties as test beds for novel concepts. During that process, firms may improve their technological trajectories and R&D infrastructures so as to further explore discontinuous ideas.

While equity ties provide firms with financial support for the improvement of skills and infrastructures, it may not be able to drive radical innovation in the manner that buyer-supplier ties do (Mahmood *et al.*, 2011). Nonetheless, access to equity ties strengthens a firm's competences in integrating external knowledge from buyer-supplier ties. Since buyer-supplier ties are helpful to the extension of the focal firm's knowledge base, equity ties within buyer-supplier networks are extremely conducive to the exploration of technological knowledge. For instance, in order to acquire core technologies, Microsoft recently launched extensive collaboration with suppliers through equity holding or sharing. Also, continuous improvement and update in skills and infrastructures driven by equity ties helps to enhance the focal firm's R&D capabilities, thus increasing the output of buyer-supplier collaboration in terms of disruptive idea development. Equity relationships with buyers or suppliers help to bridge between the focal firm's organizational routines and partners' technological knowledge (Bao *et al.*, 2012), thus facilitating the adaptation of administrative learning to the development of new technologies.

The second way that equity ties influence radical innovation in buyer-supplier networks is to improve commitment between partners in terms of technology transfer and knowledge sharing. This happens especially in case of cross holding (i.e., collaborative firms hold each other's shares). Equity ties lead to formal contractual connections through which all partners strive to fulfill their common goals and expectations. Both contractual parties' investment in each other's business can be considered as a mutual sunk-cost commitment, transforming a unilateral relation into a bilateral relationship (Kim and Mahoney, 2006). Thereafter, the reciprocity derived from buyer-supplier interactions can be strengthened in a way that facilitates knowledge exploration across organizational boundaries. The equity relationship between Toyota and Futaba provides evidence of this situation. To ensure sustainable components supplemented with high quality, Toyota developed a series of equity relationships with suppliers, including Futaba, a supplier of brake assembly and electronic controlled injection system. Such a relationship benefits Futaba in terms of both technology advancement and new market exploration. Correspondingly, firms develop cross-boundary organizational arrangements

(e.g., joint R&D teams, common affairs committee, information technology system connections) with customers and suppliers which may facilitate knowledge transfer. According to Aggarwal *et al.* (2011), a high level of interdependence entails a high degree of exploration. Hence, a firm can easily integrate external knowledge from buyer-supplier ties and develop novel conceptions.

Therefore, the more equity ties developed in the buyer-supplier network, the more a focal firm can make full use its buyer-supplier ties. With the focal firm moving towards an increasingly central position in its equity network, it can get more access to interfirm knowledge in the buyer-supplier network. In addition, a more central position in the equity network ( i.e., more equity ties) benefits firms in terms of stronger interfirm power (Perrons, 2009), enabling an advantageous position in coordinating and reallocating network knowledge embedded in buyer-supplier relationships. We thus propose:

*Proposition 3: Equity ties reinforce the positive relationship between buyer-supplier ties and radical innovation.*

Similar to the situation of buyer-supplier ties, the effect of peer collaboration ties on radical innovation can also be enhanced by equity ties. Specially, as most peer collaborations aim to combine each other's key technology and develop new products, equity cross holdings can serve to 'equalize the risk exposure of the contractual parties, and thereby reduce the economic incentive of any contractual party to behave opportunistically in the exchange process ex post' (Kim and Mahoney, 2006, p.407). Knowledge misappropriation can then be settled to some extent. Meanwhile, tightly coupled relationships motivate partners to invest more in manpower and facilities, and thus accelerate the process of joint new product development. Enhanced knowledge sharing promotes the extent of diversity of mixing-and-matching among different technology modules (Schilling, 2000), hence raising the possibility of radical innovation. In addition, equity relationships with peers benefit the focal firm in terms of capability acquisition (Mahmood *et al.*, 2011), thus accelerating the development of novel concepts. For instance, Lenovo, a world leading PC producer, has helped a number of start-up firms develop new technologies through equity investments. Therefore, we can expect that equity ties can be helpful in reinforcing the positive relationship between peer collaboration ties and radical innovation.

*Proposition 4: Equity ties reinforce the positive relationship between peer collaboration ties and radical innovation.*

## The Crowding out effect within networks

Although, as discussed above, network ties play vital roles (direct or indirect) in radical innovation, the interaction between different ties may have a detrimental influence on a firm's knowledge acquisition process. As pointed out by Luo and Deng (2009), collaboration with existing partners would inevitably induce to the crowding out of some other partners with diverse technologies (also see, Karanamos, 2011). Such crowding out effects may influence the way networks drive radical innovation. In this section, we discuss the possible impacts that the crowding out effect may exert on radical innovation.

The crowding out effect originally referred to increases in government spending crowding out private investment spending (Cox and Jimenez, 1995). This economic perspective has been discussed in-depth in the innovation field, identifying whether different kinds of financial support for new product development crowd out each other (Lach, 2002; Almus and Czarnitzki, 2003; Aerts and Schmidt, 2008). The crowding out effect exists because a firm's capacity of resource (financial or non-financial) absorption is limited. Similar crowding out also emerges when a firm chooses partners at the expense of giving up opportunities of collaborating with some others (Luo and Deng, 2009), implying that different types of knowledge and resource adhering to potential partners may also crowd out each other. In other words, some network ties are crowded out by others, thereby affecting radical innovation in networks.

Resources in a firm are limited (Pfeffer and Salancik, 1978). A firm needs to reasonably and wisely deploy its limited resources, including focused project objectives, tight collaboration with suppliers or customers of the new technologies, reuse of existing technologies and an unaggressive, bottom-up approach to change its values and norms (Pohl and Elmquist, 2010). More specifically, a limited resource base compels firms to refine their knowledge searching scope and focus on a minority of R&D projects. According to Benson and Ziedonis (2009), the effect of financial investment on technological acquisition is affected by the acquirer's internal knowledge base. Firms then have to build network ties with some partners and give up the opportunities of developing relationship with others. Such crowding out effect cuts off the access to certain external innovative resources and capabilities, and stops firms from developing discontinuous concepts. Since network ties used for radical innovations differ from those for incremental innovations in terms of knowledge creation processes, partner characteristics, as well as process learning routines (Feller et al., 2006),

some ties useful for radical innovation may be crowded out by others only capable of developing incremental innovation. In other words, radical innovation is crowded out by incremental innovation.

Inherently, network ties (buyer-supplier, equity, and peer collaboration) are based on existing businesses, and a firm has to build relationships with relevant business partners. While existing partners are mostly preoccupied by non-research business collaboration in terms of production, marketing, or supply chain affairs, the focal firm would find it difficult to acquire tacit knowledge from partners (Nieto and Santamaría, 2007). In general, collaborative R&D and knowledge creation between existing partners are foreclosed or inhibited by joint activities taken in past development (David, 1985). Self-reinforcing sequences in partnerships make it difficult to switch from one partner to another (Mahoney, 2000). Even if focal firms begin to negotiate with new potential partners, the switching cost may keep some potential partners with good resources away from a focal firm's network (Zhou, 2011). As a result, existing network ties with stable interfirm relationships may prevent new partners from entering the network, and a firm may miss opportunities of acquiring specific knowledge for radical innovation. In the long term, a firm that is involved in a specific tie may be less likely to obtain enough new knowledge required to launch a radical innovation.

Generally, crowding out in innovation networks happens in two different ways: horizontal and vertical. *Horizontal crowding out* emerges when network ties are crowded out by the same type of ties (e.g., one buyer-supplier tie crowding out by another buyer-supplier tie). For example, a supplier of DELL was told that in order to remain in a long-term relationship with them that they were not allowed to build business relationships with other PC hub enterprises, such as hp and SAMSUNG. As firms are mostly expected to obtain immediate economic rent from existing buyer-supplier ties, they would be more capable of abandoning future interests stemming from switch of buyer-supplier ties (see, Benner and Tushman, 2003). Meanwhile, the threat from partners arises because knowledge-based assets in partnerships are imperfectly protected (Cohen *et al.*, 2002) and outcomes from disruptive innovation activities are highly uncertain (Holmstrom, 1989), making it even more difficult to switch from one partner to another.

In contrast, *vertical crowding out* happens when network ties are crowded out by partners from different types of ties. For example, buyer-supplier ties may crowd out peer collaboration ties in the contest to get collaborative R&D opportunities. Especially

when equity ties set up extensive business linkages, which can cause other buyer-supplier ties or peer collaboration ties to be excluded from the focal firm's network. Equity ties encourage investment in the development of routines (Sampson, 2007) and may also foster joint governance mechanisms for common businesses. Partners from equity networks are explicitly empowered to control joint activities and protect their own investment interests. Such control and power could be used to interfere with the focal firm's development of extensive network ties.

As horizontal crowding out is related to the same type of network ties and vertical crowding out refers to different types, they may affect radical innovation independently, but will also exert such impact jointly. Especially when both crowding out effects appear simultaneously, certain network ties might reduce the potential opportunities of knowledge acquisition from all other ties, including equity relationships which could be helpful for increasing investment in R&D activities. For instance, when *Daimler Group* set up a joint R&D project with *BYD Auto* — an emergent Car maker in China — for developing electric vehicles in 2010, it actually excluded other similar collaborative opportunities, both vertically and horizontally. In such cases, limited network ties prevent firms from searching for experienced partners with diverse knowledge portfolios, thus reducing the opportunities for integrating different technology trajectories and developing new technology architecture. Therefore, both horizontal and vertical crowding out effects within networks reduce the opportunities to develop extensive network ties, and thus limit the focal firm's scope of knowledge searching and integration, which inevitably hampers the process of radical innovation. We thus propose,

*Proposition 5: The crowding out effect in networks prevents focal firms from developing diverse network ties, and thus negatively influences radical innovation.*

## Conclusion

The purpose of this paper is to offer a novel set of insights to understand how the heterogeneity in the content of network ties affects radical innovation, to help to guide future theoretical and empirical work. To develop our theoretical framework, we drew from a body of literature that has undertaken pilot studies into the relationships between network and radical innovation (e.g., Story *et al.*,

2009; Möller, 2010). By considering three types of network ties: buyer-supplier, peer collaboration, and equity ties, we have demonstrated that network ties can be effective sources of knowledge leading to radical innovation. The more the network ties a firm has, the more ability it has to acquire diverse knowledge, and pursuing different ties results in different effects on radical innovation. Buyer-supplier ties and peer collaboration ties contribute to radical innovation by providing a direct path to heterogeneous knowledge (direct effect), while equity ties spur radical innovation in an indirect way (moderating effect). Even though the three types of network ties can facilitate radical innovation, they may also crowd each other out (crowding out effect), leading to a negative impact on radical innovation. The findings of this study are summarized in Table 1

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Insert Table 1 about here.  
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Firms with buyer-supplier ties and/or peer collaboration ties are more capable of acquiring marketing and technological knowledge for radical innovation than those without such ties. In addition, the impact of peer collaboration ties may be further affected by partner similarity, because radical innovation, in contrast to incremental innovation, requires distinguishing competences (Story *et al.*, 2009) and an extensive knowledge base (Zhou and Li, 2012), thus making it difficult to develop discontinuous innovations with highly similar partners. Such a perspective implies that knowledge diversity constitutes a technology base for launching radical innovation. Compared to other two kinds of network ties (i.e., buyer-supplier and peer ties), equity ties act as more of moderating roles in networks. This is because different types of ties affect the processes of knowledge exploration in different ways. Buyer-supplier and peer collaboration ties provide direct access to heterogeneous knowledge outside of organizational boundaries. In comparison, equity ties, as boosters of interfirm knowledge flow, facilitate the use of buyer-supplier and peer collaboration ties in pursuit of radical innovation, rather than influencing radical innovation directly. When buyer-supplier ties and peer collaboration ties are coupled with equity ties, their effects on radical innovation are much stronger. Firms within an equity network develop both formal contract and informal reciprocity with their partners, thus facilitating knowledge acquisition through buyer-supplier ties or

peer collaboration ties. Furthermore, our study shows that crowding out resulting from different network ties prevents firms from searching for knowledge across the broad scope of the network, reducing the opportunities for mixing-and-matching between the different kinds of knowledge needed for radical innovation, thus calling for a systematic, deep consideration of partner selection among different types of business relations.

This study makes two contributions to existing research. First, we addressed the question of how networks and relationships influence radical innovation by identifying three types of network ties and their effects —individual and in combination — on extension of knowledge depth and breadth and development of disruptive ideas. The observation that networks and relationships can facilitate exploration of technology or market opportunities in interfirm settings underscores the importance of network ties (e.g., McEvily and Marcus, 2005; Karamanos, 2011). Moreover, our study eschewed the existing view of network ties as generic conduits for knowledge exchange between firms by exploring the heterogeneity in the content of ties. By introducing three types of network ties and their relationships with radical innovation, we focused on identifying the source of disruptive ideas and heterogeneous knowledge for developing them. Having a more specific view of the potential implications of network ties (as we attempted to do in this article) can enable more targeted research approaches. Second, we extended the existing literature by demonstrating the crowding out effect of network ties. Existing research tends to focus on the effects of resource acquisition by networks, while little work has been done to explore the situations in which firms have to abandon some network ties. We proposed that network ties may crowd out each other because of limited knowledge base and business scope, affecting the process of knowledge searching for developing disruptive ideas. Our analysis suggests that firms need to carefully choose and manage their network ties in the course of radical innovation development. Further, while radical innovation firms focus on how to get their patents and technologies out to the market (Tellis *et al.*, 2009), our study suggests a way of launching marketing strategy by selectively integrating different sources of knowledge (market, supplier, or technology) needed for commercializing radical technologies, highlighting the importance of partner selection for radical innovation among different types of firms surrounding the current market. However, we developed our theory without conducting empirical research, which is a limitation of the present study.

The propositions developed in this research can provide insightful managerial implications for managers who may choose either buyer-supplier ties or peer collaboration ties for launching radical innovation. In this sense, managers should build collaborative relationships with customers, suppliers, or competitors for not just product and service transactions, but also knowledge sharing and creation. Since customers, suppliers and competitors differ from each other in terms of knowledge configurations (Belderbos *et al.*, 2004), managers need to understand partners' knowledge demands for specific R&D or marketing projects so as to make a informed choice between buyer-supplier partnerships and peer collaborative relationships. They should also strive to extend their network ties so that a central position of such network is accessible and anticipatable. For peer collaboration ties, managers need to avoid selecting partners that have similar knowledge configurations or technological routines so as to acquire heterogeneous knowledge. For instance, if a firm serves the same market by using similar technology strategies to a competitor, then the competitor is not appropriate to be chosen as an innovation partner. In order to strengthen the ties and guarantee a stable knowledge source, we recommend that managers develop equity ties with their customers, suppliers, or competitors when configuring interfirm networks with those partners. Especially, when partners have core technologies, equity holding or sharing can be an effective way for managers to utilize external expertise. Whilst equity ties enhance trust and reciprocity between firms and their partners, they may also prevent firms from developing extensive network ties with some other partners. This effect is called crowding out. More generally, network ties can crowd out each other within collaborative innovation networks. Hence, managers need to identify and select network ties that can be helpful to long-term strategy.

### **Suggestions for future research**

The framework presented here demonstrates how network ties affect radical innovation. However, our study in the present paper is just the tip of an iceberg. Work needs to be done to identify the role of networks and relationships in radical innovation. Below are some potential avenues for future research.

*External and internal knowledge integration for radical innovation.* As demonstrated in the present paper, network ties provide

firms with access to external knowledge in pursuit of radical innovation. It is, however, still unclear how firms integrate external knowledge and internal knowledge together to spur radical innovation. Radical innovation refers to extensive knowledge base that strengthens the dynamics of knowledge integration in terms of technological trajectories and organizational routines (Zollo and Winter, 2002; Revilla and Villena, 2012). In order to integrate external knowledge into existing knowledge structures, firms may adjust their technological trajectories to existing organizational routines, or change existing organizational routines to facilitate knowledge absorption and exploration. Such dynamic courses have been loaded into a ‘black box’, and existing theories, including absorptive capacity, organizational learning, and network theory, cannot provide explanations for this. Studies on this issue can be extremely meaningful and helpful to the development of new research approaches.

*Knowledge misappropriation in radical innovation networks.* Radical innovation involves the integration of diverse knowledge, and thus leads to the risk of knowledge misappropriation between partners. Since collaboration in radical innovation may relate to partners’ core technology, knowledge misappropriation can significantly affect firms’ innovation and even long-term strategy. Therefore, research on this topic would be very useful. Future studies may focus on the antecedents and outcomes of knowledge misappropriation in radical innovation networks, and how to reduce such risk.

*Radical innovation networks in different contexts.* While different contexts entail different institutional settings and characteristics which may affect the outcomes of radical innovation (van Dijk *et al.*, 2011), it is meaningful to identify the behaviors and outcomes within radical innovation networks in different contexts. Especially, as new economies (e.g., Brazil, China, and India) emerge as important players in the world market, innovation issues in such contexts will be increasingly crucial to these countries and the whole world. For example, the fruit of radical innovation in those countries is easier to be imitated than in developed economies because of insufficient legal protection. While imitation widely exists in such economies, future research on this topic is necessary in terms of driving radical innovation in those settings. Furthermore, institutional comparison between the developed and developing countries can be valuable in forming a context-based radical innovation theory.

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Table 1 A summary of findings

Effect	Types of ties involved	Impact on radical innovation
Direct effect	Buyer-supplier ties Peer collaboration ties	<ul style="list-style-type: none"> <li>Buyer-supplier ties are positively related to radical innovation</li> <li>Peer collaboration ties are positively related to radical innovation</li> </ul>
Moderating effect	Equity ties	<ul style="list-style-type: none"> <li>Equity ties positively moderate the relationship between buyer-supplier ties and radical innovation</li> <li>Equity ties positively moderate the relationship between peer collaboration ties and radical innovation</li> </ul>
Crowding out effect	Buyer-supplier ties Peer collaboration ties Equity ties	<ul style="list-style-type: none"> <li>Different types of ties may crowd out each other, thus reducing the focal firm's scope of knowledge searching and integration.</li> </ul>