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TWO-SIDED EFFECTS OF EMBEDDEDNESS IN ALLIANCE PORTFOLIOS

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Alliance portfolios are an important source of competitive advantage for firms. Diverse resources of partners contribute to enhancing firms' performance, but relationships among the firms' partners also influence the performance. This paper, employing an embeddedness lens, aims to examine how these relationships influence the firms' innovation performance. We confirm two-sided effects of embeddedness within alliance portfolios. While the focal firms increase the size of their portfolios, dense relationships among their partners increase the performance and competitive relationships weaken the performance. For the empirical test, we collected data on 1863 technology alliances between US biotechnology and multinational pharmaceutical companies. This study highlights how firms have to consider relationships among their partners when configuring their alliance portfolios to maximise innovation performance.

Keywords: Alliance portfolio; structural embeddedness; competitive embeddeness; innovation performance.

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Introduction

There are a number of motivations for interfirm alliances such as reducing transaction costs (Kogut, 1988) and uncertainty (Kogut, 1991) or improving the competitive positioning (Gimeno, 2004; Kogut, 1988; Silverman and Baum, 2002). Moreover, alliances allow firms to access their partners' resources (Chung *et al.*, 2000; Das and Teng, 2000; Eisenhardt and Schoonhoven, 1996; Lavie, 2006), to learn from their partners (Inkpen, 2000; Kogut, 1988) and to create value and innovation. As firms build up their own alliance portfolio, a collection of alliance partners, they gain access to a larger resource stock and earn greater benefits (George *et al.*, 2001; Gulati, 2007; Hoffmann, 2007; Lavie, 2006). Previous literature has empirically verified that a larger alliance portfolio leads to a better innovation performance (Ahuja, 2000; Baum *et al.*, 2000).

Alliance portfolio research differs from previous alliance research in that it can be understood from a social network perspective. Therefore, a number of previous literature (e.g., Baum *et al.*, 2000; Ozcan and Eisenhardt, 2009; Rowley *et al.*, 2000) define an alliance portfolio as a firm's egocentric alliance network. Previous alliance portfolio literature with a social network perspective has several characteristics. First, it focuses mainly on the structural characteristics of alliance portfolios and examines structural variables which bring positive outcomes to the focal firms of the portfolios (Gnyawali and Madhavan, 2001; Walker *et al.*, 1997). Second, it pays attention to the influence of the existing alliance network on firms' further alliance formations (Goerzen, 2007; Gulati, 1995a; Gulati and Gargiulo, 1999; Walker *et al.*, 1997). Third, so far, while adopting a common social network perspective, the existing literature does not provide a consistent theoretical background.

This paper also focuses on the social network perspective of alliance portfolios and complements the existing research. In doing so, this paper adopts an embeddedness lens, a basic premise in social network literature, and aims to suggest a balanced view toward the influence of alliance portfolios on their focal firms. Specifically, we examine the impact of network resources in alliance portfolios on focal firms' innovation performance and how structural and competitive embeddedness in alliance portfolios positively or negatively moderate this impact. As a result, we are able to verify that a larger alliance portfolio leads to an improved innovation performance of the focal firm, but, at the same time, relationships among the focal firm's partners were found to affect the relationship between alliance portfolio size and focal firm performance. In terms of structural embeddedness, a cooperative and densely tied portfolio strengthens the positive impact of network resources on the focal firm's innovation performance. In terms of competitive embeddedness, a portfolio with severe competition among the partners weakens the positive impact and leads to a reduced innovation performance.

This paper makes several contributions to alliance portfolio literature and provides implications for alliance managers. First, we highlight the usefulness of embeddedness as a tool for understanding the relationships among partners in an alliance portfolio and suggest researchers and managers to care about two-sided embeddedness in configuring alliance portfolios. Second, we clarify the context in which the network density outweighs structural holes in line with the debate originating from the different views of Coleman (1988)'s social capital theory and Burt (1992)'s structural hole theory. Third, we compare the impact of the breadth and depth of competitive relations among partners in alliance portfolios and provide specific advice on how to expand and configure alliance portfolios to improve the firm's performance. These contributions allow us deeper insights into the social network perspective and management of alliance portfolios.

The remainder of the paper is organised as follows: First, we develop the theoretical background of why structural and competitive embeddedness are suitable lenses to analyse the influence of interfirm relationships within alliance portfolios. We develop hypotheses which link alliance portfolio size, firms' innovation performance and moderating variables related to structural and competitive embeddedness. Second, employing negative binomial regression, we test our hypotheses using data on 1863 technology alliance cases in the biopharmaceutical industry. Finally, we present our empirical results and conclude with a discussion of implications, limitations and directions of future research.

Theoretical Background and Hypotheses

According to the review paper of Wassmer (2010), different opinions on what exactly constitutes an alliance portfolio exist among researchers from various organisational fields. The most common approach to define an alliance portfolio is viewing it as the aggregate of all strategic alliances of a focal firm (Bae and Gargiulo, 2004; George *et al.*, 2001; Hoffmann, 2005, 2007; Lavie, 2007; Lavie and Miller, 2008; Marino *et al.*, 2002). Studies in network literature apply a network perspective and define an alliance portfolio as the focal firm's egocentric alliance network which include all direct ties with partner firms (Baum *et al.*, 2000; Rowley *et al.*, 2000; Ozcan and Eisenhardt, 2009). Organisational learning literature focuses on alliance experience and defines an alliance portfolio as a focal firm's accumulated alliance experience which includes ongoing as well as past alliances (Anand and Khanna, 2000; Kale *et al.*, 2002; Reuer *et al.*, 2002; Hoang and Rothaermel, 2005; Park and Kang, 2010). Out of the different points of view, this paper adopts the social network perspective toward alliance portfolios which highlights concepts such as network resource and embeddedness.

The influence of network resources on innovation performance

Firms ally with diverse partners and build up their alliance portfolios because it allows them to gain access to their partners' resources, expand their learning and grow their businesses (Lavie, 2007). This explains why previous literature considers expanding alliance portfolios a significant issue in terms of alliance portfolio configuration and suggests the positive impact of alliance portfolio size on focal firms' innovation performance (Ahuja, 2000; Baum *et al.*, 2000; Shan *et al.*, 1994).

Specifically, the benefits of larger alliance portfolios are as follows. First, multiple partners increase knowledge sharing (Berg *et al.*, 1982). When firms collaborate for technology development, the outcome is available to all partners (Ahuja, 2000). Thus, the collaboration provides firms a greater amount of knowledge and technology than independent R&D activities, and the effect of collaboration increases with the number of partners.

Second, collaborations with multiple partners allow the focal firm to access complementary skills (Richardson, 1972; Arora and Gambardella, 1990). Technology development often requires the simultaneous use of different sets of skills and knowledge in the innovation process (Arora and Gambardella, 1990; Powell *et al.*, 1996). However, developing and maintaining diverse sets of competencies in an environment of rapid technological change is difficult for an individual firm (Mitchell and Singh, 1996). Under such circumstances, collaborations allow firms to have an access to their partners' knowledge to complement their existing knowledge base and thereby enhance their innovation performance (Ahuja, 2000).

Third, multiple collaborations enable firms to take advantage of scale economies (Ahuja, 2000). Technology development demands various resources such as research manpower, knowledge base and capital. In the case of collaborations, firms combine their resources and share an increased output. Especially, if the technology output is characterised by increasing returns, the impact of the collaborations improves significantly (Ahuja, 2000). As firms collaborate with an increasing number of partners, they take advantage of a great deal of resources and improve their innovation performance.

Therefore, other things being equal, we suggest:

Hypothesis 1: *A firm's innovation performance increases with the size of its alliance portfolio.*

Embeddedness in alliance portfolios

Larger alliance portfolios allow firms to access more network resources and thus contribute to an increased innovation performance. But alliance portfolio size alone is not a sufficient predictor for performance (Wassmer, 2010). Previous literature suggests that in addition to size, alliance portfolio breadth (Ahuja, 2000; Gulati, 1999), efficiency (Baum *et al.*, 2000) and alliance partner quality (Stuart, 2000; Stuart *et al.*, 1999) can serve as suitable predictors for firm performance. Therefore, for firms, having access to diverse and quality partners and an efficient portfolio configuration are as or even more important for the performance than alliance portfolio size alone (Wassmer, 2010).

This paper focuses on the social network definition of alliance portfolios. A number of social network studies have adopted the concept of an embeddedness lens. The key argument of embeddedness is that actors' actions and outcomes are influenced by the relationships that surround them (Baum and Dutton, 1996; Dacin *et al.*, 1999; Granovetter, 1985). Moreover, the embeddedness perspective suggests that the interfirm network influences the flow of knowledge and resources among them (Chen, 1996; Gnyawali and Madhavan, 2001). Within its alliance portfolio, the focal firm has a structural advantage which provides it with simultaneous access to its network resources and this advantage increases with the portfolio size (Zukin and DiMaggio, 1990; Gulati, 1998). At the same time, relationships among the focal firm's partners also affect the flow of resources within the portfolio. Specifically, the flow of knowledge within the alliance portfolio is influenced by the extent to which partners are interconnected with each other (structural embeddedness) and how partners compete with each other (competitive embeddedness). In conclusion, relationships among a firm's partners determine the flow of knowledge within its alliance portfolio and affect its innovation performance. Therefore, firms should not only focus on increasing their portfolios but at the same time consider the relationships among their partners as an important configurational factor of their portfolios.

The influence of structural embeddedness

The structural embeddedness perspective suggests that a superior position in a cooperative network translates into resource advantages (Gnyawali and Madhavan, 2001). Previous literature exemplifies variables related to structural embeddedness such as structural holes (Burt, 1992), centrality (Freeman, 1979; Bonacich, 1987; Ibarra, 1993; Podolny, 1993), structural equivalence (Burt, 1987), and density (Coleman, 1988). Gnyawali and Madhavan (2001) classify them into the structural properties of firm-level, pair-level and network-level and point out the density as a network-level structural variable. Density in this context refers to the extent of interconnectedness among the actors in a network. This paper also investigates how the extent of interconnections among partners affect the flow of resources within an alliance portfolio and, therefore, among the variables related to structural embeddedness, focuses on the density.

The existing views toward the effects of network density are divergent. A dense network is advantageous in building up absorptive capacity of actors within the network but at the same time limits novelty creation within the network (Gilsing *et al.*, 2008).

Specifically, a dense alliance portfolio provides the following advantages to the focal firm. First, in the case of a large technological distance between the focal firm and one of its partners, another partner, tied to the first one, complements the focal firm's absorptive capacity and helps to narrow down the technological gap (Gilsing and Nooteboom, 2005). Connections among the focal firm's partners increase the similarity of their knowledge base and allow the focal firm to easily absorb and understand its partners' knowledge (Gilsing *et al.*, 2008). Second, the focal firm may easily judge the reliability of information from its partners through its dense alliance portfolio (Gilsing and Nooteboom, 2005). Triangulations which consists of the focal firm and its partners allow the focal firm to objectively evaluate the acquired novelty from each partner (Rowley *et al.*, 2000). Third, a dense alliance portfolio facilitates the build-up of trust, a reputation mechanism and coalitions to constrain opportunism (Gulati, 1995a,b; Hagedoorn and Duysters, 2002). These advantages are also suggested by Coleman (1999)'s network closure theory and become more effective in the case of high uncertainty of technology development (Nooteboom, 1999, 2002).

However, the dense portfolio may lead to a number of disadvantages to the focal firm. First, it inhibits the inflow of novel and diverse knowledge. In a dense network, due to knowledge spread, 'everyone knows what everyone knows' (Gilsing *et al.*, 2008). Therefore the novelty of knowledge accessed by the focal firm declines and this in turn decreases the innovation performance (Gilsing *et al.*, 2008). Second, there is a risk of undesirable spillovers which makes the focal firm reluctant to share valuable knowledge with other partners in the portfolio. This restricts the focal firm's ability to appropriate novelty in its alliance portfolio (Gilsing and Nooteboom, 2005). Third, a dense network may create a strong behavioural pressure which forces the actors to conform rather than to be radically different (Kraatz, 1998). Therefore, a dense alliance portfolio may force the focal firm into coalitions with existing partners and to show loyalty toward them and, therefore, imposes restrictions on entering relationships with new and more innovative partners (Buchko, 1994; Nooteboom, 1999; Duysters and Lemmens, 2003; Gulati *et al.*, 2000).

In summary, a dense alliance portfolio can be seen to have both advantages and disadvantages. Previous literature is inconclusive on whether a dense or a sparse network is most adventageous for the actors' innovation performance (Bae and Gargiulo, 2004). For example, McEvily and Zaheer (1999) confirm the positive relationship between alliance networks with many structural holes and firms' capabilities. On the contrary, Ahuja (2000) confirms the positive relationship between network closure and the likelihood of the firm's innovation. Based on this literature, some scholars account for the contradictory predictions with a contingency approach and examine the context in which a certain form of network prevails (e.g., Rowley *et al.*, 2000). This paper is not biased toward a specific form of network and aims to examine how the network structure of alliance portfolios interacts with the amount of network resources through an opposite set of hypotheses. Therefore, other things being equal, we suggest:

Hypothesis 2a: *An increase in network density within a firm's alliance portfolio will strengthen the positive relationship between alliance portfolio size and innovation performance.*

Hypothesis 2b: *An increase in network density within a firm's alliance portfolio will weaken the positive relationship between alliance portfolio size and innovation performance.*

The influence of competitive embeddedness

Gimeno (2004) argues for an application of the network perspective not only to alliance relations but also to competitive relations. This is due to the fact that just like within alliance relations, where there are direct and indirect partners, also competitive relations consist of direct and indirect relations (such as rivals' rivals, or rivals' partners). Thus, competitive embeddedness, which is derived from the competitive relations surrounding the actors, also affects the actors' actions and outcomes like other types of embeddedness. Competitive relations are defined as the niche overlap in which firms seek the same resources or target the same markets or customers (Gimeno, 2004; McPherson, 1983). Previous literature suggests that the overlap of firms' resource requirements translates into their competitive relations (Baum and Mezias, 1992; Hannan and Freeman, 1977, 1989). Thus, within a focal firm's alliance portfolio, partners' alliances with the focal firm in the same business field can be viewed as an overlap of resource requirements and imply competitive relations.

The reasons why competitive relations among partners within an alliance portfolio negatively influence the focal firm's innovation performance are as follows: First, the competitive relations prevent active knowledge sharing within an alliance portfolio and deteriorate the competitiveness of the portfolio. Dyer and Hatch (2004, 2006) suggest that the competitive advantage of an alliance portfolio originates from the smooth transfer of explicit and tacit knowledge among the focal firm and partners. According to this view, the alliance portfolio functions as a knowledge sharing network which contributes to the focal firm's innovation performance. However, in case of competitive relations among the partners, they are wary of knowledge spillovers via the focal firm and sharing collaborative outputs with other partners of the focal firm and do not actively participate in the alliances with the focal firm. Second, competitive relations among partners deteriorate trust within an alliance portfolio and increase concerns about the cooperation. Within a network with low trust, alliances are considered to offer a number of opportunities for cheating such as "stealing partners" technology', "providing poorer quality investments on joint projects", and "not fulfilling ex ante commitments" and, thus, successful resource sharing is not possible (Ahuja, 2000). Moreover, the focal firm faces difficulties in coordinating its relationships with its partners who are wary of the opportunistic behaviour of the focal firm and its partners (Gulati and Singh, 1998). Finally, the competitive relations might also affect the successful resource sharing by inhibiting fine-grained information transfer and joint problem solving activities (Uzzi, 1997).

In conclusion, focal firms of alliance portfolios are not able to fully utilise the advantage of their network resources in case of competitive relations among their partners. Therefore, other things being equal, we suggest:

Hypothesis 3: *An increase in competitive relations among a firm's alliance partners will weaken the positive relationship between alliance portfolio size and innovation performance.*

To describe the outline of our research more clearly, Fig. 1 shows a diagram that summarises the research model and hypotheses.

Methodology

Data and sample

To test our hypotheses, we compiled data on the alliance portfolios of US biotechnology firms. The collection of the data was performed as follows: First, we collected information on technology alliances formed between US biotechnology firms and multinational pharmaceutical companies from 2002 to 2004 through the Bioscan database. To select technology alliances, we checked the qualitative section of the Bioscan database, which describes each alliance in detail, and confirmed the technology focus of the alliances in our sample while excluding those that have a purpose other than technology development (e.g., manufacturing and equity investment) from our dataset. Then, we added firm statistics such as R&D expenditure from the Datastream database. Finally, we added patent information provided by the US Patent and Trademark Office. We counted the number

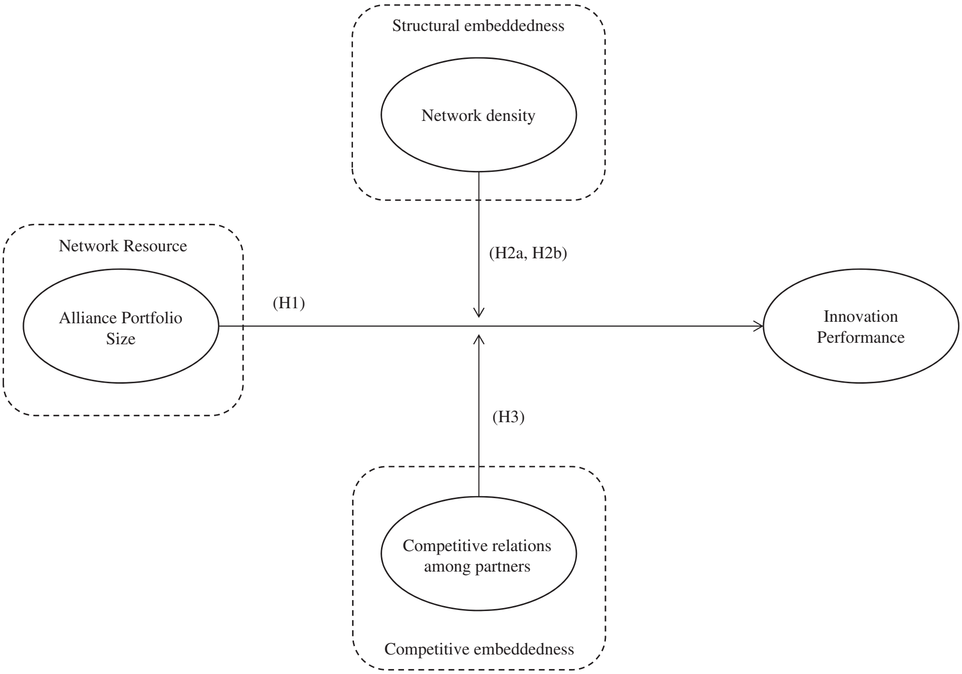

Fig. 1. The conceptual model.

of patents field by each focal firm to measure their technological capabilities and *ex-post* innovation performance. In total, we collected 1863 technology alliance cases of 125 focal firms.

High-tech industries are characterised by frequent alliances and growth from innovation (Hagedoorn, 2002). The biopharmaceutical industry shows high alliance tendencies and accounts for about 20% of alliances formed in high-tech industries (Hagedoorn, 1993). Therefore, the biopharmaceutical industry is an ideal setting to study alliance networks and the consequent innovation performance and a number of researchers have chosen this industry when doing research on related issues (Baum *et al.*, 2000; Deeds and Hill, 1996; Powell *et al.*, 1996; Shan *et al.*, 1994; Vassolo *et al.*, 2004). In addition, the highly competitive environment of the biopharmaceutical industry, where rents accrue to the first-mover firm that makes a discovery (Malik, 2012; Vassolo *et al.*, 2004), is appropriate to study competitive embeddedness. Finally, empirical tests within a single industry do not need to control for industry effects and thus raise the reliability of results (Brouthers and Hennart, 2007).

Dependent variable

The dependent variable, *innovation performance*, is the number of US patent applications filed by each focal firm of our dataset from 2005 to 2006. We focused on the amount of technological outputs which firms consider innovative at the time of their inventions and counted the number of patents filed as implemented in previous literature (e.g., Brouwer and Kleinknecht, 1999; Cheung and Lin; 2003). As patents are likely to correspond to activity immediately preceding the patent application, we used a one-year lead with respect to influences of the independent and control variables as used in previous literature (e.g., Ahuja, 2000; Cheung and Lin, 2004). By measuring the application count over a two year period, we allow sufficient time to capture the outcome of the technology alliances and at the same time can reduce the effects of unexpected annual variations which might affect a firm's patenting activities.

Independent variables

Network relationships have been described as network resources (Gulati, 1999). Accordingly, a number of previous studies count the number of partners in alliance portfolio to measure the overall level of network resources (e.g., Ahuja, 2000; Baum *et al.*, 2000; Deeds and Hill, 1996; Shan *et al.*, 1994). Likewise in our research, *portfolio size*, the variable to represent the level of network resources, is defined as the number of technology alliance partners of a firm during the 2002–2004 period.

To measure *network density*, we followed an approach used in previous literature (e.g., Rowley *et al.*, 2000) and excluded the focal firm and its relationships and solely considered the interconnections among a focal firm's partners. Scott (1991: 75) also suggests that "[i]n an egocentric network it is usual to disregard the focal agent and his or her direct contacts, concentrating only on the links which exist among these contacts". Therefore, we defined *network density* as the number of existing ties in each alliance portfolio (other than those involving the focal firm), divided by the total possible number of ties among its partners (Rowley *et al.*, 2000).

$$\text{Network density} = t/n(n-1)/2,$$

where t is the number of ties in an alliance portfolio (excluding all ties to the focal firm) and n is the number of firms in the portfolio (excluding the focal firm).

Because *network density* shows the presence or absence of ties among alliance partners, it is an appropriate measure of both the absence of structural holes in an alliance network and of its closure (Bae and Gargiulo, 2004; Borgatti, 1997; Burt, 2000; Podolny and Baron, 1997). *Network density* was analysed using alliance ties among the focal firm's partners in each alliance portfolio between 2002 and 2004.

To measure the level of competitive relations in detail and to test its influence empirically, we introduce the concept of *breadth* and *depth*. The concept is necessary to account for single-point competition in one market field and multipoint competition in more than one market field (Barnett, 1991). Competitive relations within an alliance portfolio also can intensify broadly across a variety of fields (breadth) and deeply in certain fields (depth). Thus we introduced the breadth and depth concept to measure how competitive relations build up in each alliance portfolio and to allow us to analyse their influence in more detail. Diverse subsectors in the biopharmaceutical industry related to the field of products (e.g., cancer, cell therapy, vaccines, etc.) are appropriate to measure the breadth and depth of competition. We investigated the purpose of each alliance between the focal firms and their partners. The Bioscan database relates each alliance with its purpose which corresponds to at least one or, sometimes, multiple business fields. Therefore we could measure the *breadth* and *depth* of competitive relations in the level of business fields. Specifically, the *breadth* of competitive relations is the scope of rivalry in an alliance portfolio. When target business fields of each alliance between a focal firm and its partners overlap across many different fields, the competitive relations in an alliance portfolio become broader. Therefore, the *breadth* is measured by counting the number of business fields in an alliance portfolio in which at least two partner firms are in competitive relations. The *depth* of competitive relations is the extent of rivalry within the business fields covered by the alliance portfolio. When target business fields of each alliance between a focal firm and its partners overlap in the same business, the competitive relations in an alliance portfolio become deeper. Therefore, the *depth* is measured by dividing the total competitive relations (the number of entire dyadic competitive relations) in an alliance portfolio by the number of competing business fields (*breadth*). In our study *breadth* and *depth* were analysed for the alliance portfolios consisting of alliances formed between the focal firms and their partners between 2002 and 2004.

Figure 2 shows an example of how *breadth* and *depth* are defined and measured in this study. The focal firm's alliance portfolio in this example consists of partner firms A, B and C. The target business fields of each alliance are described next to the tie between the focal firm and each partner. For example, partner A seeks the focal firm's technology in the cell therapy, cancer and vaccines field. The dotted boxes describe competitive relations between partners within this portfolio. For example, partners A and B compete with each other in this alliance portfolio because their target business fields through the alliances with the focal firm coincide with each other in the field of vaccine development. The *breadth* of competitive relations in this portfolio is simply the number of competing fields. Since partners are competing in the vaccines and cancer fields, the *breadth* in this example is 2. There are a total of two dyadic competitive relations in this portfolio. As mentioned earlier, partners A and B compete with each other in the vaccine field. Also, partners A and C compete with each other in the cancer field. To measure the *depth*, we should divide these two dyadic competitive relations by the

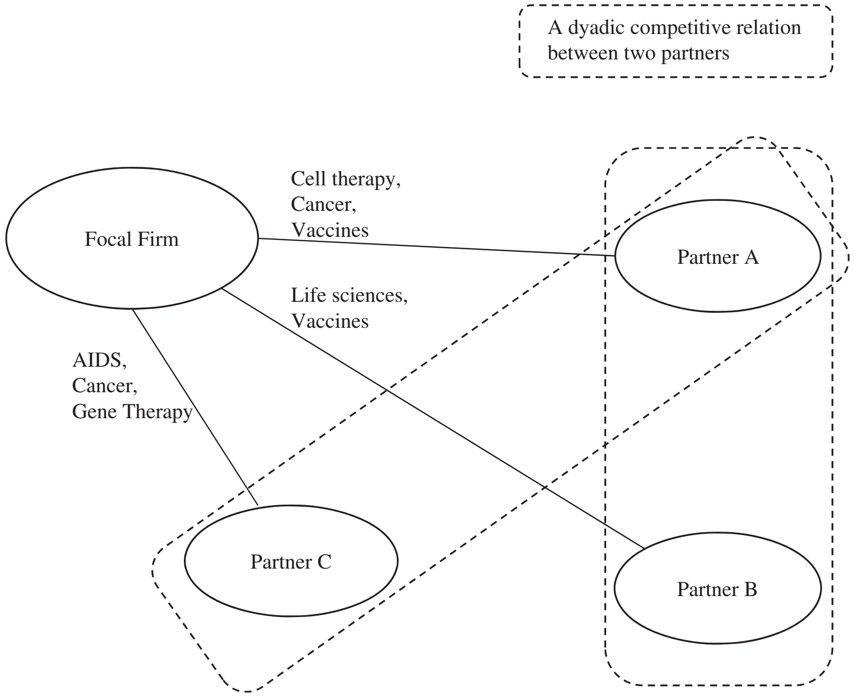

Fig. 2. An example of competitive relations among a focal firm's partners.

breadth of this portfolio. Consequently, the *depth* of competitive relations in this portfolio is 2 over 2, simply 1.

Control variables

We added six control variables which describe some characteristics of the focal firms and may directly affect our dependent variable. First, *technological capability* is measured by counting the total number of US patent applications filed by each focal firm until 2004. Previous literature suggests that the patenting record can be understood as a firm's technological stature (Narin *et al.*, 1987; Trajtenberg, 1990), and counts the number of cumulative patents field by a firm to measure its technological capability (Park and Kang, 2013; Silverman, 1999). Second, *R&D expenditure* is the logarithm of a focal firm's averaged annual expenditure for R&D during the period of 2002–2004. Third, prior *M&A experience* is a dummy variable coded as 1 (previous experience) or 0 (no experience). Fourth, prior *manufacturing alliance experience* is coded as 1 (previous experience) or 0 (no experience). M&A experience and manufacturing alliance experience of focal firms might lead to opportunities for accessing external knowledge outside their

Table 1. Descriptive statistics and correlations matrix.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Mean	SD
Technological capability	1.00														98.096	329.28
R&D expenditure	0.50	1.00													1.55	0.75
M&A experience	0.22	0.05	1.00												0.07	0.26
Manufacturing alliance	0.25	0.19	0.07	1.00											0.22	0.42
Firm age	0.32	0.42	0.14	0.18	1.00										9.18	4.83
IPO	0.11	0.10	−0.00	0.14	0.20	1.00									0.78	0.41
Portfolio size	0.12	0.30	0.16	0.36	0.23	0.12	1.00								5.26	3.15
Network density	−0.11	−0.22	−0.12	−0.31	−0.23	−0.07	−0.71	1.00							0.50	0.23
Breadth	0.12	0.18	0.22	0.33	0.06	0.08	0.61	−0.37	1.00						1.45	1.27
Depth	−0.00	−0.01	−0.01	−0.00	−0.04	0.08	0.42	−0.24	0.09	1.00					2.73	9.58
Portfolio size × network density	0.17	0.07	0.20	0.07	0.05	0.07	0.06	0.41	0.23	0.03	1.00				2.11	0.28
Portfolio size × breadth	0.09	0.25	0.10	0.30	0.16	0.09	0.81	−0.42	0.78	0.12	0.10	1.00			10.06	19.58
Portfolio size × depth	−0.01	−0.00	−0.02	−0.01	−0.03	0.07	0.41	−0.22	0.06	0.99	−0.00	0.13	1.00		27.01	151.16
Innovation performance	0.98	0.48	0.25	0.25	0.33	0.11	0.13	−0.12	0.14	−0.00	0.18	0.10	−0.01	1.00	59.43	210.20

existing network and thus might affect the dependent variable. Fifth, *firm age* measures the number of years between the year a focal firm's recorded its first sales and 2004. Finally, the initial public offering (IPO) distinguishes public companies (coded as 1) from private companies (coded as 0). Compared to private companies, the ownership of public companies is decentralised and public companies have to publicise their information and performance. Therefore their strategy and decision making would be different from those of private companies. In summary, we controlled for a few variables to increase the reliability of the test results and examine the direct effects of network resource and embeddedness on the focal firms' innovation performance.

Empirical model specification

In the current study, the dependent variable is innovation performance which is proxied by the number of patent applications. Therefore, the dependent variable is for discrete events and has a positive integer value. Besides, the dependent variable shows an over-dispersion distribution. The standard deviation, 210.20, is greater than the mean value, 59.43, as indicated in Table 1. In the case of a dependent variable with over-dispersed count data, negative binomial regression is appropriate to analyse the model (Barron, 1992; Cameron and Trivedi, 1986; Ranger-Moore *et al.*, 1991).

Table 1 presents a summary of descriptive statistics and correlations among the variables. Some variables show relatively high correlations (higher than 0.6) with other variables. Thus, we conducted an additional variance inflation factor (VIF) analysis to examine whether a multicollinearity problem exists. We excluded moderating variables (products of main effect variables) from the analysis because multicollinearity can be ignored when the high variance inflation factors are

Table 2. VIF test results.

Variables	VIF
Technological capability	1.51
R&D expenditure	1.63
M&A experience	1.13
Manufacturing alliance	1.28
Firm age	1.36
IPO	1.07
Portfolio size	3.84
Network density	2.08
Breadth	1.84
Depth	1.41
Average	1.72

caused by the inclusion of products or powers of main effect variables in the model (Allison, 2012). Table 2 presents the result of the VIF analysis and it can be seen that *portfolio size* exhibits the highest value (3.84). There is no multicollinearity problem when the VIF value is less than 10 (Hair *et al.*, 1995). Therefore, we conclude that the correlations among variables in our study do not lead to a multicollinearity problem.

Results

Table 3 presents the results from the negative binomial regression. The following analysis of the results is based on model 3 of Table 3 which includes all variables and shows greater likelihood compared to the other models.

The *portfolio size* is positively related with the focal firms' future innovation performance and this relationship is significant ($p < 0.1$). Therefore our hypothesis 1 is supported. This result implies that a focal firms' innovation performance increases when they have more partners in their alliance portfolios.

Furthermore, interaction terms (products of the main effect variable and moderating variables) are introduced to examine whether structural embeddedness and competitive embeddedness strengthen or weaken the positive influence of alliance portfolio size on the focal firms' innovation performance. They are Portfolio size × Network density, related to structural embeddedness, and Portfolio size × Breadth as well as Portfolio size × Depth, related to competitive embeddedness.

First, the coefficient of Portfolio size × Network density is positive and significant ($p < 0.1$). Therefore hypothesis 2a is supported and hypothesis 2b is not supported. This result implies that dense alliance portfolios contribute more to the focal firm's innovation performance than sparse ones. When focal firms increase their alliance portfolio size, they should also aim to have their partners increase the collaboration with one another for better innovation performance.

Second, among the variables relating to competitive relations among the partners, only Portfolio size × Breadth exhibits a significant coefficient. The coefficient of Portfolio size × Breadth is negative and significant ($p < 0.05$). Therefore hypothesis 3 is supported. This result implies that competitive relations among partners within an alliance portfolio lessen the positive effect of alliance portfolio size on innovation performance. Especially, when target business fields of each alliance between a focal firm and its partners overlap across many different fields, the resulting competition significantly weakens the contribution of alliance portfolio size to innovation performance.

The coefficients of some control variable also show significant values. Expectedly, the influence of *R&D expenditure* and *technological capability* on innovation performance is positive and highly significant ($p < 0.01$). Firms with

Table 3. Negative binomial regression results.

	Model 1		Model 2		Model 3	
Depend variable: Innovation performance	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E
Control variables						
R&D expenditure	1.0284***	0.1915	0.9992***	0.1866	0.9132***	0.1813
Technological capability	0.0024***	0.0007	0.0024***	0.0007	0.0026***	0.0006
M&A experience	0.2654	0.3831	0.0882	0.3940	−0.4086	0.4010
Manufacturing alliance	−0.2256	0.2496	−0.3947	0.2659	−0.6421**	0.2630
Firm age	−0.0253	0.0219	−0.0304	0.0214	−0.0500**	0.0219
IPO	0.3568	0.2476	0.3646	0.2474	0.4843**	0.2415
Independent variables						
Portfolio size			0.0769*	0.0455	0.2355*	0.1433
Network density					−1.4651	1.2871
Breadth					0.1172	0.1633
Depth					−0.2044*	0.1126
Portfolio size × network density					1.3510*	0.7807
Portfolio size × breadth					−0.0461**	0.0181
Portfolio size × depth					0.0104	0.0071
N	125		125		125	
Log likelihood	−495.013		−493.477		−484.802	
Pseudo R^2	0.1263		0.1291		0.1444	
LR Chi^2	143.18		146.25		163.60	
Regression p-value	0.0000		0.0000		0.0000	

Notes: $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

manufacturing alliance experience and older firms (*firm age*) show less innovation performance. Public companies (*IPO*) show better innovation performance than private firms.

Discussion

Theoretical implications

We empirically confirm the positive influence of alliance portfolio size on innovation performance that has been suggested in previous literature (Ahuja, 2000; Baum *et al.*, 2000; Shan *et al.*, 1994). The positive relationship between alliance portfolio size and innovation performance originates from knowledge sharing, complementarity and scale economies within alliance portfolios (Ahuja, 2000; Arora and Gambardella, 1990; Berg *et al.*, 1982; Richardson, 1972). In addition to this empirical test, our study conveys three key findings and related theoretical implications.

First, we find a positive moderating effect of structural embeddedness and a negative moderating effect of competitive embeddedness. Specifically, increasing network density within an alliance portfolio strengthens the relationship between the portfolio size and innovation performance, and broad competitive relations among a focal firm's partners weaken this relationship. Our findings clarify how synergies and conflicts occur within an alliance portfolio and how they affect the focal firm. The synergies and conflicts within an alliance portfolio arise from the independencies of the focal firm' partners and make the overall value of the portfolio greater or smaller than the sum of the value of each alliance in the portfolio (Parise and Casher, 2003; Vassolo *et al.*, 2004). Despite their significance, previous literature on the synergies and conflicts has not sufficiently examined the process of how they arise and has not empirically verified their effects (Wassmer, 2010). With an embeddedness lens, our study suggests that dense cooperative relationships among partners lead to synergies in an alliance portfolio and broad competitive relationships among partners lead to conflicts in the portfolio, and that these cooperative and competitive relationships, respectively, positively and negatively affect the focal firm's innovation performance. We also operationalised these relationships and empirically verified their effects. Furthermore, we suggest the relationships among partners as another configurational factor of alliance portfolios which affects the focal firm's innovation performance together with factors suggested in previous literature such as portfolio size (Ahuja, 2000; Baum *et al.*, 2000; Shan *et al.*, 1994), portfolio breadth (Ahuja, 2000; Gulati, 1999), efficiency (Baum *et al.*, 2000) and alliance partner quality (Stuart, 2000; Stuart *et al.*, 1999).

Second, it is more beneficial for focal firms to form dense alliance portfolios compared to sparse ones. What constitutes a social structure for enabling one type of action may be disabling others (Podolny and Baron, 1997). Therefore, the more advantageous network structure, a dense network or a network with many structural holes, is likely to be contingent on what actors aspire to enable through it (Ahuja, 2000). In this paper, in the case of technology alliances in the biopharmaceutical industry, based on our empirical analysis we suggest that dense alliance portfolios contribute more to the focal firms' innovation performance compared to portfolios with many structural holes. This is in agreement with previous literature which specifies the context in which a dense network outweighs structural holes. Ahuja (2000) suggests that, in the case of interorganisational collaborations, benefits of trust building, sharing collaboration routines, and blocking opportunism that result from a group of cohesive interconnected partners outweigh the disadvantages of not having the diverse information that is yielded from many structural holes within a firm's alliance portfolio. Further, many interlocking ties facilitate the cooperation and contribute to standard setting in high-tech industries (Kogut *et al.*, 1995; Oliver, 1990). The biopharmaceutical industry is also characterised by the significance of strategic preoccupancy of technology (Kim, 2013). Thus, the cooperation through cohesive alliance portfolios leads to better technology performance in the industry. On the contrary, structural holes matter when firms have diverse partners from different industries and provide brokering among them (Ahuja, 2000). Therefore, the samples of previous literature, which support the significance of structural holes, tend to include portfolios composed of firms from various industries. For example, Hargadon and Sutton (1997) investigate the role of product-development consulting firms that bridge structural holes between clients in different industries. This paper investigates technology collaborations within the biopharmaceutical industry and, therefore, does not correspond to a context in which structural holes prevail.

Third, competitive relations among a focal firm's partners across many different business fields deteriorate the innovation performance of the focal firm. Previous literature suggests that alliance portfolio breadth is one of the significant factors which explain the benefits firms achieve from their alliance portfolios (Ahuja, 2000; Gulati, 1999). However, although a focal firm has a number of partners in a broad range of fields, it cannot fully take advantage of its alliance portfolio in case of competition among the partners across those fields. It is because they are not willing to actively participate in alliances with the focal firm when they are put in competitive relationships with each other and seek the same resource of the focal firm (Khanna *et al.*, 1998). Thus, our study suggests that competition among a focal firm's partners across a broad range of fields deteriorates the advantage the focal could enjoy from their diverse alliances.

Moreover, this also reduces the efficiency of an alliance portfolio, another significant factor which accounts for alliance portfolio performance (Baum *et al.*, 2000), due to the high costs of coordinating the portfolio (Bamford and Ernst, 2002; Gulati and Singh, 1998).

Managerial implications

Based on the findings of this study, we suggest firms to increase their alliance portfolio size and, at the same time, to keep an eye on the two-sided characteristic of their portfolios, which is the connectivity and competition among their partners. As firms obtain more alliance partners, they might experience positive effects on their innovation performance as a result of increasing connectivity, but might also be confronted with the negative influence of competition within their portfolio. Therefore, firms should foster collaborations among their partners and, at the same time, avoid the overlap of partners around the same business fields.

Specifically, we suggest alliance managers to increase the network density within their alliance portfolios. If firms ally with their indirect partners (partners' partners), they can increase both the size and network density of their alliance portfolios and, consequentially, their innovation performance. Another way of fostering interconnections within an alliance portfolio is to develop joint projects which involve the focal firm and multiple partners from within the portfolio. These joint projects are likely to result in more ties among the focal firm's partners (higher network density) and can lead to an increased innovation performance of the focal firm by fostering active knowledge sharing between the multiple parties.

We also suggest alliance managers to restrict competitive relations across broad fields in their alliance portfolios. Our study subdivides the measure of competitive relations into breadth and depth and verifies the negative influence of competitive relations across broad fields on the innovation performance of focal firms. Focal firms face difficulties in absorbing knowledge throughout portfolios that include competitive relations across a number of (broad) fields. In such case, alliance portfolios turns into a conflict pool rather than a resource pool and do not significantly contribute to the focal firms' innovation performance. Accordingly, when firms increase their alliance portfolios, they should form alliances with the most suitable partner in each field rather than with many partners in the same field.

Limitations and directions for future research

First, the dependent variable in this study, focal firms' innovation performance, is based on patent applications and does not consider whether the patent would be actually granted or the significance of the underlying knowledge and technology.

We focused on the amount of technological outputs which the firms themselves consider innovative at the time of their invention and follow previous literature (e.g., Brouwer and Kleinknecht, 1999; Cheung and Lin, 2004) in using patent applications as a proxy for innovation performance. In addition, we focused on the amount of innovation output and counted the number of patent applications following the way widely used in previous literature (e.g., Ahuja, 2000; Baum *et al.*, 2000; Shan *et al.*, 1994). However, it does not consider the significance of the underlying knowledge and technology of each invention. Thus, we expect future research to consider this significance and introduce a better way for measuring innovation performance.

Second, we expect further research on the influence of embeddedness in alliance portfolios. Previous literature deals with structural variables of the firm network and studies the influence of structural embeddedness. On top of the existing research, we apply the structural embeddedness concept, together with competitive embeddedness, to firms' egocentric networks. In case of competitive embeddedness, recent studies including Gimeno (2004) and Trapido (2007) initiate the discussion and much of this field is still unexplored. Though not explicit, competitive relationships are ubiquitous among firms and affect their actions and outcomes. We hope for future research to study the influence of competitive embeddedness on alliance portfolios and focal firms in multifaceted ways. Moreover, we expect future research on other types of embeddedness, i.e., relational embeddedness and sectoral embeddedness, and their influence on alliance portfolios. This will lead to deeper understanding on how to configure alliance portfolios in terms of social network perspective.

Conclusion

Nowadays, most firms ally with diverse partners and innovate on the network or group level instead of the individual firm level (Gomes-Casseres, 2006; Lavie, 2007). Thus, alliance portfolios are seen as a source of competitive advantage for firms and researchers and managers are concerned with how to utilise them to improve firm performance. This paper supports previous literature that highlights the advantage of larger alliance portfolios and studies the influence of relationships among partners of focal firms, together with alliance portfolio size, on the focal firms' innovation performance. We introduce an embeddedness lens, one of the basic assumptions in social network perspective, and analyse relationships among focal firms' partners. This study suggests that researchers and managers pay close attention not only to the relationships between a focal firm and its partners, but also to the relationships among the focal firms' partners. In particular, as firms cooperate with more partners, they should shape their alliance portfolios to foster close cooperation between their partners while at the same time reducing competition between them.

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