OPEN ACCESS
International Journal of Innovation Management
Vol. 26, No. 7 (September 2022) 2250053 (35 pages)

DOI: 10.1142/S1363919622500530

EXPLORATORY INNOVATION THROUGH GAINING KNOWLEDGE FROM ALLIANCE PORTFOLIO: INTERPLAY BETWEEN NETWORK STRUCTURE AND KNOWLEDGE COMPOSITION

S. JOSEPH YOON[*,§], GIL S. JO[†,¶] and JINA KANG[‡,||]

**Technology Management, Economics and Policy Program, Seoul National University*
1 Gwanak-ro, Gwanak-gu, Seoul 08826, South Korea
[†]*Associate Research Fellow, Center of Future Growth Strategy,*
Korea Institute of S&T Evaluation and Planning, Dongwon Industries Building,
68 Magang-ro, Seocho-gu, Seoul 06775, South Korea
[‡]*Professor of Strategy & Technology Management, Technology Management,*
Economics and Policy Program, Seoul National University
1 Gwanak-ro, Gwanak-gu, Seoul 08826, South Korea
[§]*hiai@snu.ac.kr*
[¶]*gilsoojo@kistep.re.kr*
[||]*profkang@snu.ac.kr*

Published 5 January 2023

Building an alliance portfolio is an important knowledge-sourcing strategy for firms to create exploratory innovation. By proposing a framework of knowledge flow and search flexibility, we examine the effects of a firm's network position and knowledge composition of the alliance portfolio on the creation of exploratory innovation. Particularly, we explore their interactions that create synergy and offset mutual disadvantages. Using panel data of 142 pharmaceutical companies from 1996 to 2010, we find that central and brokering positions have an inverted U-shape relationship with the creation of exploratory innovation. We also find two combinations of network position and knowledge composition advantageous for increasing exploratory innovation: a central position with partners' wide scope of new knowledge, and a brokering position with partners' wide scope of shared knowledge. This study contributes to the literature by identifying interaction effects between social network theory and the knowledge-based view and suggests implications for designing a firm's alliance strategy.

Keywords: Alliance portfolio; exploratory innovation; network position; knowledge composition.

[||]Corresponding author.

Introduction

Exploratory innovation, which refers to the generation of something valuable by using unfamiliar knowledge obtained from exploration, has received considerable attention as an important way to gain a competitive advantage and achieve sustainable growth (Ali, 2021; Gilsing *et al*., 2008; Luo *et al*., 2018; Rothaermel and Deeds, 2004). However, owing to a firm's resource constraints and path-dependent tendencies, it is not easy to explore new knowledge relying only on internal R&D (Hagedoorn and Schakenraad, 1994). Accordingly, establishing strategic alliances, which together form an alliance portfolio, becomes a vital external knowledge-sourcing strategy that firms can search for, adopt, and create new knowledge (Duysters and Lokshin, 2011; Grant and Baden-Fuller, 2004; McConnell and Cross, 2019; Powell, 1998; Rosenkopf and Nerkar, 2001; Slavova and Jong, 2021; Srivastava and Gnyawali, 2011; Van de Vrande *et al*., 2006). This paper aims to reveal the effective way to source external knowledge among alliance partners to create exploratory innovation. Specifically, we examine the effects of a firm's external knowledge environment, i.e., the configuration of the alliance portfolio, on its creation of exploratory innovation.

Previous literature has adopted the social network theory and the knowledge-based view as the primary theoretical lenses in consideration of the structural factors affecting firms' access to external knowledge resources or the compositions of knowledge that the alliance partners possess (Cao *et al*., 2021; Gilsing *et al*., 2008; Kogut and Zander, 1992; Luyun *et al*., 2019; Phelps, 2010; Wassmer, 2010; Yu and Chen, 2020). From social network theory, central or brokering positions have been investigated to capture important aspects of network embeddedness (Gnyawali and Madhavan, 2001; Gulati and Gargiulo, 1999; Lin *et al*., 2009; Ma *et al*., 2020). A central position refers to a high social status, which allows a firm to directly access the knowledge of its alliance partners (Bonacich, 1987; Podolny, 1993, 2001; Powell, 1998; Powell *et al*., 1996). At the same time, high-status firms face difficulties in exploring new ideas because of their close relationship with their partners (Locke *et al*., 1999). A brokering position refers to a bridge of different and often unconnected groups, which may provide a potential source of novel ideas by accessing the different information flows among separate groups (Burt, 2000; Zaheer and Bell, 2005). However, it may prevent a firm from accessing its partners' knowledge because of its loose connection (Burt, 2004).

The knowledge-based view focusses on the knowledge characteristics, e.g., the scope of new (or shared) knowledge available to the focal firm, to identify and capture the value of knowledge resources in alliance portfolio (Cui and O'Connor, 2012; Wuyts and Dutta, 2014). As exploratory innovation is created from the recombination or reconfiguration of knowledge elements, a wide scope of new knowledge is an important source of exploratory innovation (Crescenzi and Gagliardi, 2018; Fleming, 2001; Marhold *et al*., 2017). However, if the scope of new knowledge is too wide, information overflow may arise (Koput, 1997). While a wide scope of shared knowledge provides the absorptive capacity, i.e., a firm's ability to value, assimilate, and apply external knowledge (Cohen and Levinthal, 1990; Schildt *et al*., 2012; Zahra and George, 2002), homogeneous knowledge may hinder the creation of exploratory innovation (Uzzi, 1996).

Although many studies have employed these two theoretical lenses, important research gaps remain. First, from the viewpoint of social network theory, previous literature has assumed that firms in an equivalent network position can access and utilise the same quality of resources from their alliance partners. However, knowledge differs between their alliance partners in reality, even though firms occupy the same position from a network structure perspective. Second, from the viewpoint of knowledge-based theories, previous literature assumes the same resource accessibility if firms have the same partners, regardless of any variance in their social network position. This assumption also ignores the reality of structural differences among firms' network positions, even though they form alliances with the same partners. The difference between these implicit assumptions and reality leads to an incomplete understanding of alliance portfolio characteristics and their effects on subsequent exploratory innovation. To overcome this limitation, it is necessary to employ these two theoretical lenses separately and investigate the interaction effects between structural and nodal properties, i.e., a firm's position among its alliance partners and their knowledge characteristics. Following this objective, our research investigates which combinations of network positions and knowledge composition in the alliance portfolio are beneficial for increasing the focal firm's exploratory innovation.

For a holistic approach, we propose a framework considering two key factors, knowledge flow and search flexibility, to deal with the two fundamental challenges that firms may face, i.e., the search and transfer problems in creating exploratory innovation (Hansen, 1999; Lee, 2011). Using this framework, we hypothesise that both network positions facilitate knowledge flow or search flexibility, but hinder the other factor as their positional effects increase beyond a certain level. In addition, we presume that the effects of the network position and knowledge composition complementarily interact. Accordingly, the potential negative effect on either knowledge flow or search flexibility from a network position can be compensated by the effects stemming from the knowledge composition in the alliance portfolio.

Our empirical analysis on a panel dataset of 145 international pharmaceutical companies confirms the proposed inverted U-shape relationship between central/brokering network positions and the creation of exploratory innovation. We find that a central position promotes smooth knowledge flow with partners, however, it may decrease search flexibility beyond a certain level. Our findings also clarify that a brokering position increases search flexibility, however, it may decrease knowledge flow when exceeding a certain level. Furthermore, the results of our study confirm that two combinations of network position and knowledge composition have positive interaction effects on exploratory innovation: a central position with partners possessing a wide scope of new knowledge, and a brokering position with partners possessing a wide scope of shared knowledge. In other words, new knowledge breadth can help to mitigate the low search flexibility resulting from a central position, and shared knowledge breadth can increase absorptive capacity, which helps to increase the knowledge flow that is typically insufficient in a brokering position.

This study makes three important contributions: First, this study provides new theoretical insights by establishing a comprehensive view combining both social network theory and the knowledge-based view. Specifically, this study highlights the interrelationship between the effects of network position and knowledge composition in the alliance portfolio, and claims that potential negative effects resulting from the network position can be compensated when the knowledge composition is well-matched. Second, we suggest two key factors for creating exploratory innovation, i.e., knowledge flow and search flexibility, and uncover the conditions that satisfy both key factors simultaneously. Although the extant studies have considered them to be in a trade-off relationship, this study identifies combinations between network position and knowledge composition in the alliance portfolio, allowing them to compensate for each other's weak points, ultimately fostering knowledge flow and search flexibility at the same time. Third, from a practical perspective, this study advises managers to set up a suitable alliance strategy for exploratory innovation, considering the network position and knowledge composition at the same time. Specifically, we reveal that both central and brokering network positions possess advantages and disadvantages in creating exploratory innovation, and suggest solutions to overcome those disadvantages by utilising appropriate knowledge resources from the relevant alliance partners.

This paper is arranged as follows. In the next section, we propose our research framework based on the literature and develop four hypotheses to identify the individual effects of central and brokering positions, and the interaction effects between those network positions and the knowledge compositions on exploratory innovation. Next, we conduct empirical analysis using panel data of 142 pharmaceutical companies from 1996 to 2010 and explain the result. Finally, we derive theoretical and managerial contributions from those results, and leave comments for future research.

Theory and Hypothesis

A framework for creating exploratory innovation: knowledge flow and search flexibility

Many studies in the innovation stream adopted the perspective that innovation emerges through the process of knowledge creation, i.e., recombining and reconfiguring the knowledge resources which the innovator can reach and access (Fleming, 2001; Goerzen and Beamish, 2005; Grant, 1996a, 1996b; Hargadon and Sutton, 1997; Henderson and Clark, 1990; Nelson and Winter, 1982; Schumpeter, 1934; Weitzman, 1998). From this knowledge-driven innovation perspective, absorption and creation of new knowledge are necessary for exploratory innovation (Luo *et al*., 2018; Wang *et al*., 2014; Yoon *et al*., 2017). However, prior studies have highlighted two difficulties in new knowledge absorption and creation (Lee, 2011): First, the absorption of new knowledge is difficult due to the intrinsic nature of knowledge. The knowledge that can bring a competitive advantage to the firm is generally complex, tacit, and interdependent (Grant, 1996b; Nonaka, 1991; Zander and Kogut, 1995). This type of knowledge is not yet explicated and embedded in the members, tools, and tasks of an organisation (Argote and Ingram, 2000; Spender, 1993). These characteristics give rise to "stickiness" problems in transferring knowledge (Szulanski, 1996). Second, technology and market uncertainties make it difficult to create new knowledge. Developing relevant knowledge is necessary to deal with these uncertainties, but it is hard to forecast which knowledge will help the firm gain a competitive advantage in the future (Becker and Lillemark, 2006). The past shows that many firms fail to cope with disruptive innovation and cease to exist (Christensen, 1997; Christensen and Raynor, 2003).

For these reasons, firms that pursue exploratory innovation face two different needs: to effectively transfer complex, tacit, and interdependent knowledge and to maintain search flexibility for relevant knowledge in response to technological/market uncertainty. In other words, uninterrupted knowledge flow and unconstrained search flexibility are required for those firms (Hansen, 1999; Lee, 2011). Knowledge flow has been an important research subject in the knowledge management literature (Szulanski, 1996). According to prior studies, effective knowledge transfer is realised in the presence of trust, a strong bonding with partners, a high level of collaboration, and a well-established communication channel (Heide, 1994; Powell and Smith-Doerr, 1994; Rindfleisch, 2000). In other words, the efforts for closely cooperating with partners facilitate an understanding of the partner's intentions and the sharing and integration of knowledge resources (Dyer and Singh, 1998). Therefore, effective coordination with partners promotes an uninterrupted knowledge flow. Besides knowledge flow, search flexibility has been considered an influential factor in dealing with technological uncertainty. In a fast-changing environment, searching, contacting, and cooperating with partners are required in order to create multiple alternatives and become agile and competitive (Uzzi, 1996). Because technological uncertainty, market uncertainty, and the fast-changing environment make it difficult to predict future developments, securing a variety of alternatives is necessary to cope with these environmental uncertainties. However, obtaining alternatives can be interrupted by, e.g., alliance partners when there is a conflict of interest (Folta, 1998; Folta and Miller, 2002). Accordingly, a firm needs to maintain autonomy in decision making to increase alternatives. Keeping a distance from their partners, i.e., lowering interdependence and maintaining weak interorganisational relationships, is required to retain unconstrained search flexibility. Autonomy, which comes from the freedom of the constraint that accompanies partners, helps managers execute their various ongoing tasks and responsibilities (Burt, 2004; Moran, 2005; Shipilov, 2009).

In summary, effective coordination to retain uninterrupted knowledge flow and keeping a distance to promote unconstrained search flexibility for exploratory innovation are in a trade-off relationship, since they require different degrees of interorganisational relationship. However, we suppose that appropriate combinations of the network position and knowledge composition can solve this problem from a trade-off relationship because they have different effects on knowledge flow and search flexibility. Based on this train of thought, we develop a series of hypotheses. First, we investigate the effects of the network position on the firm's exploratory innovation in terms of the knowledge flow and search flexibility. Second, we build hypotheses on appropriate combinations of network position and knowledge composition for overcoming this problem.

Central network position and exploratory innovation

The central position among alliance partners indicates the extent of connectedness among members of an alliance network (Freeman, 1979). A central firm can gain a "high social status" and "technological prestige" among the alliance partners through having accumulated broad or in-depth knowledge (Ahuja, 2000b; Podolny, 1993; Stuart, 1998). Thus, potential partner firms want to build a strong relationship with the firm. These characteristics of firms in a central position may have effects on knowledge flow and search flexibility.

The central position facilitates the interfirm knowledge flow which has positive effects on the creation of exploratory innovation. A firm in a central position is able to access more closely guarded information through its direct contact with multiple partners (Koka and Prescott, 2008). The partners try to interact with a central firm to benefit from its accumulated knowledge. Frequent interaction with partners increases partners' resource commitments and makes them interdependent with each other (Rowley *et al*., 2000). Accordingly, partner firms share more knowledge that is not opened to other firms with a central firm. Throughout this process, a firm in a central position can establish well-developed communication channels with fewer intermediaries. It helps the firm to receive the tacit and complex knowledge of the partners (Larson, 1992). Also, a large number of partners would increase the quantity of knowledge flow to the firm. In addition, a central firm can take advantage of benefits arising from control over its R&D partners using its high prestige (Podolny, 1993) and can mobilise support from its partners to integrate knowledge resources more easily (Stuart, 1998). Furthermore, the central firm can allow its partners to filter and clarify the relevant knowledge benefits to the central firm and informed risk to be avoided (Wang *et al*., 2014).

Conversely, if a firm is located too close to a central position, increased negative influences on the search flexibility would reduce the firm's exploratory innovation. A central firm is regarded as an expert on extant knowledge who have accumulated its technological prestige. Searching and adopting knowledge totally different from the extant knowledge may result in the central firm losing reputation and a rearrangement of the status order within the alliance portfolio (Burkhardt and Brass, 1990; Wang *et al*., 2014). This reduces the incentive of the central firm to explore new ideas and encourage it to stay focussed on its existing knowledge base while narrowing the scope of the search (March, 1991). Additionally, a central firm is tightly connected to its partners with a strong sense of belonging. In this situation, it is difficult to establish new partnerships without the existing partners' consent, since these new alliances might have strong effects on the existing relationships (Park *et al*., 2015). These concerns may constrain the central firm from searching and developing new partnerships. Moreover, because of the central firm's tightly connected relationships, its every move, including its intentions, strategies, behaviours, can be known to its partners. This "hard to conceal", "information-sharing" situation constraints the central firm in finding new knowledge that does not belong to the existing partners, even if the central firm has strong motivations and capabilities for exploration. Lastly, the central firm having more interaction with its direct partners can increase the density of the interfirm network, resulting in a high degree of redundancy of partners' knowledge resources (Wassmer, 2010). Since exploratory innovation is created by combining new/different knowledge elements, this resource redundancy can degrade opportunities for knowledge search and combination activities.

In summary, as the firm is closer to the central position among the alliance partners, increasing positive effects on the knowledge flow leads to successful exploratory innovation. Too close to the central position, however, negative effects on the search flexibility arise and overwhelm the positive effects and, as a result, hinder from creating exploratory innovation. Together, these positive and negative effects lead us to the following hypothesis:

Hypothesis 1: *There is an inverted-U shape relationship between the firm's level of central position among its alliance partners and the creation of exploratory innovation.*

Brokering network position and exploratory innovation

The brokering position among the alliance partners refers to a position linking different and often unconnected groups of firms following the concept of structural holes (Burt, 1992). This position may be closely associated with search flexibility which positively influences the creation of exploratory innovation. A firm in a brokering position may be located between different strategic groups with dissimilar expertise and resources (Koka and Prescott, 2002, 2008). Thus, the firm in the brokering position can act as a bridge between them and take advantage of the information flow, e.g., by receiving different knowledge from separate groups (Burt, 2004; Ozer and Zhang, 2019; Rhee, 2004; Wen *et al*., 2021; Zang, 2018). This helps the firm to broaden its technological window to search and track novel technologies that will lead to a possible technological change. The brokering position also provides information benefits that increase the possibility of discovering knowledge elements which are from unrelated or distant fields (Zaheer and Bell, 2005). In the course of combining these knowledge elements, the firm can increase inventive opportunities which lead to the creation of exploratory innovation. In addition, if the firm is close to a brokering position, the firm is likely to have autonomy in decision making since the firm typically is unaffiliated with the neighbouring groups of firms (Shipilov and Li, 2008). This results in the firm having fewer constraints in exploring new ideas and allows it to ally with new partners more easily if they possess novel technology.

Meanwhile, if the firm is too close to the brokering position, allowing the firm not to belong to any particular group of firms, negative effects on the knowledge flow will arise. Assuming the opposite case, i.e., firms within a group, they can share the same context; for example, the same interests, objectives, culture, and background knowledge (Rindfleisch, 2000). They can communicate with each other based on a comprehensive understanding with a shared context, which increases the absorptive capacity that is important to understand tacit and complex knowledge (Cohen and Levinthal, 1990). On the other hand, a firm that does not belong to a particular group faces difficulties in communicating with the firms within the group because they do not share the knowledge that is the foundation of absorptive capacity. Without absorptive capacity, the firm cannot understand tacit, complex, and interdependent knowledge. In a similar vein, a firm in a brokering position is likely to be unaffiliated with any group of firms, so it may suffer from a lack of a strong sense of fellowship. Therefore, a firm in a brokering position will have a hard time mobilising support from its partners to integrate knowledge resources and to create exploratory innovation.

In summary, while the level of brokering position among alliance partners initially increases search flexibility, beyond a certain level, increasing negative effects on the knowledge flow outweigh the positive effects of search flexibility and prevent the firm from creating exploratory innovation. Together, these positive and negative effects lead us to the following hypothesis:

Hypothesis 2: *There is an inverted U-shape relationship between the firm's level of brokering position among its alliance partners and the creation of exploratory innovation.*

Central position with partners' wide scope of new knowledge and exploratory innovation

The effects of the network position can be affected by the partner's knowledge composition. The interaction effect can be viewed from two sides: the effect of new knowledge breadth on the central position, and vice versa.

As mentioned above, the central position benefits knowledge flow, which is essential for a firm to create exploratory innovation. A wide scope of new knowledge, in this case, can boost this positive effect of the knowledge flow in a central position on the creation of exploratory innovation. First, a central firm usually established high technological prestige through long-term collaborations with its partners. Through such a collaborative process, they can set up well-developed communication channels, which allow them to share large amounts of knowledge and experience to increase absorptive capacity (Stuart, 1998) and help them understand their partners' tacit and complex knowledge (Larson, 1992). If the partners possess a wide scope of new knowledge, the central firm can learn and absorb novel ideas beyond its knowledge stock more easily, which can help to increase the central firm's exploratory innovation. Second, a central firm has better control over its partners in order to filter and clarify the relevant knowledge beneficial to it (Wang *et al*., 2014). If the partners possess a wide scope of new knowledge, they can provide more potential but refined knowledge, which may result in the central firm creating exploratory innovation. Overall, a wide scope of new knowledge strengthens the positive relationship between the central position and the creation of exploratory innovation.

In terms of search flexibility, however, the central position has a weakness resulting from the tightly connected relationships with a strong sense of belonging. These could hamper the creation of alternatives, i.e., seeking new partners with relevant technology and building collaborative relationships. In this situation, a wide scope of new knowledge can compensate this negative effect of the insufficient search flexibility. The central firm can take advantage of its position, which allows it to identify and access the new technologies held by its surrounding partners (Powell *et al*., 1996). If those partners possess diverse knowledge, the focal firm is exposed to the diverse scope of knowledge and finds it easier to discover new technologies among them. Put together, a wide scope of new knowledge in an alliance portfolio can boost the positive effect, as well as mitigate the negative effect of the central position on the creation of exploratory innovation.

From another point of view, the central position may affect the influence of new knowledge breadth as well. Prior studies have confirmed that new knowledge breadth helps to provide possible sets of knowledge combinations, however, if the scope of new knowledge exceeds a certain level, it may cause an information overflow problem (Koput, 1997). This leads to a management problem that incurs a cost and effort to identify and assess the value of each combination (Srivastava and Gnyawali, 2011). A centrally located firm, however, may overcome this management problem more easily compared to firms located outside the centre. The central position provides the advantage of being able to monitor and control the surrounding partners, so a focal firm can prevent its partners from providing irrelevant knowledge in advance and calibrate the knowledge to meet the focal firm's requirement (Koka and Prescott, 2008). Consequently, this reduces the management problems resulting from the information overflow.

In summary, a wide scope of new knowledge positively influences both the knowledge flow and the search flexibility in a central position. At the same time, the central position can help to solve the management issues which arise from increased new knowledge breadth. Together, these effects lead to the following hypothesis:

Hypothesis 3: *The new knowledge breadth of the firm's alliance portfolio has positive interaction effects on the relationship between the central position and subsequent exploratory innovation.*

Brokering position with partners' wide scope of shared knowledge and exploratory innovation

The interaction effect of the brokering position and the shared knowledge breadth of the alliance portfolio can be seen as the effect of shared knowledge breadth on the brokering position, and vice versa.

The brokering position is advantageous for search flexibility, which is an important factor for a firm to create exploratory innovation. A wide scope of shared knowledge can boost this positive effect of the brokering position's search flexibility on the creation of exploratory innovation. First, a brokering position allows intercepting the information flow among separate groups (Burt, 2004; Rhee, 2004). Therefore, a brokering firm can broaden its search window to recognise and track novel ideas that will lead to opportunities for innovation. If the separate groups share a wide scope of knowledge with the focal firm, the shared knowledge can help to become more aware of each partner's inside story and provide further information on which knowledge of each firm is most valuable. Consequently, it may help to more easily capture useful knowledge to increase inventive opportunities which lead to exploratory innovation. Second, a brokering firm can increase its possibility of discovering knowledge elements which are from unrelated or distant fields (Zaheer and Bell, 2005). In this situation, if there is a wide scope of shared knowledge among firms in the alliance portfolio, it may help to identify and match useful combinations of different knowledge elements even though they originated from the unfamiliar field. This is because the shared knowledge provides various experiences of trial and error in the R&D experiments and guides to successful inventions which help the creation of exploratory innovation. Overall, a wide scope of shared knowledge further increases the positive relationship between the brokering position and the creation of exploratory innovation.

On the other hand, firms in a brokering position often have a disadvantage in terms of knowledge flow, which requires a certain level of relative absorptive capacity between knowledge donors and recipients as one firm's ability to learn from another is closely related to the similarity of both firms' knowledge bases (Cohen and Levinthal, 1990; Easterby-Smith *et al.*, 2008; Lane and Lubatkin, 1998).

A firm in a brokering position may be located between different groups, finding it hard to achieve strong social cohesion and build communication channels for a stable knowledge flow. This non-affiliation results in the brokering firm becoming isolated from sharing knowledge and experience with its partners, resulting in a lack of relative absorptive capacity. Under this condition, if a focal firm shares common knowledge with its alliance partners, it can increase relative absorptive capacity, which is essential to understand the partners' knowledge base and to improve communication with each other. Thus, a firm in a brokering position with shared knowledge breadth is likely to perform better in its messenger role and more effectively deliver information and knowledge between different groups. Consequently, a wide scope of shared knowledge in an alliance portfolio can boost the positive effects as well as mitigate the negative effect of the brokering position on the creation of exploratory innovation.

From a different point of view, a brokering position also affects the effect of the shared knowledge breadth. If the scope of knowledge shared by a group is high, the group is likely to become more homogeneous. As the firms from the homogeneous group possess the same way of thinking, the methods of knowledge application become rigid, and the increasing inertia prevents firms from exploring new ideas. It also gives rise to the negative effects of the competency trap, myopia of learning, group think or NIH syndrome (Janis, 1972; Katz and Allen, 1982; Levinthal and March, 1993; Levitt and March, 1988). However, a firm in a brokering position is not likely to belong to a group even though it is sharing a large extent of knowledge with surrounding partners since this position intrinsically enjoys autonomy (Shipilov, 2009). The different groups have a different culture, norms, routines, and ways of doing things, which prevents them from becoming homogeneous. Thus, a firm in a brokering position might not be caught in a rigidity trap which would impede the adoption of new knowledge.

In summary, a wide scope of shared knowledge provides positive effects on both the knowledge flow and the search flexibility in a brokering position. At the same time, the brokering position can prevent firms sharing knowledge with partners from becoming homogeneous which would hinder their creation of exploratory innovation. Together, it leads us to the following hypothesis:

Hypothesis 4: *The shared knowledge breadth between the focal firm and its alliance portfolio has positive interaction effects on the relationship between the brokering position and subsequent exploratory innovation.*

Method

Sample and data

For the empirical testing of our hypotheses, we constructed a panel dataset of 145 international pharmaceutical companies in the bio-pharmaceutical industry (SIC 2833–2836) from 1996 to 2010. The bio-pharmaceutical industry is selected as a suitable setting for our study for the following reasons: First, it is a high-tech industry in which constant exploratory innovation, e.g., the change from basic chemistry to molecular genetics as the key method for developing new drugs, is critical for firms to gain and defend a competitive advantage (Rothaermel and Deeds, 2004; Rothaermel and Hess, 2007). Second, interfirm R&D alliances are frequently used to share the large cost and risks related to drug development (Grant and Baden-Fuller, 2004; Hagedoorn, 1993). Third, this industry has a high propensity to patent its inventions, which enables us to employ patents to objectively measure their knowledge base and technological expertise (Wuyts and Dutta, 2014).

The dataset is compiled from the Thomson Reuters SDC Platinum, Compustat, and the United States Patent and Trademark Office (USPTO) databases. We have performed several steps to connect the alliance data, financial data, and granted patent data using CUSIP, Fung Institute's firm-patent matching data (Fierro, 2014), and a fuzzy name match. To construct the firms' alliance portfolios, we collected information on all announced R&D alliance deals conducted by firms in the bio-pharmaceutical industry from 1996 to 2010 from the Thomson Reuters SDC Platinum database. During these years, the 145 focal firms concluded strategic alliances with 611 different partner firms. The industrial background of partner firms is as follows: 5 firms in the research, development and testing services (SIC 8732, 8733, 8734), 382 firms in the biopharmaceutical services (SIC 2834–2836), 5 firms in the manufacturing of chemicals (SIC 2844, 2899, 2911), 20 firms in the biopharmaceutical and biomedical suppliers (SIC 3841, 3674, 5047, 5049), 65 firms in the commercial research and management services (SIC 8731, 8741, 7839), 2 firms in the distribution and promotion services (SIC 5122, 4226), 5 firms in the medical laboratories and hospitals (SIC 8071), 1 firm in the non-for-profit and government sector (SIC 8641, 8399, 9999), 126 firms in the others (Caner *et al.*, 2018).

This information on the alliance deals was used to construct the firms' alliance portfolios and the entire alliance network. Since for most alliances, no information on the termination date is available, we need to assume a typical alliance duration. Rothaermel (2001) stated that the average duration of alliances in the bio-pharmaceutical industry is more than three years. We follow previous literature (Kogut, 1988; Lavie, 2007; Lin *et al.*, 2009) in setting up a 5-year window for including alliance deals into each firm's alliance portfolio. We then shift this 5-year window portfolio by one year at a time and construct 10 observation samples from 1996 to 2009 for each firm.

To identify the knowledge composition, we calculated the knowledge base of each focal firm and the corresponding alliance portfolio using patent data. Using the same 5-year window, we collected information on the patent classes listed in all patents applied by the focal firm to describe its knowledge base. Similarly, we collected the same information for all the firms in the firm's alliance portfolio for the same observation window. We repeated this process by shifting the 5-year observation window by a year, for a total of 10 times. We then used patent data to calculate the focal firms' exploratory innovation and supplemented the dataset with firm-level information such as annual sales, R&D expenses, and the number of employees from the Compustat database. The final panel dataset of our study consists of 145 focal firms and 792 firm-year observations.

Dependent variable

This study focusses on the effects of a firm's network position and alliance partner's knowledge composition on the creation of exploratory innovation. While the literature on exploratory innovation reached a consensus about the concept of exploratory innovation, i.e., explored, advanced, and impactful innovation which is created from knowledge new to the firm's extant stock of knowledge, the measurement of this concept varies among researchers. Wang *et al*. (2014) operationalised exploratory innovation as the number of patents including at least one technology class that is new to the firm's extant stock of knowledge. Guan and Liu (2016) measured exploratory innovation as the sum of the family size-weighted patents instantiated by at least one technology class new to the focal organisation. Dibiaggio *et al*. (2014) defined exploratory innovation as any invention that introduces a new technological combination to the firm, i.e., a patent including more than two technology classes which originate from the firm's extant knowledge stock but had not been previously listed in the same patent. In this paper, we define exploratory innovation as an innovation which is created by new to the firm according to the concepts found in previous literature, but add the constraint that the new innovation must have been created under the influence of the firm's external knowledge sourcing, i.e., influenced by the firm's alliance portfolio. Thus, we generalise that a firm pursuing exploratory innovation should seek new knowledge from its alliance partners and make an internal effort to assimilate their knowledge and transform it into the firm's own expertise (Mazloomi Khamseh and Nasiriyar, 2014; Wen and Chuang, 2010). Consequently, *Exploratory innovation*, the dependent variable of this study, was selected to represent a firm's innovation created from unfamiliar technological fields which are obtained from the firms in the alliance portfolio. It is measured by the number of new patents which include a technology class that was not a part of the focal firm's knowledge base during the preceding five years. The dependent variable is calculated in year t, lagged from the observation window of the independent variables (from year t–5 to t–1) to capture the causal relationship (Guan and Liu, 2016; Wang *et al*., 2014). To confirm that the creation of a firm's innovation is influenced by the firm's alliance portfolio, we only considered cases in which the technology class listed in a new patent appears in the knowledge base of the alliance portfolio.

Independent variables

The independent variables of our study represent the structural properties associated with the network position and the nodal properties related to knowledge composition. First, the two network position variables are *Central position* and *Brokering position*. Prior studies have employed several centrality measures, e.g., degree centrality, representing the number of actors tied to a focal firm, between centrality representing the extent to which a focal firm lies on paths between other actors, and closeness centrality which is defined by the average distances to all other actors and shows the extent of clustering in a network. In this study, *Central position* indicates the extent of connectedness to the surrounding R&D partners. Consequently, we selected degree centrality as the most suitable measure to capture the concept of the variable (Wang *et al*., 2014). *Brokering position* refers to a location which can act as a bridge between separate groups. This concept can be captured using the concept of structural holes, which indicates the extent of disconnectedness among actors (Burt, 1992). Following many prior studies, we employ the structural hole measure as a proxy of *Brokering position* (Ahuja, 2000a; Burt, 1991; Koka and Prescott, 2008). Both network position variables are calculated based on the alliance network formed by all sample firms and their partners from t–5 to t–1 using UCINET6 (Borgatti *et al*., 2002). By following Burt's measure of structural holes, the ratio of non-redundant contacts to total contacts for the ith firm is computed as

$$\left[\sum_j \left[1 - \sum_q p_{iq} m_{jq}\right]\right] \Big/ c_i ,$$

where p_{iq} is the proportion of 's relations in connection with contact q, m_{jq} is the marginal strength of the relationship between contact j and q, and C_i is the total number of contacts for firm i. The index range is from 0 to 1; the higher value reflects that the firm's ego networks are rich in structural holes. If all of a firm's partners are unconnected to each other, the index takes a value of 1, indicating that none of the firm's contacts are redundant. Similarly, a lower value for this index reflects higher redundancy and fewer structural holes.

The two variables associated with knowledge composition are *New knowledge breadth* and *Shared knowledge breadth*. The measurement of knowledge breadth in prior literature can be categorised into entropy measurement (Schildt *et al*., 2012; Wu and Shanley, 2009) and the total number of patent classes in which a firm applied for patents (Kotha *et al*., 2011; Zhang and Baden-Fuller, 2010). Each measurement represents a different dimension of knowledge breadth. Entropy measurements are more frequently used and indicate how the knowledge base of a firm is dispersed over diverse patent classes. In other words, they only capture the distribution of the knowledge base. The alternative, i.e., measuring the total number of patent classes allows capturing the absolute amount of dispersion. Accordingly, the latter measurement is more appropriate for our study and allows us to deliver the exact meaning of our framework. *New knowledge breadth* indicates the scope of new technological knowledge in the alliance portfolio that serves as the focal firm's external knowledge pool. It is measured as the number of technology classes found in the patents granted to the firms in the alliance portfolio, that are not found in the focal firm's knowledge base from year *t*–5 to *t*–1. *Shared knowledge breadth* represents the degree of shared knowledge between a focal firm and its partners in the alliance portfolio. Similar to the operationalisation of *New knowledge breadth*, it is measured as the number of technology classes which are shared between the focal firm and at least one firm in the alliance portfolio in patents granted from year *t*–5 to *t*–1 and captures the degree to which the focal firm and its partners are sharing technological expertise.

Control variables

Based on prior literature, we controlled for well-known factors that may affect exploratory innovation associated with the knowledge base, alliance portfolio, and firm level. First, we controlled for the size and scope of the focal firm's knowledge base, which may affect its technological search and innovative capabilities (Ahuja and Katila, 2001; Henderson and Cockburn, 1994). *Technology classes in knowledge base* refers to the scope of the focal firm's knowledge base, which is measured by the number of the technology classes listed in the patents the firm applied for from year *t*–5 to *t*–1 (Dibiaggio *et al.*, 2014). Similarly, *Patent stock in knowledge base* indicates the size of the focal firm's knowledge base, which is defined as the number of patents the firm applied for from year *t*–5 to *t*–1 (Wuyts and Dutta, 2014). Next, we controlled for variations between our sample firms in terms of their alliance experience and configuration of their alliance portfolio (Hoang and Rothaermel, 2005). Prior alliance experience may enhance the impact of an alliance portfolio on innovation performance since firms with experience may better manage their alliance activities than firms without (Anand and Khanna, 2000). *Alliance portfolio experience* indicates how many alliances the firm concluded in the past, which can affect the performance outcomes of the alliance portfolio. It is defined as the number of R&D alliance deals conducted by each focal firm as recorded in the SDC platinum database from 1984 to the year *t*–1 . We also include the variable *Ratio of biopharmaceutical firms in alliance portfolio* which indicates the proportion of horisontal alliances which may affect the competitive strength and the distribution of shared knowledge (Lavie, 2007; Wassmer and Dussauge, 2012). It is measured by the number of biopharmaceutical firms divided by the number of all partners in the focal firm's alliance portfolio. We also added *Ratio of marketing*(*manufacturing*) *deals in alliance portfolio* because we covered only R&D alliance deals to construct the alliance portfolio, but our dataset includes the multi-functional deals covering marketing and manufacturing activities (Lavie, 2007). The assumption is that the different type of agreement entails different interdependence and interaction with partners as well as different purposes for cooperation (Rowley *et al*., 2000). In addition, we added *Firm size* and *R&D intensity* to control the effects of scale and scope on technological search, which may affect the firm's inventive activities (Dibiaggio *et al*., 2014; Henderson and Cockburn, 1996; Wang *et al*., 2014). We controlled for the effects of *Firm size*, which might affect the firm's innovation performance due to the availability or constraints of resources (Yayavaram and Ahuja, 2008). Larger firms have more resources and may find it easier to manage inventive activities. It is measured as the log-transformed number of employees of the focal firm in the year t−1. Prior empirical research suggests that investment in R&D activities is an important source of innovation (Cohen and Levinthal, 1990) and thus can significantly affect the firm's innovation outcomes (Ahuja and Lampert, 2001). Consequently, we control for the focal firm's *R&D intensity*, which is the total R&D expenses divided by the total sales of the focal firm in the year t−1. Finally, we included year dummy variables to control for possible environmental changes over time.

Statistical analyses

As the dependent variable, *Exploratory innovation* is a count variable that takes only non-negative integer values, a negative binomial regression model is employed. As the variable's variance is larger than its mean, a negative binomial regression, rather than Poisson regression is used (Long, 1997). Following the result of a Hausman test, we applied a fixed-effect model to our panel data, which assumes a strict heterogeneity, i.e., the unobserved attributes of each entity may not change over time (Hausman, 1978).

To test the interaction effects proposed in Hypotheses 3 and 4, we followed the suggestion by Haans *et al*. (2016). Haans *et al*. (2016) state that one should be aware of separating a linear benefit and a convex cost curve benefit while testing interaction effects. A turning point shift occurs when interaction effects have a linear benefit, but flattening or steepening occurs when the interaction effects have a convex cost curve benefit. Thus, a test method should be modified in accordance with the author's prediction of the inverted U-shape change. Because both Hypotheses 3 and 4 imply that both a turning point shift and flattening occur, we multiplied the interaction term with both the linear and squared terms of the independent variables.

Result

Table 1 presents a summary of the descriptive statistics and correlations among the variables used in the empirical analysis. Some variables show relatively high

Table 1. Descriptive statistics and correlations.

(obs = 792)	Mean	S.D.	Min.	Max.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Exploratory innovations	1.93	6.49	0	143	1.00											
(2) Technology classes in knowledge base	14.80	15.50	1	108	–0.03	1.00										
(3) Patent stock in knowledge base	647.95	1,148.76	2	7,793	0.01	0.78	1.00									
(4) AP experience	12.60	16.59	1	88	0.02	0.58	0.76	1.00								
(5) Ratio of biopharmaceutical firms in AP	0.82	0.30	0	1	–0.05	–0.12	–0.08	0.00	1.00							
(6) Ratio of marketing deals in AP	0.23	0.34	0	1	–0.03	0.10	0.03	0.00	0.06	1.00						
(7) Ratio of manufacturing deals in AP	0.14	0.30	0	1	–0.03	–0.01	–0.09	–0.14	0.06	0.84	1.00					
(8) Firm size*	–0.65	2.46	–6.91	4.80	0.00	0.67	0.63	0.61	–0.11	0.05	–0.06	1.00				
(9) R&D intensity	418.22	5,128.38	0	109,670	0.05	–0.03	–0.03	–0.05	0.05	–0.02	–0.02	–0.06	1.00			
(10) Central position	3.03	3.26	1	21	0.06	0.50	0.65	0.78	–0.05	–0.02	–0.20	0.51	–0.04	1.00		
(11) Brokering position	0.38	0.35	0	1	0.08	0.33	0.41	0.56	–0.09	–0.06	–0.28	0.46	–0.06	0.73	1.00	
(12) New knowledge breadth	25.35	26.18	0	196	0.15	–0.07	0.03	0.04	–0.02	0.01	–0.02	–0.09	0.04	0.26	0.30	1.00
(13) Shared knowledge breadth	8.48	8.05	0	47	0.02	0.77	0.76	0.67	0.01	0.06	–0.09	0.57	–0.01	0.70	0.51	0.23

Note: * Log-transformed.

correlations (higher than 0.6). However, this unavoidable correlations can be explained by the natural relatedness of the variables and was also observed in prior literature (Dibiaggio *et al*., 2014; Wang *et al*., 2014; Yayavaram and Ahuja, 2008). A variance inflation factor (VIF) analysis was conducted to check for the existence of a multicollinearity problem. The results of the VIF test show low values (below 10) and indicate that our sample does not suffer from a multicollinearity problem (Kleinbaum *et al*., 2013; Myers, 1990). Table 2 contains the results of our analysis using negative binomial regression. The effects of the control variables are reflected in Models 1–5. Two control variables show significant results, *Firm size*

Table 2. Results of fixed-effect negative binomial regression analysis.

	Exploratory innovations				
Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	–1.118***	–1.759***	–2.003***	–2.588***	–2.214***
	(0.324)	(0.382)	(0.407)	(0.453)	(0.477)
Control Var.					
Technology classes in knowledge base	–0.022**	–0.022**	–0.022**	–0.021**	–0.020
	(0.010)	(0.010)	(0.011)	(0.011)	(0.014)
Patent stock in knowledge base	2.1E–04	1.9E–04	2.0E–04	1.7E–04	5.1E–05
	(1.5E–04)	(1.5E–04)	(1.5E–04)	(1.5E–04)	(1.5E–04)
AP experience	0.012	–0.007	–0.005	0.005	0.012
	(0.009)	(0.011)	(0.011)	(0.011)	(0.011)
Ratio of biopharmaceutical firms in AP	–0.211	–0.180	–0.218	–0.351	–0.284
	(0.270)	(0.286)	(0.289)	(0.299)	(0.304)
Ratio of marketing deals in AP	0.110	–0.151	–0.282	–0.354	–0.478
	(0.400)	(0.419)	(0.434)	(0.479)	(0.455)
Ratio of manufacturing deals in AP	0.145	0.641	0.867*	0.736	0.835
	(0.468)	(0.493)	(0.524)	(0.578)	(0.551)
Firm size	0.117***	0.096	0.096	0.140**	0.165***
	(0.057)	(0.059)	(0.060)	(0.063)	(0.064)
R&D intensity	9.6E–06	1.1E–05	1.3E–05	1.0E–05	1.3E–05
	(8.9E–06)	(8.9E–06)	(9.0E–06)	(9.0E–06)	(9.0E–06)
Independent Var.					
Central position		0.274***	0.388**	0.514**	0.395*
		(0.074)	(0.187)	(0.224)	(0.233)

Table 2. (*Continued*)

	Exploratory innovations				
Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Central position^2		–0.009**	–0.012*	–0.023**	–0.026**
		(0.004)	(0.007)	(0.011)	(0.011)
Brokering position			2.403**	1.851*	3.543**
			(1.066)	(1.104)	(1.496)
Brokering position^2			–3.572*	–3.445*	–5.996***
			(2.036)	(2.074)	(2.290)
New knowledge breadth				0.032***	0.041***
				(0.007)	(0.008)
Central position × New knowledge breadth				–0.006**	–0.007**
				(0.003)	(0.003)
Central position^2 × New knowledge breadth				3.7E–04**	4.2E–04**
				(1.8E–04)	(1.9E–04)
Shared knowledge breadth					–0.099**
					(0.043)
Brokering position × Shared knowledge breadth					–0.122
					(0.168)
Brokering position^2 × Shared knowledge breadth					0.332*
					(0.178)
Year (Dummy)			*~Included~*		
Number of observations	792	792	792	792	792
Number of firms	145	145	145	145	145
Log likelihood	–726.816	–718.652	–716.036	–701.280	–693.198
Wald chi2	41.54	58.11	61.44	86.13	106.34
Prob > chi2	0.000	0.000	0.000	0.000	0.000

Note: $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$. Standard errors are in parentheses.

shows significant results in all models and *Technology classes in knowledge base* shows significant results, not just in Model 5.

Models 2–5 test Hypothesis 1, which predicts an inverted U-shape relationship between the focal firm's central position and the creation of exploratory innovation. In Models 2–5, the coefficient of the linear term *Central position* is positive and statistically significant while the quadratic term *Central position squared* is negative and significant. Therefore, Hypothesis 1 is supported. In addition, we adopt the procedure by Lind and Mehlum (2010) to properly test for the presence of an inverted U-shape relationship. The result confirms that Hypothesis 1 meets all three steps (testing of the coefficient of the square term, steep slopes at the extremes of the data range, and the location of the turning point within the data range).

Hypothesis 2 predicted an inverted U-shape relationship between the focal firm's brokering position and the creation of exploratory innovation. In Models 3–5, the coefficient of *Brokering position* is positive and statistically significant while its quadratic term is negative and statistically significant. These results support Hypothesis 2. The results also pass the test suggested by Lind and Mehlum (2010).

In Model 4, we test Hypothesis 3 which predicted a positive moderating effect of new knowledge breadth on the relationship between the focal firm's central position and exploratory innovation. *Central position* × *New knowledge breadth* and *Central position squared* × *New knowledge breadth* are both significant and follow the predicted direction of the effect, thereby confirming Hypothesis 3. This moderation effect of *New knowledge breadth* is plotted in Fig. 2. The moderation effect of an inverted U-shape relationship results in a turning point shift and/or a flattening or steepening of the curve (Haans *et al.*, 2016). One can see that the curve shifts up-left and its shape flattens. This means that the moderation effect of *New knowledge breadth* increases overall exploratory innovation. In other words, *New knowledge breadth* boosts the positive effects and mitigates the negative effects of *Central position* on the creation of exploratory innovation.

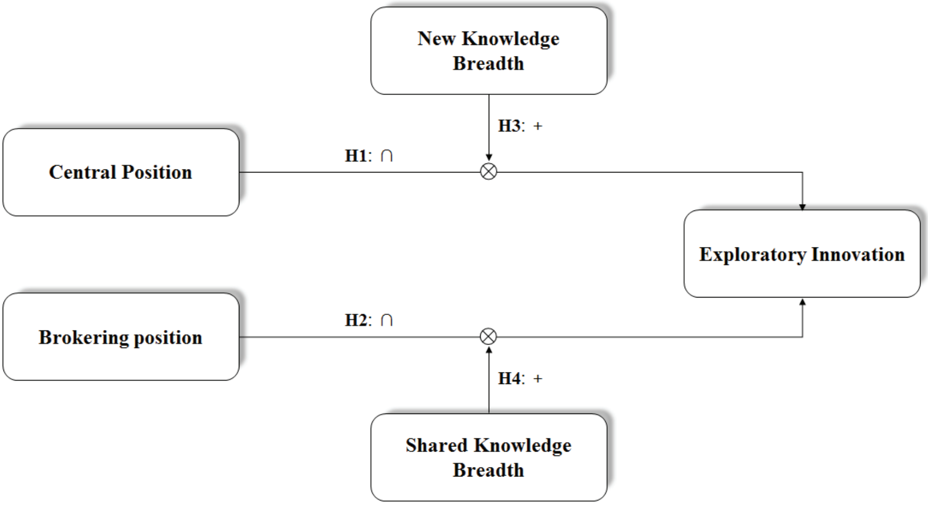

Fig. 1. Conceptual diagram.

Model 5 is the full Model and tests our Hypothesis 4, which predicted a positive moderating effect of *Shared knowledge breadth* on the relationship between the focal firm's brokering position and exploratory innovation. As can be seen in Table 2, the coefficient for *Brokering position* × *Shared knowledge breadth* is statistically insignificant. However, the coefficient for *Brokering position squared* × *Shared knowledge breadth* is positive and significant. Summarising the results for *Brokering position* × *Shared knowledge breadth* and *Brokering position squared* × *Shared knowledge breadth*, we find statistical support for Hypothesis 4. The moderation effect of *Shared knowledge breadth* is also plotted in Fig. 3. According to Fig. 3, the phenomenon of "shape-flip" occurs. This is interesting because

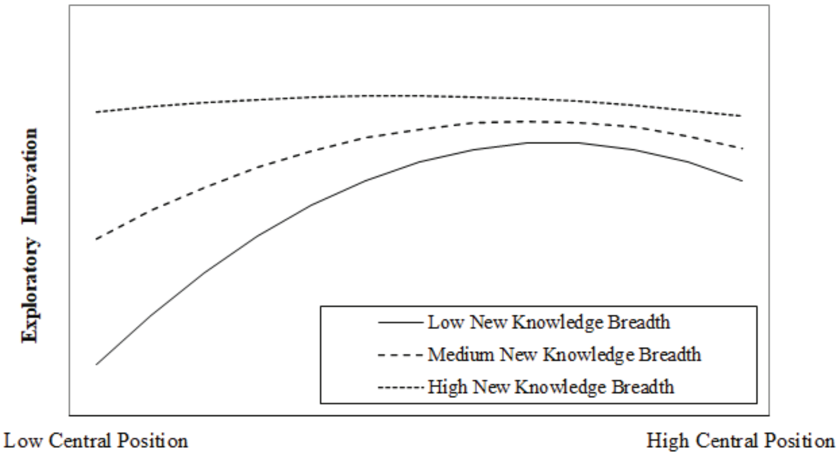

Fig. 2. The interaction effects 1.

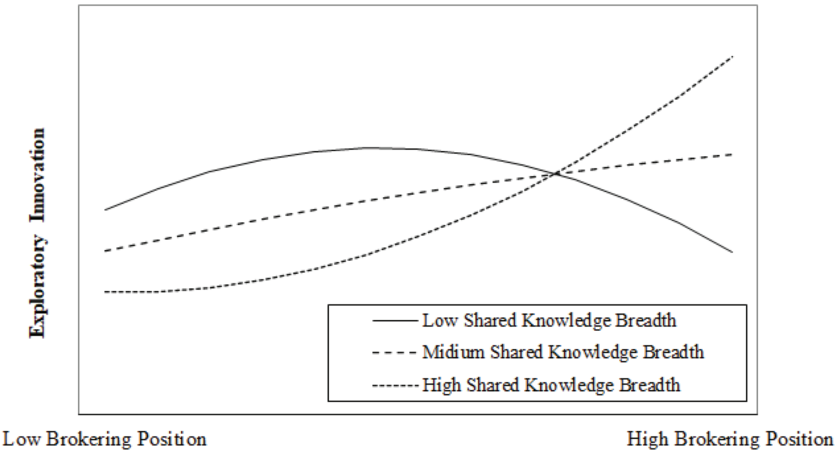

Fig. 3. The interaction effects 2.

"the fundamental nature of the relationship between independent variable and dependent variable now depends on the moderator" (Haans *et al.*, 2016, p. 1190). In other words, it implies that the effect of the moderator is extremely strong. Theoretically, this can be interpreted as follows: the positive moderating effect of *Shared knowledge breadth* alleviates the negative effect of a high *Brokering position* and rather changes the negative effect to a positive. One should be aware that the inverted U-shape relationship turns into a U-shape relationship as *Shared knowledge breadth* increases. This change results from the negative direct effects of *Shared knowledge breadth*. In other words, a too large scope of shared knowledge, solely, gives rise to overall negative effects on exploratory innovation. Therefore, to exploit the positive effects of shared knowledge breadth, a high brokering position and an appropriate level of shared knowledge breadth are required.

Discussion

Findings

Prior studies examining alliance portfolios as a source of external knowledge have recognised two key factors affecting the creation of exploratory innovation: First, from the social network theory perspective, they highlighted the role of a firm's network position. Second, from the perspective of the knowledge-based view, they highlighted the role of knowledge resources. These factors influence exploratory innovation individually as well as simultaneously. Consequently, the inclusion of both factors in the present study results in a comprehensive view that enables us to investigate the interaction effects of both network and knowledge factors. In this regard, we first suggested two hypotheses on the individual effect of two characteristics of network position, i.e., central and brokering positions, on exploratory innovation. We then proposed two additional hypotheses focussing on the interaction effects of network position and knowledge composition in an alliance portfolio. The interaction effects focus on the complementary nature of the central position with a wide scope of new knowledge and the brokering position with a wide scope of shared knowledge.

Our empirical analysis on a panel dataset of 145 pharmaceutical companies reveals the proposed inverted U-shape relationship between network positions and the creation of exploratory innovation (Hypotheses 1 and 2). These results confirm that although the effects of a central and a brokering position are different, they influence a firm's exploratory innovation in both positive and negative ways. To explain these double-sided effects, we propose a new research framework based on two factors, knowledge flow and search flexibility, which are important for the creation of exploratory innovation. Using this framework, we explain that both network positions positively affect one of the two factors but negatively affect the other factor if their positional effects grow excessively. Specifically, we confirm that a central position promotes knowledge flow with partners due to the focal firm's high social status, allowing it to access valuable knowledge from its partners in terms of quantity and quality. However, beyond a certain level, the central position decreases search flexibility due to the constraint on decision making caused by strong relationships. Our findings also clarify that a brokering position fosters search flexibility as it allows the focal firm to control information flows. However, exceeding a certain level, the lack of absorptive capacity negatively influences knowledge flow.

Furthermore, the results of our study confirm that two combinations of network position and knowledge composition in the alliance portfolio lead to positive interaction effects: a central position among partners who possess a diverse scope of technological knowledge, and a brokering position between partners who share a large extent of knowledge (Hypotheses 3 and 4). These results support our argument that the effects of network position and knowledge composition can complementarily interact with each other, thus potentially compensating for the negative effects on either knowledge flow or search flexibility. The outcomes of the analysis also reveal that the interaction effects of the brokering position and shared knowledge breadth even contribute to changing the negative slope to a positive one beyond a certain level of brokering position. Specifically, the results confirm that new knowledge breadth can contribute to increasing the low search flexibility resulting from the effect of a central position, and the central position allows firms to better deal with the information overflow that is often associated with large increases of new knowledge breadth. The results also confirm that the shared knowledge breadth with partners can increase absorptive capacity, which helps the firms to better understand each other and ultimately increases the knowledge flow that is often insufficient for firms in a brokering position. At the same time, the brokering position can prevent firms from becoming too similar to their partners, which would harm the exploration of new ideas.

Theoretical implications

This study makes two important theoretical contributions: First, this study extends the literature on alliance portfolios by clearly distinguishing viewpoints from social network theory and the knowledge-based view, which were loosely connected in the prior literature on exploratory innovation. Many prior studies investigated alliance portfolios as a source of external knowledge by focussing on structural properties, such as a firm's network position, or by focussing on nodal properties, such as a firm's knowledge base. This led to the emergence of two distinct streams of research on alliance portfolios originating from social network theory and the knowledge-based view. However, those viewpoints were applied in a mixture to infer both structural and nodal properties, and each consequence was inconsistent in the extant literature on innovation. We linked those two viewpoints to alliance portfolios' structural/nodal properties, respectively, and opened up opportunities to elucidate each viewpoint's independent and interrelational effects on exploratory innovation.

Second, this study contributes to innovation literature by proposing ways to overcome the "search and transfer" trade-off relationship, which has long been a subject in the knowledge-creating relationship. The theoretical basis was presented by proposing two key factors corresponding to the search and transfer problem to better understand the mechanisms of creating exploratory innovation. By analysing the effects of those two key factors, we claim that potential negative effects from a firm's network position can be overcome under specific conditions through a suitable knowledge composition. Prior studies state that knowledge flow corresponds with strong relationships, while search flexibility is associated with weak relationships. As both knowledge flow and search flexibility are required for exploration, prior studies focussed on finding the optimum level of organisational integration (Folta, 1998) or the relevant strategic choice contingent on the firm's situation (Ghosh and John, 2005). However, we reveal that a particular combination between a firm's network position and the knowledge composition of its alliance portfolio can complement both factors' shortcomings, ultimately presenting the possibilities to overcome the search and transfer problem.

Managerial implications

This research provides some managerial implications for firms trying to create exploratory innovation through their alliance portfolios. First, firms in the central position need to find a partner firm with a wide range of heterogeneous knowledge to make good use of the benefits of the central position in creating exploratory innovation. For managers in this situation, efforts to find a partner who expands the breadth of new knowledge in various dimensions, such as different business domains, functions, and attributes, are necessary. Second, firms in the brokering position need to find a partner firm with a common knowledge base to take advantage of the brokering position that helps exploratory innovation. For managers in this situation, efforts to check whether the partner firm has a denominator to the focal firm in terms of knowledge base, such as business domains and functions, and to create a common knowledge base to better understand a partner's knowledge are necessary. Those two suggestions are derived from the finding that certain network positions possess advantages and disadvantages in creating exploratory innovation. Those disadvantages can be overcome through the partners' knowledge resources, which helps the firm increase its search flexibility and knowledge flow with its alliance partners. These findings suggest managers care about network position and knowledge composition in configuring their firms' alliance portfolios.

Limitations and future studies

Despite making important contributions, this study has limitations that provide promising future research opportunities. First, this study focusses only on the bio-pharmaceutical industry to test its hypotheses, which limits the generalisation of its results to other industries. Although the bio-pharmaceutical industry has been frequently used to investigate cooperative R&D activities among firms (Hess and Rothaermel, 2011; Hoang and Rothaermel, 2005; Powell *et al*., 1996), the characteristics of this industrial context may influence the firm's alliance activities and the process of innovation. For this reason, we look forward to seeing future research attempt similar to research using datasets from other industries.

Second, we focus on capturing firms' exploratory innovation created from knowledge gained from its alliance partners. However, depending on the research context, different concepts and measures of exploratory innovation can be employed. For example, Wen and Chuang (2010) categorised exploratory innovation through interfirm collaboration into two types: learning new knowledge from partners and transforming it to the firm's own knowledge, and "co-exploration" which is creating new knowledge to both the focal firm and its partners. Future research can employ such categorisations to capture various dimensions of exploratory innovation.

Third, this study relies on patent data for its measure of exploratory innovation. Following innovation literature, this study defines exploratory innovation as new patents emerging from technological fields new to the focal firm. Patents are a useful tool to make objective observations of the output of a firm's R&D efforts. However, not all innovations are patented either due to the stringent regulations on what constitutes a patentable innovation or for other reasons. We hope that future researches attempt to employ measurements to try and capture non-patented ideas and inventions derived from the knowledge in the alliance portfolio.

Fourth, this study focusses on the positions of an individual firm in the alliance network, not on the entire network's characteristics, e.g., the degree of centrality of the entire alliance network. Different results and implications can be derived if the network's overall characteristics are applied to research from a different level of analysis, i.e., industry-level perspective. For instance, in the case of a (de)centralised network, the effects of centrally located firms with many contacts on innovation and the effects of firms in peripheral parts of the network on innovation are different but present simultaneously. Thus, the degree of (de)centrality of the entire network should reasonably lead to the network's overall innovative efficiency being positively or negatively affected (Cummings and Cross, 2003; Grund, 2012; Krackhardt and Stern, 1988; Sparrowe *et al*., 2001). We hope future researchers apply a different level of analysis to topics we dealt with to open up wider research opportunities.

Lastly, we suggest some other approaches and subjects for conducting more diverse research. Different types of work, for instance, collecting different primary data or conducting a qualitative study, can bring new perspectives and confirm (or not) the findings of this work. In addition, different aspects of network structures, e.g., tie strength (Yang *et al*., 2022), network density (Tian *et al*., 2022), an indirect network effect (Zhang *et al*., 2020), and phenomena referred to recent innovation research, e.g., innovation readiness (Ojiako *et al*., 2022; Orozco and Grundmann, 2022), level of absorptive capacity (Crescenzi and Gagliardi, 2018; Horvat *et al*., 2019; Solís-Molina *et al*., 2018; Vlačić *et al*., 2019), knowledge co-creation (Abbate *et al*., 2019), digitalisation (Agostini *et al*., 2020; Gobble, 2018; Kraus *et al*., 2019), organisational slack (Hu *et al*., 2021), strongly impact the firm's ability to innovate using external knowledge. We hope these possible lines of investigation will be valuable to the other researchers.

Acknowledgement

The authors would like to thank The Institute of Engineering Research at Seoul National University for their support.

References

Abbate, T, AP Codini and B Aquilani (2019). Knowledge co-creation in open innovation digital platforms: Processes, tools and services. *Journal of Business & Industrial Marketing*, 34(7), 1434–1447.

Agostini, L, F Galati and L Gastaldi (2020). The digitalisation of the innovation process: Challenges and opportunities from a management perspective. *European Journal of Innovation Management*, 23(1),1–12.

Ahuja, G (2000a). Collaboration networks, structural holes, and innovation: A longitudinal study. *Administrative Science Quarterly*, 45(3), 425–455.

Ahuja, G (2000b). The duality of collaboration: Inducements and opportunities in the formation of interfirm linkages. *Strategic Management Journal*, 21(3), 317–343.

Ahuja, G and CM Lampert (2001). Entrepreneurship in the large corporation: A longitudinal study of how established firms create breakthrough inventions. *Strategic Management Journal*, 22(6–7), 521–543.

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

Ali, M (2021). Imitation or innovation: To what extent do exploitative learning and exploratory learning foster imitation strategy and innovation strategy for sustained competitive advantage? *Technological Forecasting and Social Change*, 165, 120527.

Anand, BN and T Khanna (2000). Do firms learn to create value? The case of alliances. *Strategic Management Journal*, 21(3), 295–315.

Argote, L and P Ingram (2000). Knowledge transfer: A basis for competitive advantage in firms. *Organisational Behavior and Human Decision Processes*, 82(1), 150–169.

Becker, MC and M Lillemark (2006). Marketing/R&D integration in the pharmaceutical industry. *Research Policy*, 35(1), 105–120.

Bonacich, P (1987). Power and centrality: A family of measures. *American Journal of Sociology*, 92(5), 1170–1182.

Borgatti, SP, MG Everett and LC Freeman (2002). UCINET 6 for Windows: Software for social network analysis (Version 6.102). Analytic Technologies, Harvard, MA.

Burkhardt, ME and DJ Brass (1990). Changing patterns or patterns of change: The effects of a change in technology on social network structure and power. *Administrative Science Quarterly*, 35(1), 104–127.

Burt, RS (1991). *Structure Reference Manual, Version* 4.2, pp. 76–82. New York: Center for the Social Sciences, Columbia University.

Burt, RS (1992). *Structural Holes: The Social Structure of Competition*. Boston, MA: Harvard Business Press.

Burt, RS (2000). The network structure of social capital. *Research in Organisational Behavior*, 22, 345–423.

Burt, RS (2004). Structural holes and good ideas. *American Journal of Sociology*, 110(2), 349–399.

Caner, T, O Bruyaka and JE Prescott (2018). Flow signals: Evidence from patent and alliance portfolios in the us biopharmaceutical industry. *Journal of Management Studies*, 55(2), 232–264.

Cao, X, Z Xing and L Zhang (2021). Effect of dual network embedding on the exploitative innovation and exploratory innovation of enterprises-based on the social capital and heterogeneous knowledge. *Technology Analysis & Strategic Management*, 33(6), 638–652.

Christensen, CM (1997). *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Boston, MA: Harvard Business Press.

Christensen, CM and ME Raynor (2003). *The Innovator's Solution: Creating and Sustaining Successful Growth*. Boston, MA: Harvard Business Press.

Cohen, WM and DA Levinthal (1990). Absorptive-capacity—A new perspective on learning and innovation. *Administrative Science Quarterly*, 35(1), 128–152.

Crescenzi, R and L Gagliardi (2018). The innovative performance of firms in heterogeneous environments: The interplay between external knowledge and internal absorptive capacities. *Research Policy*, 47(4), 782–795.

Cui, AS and G O'Connor (2012). Alliance portfolio resource diversity and firm innovation. *Journal of Marketing*, 76(4), 24–43.

Cummings, JN and R Cross (2003). Structural properties of work groups and their consequences for performance. *Social Networks*, 25(3), 197–210.

Dibiaggio, L, M Nasiriyar and L Nesta (2014). Substitutability and complementarity of technological knowledge and the inventive performance of semiconductor companies. *Research Policy*, 43(9), 1582–1593.

Duysters, G and B Lokshin (2011). Determinants of alliance portfolio complexity and its effect on innovative performance of companies. *Journal of Product Innovation Management*, 28(4), 570–585.

Dyer, JH and H Singh (1998). The relational view: Cooperative strategy and sources of interorganisational competitive advantage. *Academy of Management Review*, 23(4), 660–679.

Easterby-Smith, M, MA Lyles and EW Tsang (2008). Inter-organisational knowledge transfer: Current themes and future prospects. *Journal of Management Studies*, 45(4), 677–690.

Fierro, G (2014). Processing USPTO patent data. Coleman Fung Institute for Engineering Leadership.

Fleming, L (2001). Recombinant uncertainty in technological search. *Management Science*, 47(1), 117–132.

Folta, TB (1998). Governance and uncertainty: The trade-off between administrative control and commitment. *Strategic Management Journal*, 19(11), 1007–1028.

Folta, TB and KD Miller (2002). Real options in equity partnerships. *Strategic Management Journal*, 23(1), 19(11), 77–88.

Freeman, LC (1979). Centrality in social networks conceptual clarification. *Social Networks*, 1(3), 215–239.

Ghosh, M and G John (2005). Strategic fit in industrial alliances: An empirical test of governance value analysis. *Journal of Marketing Research*, 42(3), 346–357.

Gilsing, V, B Nooteboom, W Vanhaverbeke, G Duysters and van den A Oord (2008). Network embeddedness and the exploration of novel technologies: Technological distance, betweenness centrality and density. *Research Policy*, 37(10), 1717–1731.

Gnyawali, DR and R Madhavan (2001). Cooperative networks and competitive dynamics: A structural embeddedness perspective. *Academy of Management Review*, 26(3), 431–445.

Gobble, MM (2018). Digitalisation, digitisation, and innovation. *Research-Technology Management*, 61(4), 56–59.

Goerzen, A and PW Beamish (2005). The effect of alliance network diversity on multinational enterprise performance. *Strategic Management Journal*, 26(4), 333–354.

Grant, RM (1996a). Prospering in dynamically-competitive environments: Organisational capability as knowledge integration. *Organisation Science*, 7(4), 375–387.

Grant, RM (1996b). Toward a knowledge-based theory of the firm. *Strategic Management Journal*, 17(S2), 109–122.

Grant, RM and C Baden-Fuller (2004). A knowledge accessing theory of strategic alliances. *Journal of Management Studies*, 41(1), 61–84.

Grund, TU (2012). Network structure and team performance: The case of English Premier League soccer teams. *Social Networks*, 34(4), 682–690.

Guan, J and N Liu (2016). Exploitative and exploratory innovations in knowledge network and collaboration network: A patent analysis in the technological field of nano-energy. *Research Policy*, 45(1), 97–112.

Gulati, R and M Gargiulo (1999). Where do interorganisational networks come from? *American Journal of Sociology*, 104(5), 1439–1493.

Haans, RF, C Pieters and ZL He (2016). Thinking about U: Theorising and testing U- and inverted U-shaped relationships in strategy research. *Strategic Management Journal*, 37(7), 1177–1195.

Hagedoorn, J (1993). Understanding the rationale of strategic technology partnering: Interorganisational modes of cooperation and sectoral differences. *Strategic Management Journal*, 14(5), 371–385.

Hagedoorn, J and J Schakenraad (1994). The effect of strategic technology alliances on company performance. *Strategic Management Journal*, 15(4), 291–309.

Hansen, MT (1999). The search-transfer problem: The role of weak ties in sharing knowledge across organisation subunits. *Administrative Science Quarterly*, 44(1), 82–111.

Hargadon, A and RI Sutton (1997). Technology brokering and innovation in a product development firm. *Administrative Science Quarterly*, 42(4), 716–749.

Hausman, JA (1978). Specification tests in econometrics. *Econometrica: Journal of the Econometric Society*, 46(6), 1251–1271.

Heide, JB (1994). Interorganisational governance in marketing channels. *The Journal of Marketing*, 58(1), 71–85.

Henderson, RM and KB Clark (1990). Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly*, 35(1), 9–30.

Henderson, RM and I Cockburn (1994). Measuring competence? Exploring firm effects in pharmaceutical research. *Strategic Management Journal*, 15(S1), 63–84.

Henderson, RM and I Cockburn (1996). Scale, scope, and spillovers: The determinants of research productivity in drug discovery. *RAND Journal of Economics*, 27(1), 32–59.

Hess, AM and FT Rothaermel (2011). When are assets complementary? Star scientists, strategic alliances, and innovation in the pharmaceutical industry. *Strategic Management Journal*, 32(8), 895–909.

Hoang, H and FT Rothaermel (2005). The effect of general and partner-specific alliance experience on joint R&D project performance. *The Academy of Management Journal*, 48(2), 332–345.

Horvat, D, C Dreher and O Som (2019). How firms absorb external knowledge—Modelling and managing the absorptive capacity process. *International Journal of Innovation Management*, 23(1), 1950041.

Hu, H, L Chen, Y Zhou, Y Liu and Q Qu (2021). Unpacking the effects of organisational slack on exploitative and exploratory innovation: A study of knowledge-intensive firms. *Innovation*, 1–23.

Janis, IL (1972). Victims of groupthink: A psychological study of foreign-policy decisions and fiascoes. Houghton Mifflin.

Katz, R and TJ Allen (1982). Investigating the Not Invented Here (NIH) syndrome: A look at the performance, tenure, and communication patterns of 50 R & D Project Groups. *R&D Management*, 12(1), 7–20.

Kleinbaum, D, L Kupper, A Nizam and E Rosenberg (2013). *Applied Regression Analysis and Other Multivariable Methods*. Scarborough: Nelson Education.

Kogut, B (1988). Joint ventures: Theoretical and empirical perspectives. *Strategic Management Journal*, 9, 319–332.

Kogut, B and U Zander (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organisation Science*, 3(3), 383–397.

Koka, BR and JE Prescott (2002). Strategic alliances as social capital: A multidimensional view. *Strategic Management Journal*, 23(9), 795–816.

Koka, BR and JE Prescott (2008). Designing alliance networks: The influence of network position, environmental change, and strategy on firm performance. *Strategic Management Journal*, 29(6), 639–661.

Koput, KW (1997). A chaotic model of innovative search: Some answers, many questions. *Organisation Science*, 8(5), 528–542.

Kotha, R, Y Zheng and G George (2011). Entry into new niches: The effects of firm age and the expansion of technological capabilities on innovative output and impact. *Strategic Management Journal*, 32(9), 1011–1024.

Krackhardt, D and RN Stern (1988). Informal networks and organisational crises: An experimental simulation. *Social Psychology Quarterly*, 51(2), 123–140.

Kraus, S, N Roig-Tierno and RB Bouncken (2019). Digital innovation and venturing: An introduction into the digitalisation of entrepreneurship. *Review of Managerial Science*, 13(3), 519–528.

Lane, PJ and M Lubatkin (1998). Relative absorptive capacity and interorganisational learning. *Strategic Management Journal*, 19(5), 461–477.

Larson, A (1992). Network dyads in entrepreneurial settings: A study of the governance of exchange relationships. *Administrative Science Quarterly*, 37(1), 76–104.

Lavie, D (2007). Alliance portfolios and firm performance: A study of value creation and appropriation in the US software industry. *Strategic Management Journal*, 28(12), 1187–1212.

Lee, J (2011). The alignment of contract terms for knowledge-creating and knowledge-appropriating relationship portfolios. *Journal of Marketing*, 75(4), 110–127.

Levinthal, DA and JG March (1993). The myopia of learning. *Strategic Management Journal*, 14(S2), 95–112.

Levitt, B and JG March (1988). Organisational learning. *Annual Review of Sociology*, 14, 319–340.

Lin, Z, HB Yang and B Arya (2009). Alliance partners and firm performance: Resource complementarity and status association. *Strategic Management Journal*, 30(9), 921–940.

Lind, JT and H Mehlum (2010). With or without U? The appropriate test for a U-shaped relationship. *Oxford Bulletin of Economics and Statistics*, 72(1), 109–118.

Locke, EA, NG Noorderhaven, JP Cannon, PM Doney and MR Mullen (1999). Some reservations about social capital. *Academy of Management Review*, 24(1), 8–11.

Long, JS (1997). Regression Models for Categorical and Limited Dependent Variables. Thousand Oaks, CA: Sage.

Luo, BN, S Lui, C-H Liu and R Zhang (2018). Knowledge exploration and innovation: A review and an inverse S-curve proposition. *Journal of Management & Organisation*, 24(6), 870–892.

Luyun, X, Z Deming and Z Yunsheng (2019). Knowledge cluster, patterns of R&D collaboration and exploratory innovation performance: An empirical study on Chinese automotive industry. *Management Review*, 31(6), 68.

Ma, D, Y-R Zhang and F Zhang (2020). The influence of network positions on exploratory innovation: An empirical evidence from China's patent analysis. *Science, Technology and Society*, 25(1), 184–207.

March, JG (1991). Exploration and exploitation in organisational learning. *Organisation Science*, 2(1), 71–87.

Marhold, K, MJ Kim and J Kang (2017). The effects of alliance portfolio diversity on innovation performance: A study of partner and alliance characteristics in the bio-pharmaceutical industry. *International Journal of Innovation Management*, 21(1), 1750001.

Mazloomi Khamseh, H and M Nasiriyar (2014). Avoiding alliance myopia: Forging learning outcomes for long-term success. *Journal of Business Strategy*, 35(4), 37–44.

McConnell, DP and SE Cross (2019). Realising the value of industry-university innovation alliances. *Research-Technology Management*, 62(2), 40–48.

Moran, P (2005). Structural vs. relational embeddedness: Social capital and managerial performance. *Strategic Management Journal*, 26(12), 1129–1151.

Myers, R (1990). Detecting and combating multicollinearity. *Classical and Modern Regression with Applications*, 368–423, Duxbury Press Belmont, CA.

Nelson, RR and SG Winter (1982). The Schumpeterian tradeoff revisited. *The American Economic Review*, 72(1), 114–132.

Nonaka, I (1991). The knowledge-creating company. *Harvard Business Review*. 69, 96–104.

Ojiako, U, HJE AlRaeesi, M Chipulu, A Marshall and H Bashir (2022). Innovation readiness in public sector service delivery: An exploration. *Production Planning & Control*, 1–24.

Orozco, R and P Grundmann (2022). Readiness for innovation of emerging grass-based businesses. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(4), 180.

Ozer, M and G Zhang (2019). The roles of knowledge providers, knowledge recipients, and knowledge usage in bridging structural holes. *Journal of Product Innovation Management*, 36(2), 224–240.

Park, G, MJ Kim and J Kang (2015). Competitive embeddedness: The impact of competitive relations among a firm's current alliance partners on its new alliance formations. *International Business Review*, 24(2), 196–208.

Phelps, C (2010). A longitudinal study of the influence of alliance network structure and composition on firm exploratory innovation. *Academy of Management Journal*, 53(4), 890–913.

Podolny, JM (1993). A status-based model of market competition. *American Journal of Sociology*, 98(4), 829–872.

Podolny, JM (2001). Networks as the pipes and prisms of the market. *American Journal of Sociology*, 107(1), 33–60.

Powell, WW (1998). Learning from collaboration: Knowledge and networks in the biotechnology and pharmaceutical industries. *California Management Review*, 40(3), 228–240.

Powell, W. W., & Smith-Doerr, L. (1994). Networks and economic life. The handbook of economic sociology, 368, 380.

Powell, WW, KW Koput and L Smith-Doerr (1996). Interorganisational collaboration and the locus of innovation: Networks of learning in biotechnology. *Administrative Science Quarterly*, 41(1), 116–145.

Rhee, M (2004). Network updating and exploratory learning environment. *Journal of Management Studies*, 41(6), 933–949.

Rindfleisch, A (2000). Organisational trust and interfirm cooperation: An examination of horisontal versus vertical alliances. *Marketing Letters*, 11(1), 81–95.

Rosenkopf, L and A Nerkar (2001). Beyond local search: Boundary-spanning, exploration, and impact in the optical disk industry. *Strategic Management Journal*, 22(4), 287–306.

Rothaermel, FT (2001). Incumbent's advantage through exploiting complementary assets via interfirm cooperation. *Strategic Management Journal*, 22(6–7), 687–699.

Rothaermel, FT and DL Deeds (2004). Exploration and exploitation alliances in biotechnology: A system of new product development. *Strategic Management Journal*, 25(3), 201–221.

Rothaermel, FT and AM Hess (2007). Building dynamic capabilities: Innovation driven by individual-, firm-, and network-level effects. *Organisation Science*, 18(6), 898–921.

Rowley, T, D Behrens and D Krackhardt (2000). Redundant governance structures: An analysis of structural and relational embeddedness in the steel and semiconductor industries. *Strategic Management Journal*, 21(3), 369–386.

Schildt, H, T Keil and M Maula (2012). The temporal effects of relative and firm-level absorptive capacity on interorganisational learning. *Strategic Management Journal*, 33(10), 1154–1173.

Schumpeter, JA (1934). *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*, Vol. 55. Piscataway: Transaction Publishers.

Shipilov, AV (2009). Firm scope experience, historic multimarket contact with partners, centrality, and the relationship between structural holes and performance. *Organisation Science*, 20(1), 85–106.

Shipilov, AV and SX Li (2008). Can you have your cake and eat it too? Structural holes' influence on status accumulation and market performance in collaborative networks. *Administrative Science Quarterly*, 53(1), 73–108.

Slavova, K and S Jong (2021). University alliances and firm exploratory innovation: Evidence from therapeutic product development. *Technovation*, 107, 102310.

Solís-Molina, M, M Hernández-Espallardo and A Rodríguez-Orejuela (2018). Performance implications of organisational ambidexterity versus specialisation in exploitation or exploration: The role of absorptive capacity. *Journal of Business Research*, 91, 181–194.

Sparrowe, RT, RC Liden, SJ Wayne and ML Kraimer (2001). Social networks and the performance of individuals and groups. *Academy of Management Journal*, 44(2), 316–325.

Spender, JC (1993). Competitive advantage from tacit knowledge? Unpacking the concept and its strategic implications. *Paper presented at the Academy of Management Proceedings*, 1993(1), 37–41.

Srivastava, MK and DR Gnyawali (2011). When do relational resources matter? Leveraging portfolio technological resources for breakthrough innovation. *Academy of Management Journal*, 54(4), 797–810.

Stuart, TE (1998). Network positions and propensities to collaborate: An investigation of strategic alliance formation in a high-technology industry. *Administrative Science Quarterly*, 43(3), 668–698.

Szulanski, G (1996). Exploring internal stickiness: Impediments to the transfer of best practice within the firm. *Strategic Management Journal*, 17(S2), 27–43.

Tian, M, Y Su and Z Yang (2022). Exploration versus exploitation: The influence of network density on firm's strategic choice between two types of innovation. *Technology Analysis & Strategic Management*, 1–14.

Uzzi, B (1996). The sources and consequences of embeddedness for the economic performance of organisations: The network effect. *American Sociological Review*, 61(4), 674–698.

Van de Vrande, V, C Lemmens and W Vanhaverbeke (2006). Choosing governance modes for external technology sourcing. *R&D Management*, 36(3), 347–363.

Vlačić, E, M Dabić, T Daim and D Vlajčić (2019). Exploring the impact of the level of absorptive capacity in technology development firms. *Technological Forecasting and Social Change*, 138, 166–177.

Wang, C, S Rodan, M Fruin and X Xu (2014). Knowledge networks, collaboration networks, and exploratory innovation. *Academy of Management Journal*, 57(2), 484–514.

Wassmer, U (2010). Alliance portfolios: A review and research agenda. *Journal of Management*, 36(1), 141–171.

Wassmer, U and P Dussauge (2012). Network resource stocks and flows: How do alliance portfolios affect the value of new alliance formations? *Strategic Management Journal*, 33(7), 871–883.

Weitzman, ML (1998). Recombinant growth. *Quarterly Journal of Economics*, 113(2), 331–360.

Wen, J, WJ Qualls and D Zeng (2021). To explore or exploit: The influence of inter-firm R&D network diversity and structural holes on innovation outcomes. *Technovation*, 100, 102178.

Wen, SH and C-M Chuang (2010). To teach or to compete? A strategic dilemma of knowledge owners in international alliances. *Asia Pacific Journal of Management*, 27(4), 697–726.

Wu, J and MT Shanley (2009). Knowledge stock, exploration, and innovation: Research on the United States electromedical device industry. *Journal of Business Research*, 62(4), 474–483.

Wuyts, S and S Dutta (2014). Benefiting from alliance portfolio diversity the role of past internal knowledge creation strategy. *Journal of Management*, 40(6), 1653–1674.

Yang, J, D Zeng, J Zhang and H Dai (2022). How tie strength in alliance network affects the emergence of dominant design: The mediating effects of exploration and exploitation innovation. *Technology Analysis & Strategic Management*, 34(1), 112–124.

Yayavaram, S and G Ahuja (2008). Decomposability in knowledge structures and its impact on the usefulness of inventions and knowledge-base malleability. *Administrative Science Quarterly*, 53(2), 333–362.

Yoon, SJ, K Marhold and J Kang (2017). Linking the firm's knowledge network and subsequent exploratory innovation: A study based on semiconductor industry patent data. *Innovation*, 19(4), 463–482.

Yu, S-H and H-C Chen (2020). External knowledge, intraorganisational networks and exploratory innovation: An empirical examination. *Innovation*, 22(3), 250–269.

Zaheer, A and GG Bell (2005). Benefiting from network position: Firm capabilities, structural holes, and performance. *Strategic Management Journal*, 26(9), 809–825.

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

Zander, U and B Kogut (1995). Knowledge and the speed of the transfer and imitation of organisational capabilities: An empirical test. *Organisation Science*, 6(1), 76–92.

Zang, J (2018). Structural holes, exploratory innovation and exploitative innovation. *Management Decision*, 56(8), 1682–1695.

Zhang, G, X Wang and H Duan (2020). Obscure but important: Examining the indirect effects of alliance networks in exploratory and exploitative innovation paradigms. *Scientometrics*, 124(3), 1745–1764.

Zhang, J and C Baden-Fuller (2010). The influence of technological knowledge base and organisational structure on technology collaboration. *Journal of Management Studies*, 47(4), 679–704.