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ARTICLE

Knowledge sharing in inter-organisational teams: the role of the advice network and the substitutive role of the formal network in an R&D alliance

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ABSTRACT

Innovation is about individuals collaborating to share existing knowledge and create new knowledge. Increasingly these collaborations cross organisational boundaries, like in R&D alliances. Many of these alliances are coopetitive, partners cooperate, but also compete with each other. Although knowledge sharing in coopetitive settings has been studied on the firm and the unit level, the micro (individual) level is underresearched. We consider individual alliance-related work performance of alliance members in a (moderately) coopetitive R&D alliance, drawing on social network theory and the organisational coordination perspective. We examine the influence of individual alliance members' position and level of activity in the alliance advice network on their work performance. We also examine the substitutive role of the alliance formal network, representing the official channels of knowledge sharing. We suggest that individuals' work performance is better explained by their position in the formal network, rather than in the advice network.

KEYWORDS
Coopetitive R&D alliance; knowledge sharing; individual work performance; advice network; tie strength; formal network

1. Introduction

Innovation has become an integral part of every organisation's ongoing operations (Carrillo, Druehl, and Hsuan 2015) and an inherently collaborative effort (Dolfsma and Leenders 2016). Crucial for the success of these collaborations is that people mutually share tacit and highly specialised knowledge and that they create new knowledge on the basis of these shared parts of existing knowledge (Aalbers, Dolfsma, and Koppius 2014; Chandrasekaran and Linderman 2015; Grant 1996; Hansen, Mors, and Lovas 2005). Increasingly these collaborations cross organisational boundaries, for instance in R&D alliances. Many of these R&D alliances are so-called coopetitive alliances where partners cooperate, but also compete with each other (Tsai 2002).

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The transfer of knowledge and information is not straightforward, it asks for coding, transferring, receiving, recoding and assembling (Cohen and Levinthal 1990; Grant 1996). The more tacit and specialised the knowledge, the more difficult the transfer is. It is even more difficult in the coopetitive R&D alliance setting where partner firms have to balance the tensions between the required knowledge sharing to realise the alliance goal and the control of the knowledge to avoid unintended and potentially competitively damaging leakages (Li et al. 2012; Martinez-Noya and Narula 2018; Sampson 2007; Tsai 2002; Taylor 2005).

Although the knowledge transfer in a coopetitive setting has been studied on firm and unit level (Sampson 2007; Tsai 2002), there is still some work to do, as knowledge transfer is one of the main challenges in coopetitive R&D alliances and the performance of many of these alliances falls short of expectations (Ernst, Lichtenthaler, and Vogt 2011; Sambasivan et al. 2013). We will study the knowledge transfer in a coopetitive R&D alliance on the micro level. This level has been underresearched until now (Foss, Husted, and Michailova 2010; Tasselli, Kilduff, and Menges 2015). Without going into empirical detail, some researchers suggest that stimulating micro-level knowledge sharing behaviour in an R&D alliance may lead to more knowledge sharing at the level of the R&D alliance (Foss, Husted, and Michailova 2010; Sabherwal and Becerra-Fernandez 2003). An effective way of developing, transferring, integrating and applying knowledge will positively affect the performance of the members of the allying partner firms (Ireland, Hitt, and Vaidyanath 2002; Kliman and Price 2015). Therefore, we consider the alliance-related work performance of the alliance members of a (moderately) coopetitive R&D alliance as our dependent variable (Steward, Courtright, and Barrick 2012; Welbourne, Johnson, and Erez 1998).

As firm-specific antecedents of individual work performance have already been studied (see e.g., Scott and Bruce 1994) and the main challenge of alliance members is to gain knowledge from members of the other partner firm(s), we will consider the social networks of the alliance members as independent variables, controlling for firm-specific variables (Cross and Cummings 2004). Building on social network theory (Anderson 2008; Burt 2004; Dolfsma and Leenders 2016) and the organisational coordination perspective (Gulati and Singh 1998; Sampson 2007; Tsai 2002), we first examine the alliance informal network of the alliance members. In previous within-firm research this appeared to be the most important network to share knowledge (Allen 1977; Allen, James, and Gamlen 2007; Cross and Cummings 2004; Hinds and Kiesler 1995). In particular, we will examine the alliance advice network which is self-initiated by alliance members and connects parts of actors voluntarily giving advice to one another (Gulati and Puranam 2009; Smith-Doerr and Powell 2005). The individual contribution of alliance members to the alliance goal can be expected to differ depending on their position in the advice network. But not only their position is of importance, also their level of activity in the network may have impact. Therefore, we also take into account the frequency of contacts alliance members have with other members in the alliance advice network, the strength of ties they maintain in the alliance advice network. Finally, we also consider the alliance formal network in our examination, the workflow connections and interactions that are mandated by management (McEvily, Soda, and Tortoriello 2014). Thus, one alliance member can have (informal) advice ties and formal (workflow) ties with other members of the alliance. We will examine which of the two networks has most impact on the individual work performance of alliance members in the coopetitive R&D alliance setting.

Despite the fact that we only consider a case study of one R&D alliance being moderately coopetitive, we have several potential contributions to the literature. First, we suggest the R&D alliance literature that even a moderately coopetitive setting already has influence on the individual (micro) level knowledge sharing process. Moreover, to the best of our knowledge, this is the first quantitative study explaining the work performance of individual alliance members in an R&D alliance. Second, this study suggests the social network theory that in a (moderately) coopetitive setting, contrary to the within-firm setting (Allen 1977; Allen, James, and Gamlen 2007; Cross and Cummings 2004; Hinds and Kiesler 1995) the alliance formal network is of greater importance to performance than the alliance advice network. Third, in our case study we empirically validated the organisational coordination perspective (Gulati and Singh 1998; Sampson 2007; Tsai 2002). Indeed, in our coopetitive setting the strength of advice ties negatively impacts the benefits of the alliance advice network for individual work performance.

2. Literature review

2.1. R&D alliances

Today the use of R&D alliances is considered a strategic need for firms to keep pace with global competition (Cassiman and Veugelers 2006; Martinez-Noya and Narula 2018; Sampson 2007). We define R&D alliances as innovation-based relationships formed by two or more partners pooling their resources and coordinating their activities to reach a common goal (Martinez-Noya and Narula 2018). Partners can collaborate horizontally (then they actually are competitors), vertically (then they are each other's suppliers or customers), and institutionally (then at least one of the partners is a university or a research institute) (Belderbos, Carree, and Lokshin 2004). Collaborations can also be partially horizontal and partially institutional as in our empirical setting.

The practical importance of R&D alliances has resulted in a bunch of research papers about the topic. Researchers studied, for instance, the motives to start an alliance (Pun and Ghamat 2016; Sambasivan et al. 2013; Taylor 2005), the kind of partners that has to be selected for the alliance (similar, or dissimilar to the firm in terms of technological background) (Makri, Hitt, and Lane 2010), the organisation of the alliance (Gulati and Singh 1998; Sampson 2007), and whether alliance capabilities can be learned (Heimeriks and Duysters 2007; Sampson 2005). It is beyond the aim of this study to summarise all R&D alliance literature. However, two observations can be made that are of importance to our study: (1) a major challenge in R&D alliances is sharing of knowledge between different partners and creating new and useful knowledge on the basis of this shared knowledge, and (2) this knowledge sharing and creating process still has to be improved as the performance of R&D alliances often falls short of expectations (Ernst, Lichtenthaler, and Vogt 2011; Sambasivan et al. 2013).

Knowledge that is used in innovative projects usually is highly specialised and tacit (Aalbers, Dolfsma, and Koppius 2014; Chandrasekaran and Linderman 2015; Hansen, Mors, and Lovas 2005; Mintzberg 1979; Taylor 2005). The sharing of this knowledge among team members, or across teams or units in an organisation is already difficult (Grant 1996; Cohen and Levinthal 1990). An additional problem for R&D alliances is that with the knowledge sharing process firm boundaries have to be crossed. Especially, in a so-called coopetitive setting where partners of the R&D alliance are also partially competitors, the knowledge sharing can really be difficult (Martinez-Noya and Narula 2018; Sampson 2007; Tsai 2002). In that case the partner firms may have concerns that the competitive value of their knowledge resources may erode due to unintended knowledge transfer to the partner firms (Sampson 2007; Taylor 2005). So, while a close interaction between members of different partner firms is required to share highly specialised and tacit knowledge, in reality the knowledge sharing process will be harmed due to appropriability concerns.

This knowledge sharing problem in a coopetitive setting has been studied on firm level for competing firms in an R&D alliance (Sampson 2007) and on unit level for competing units in a firm (Tsai 2002). Following calls for future research of Foss, Husted, and Michailova (2010) and Tasselli, Kilduff, and Menges (2015) we will study this phenomenon on the level of the members of a (moderately) coopetitive R&D alliance.

2.2. Individual's knowledge sharing and individual alliance-related work performance

The dependent variable in our study is the individual alliance-related work performance of the alliance members, i.e. the individual's behaviours or actions that are relevant to the goal of the R&D alliance (Campbell 1990). This individual work performance of alliance members is influenced by a great number of factors, like individual attributes, resources available, management support, psychological climate (see e.g., Scott and Bruce 1994), and in a knowledge-intensive setting the social networks of the alliance members (Cross and Cummings 2004). In our study we assume that in order to realise the goal of the R&D alliance, alliance members predominantly need to integrate knowledge from members of the other partner firm(s) into their own knowledge base. So, we assume that the ability of an alliance member to share knowledge with members from the other partner(s) is most influential to his/her alliance-related work performance. This ability depends on the propensity of the alliance member to exchange knowledge with members from the other partner(s) (Cohen and Levinthal 1990; Tomasello, Tessone, and SCHWEITZER 2016; Vaccario et al. 2018), and the number of alliance members with whom one can interact and collaborate profitably (Tomasello, Tessone, and SCHWEITZER 2016; Vaccario et al. 2018). With alliance members within the same firm it is relatively easy to interact, but the collaboration with alliance members of the partner firm(s) probably is much more profitable. Following Cross and Cummings (2004) we will focus here on the social networks of the alliance members and control for the individual's propensity to exchange knowledge and firm-specific factors, like location (Siegel, Westhead, and Wright 2003) and position within the firm. Below we will explain the alliance social networks in more detail.

2.3. Social networks

A social network is defined as a set of nodes connected by meaningful relationships. The nodes can be firms, units within a firm, teams, or individuals. In this study we focus on the individual. The meaningful relationships can be friendship, co-working, or advice-giving (Aalbers and Dolfsma 2015; Dolfsma and Leenders 2016; Lea et al. 2006). In recent years in social network research, two networks, rather than just a single one, have been considered: the informal and the formal networks (Aalbers, Dolfsma, and Koppius 2014; Allen 1977; Blau and Scott 1962; Gulati and Puranam 2009; Ibarra 1993; Mehra, Kilduff, and Brass 2001; Simon 1976). Thus, two individuals can be connected in different networks. Methodologically, it is shown that by asking the correct, validated name-generator questions in a survey, data for the different networks can be collected (Aalbers and Dolfsma 2015; Brass and Burkhardt 1992; Cross and Cummings 2004; Whitbred et al. 2011).

The informal network refers to the interpersonal relationships between actors that are not formally mandated but rather self-initiated (Mehra, Kilduff, and Brass 2001; Simon 1976). These interpersonal interactions are not mandated and cannot be sanctioned by management if not occurring (Gibney, Copeland, and Murie 2009). In particular, the self-initiated advice network will probably be based on the individuals' reputation and possession of relevant expertise. By the advice contacts individuals may be inspired to take a fresh look at their work. We concentrate here on the emergent and discretionary advice contacts among the alliance members.

The formal network is the formally prescribed set of interdependencies between actors set forth in job descriptions and reporting relationships (Aalbers, Dolfsma, and Koppius 2014; Gulati and Puranam 2009; McEvily, Soda, and Tortoriello 2014; Mehra, Kilduff, and Brass 2001). In the formal network for an R&D alliance, it is prescribed with which other alliance members a particular actor should share what kind of knowledge as part of his or her job responsibilities (Aalbers, Dolfsma, and Koppius 2014).

In our hypotheses below we will examine the role of the alliance advice network and the (substitutive) role of the formal alliance network in individual alliance-related work performance. Former within-firm studies have mainly favoured the role of the advice network over the formal network. Allen (1977) found that people who had a strong position in the communication network of laboratories usually did not have a strong position in the formal organisation. Hinds and Kiesler (1995) found that 30% of the technical and administrative employees' communication using technology was (traditional) hierarchical, while 70% of the communication was lateral or diagonal. Cross and Cummings (2004) found a strong positive relationship between a central position in the firm's awareness network (which can be used for future advices) and individual work performance, while the role of hierarchical ties was less outspoken. Allen, James, and Gamlen (2007) showed that the informal networks that were used for knowledge exchange between technicians were markedly different from the formal organisational structure implemented to encourage this knowledge exchange. Tsai (2002) found that in a coopetitive multiunit setting of a firm the informal network has positive impact on inter-unit knowledge sharing, while the formal organisation had negative impact. Finally, Aalbers, Dolfsma, and Koppius (2014) found a similar, positive impact of both advice and formal networks on innovative knowledge transfer. In the next sections we will predict and empirically examine how this works out in a (moderately) coopetitive R&D alliance setting.

3. Hypotheses

3.1. Influence of alliance advice network

Individuals have discretion about whether to be active in the advice network and what the nature of the advice will be (Sparrowe et al. 2001). Therefore, we expect some variance in the number of advice ties each alliance member has with other alliance members. An interesting position in the alliance advice network is the bridging or brokering position, in which an alliance member (as one of only a few) bridges between two more dense parts of the alliance advice network. In such a mediating role alliance members have a high *betweenness centrality* (Borgatti 2005; Wasserman and Faust 1994). It is of particular importance if it concerns the bridging of alliance members between the partner firms. Thus, we will concentrate on the betweenness centrality of alliance members. Social network theory predicts that a high betweenness centrality of an alliance member will be beneficial for his or her individual alliance-related work performance (Anderson 2008). This is the core statement in the Structural Holes theory of Burt (1992, 2004). The alliance member will have access to a diversity of input from other alliance members. He or she has a direct knowledge advantage over other alliance members, which can be used to increase the individual alliance-related work performance.

From an organisational coordination perspective however, a less smooth information processing of alliance members with high betweenness centrality is predicted, which may hamper the advantages of a bridging position of an alliance member (Gulati and Singh 1998; Sampson 2007; Tsai 2002). Especially in a coopetitive setting, partner firms may try to exercise control on the alliance members employed by them in order to protect knowledge that has competitive value (Tsai 2002; Sampson 2007). Therefore, the input the alliance member with high betweenness centrality receives may be strained, and thus, less interesting, while the member will be pressed by one of the partner firms not to use the information he or she received in the alliance processes. This would make the betweenness centrality position less attractive for the member's individual alliance-related work performance.

Finally, it is known that individuals sometimes give each other advice, even if they explicitly are not allowed to do so by the management of the firm that employs them (e.g., Bouty 2000). This is especially hard to control by the management of the partner firms in case of an alliance advice network.

All in all, we do not believe that a high betweenness centrality in an alliance advice network is as beneficial as predicted in social network theory. However, given all the arguments mentioned here and the difficulty of the management of the partner firms to exercise control on individual members, we suggest it is still beneficial for an alliance member's alliance-related work performance to have a high betweennness centrality in the alliance advice network. We therefore hypothesise:

Hypothesis 1: An attractive (central) position in the alliance advice network is positively associated with individual (alliance-related) work performance.

3.2. Moderating role of tie strength in alliance advice network

In the former section we argued that there may be a limited information and knowledge flow in the advice network due to appropriability issues. However, we argued, having a central position in this network will still be beneficial for the (alliance-related) work performance. Yet, the intensity of the interaction between the actors and their direct contacts in the advice network may influence this relationship (McFadyen and Cannella 2004). Tie strength indicates the frequency of interactions or a social relation's intensity, intimacy, or depth of affection and trust (Granovetter 1973). A strong tie between individuals signifies that the knowledge that they have in common and share is strongly embedded socially.

Brokerage roles need time and effort to develop and sustain (Aalbers and Dolfsma 2015; Allen 1977). Developing a brokerage tie is especially difficult for positions between individuals from different alliance partners such as in an R&D alliance. Such individuals have fewer opportunities to socialise; in addition, concerns over possibly inadvertent knowledge leakage might prevent socialising from happening if there are such opportunities. The information and knowledge accessed through their bridging role will be weighed against time and effort invested as well as the possible risks associated with such a role. Transfer of complex and specialised knowledge between individuals is, however, more likely between individuals who have a strong tie between them (Hansen 1999; Uzzi 1996, 1997). One reason for this is that knowledge or information transfer requires a number of different steps: coding, transferring, receiving, recoding and assembling. The more tacit and specialised the knowledge to be transferred, the more difficult, time-consuming, costly, and prone to failure these steps are. All these steps take time and in all of them interpretation problems may arise in particular when the connection between exchange partners is weak.

Although strong ties help the exchange of tacit and specialised knowledge (Byrne 1971; Ibarra 1995; Lakin and Chartrand 2003; Mollica, Gray, and Trevino 2003; Ruef, Aldrich, and Carter 2003), following social network theory we assume that they also lead to less diverse information and knowledge at the brokerage position, for two reasons. First, resonating the arguments of Granovetter (1973) about the strength of weak ties, the knowledge exchanged between individuals who maintain strong ties may be more similar and redundant, compared to individuals connected by weak ties. Second, an individual can be expected to maintain a limited number of ties as ties are 'expensive' to develop and sustain. Thus, the stronger ties are, the fewer someone can maintain, since such ties are more 'costly' to develop and maintain. People who maintain strong ties can be expected to have fewer contacts (e.g., Anderson 2008), which reduces the diversity of information and knowledge they can conceivably access. Thus, given a potentially already more limited flow of information and knowledge in an R&D alliance's advice network as predicted by the organisational coordination perspective (Gulati and Singh 1998; Sampson 2007; Tsai 2002), and the additional decreasing access to diverse information and knowledge in case of strong ties at the brokerage position, we believe that tie strength will have a negative moderating influence on the otherwise positive effect for an individual's performance of holding a brokerage position in the R&D alliance's advice network. Therefore, we hypothesise:

Hypothesis 2: Tie strength negatively moderates the relation between an attractive (central) position in the alliance advice network and individual (alliance-related) work performance.

3.3. Substitutive role of alliance formal network

The alliance formal network consists of the alliance members and the mandated connections among them. In such mandated contacts it is prescribed with whom which information and knowledge should be shared. It cannot be assumed that what knowledge is transferred from individual A to individual B can also be freely shared by individual B to his or her other alliance contacts. Thus, information and knowledge in the alliance formal network cannot be assumed to flow freely. Therefore, a strong or central position in the alliance formal network is, in contrast to the alliance advice network, more locally determined. As a centrality index for the formal network the degree centrality, the direct alliance contacts an alliance member has, is often taken (Balkundi and Harrison 2006; Bono and Anderson 2005; Brass 1984; Cross and Cummings 2004; Freeman 1979; Mehra, Kilduff, and Brass 2001). So we focus on the degree centrality of the alliance members in the alliance formal network.

In a coopetitive R&D alliance partner firms may try to protect their proprietary knowledge that is very sensitive or of high competitive value (Sampson 2007; Tsai 2002), so firms determine carefully which individuals in the alliance are allowed to share what information and knowledge with whom. An R&D alliance will fail in case of a too protective attitude of each of the firms, but a firm will be hurt if too much is (inadvertently) shared (Gulati and Singh 1998; Lubatkin, Florin, and Lane 2001; Sampson 2007; Tsai 2002). However, when the alliance formal network has been approved by the partner firms, the alliance formal network can show clear and transparent flows of information and knowledge among the alliance network members.

Given the pressure on members of the alliance advice network by the partner firms not to share the sensitive or highly competitive knowledge as predicted by the organisational coordination perspective (Gulati and Singh 1998; Sampson 2007; Tsai 2002), we expect that at the presence of an alliance formal network alliance members will shift their attention with respect to information and knowledge sharing from the alliance advice network to the alliance formal network. So, instead of using their (central) position in the alliance advice network, they will use their (central) position in the alliance formal network, which is considered a much 'safer' information channel. Thus, we hypothesise:

Hypothesis 3: The positive contribution to an individual's alliance-related work performance of an attractive (central) position in the alliance advice network can be substituted for by an attractive (central) position in the alliance formal network.

4. Method

4.1. Organisational settings

We collected data about individuals active in an alliance between a company developing and producing fuel cells in China (the Company) and a research organisation focusing on chemical physics and in particular fuel cell research (the Institute). The Company, located in a high-tech zone and leading in the development and commercialisation of fuel cells, is founded in 2001 and by now employs 150 individuals. The Company has a unit structure with intensive cooperation between the units. In order to obtain in-depth research-based knowledge to develop more advanced products, the Company allied with the Institute in which basic research is conducted. It intends to develop more core competitiveness in terms of more advanced technologies and patents based on the knowledge from the institute.

The Institute, located about 10 kilometres from the company and founded in 1961, is famous in China for its research in chemical physics. It is structured in divisions. The fuel cell division employs 50 scientists. In addition to basic research, this division also makes innovative breakthroughs in fuel cells and at the time of collection of data held 25 highly influential patents. Under the background of increasingly more research institutions conducting commercialisation of their scientific and technological achievements, the institute has motives to produce more commercializable and advanced technologies for sale.

The R&D alliance (the Alliance) started in 2008 and focuses on fuel cell technology development and application. The alliance consists of several projects coordinated by project leaders and directors from the Company and the Institute. To monitor the progress of the projects, there are regular meetings between alliance members. Besides the project work, within the Alliance there are personnel trainings, technology consulting, testing, and regular seminars about recent developments in the forefront of the relevant technology. In terms of the alliance life cycle (Chao 2011) the alliance just started the reconfiguration phase, assessing the performance realised until that time and thinking about a new strategy with more diverse partners.

For several reasons we classify this R&D alliance as a moderately coopetitive R&D alliance, although it is partly institutional and partly horizontal. First, there is a moderate-to-high need for both mutual cooperation and competition (Luo 2007). The Company wants to advance their products into a more science-based direction, making use of the newest scientific ideas in chemical physics. The Institute wants to produce more commercializable and advanced technologies for sale, and, thus, needs knowledge in industrial manufacturing. So, both markets of the Company and the Institute will be positioned closer to each other in the near future. Second, both Company and Institute are also part of other alliances, so knowledge leakage in the focal R&D alliance may have consequences for more direct competitors in the other alliances. Third, both partners compete for the acquisition of limited governmental projects and funding with respect to fuel cell technology and can use each other's knowledge, clients, and personnel to realise a better competitive position. Finally, and most importantly, managers from both partners have been interviewed and emphasised in their introductory interviews that they see the other partner as a competitor, so the managers who are the most powerful in the decision making see the R&D alliance as a coopetitive one.

4.2. Data collection

Data on the individual (alliance-related) work performance of the alliance members were collected from the two alliance directors of the Company and the Institute. Data on the social network variables were collected from the alliance members. So, we used two different sources for our data collection: the two alliance directors for the dependent variable and the alliance members for the other variables. This study used snowball sampling to obtain data about the whole social network. Snowball sampling is especially useful if the population is not clear from the beginning (Aalbers, Dolfsma, and Koppius 2014; Marsden 1990, 2002; Wasserman and Faust 1994), which holds true especially for the advice network in our study. The online survey included validated name generator questions to have the correct data about each of the two networks (Aalbers, Dolfsma, and Koppius 2014; Sparrowe et al. 2001). This is a typical survey method for gathering social network data. Via one or more name generator queries the names of individuals are elicited with whom a particular individual has direct contact (Burt 1984; Marsden 1990). In the query the type of contact is specified. To reduce ambiguity with respect to the interpretation of the questions by the respondents, the questions were formulated in the native language. The invitation to participate in the survey was distributed by the two alliance directors via an email to each of the alliance members, accompanied by an introduction of the survey and the hyperlink to the online survey.

In order to obtain the high response rate that a study using network data requires, the survey was sent in three rounds to obtain data from all alliance members for both of the networks (Wasserman and Faust 1994). The number of respondents is 66, with a 97% response rate of people engaged in the Alliance from the Company and a 100% response rate from the Institute. While this may appear a small number of observations, earlier studies also analysed networks of such size (e.g., Aalbers et al. 2013; Aalbers, Dolfsma, and Koppius 2014; Albrecht and Hall 1991; Dholakia, Bagozzi, and Pearo 2004; Tichy, Tushman, and Fombrun 1979), providing robust outcomes (Aalbers et al. 2013; Costenbader and Valente 2003). See Table 1 for some structural characteristics of both the alliance advice and the alliance formal network.

In Figure 1 the visual representation of the advice network can be seen and in Figure 2 the representation of the formal network. Both networks indicate that they are denser on the Institute side.

Table 1. Structural characteristics of the social networks.

	Advice network	Formal network
Total number of ties	273	312
Average number of Company ties (St. dev.)	3.27 (2.85)	5.00 (2.76)
Average number of Institute ties (St. dev.)	10.42 (4.05)	10.00 (4.17)
Average tie strength Company (St. dev.)	3.57 (2.19)	-
Average tie strength Institute (St. dev.)	5.31 (0.97)	-
Average degree centrality (St. dev.)	10.63 (7.80)	11.75 (6.93)
Average betweenness centrality (St. dev.)	2.06 (3.15)	1.65 (2.72)
`Number of respondents Company	33 of 34 (97%)	
Number of respondents Institute	33 of 33 (100%)	

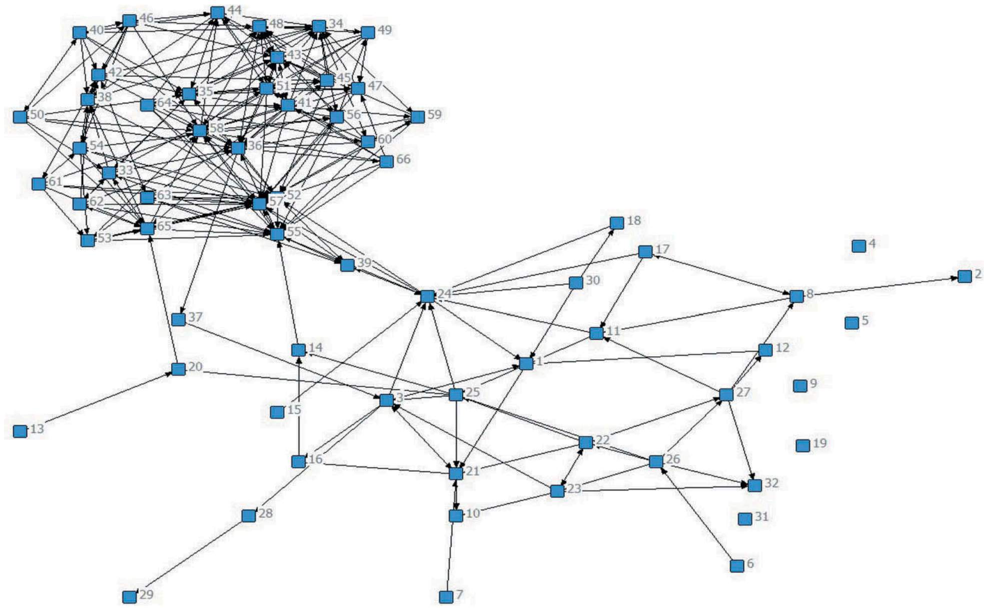

Figure 1. Advice network.

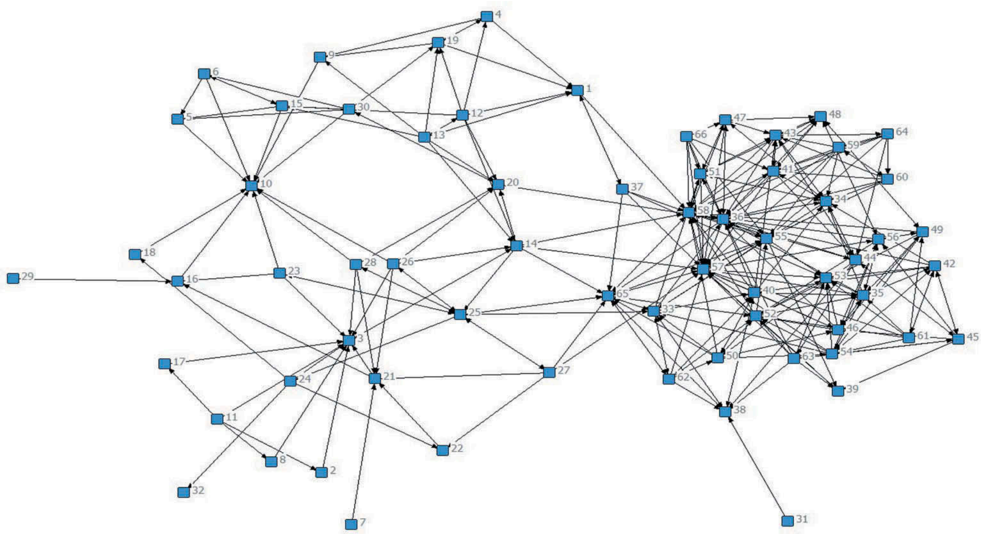

Figure 2. Formal network.

4.3. Measures

4.3.1. Dependent variable

4.3.1.1. Individual alliance-related work performance. Individual alliance-related work performance was measured by means of a seven-point Likert type scale in ascending order, which means the higher the rating, the better the performance. The individual work performance includes five dimensions: individual work quality, efficiency, innovativeness, knowledge, and interpersonal capability (Barrick, Mount, and Strauss 1993; Cross and Cummings 2004; Steward, Courtright, and Barrick 2012; Welbourne, Johnson, and Erez 1998). The five dimensions are significant for indicating one's work performance in general, but also particularly in the R&D alliance. In such a knowledge-intensive setting members cannot develop breakthrough technologies without knowledge, quality and innovativeness. Moreover, for the Alliance time-to market is very important to be able to compete with rivals, thus work efficiency is an important dimension. Finally, especially in an alliance knowledge must actually be shared which asks for interpersonal capability of the alliance members.

We purified the measurement scale of individual alliance-related work performance by performing an exploratory factor analysis using principle component analysis. Standardised factor loadings are presented in Table 2. Also the wordings of the survey questions for this scale can be found in Table 2.

4.3.2. Networkvariables

The network variables were determined by the use of the aforementioned name generator questions. See for the wording of the network survey questions Table 3.

4.3.2.1. The advice network. The advice network was identified by asking individual respondents whom in the Alliance they ask for advice, or whom they give advice when

Table 2. Standardised factor loadings and Cronbach's alpha of the dependent variable.

Construct item	Item wording	Factor loadings and Cronbach's α
Individual alliance-related work performance		α = 0.868
1	He or she contributed to the alliance with his or her work output quality	0.866
2	He or she contributed to the alliance with his or her work efficiency	0.879
3	He or she contributed to the alliance with his or her innovativeness	0.915
4	He or she contributed to the alliance with his or her job knowledge	0.786
5	He or she contributed to the alliance with interpersonal ability	0.597

Table 3. Network survey questions.

Advice network	Who are the key people within the Alliance to whom you ask for advice, or whom you give advice when either of you meet a problem at work for which you do not have the appropriate knowledge to address?	Hansen (1999); Mehra, Kilduff, and Brass (2001)
Tie strength in the advice network	What is the contact frequency of your interactions with each of the individuals mentioned in the former question? (Anchor.1 = once every three months or less, 2 = once every two months, 3 = once a month, 4 = twice a month, 5 = once a week, 6 = twice a week, 7 = daily)	Hansen (1999); Mehra, Kilduff, and Brass (2001)
Formal network	Who are the key people within the Alliance with whom you are supposed to discuss ideas or solutions at work?	Aalbers, Dolfsma, and Koppius (2014); Mehra, Kilduff, and Brass (2001)

they meet a problem at work for which they do not possess the appropriate knowledge to address (Aalbers, Dolfsma, and Koppius 2014; Ibarra 1992; Rodan 2010).

4.3.2.2. The formal network. The formal network was identified by asking individual respondents with whom within the Alliance they are supposed to discuss ideas or solutions at work (Aalbers, Dolfsma, and Koppius 2014; Mehra, Kilduff, and Brass 2001).

We provided a guideline of naming seven employees for each network to make sure that only the most important contacts per employee were mentioned. Further contacts could be added, however.

4.3.2.3. Tie strength in the advice network. Tie strength in the advice network was measured by a seven-point scale measuring the frequency actors interact with each other within a time phase in the advice network (Hansen 1999; Levin and Cross 2004). It was measured in terms of frequency as the alliance members are from different partner organisations; therefore, the connections among them can hardly involve intimacy or depth of affection.

4.3.2.4. Centrality. Centrality in both networks was calculated by using Ucinet 6.0 (Borgatti, Everett, and Freeman 2002; Freeman 1979) and using the network data that were gained by the network survey. We already discussed in a former section that betweenness centrality is the most interesting centrality variable in the advice network, while degree centrality is most interesting in the formal network.

4.3.2.5. Betweenness centrality in the advice network. Betweenness centrality in the advice network is calculated as the number of cases in which an individual can interrupt (can mediate) as they are on the shortest path between any pair of two other individuals. This indicates an individual actor's structural position as a bridge in a network (Borgatti 2005; Freeman 1979; Wasserman and Faust 1994).

4.3.2.6. Degree centrality in the formal network. Degree centrality in the formal network was calculated by counting how many direct contacts an actor has (Balkundi and Harrison 2006; Bono and Anderson 2005; Brass 1984; Cross and Cummings 2004; Freeman 1979; Mehra, Kilduff, and Brass 2001).

Both centrality variables are independent variables in our study.

4.3.3. Control variables

We control for firm (Company = 1 and Institute = 2) and work-related knowledge and experience of alliance members: *Job title* has been measured by a dummy variable, indicating whether the job concerns administrative or technical support in the Company or the Institute (1) or engineering work in the Company or scientific work in the Institute (2). *Rank* (hierarchy) has been measured by a dummy variable indicating whether the individual has a relatively low (1) or high (2) position in his or her own organisation. *Tenure* was measured by the length of time an alliance member works in a specific field. By a mean-split of the number of month the alliance members worked in a specific field, we created a dummy variable indicating whether the alliance member has a relatively low (1) or high (2) tenure in his or her specific field.

4.4. Method bias and reversed causality

As mentioned before, information with respect to the dependent variable, the individual alliance-related work performance was obtained from the two alliance directors of the Company and the Institute. Data on the social network variables were collected from the alliance members. An advantage of this approach is that it strongly decreases the likelihood of common method bias (Podsakoff et al. 2003). A disadvantage may be that managers perceive the contribution of the alliance members closer to them as stronger than members more on distant. In the next sections we will see that the rank variable indeed mostly is positively associated with the performance of the alliance members. However, the association is mostly weaker than the association of the network variables.

We also checked whether the scores of the directors were influenced by the extent of participation of the alliance members. However, the correlation between the individual work performance scores and the hours the members participated in the alliance was insignificant ($r = 0.15$, $p = 0.24$). Moreover, we checked whether both directors had the same standard in mind by correlating the individual work performance scores with the firm (1 = Company, 2 = Institute). We found a highly significant correlation of 0.49 ($p < 0.001$). So, the Institute director systematically scored his or her members higher compared to the Company director. We dealt with this issue by standardising each member's score within each alliance partner, making the alliance member scores comparable between the partners, assuming that in a fair scoring process the average score of a member in the firm probably will be equal to the average score of an institutional member. In our analysis we will use these standardised scores. Finally, we checked for endogeneity in our data, especially reversed causality. Reversed causality may occur in our data as one may argue that individual alliance-related work performance can also lead to a central position in particularly the formal network, or to a higher rank in the firm. As we use cross-sectional data we cannot rule out this possibility. However, according to the Durbin-Wu-Hausman test (Greene 2012), comparing 2SLS instrumental variable regression with our original regression results, we are well below the χ^2 thresholds. We took the tie strength in the formal network with only members from the other partner as an instrument in the case of the central position in the formal network. This tie strength variable is not correlated with the (standardised) individual (alliance-related) work performance ($r = 0.05$, $p = 0.69$) but it is correlated with the degree centrality in the formal network ($r = 0.37$, $p < 0.01$). With probability of 99% the 2SLS model does not deviate from the results we present. For rank we used the interplay between the degree centralities of the formal and the advice network as an instrument. This variable is not correlated with (standardised) individual alliance-related work performance ($r = 0.18$, $p = 0.15$), but it is correlated with rank ($r = 0.48$, $p < 0.001$). Also in this case with probability of 99% the 2SLS model does not deviate from the results we present. Thus, it is unlikely that reversed causality will affect (inflate) our outcomes. See Appendix A1 for the endogeneity tests.

4.5. Analysis

Descriptive statistics and correlations between the study variables are presented in Table 4.

Table 4. Descriptive statistics and correlations.

Variable	Mean	Std. dev.	1	2	3	4	5	6	7	8
1 Work performance	0.00	0.99	1.00							
2 Betweenness centrality (Advice network)	2.06	3.15	0.26**	1.00						
3 Advice-network tie strength	4.44	1.90	−0.19	0.08	1.00					
4 Degree centrality(Formal network)	11.75	6.93	0.25**	0.45**	0.15	1.00				
5 firm	50% (1)	-	0.00	0.40**	0.46**	0.68**	1.00			
6 Job title	92% (1)	-	0.01	-0.17	0.14	0.12	−0.06	1.00		
7 Rank	88% (1)	-	0.43**	0.26*	0.06	0.31*	0.19	0.11	1.00	
8 Tenure	38% (1)	-	0.41**	0.16	−0.32**	−0.01	−0.22	−0.01	0.38**	1.00

*p < 0.05; **p < 0.01. Note that for continuous – continuous and continuous – nominal combinations of variables we calculated the Pearson correlation, for continuous – ordinal combinations Kendall's tau, as well as for ordinal – ordinal combinations, for ordinal – nominal combinations we calculated Spearman correlation and for nominal – nominal combinations the phi coefficient.

This study utilises ordinary least squares multiple regression to test the hypotheses formulated (see Table 5). We involve 66 observations of the advice network, and 66 observations of the formal network. Since the network data are mutually dependent we use the bootstrapping option in STATA (version 13), with 2000 samples and confidence interval at 95% (Efron and Tibshirani 1993).

We first examine the control variables' effects on individual (alliance-related) work performance in model A. Then we add the main factor of betweenness centrality in the advice network in model B. Afterwards, we test the moderating effect of tie strength in the advice network in model C. Then the effects of the main factors and the moderating

Table 5. Individual (alliance-related) work performance (bootstrap regression coefficient estimates).

	A	B	C	D
Firm	0.004	-0.070	0.027	-0.161
	(0.117)	(0.123)	(0.128)	(0.167)
Job title	-0.017	0.017	0.038	-0.029
	(0.085)	(0.091)	(0.084)	(0.077)
Rank	0.314**	0.242†	0.302*	0.261*
	(0.111)	(0.130)	(0.124)	(0.125)
Tenure	0.290*	0.228†	0.165	0.147
	(0.136)	(0.135)	(0.147)	(0.149)
Betweenness centrality (advice network)		0.353*	0.298*	0.101[a]
		(0.152)	(0.139)	(0.162)
Tie strength advice network			-0.266†	-0.305*
			(0.143)	(0.130)
Betweenness centrality advice network X tie strength advice network			-0.201†	-0.328*
			(0.122)	(0.130)
Degree centrality formal network				0.401†
				(0.208)
n	66	66	66	66
Wald χ^2	35.76	42.49	49.33	49.08
R^2	0.255	0.367	0.411	0.462
Adjusted R^2	0.206	0.310	0.339	0.387
F-test for ΔR^2		10.616**	7.681***	5.483***

† p <.010; * p <.05; ** p <.01; *** p <.001. [a] It is unlikely that this result is due to a lack of statistical power; in a robustness check we skipped all insignificant results in model D except the brokerage position in the advice network; in the robustness analysis the brokerage position in the advice network remained insignificant.

factor are tested together when the two networks are considered simultaneously, in model D, where the degree centrality of the formal network is added to the model. Introducing independent and moderating variables in general significantly increases model-fit indicators at $p = 0.01$ and $p = 0.001$. As suggested by Kenny and Judd (1984) as well as Aiken and West (1991), all the variables that are part of the interactions in the models are mean-centred before the regressions to avoid multicollinearity – all VIF values remain below 3.40.

5. Results

The multiple regression analyses in Table 5 display the findings with regard to hypotheses 1, 2 and 3. As hypothesis 1 suggests, an individual's betweenness centrality in the advice network significantly would enhance that individual's (alliance-related) work performance: hypothesis 1 indeed is supported (see model B; β-value is 0.353, $p < 0.05$). Hypothesis 2 suggests that tie strength in the advice network plays a significantly negative moderating role in the relationship between betweenness centrality in the advice network and individual (alliance-related) work performance. This hypothesis could also be confirmed. In model C the β-value is significantly negative ($\beta = -0.201$, $p < 0.10$). Finally, hypothesis 3 is fully confirmed, the results in model D show an insignificant effect of betweenness centrality in the advice network, a significantly negative moderating effect of tie strength in the advice network (β-value is −0.328, $p < 0.05$) and a significantly positive effect of degree centrality in the formal network (β-value is 0.401, $p < 0.10$).

With respect to the control variables, in most models our findings show a positive and significant relationship between rank and individual (alliance-related) work performance, meaning that a higher position in the company or the institute leads to higher (alliance-related) work performance. In only two of four models tenure is positively associated with individual (alliance-related) work performance, while in two models tie strength in the advice network is negatively associated with individual (alliance-related) work performance.

5.1. Robustness checks

We did a few robustness checks to better validate our empirical results. We first checked whether we could empirically differentiate between the alliance formal network and the alliance advice network. Although the name generator questions are well-known and well-validated in empirical social network research (Burt 1984; Marsden 1990) we wanted to be sure that in our data the networks did not substantially overlap. To see the overlap and the difference between the two networks we calculated the Jaccard Similarity index (see e.g., Tröster et al. 2019). This index can have values between 0 and 1, in the neighbourhood of 0 both networks are highly dissimilar, in the neighbourhood of 1 they are highly similar. The average index in our study was 0.34, suggesting that the networks are more dissimilar than similar.

We next checked whether using degree centrality in the advice network instead of the suggested betweenness centrality would give different results. That is not the case. The results are consistent with what we report in this paper about betweenness centrality in the advice network. The same holds when we consider betweenness centrality in the formal network instead of degree centrality. Results remain consistent with what we report in Table 5. Thus, conceptually it seems more logically to use the betweenness centrality in the alliance advice network and the degree centrality in the alliance formal network, but results remain robust if we take the other centrality index. See Appendix A2 for the robustness checks.

6. Discussion

6.1. Theoretical implications

Sharing tacit and highly specialised knowledge in the setting of a coopetitive R&D alliance is a real challenge. Knowledge sharing in coopetitive settings has been studied on firm and unit level (Sampson 2007; Tsai 2002), but the micro level is underresearched despite calls for micro-level future research (Foss, Husted, and Michailova 2010; Tasselli, Kilduff, and Menges 2015). We have partly filled this gap by conducting a case study in a (moderately) coopetitive R&D alliance examining the influence of alliance social networks of alliance members on the individual alliance-related work performance of these members. We find a positive impact of the alliance advice network on individual alliance-related work performance, a negative moderating impact of tie strength on this relationship and when the alliance formal network is present, a substitutive role of this formal network in sharing knowledge at the cost of the alliance advice network. In our most extensive model our study variables explain about 46% of the individual alliance-related work performance.

Our findings have potential implications for the R&D alliance literature. Besides that to the best of our knowledge this is the first quantitative case study on micro-level knowledge sharing in a (moderately) coopetitive R&D alliance, we found that this coopetitive setting matters also on the micro level. Probably due to pressures of the management of the partner firms not to leak knowledge with high competitive value, the alliance advice network becomes less beneficial for individual alliance-related work performance, so less really interesting knowledge is shared in the advice network. This phenomenon can be observed by the negative moderating role of tie strength in the alliance advice network and the substitutive role of the alliance formal network when it is added to the analysis. While the finding in our most extensive model that the position of the individual in the advice network not to contribute at all is a remarkable finding in itself, the subsequent finding that the impact turns significantly negative once tie strength is included as well is striking. These findings also relate to the social network theory and the organisational coordination perspective.

With respect to the social network theory, we extended this theory with ideas from a micro-level case study of a (moderately) coopetitive R&D alliance. The within-firm results from previous research showed that the informal (advice) network was favoured over the formal network (Allen 1977; Allen, James, and Gamlen 2007; Cross and Cummings 2004; Hinds and Kiesler 1995; Tsai 2002). In our case study we find the opposite. In our moderately coopetitive context cooperation and competition are opposing objectives. Knowledge not part of the remit of the R&D alliance may (inadvertently) be leaked from one alliance partner to the other alliance partner through the advice contacts. Reconciling these different objectives, managers may prioritise formal relations as the preferred route for knowledge transfer. This is in line with a recent re-valuation of formal relations and structures in organisations (Aalbers, Dolfsma, and Koppius 2014; Gulati and Puranam 2009; McEvily, Soda, and Tortoriello 2014). Gulati and Puranam (2009) suggested a compensatory fit between the informal and the formal network, we find a substitutive role of the formal network in our case study. Given the impact of the formal network compared to the advice network in our case, it is likely that the inter-firm alliance specific routines (Zollo and Winter 2002; Zollo, Reuer, and Singh 2002) ultimately necessary for alliance success are primarily shaped in this formal network. Using social network analysis, longitudinally, should allow for a detailed study of the emergence of such inter-firm routines.

The organisational coordination perspective claims that partner firms exercise control on the knowledge and information that is shared in the alliance advice network. This claim is confirmed in our case study as is shown by the negative impact of the alliance advice network on the individual alliance-related work performance when there are strong advice ties. We propose that knowledge exchange in an R&D setting is contentious, and may be left at least initially to individuals more highly ranked or given a formal mandate to do so. Absence of an effect of position in the advice network, and a negative moderator for tie strength of advice relations that do exist, may be due to individuals alliance members perceiving such relations across alliance partner boundaries with distrust.

Our case study suggests that the social interactions, structures and levels of activity in a coopetitive R&D alliance offer a quite different pattern of results from what the literature focusing on within-firm dynamics suggests. To explain how knowledge spreads among individual alliance members, affecting their work performance, previous studies have argued and shown that multiple types of network interactions at the same time should be studied (Aalbers, Dolfsma, and Koppius 2014). While the complexity of social interactions can only be comprehensively grasped by adopting a multi-network research design, the way in which networks will impact each other to produce outcomes will probably differ in a(n) (coopetitive) R&D alliance compared to a within-firm setting.

6.2. Managerial implications

This case study has potential implications for innovation and R&D managers. As innovation increasingly is a collaborative effort with external partners, managers must notice that our case study findings suggest that knowledge transfer and creation by individual alliance members is particularly influenced by the position in especially the formal network. Rather than the informal advice network, the formal network is, of course, what managers are most capable of influencing the shape of. We suggest that giving shape to formal connections crossing alliance partner boundaries, with appropriately formulated job descriptions and reporting lines and terms of reference for meetings, will help making alliances more successful. Individual alliance members of sufficient rank should be involved and should (be made to) 'own' the alliance. Individual members of an R&D alliance may be discouraged from investing too much in creating (strong) ties in self-initiated, informal (advice) networks, at least initially. There are circumstances under which informal advice network relations might negatively impact individual alliance member performance.

6.3. Limitations and future research

We highlight four limitations of our research, and suggest future research directions to address some of these. First, in this study two sources of data collection are used, alliance managers and alliance members. The advantage is a low likelihood of common method bias (Podsakoff et al. 2003), but it also has a disadvantage, as it cannot be ruled out that managers perceive people in their neighbourhood as more important and better at the alliance-related work performance than people more on a distance. Second, this study explored the influence of social network variables on the work performance of alliance members. In depth, qualitative research is required to further clarify the relationships between alliance-internal dynamics on the individual level on the one hand, and alliance-level dynamics on the other hand. Third, and following on the second limitation, studying the dynamics of social interactions over a longer period of time would generate significant insights. This can both be done quantitatively as well as qualitatively – a multi-method research design is conceivable. Fourth, as is the nature of social network analysis, despite the wealth of insights generated, this study does not allow for cross-sectional analysis across cases (see Aalbers and Dolfsma 2015; Dolfsma and Leenders 2016; Marsden 1990, 2002); our findings are based on data from one moderately coopetitive R&D alliance, in the field of chemical physics, in China. The external validity for the findings in our study can be provided by future research replicating our study in other industries, countries, as well as other types of alliances.

6.4. Conclusions

Despite the increasing importance of inter-organisational collaboration in innovation, we have limited understanding of individual knowledge-sharing behaviour in such collaborations. Knowledge-sharing behaviour is of particular importance in an R&D alliance setting. R&D alliances are of substantial strategic importance yet outcomes can be expected only in the long term. At the same time, R&D alliances are more likely to fail than other alliances or types of inter-firm cooperation. As about 50% of alliances fail (Ernst, Lichtenthaler, and Vogt 2011; Sambasivan et al. 2013), insights offered here are valuable since they may lead to better knowledge-sharing behaviour in alliances.

For R&D alliances in particular, collaboration between employees from the allying partners is crucial. We show for a moderately coopetitive R&D alliance that individual (alliance-related) work performance is determined by the formally mandated relations between individuals rather than the voluntary, self-initiated relations in the advice network. Indeed, being positioned in a way that would otherwise serve an individual well might actually weaken individual performance, confirming our expectations. We suggest that governance of R&D alliances should take the specific nature of these organisational settings into account.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix A1 (Endogeneity checks)

Dependent variable: Standardized individual alliance-related work performance	Instrumental variable regression (instrument is tie strength in the formal network with only members from the other partner)	Ordinary Least Squares regression
Firm	-0.258	-0.509†
Job title	-0.193	-0.283
Rank	0.214	0.150
Tenure	0.006*	0.005*
Degree centrality formal network	0.027	0.060**
Wald χ^2	26.20***	
R^2	0.332	0.360

†p<0.10; *p<0.05; **p<0.01; ***p<0.001
Durbin-Wu-Hausman test: $\chi^2(5) = 0.13$; $p > \chi^2 = 0.9997$

Dependent variable: Standardized individual alliance-related work performance	Instrumental variable regression (instrument is interplay between the degree centralities of the formal and the advice network)	Ordinary Least Squares regression
Firm	-0.073	-0.049
Job title	-0.137	-0.118
Tenure	0.005	0.006*
Rank	0.320	0.268*
Wald χ^2	20.58***	
R^2	0.263	0.265

*p<0.05; **p<0.01; ***p<0.001
Durbin-Wu-Hausman test: $\chi^2(4) = 0.05$; $p > \chi^2 = 0.9997$

Appendix A2 (robustness checks)

Calculation Jaccard Similarity Index:

Respondent	Number of formal ties (#A)	Number of advice ties (#B)	Overlap in formal and advice ties (#A⌒B)	Jaccard Similarity index = #A⌒B/(#A+#B-#A⌒B)
01	6	5	1	0.1
02	2	1	0	0
03	10	8	4	0.29
.	.	.	.	.
.	.	.	.	.
66	7	7	7	1
Average				0.34

Robustness checks degree centralities:

	Centrality index = betweenness centrality	Centrality index = degree centrality [a]	Centrality index = degree centrality
Firm	0.057	-0.130	
Job title	0.025	-0.057	
Rank	0.217†	0.227	0.304**
Tenure	0.185	0.179	
Betweenness centrality advice network	0.168		
Degree centrality advice network		0.076	-0.039
Tie strength advice network	-0.245†	-0.393	-0.566*
Betweenness centrality advice network* tie strength advice network	-0.204†		
Degree centrality advice network* tie strength advice network		-0.261	-0.374†
Degree centrality formal network	0.255*	0.387	
Betweenness centrality formal network			0.431†
R^2	0.45	0.38	0.34

† p<.010; * p<.05; ** p<.01.

[a]It is likely that this result is due to a lack of statistical power; thus we skipped all unimportant insignificant results in the model and then found results similar to Table 5 (see last column).