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The Effect of the Distance between Partners' Knowledge Components on Collaborative Innovation

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The alliance literature has recognized distance between partners' knowledge as important for innovation. However, theoretical reasoning as well as empirical results differ concerning the relationship of partners' knowledge base distance and innovation performance. We assume that the mixed results are caused by neglecting the role of relevant knowledge types. In this study, we examine the effect of technological and managerial knowledge distance on collaborative innovation performance. We examined 53 collaborative development projects and we find an inverse U-shaped relationship between technological knowledge distance and innovation performance, explained by the knowledge-based view and absorptive capacity. Our results also reveal that a short managerial knowledge distance is beneficial for innovation, which can be explained by transaction cost theory. Overall, our research helps to better explain knowledge distance's effect on collaborative innovation performance.

Keywords: innovation; technological knowledge; managerial knowledge; knowledge base distance; alliances; collaboration

Introduction

In order to develop innovative products, firms often acquire knowledge that lies outside their core competencies (Cowan and Jonard, 2009), whereas they attain knowledge by forming development alliances (Faems *et al*., 2005; Grunwald and Kieser, 2007). The alliance literature has recognized distance between partners' knowledge as being influential on innovation performance. However, theoretical reasoning as well as empirical results differ concerning the relationship of partners' knowledge base distance and innovation performance (Rindfleisch and Moorman, 2001). Two groups of studies can be distinguished. The first group concentrates on theoretical and empirical explanations of technological knowledge distance, identifying almost unitarily a moderate distance as optimal (Mowery *et al*., 1998; Cantwell and Colombo, 2000; Liyanage and Barnard, 2003; Schoenmakers and Duysters, 2006). The second group does not specify the type of knowledge investigated and finds mixed and contrasting results (e.g., Lane and Lubatkin, 1998; Simonin, 1999; Laursen and Salter, 2006; Cowan and Jonard, 2009). Overall, the literature on allies' knowledge base distance has largely neglected the role of relevant types of knowledge other than technological knowledge (Sammarra and Biggiero, 2008). In addition, scholars have used fairly different theories to derive theoretical rationales for knowledge base distance (Ireland *et al*., 2002).

In this study, we first consider different knowledge base components. Building on Sammarra and Biggiero's (2008) specification of knowledge types in innovation alliances, we examine the effect of technological and managerial knowledge distance on collaborative innovation performance. While technological knowledge comprises the idiosyncratic resources that form the basis for innovation, managerial knowledge is indispensable to jointly coordinate knowledge (Hamel, 1991; Grant, 1996; Joshi and Sarker, 2007), as well as to integrate these for eventual innovation success (Sammarra and Biggiero, 2008). Second, we use the theoretical frames of the knowledge-based view and transaction cost theory (Williamson, 1979; Grant, 1996), showing that they are complementary and help us explain the effect of knowledge distance on collaborative innovation performance.

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In line with prior research, we find an inverse U-shaped relationship between technological knowledge distance and innovation performance, as explained by the knowledge-based perspective and absorptive capacity. Our results also reveal that a short managerial knowledge distance is beneficial, which can be explained by the transaction cost theory.

Thus, our research contributes to a more complete understanding of the relationship between knowledge distance and innovation performance. First, we find evidence that a more fine-grained consideration of knowledge is important. The most beneficial knowledge distance is not unitary but depends on the knowledge type, namely, the knowledge base component. Second, together with a combined adoption of theoretical perspectives, that to date have been discussed separately; our study also contributes to the better interpretation of the inconsistent results of studies that do not specify knowledge types or components. Furthermore, we contribute to the emergent literature on partner selection (Deeds and Hill, 1996; Lane and Lubatkin, 1998; Emden *et al*., 2006; Schoenmakers and Duysters, 2006), providing the theoretical reasoning for more informed decisions.

This paper is organized as follows: In Section 2, we define innovation performance, a firm's knowledge base, and knowledge base distance. In Section 3 we hypothesize the relationship between the degree of development partners' technological and managerial knowledge distance and innovation performance. In Section 4, we test our hypotheses using data collected from 53 development alliances. The data was gathered from the automotive industry in German-speaking countries in Europe. In Section 5, we provide our empirical results, and in Section 6, we discuss our findings concerning their implications for theory and management.

Conceptual background

Innovation performance

There are different approaches to defining innovation performance: some researchers see innovation as a multidimensional phenomenon related to technology, market, organizational change, and environmental changes (e.g., Danneels and Kleinschmidt, 2001; Gemünden *et al*., 2005). In this study, the specific project outcome (i.e., process, product, or software) was achieved by two development partners, which, with the exception of their collaboration on the project are completely independent from each other. Evaluating each partner's internal organizational changes or environmental changes would therefore be difficult or even impossible. As a result, we decided to only define innovation performance according to the two classical dimensions proposed by Hagedoorn (1993), who states that the two basic motivations for creating development alliances relate to market and technology. In this study, we thus define innovation performance as the degree to which the jointly developed product creates a novel customer benefit, improves the market position of at least one alliance partner (market dimension), and follows a technological principle that is new to the relevant unit of adoption (Dewar and Dutton, 1986).

Knowledge base components

Alliance researchers agree that the selection of a development partner is critical with regard to the distance between their knowledge bases (e.g., Gulati, 1995; Deeds and Hill, 1996; Lane and Lubatkin, 1998). However, the specification of components of a knowledge base (i.e., types of knowledge) has received limited scholarly attention (Faulkner, 1994; Sammarra and Biggiero, 2008). Furthermore, different theories are used to derive theoretical rationales for the optimal knowledge distance (Ireland *et al*., 2002). In particular, one stream of research has concentrated on theoretical and empirical explanations of technological knowledge distance. Scholars of this research stream postulate and find support for a moderate distance (i.e., inverted U-shaped relationship) as being most beneficial for collaborative innovation (e.g., Cantwell and Colombo, 2000; Liyanage and Barnard, 2003). Thereby, most studies have assumed that partner firms are not direct competitors in end product markets (Oxley and Sampson, 2004). Theoretically, this stream of research builds on the knowledge-based perspective, which suggests that firms collaborate to develop a collection of value-creating resources that one firm cannot create independently (e.g., Mowery *et al*., 1998; Oxley and Sampson, 2004; Schoenmakers and Duysters, 2006). The second stream, which does not specify the knowledge base contents it investigated, is characterized by ambiguity. Researchers refer fairly generally to partners' knowledge (e.g., Simonin, 1999; Inkpen, 2000). Further, these researchers build their arguments not only on the additional theoretical perspective of transaction cost economics (Kotabe and Swan, 1995; Grant, 1996; Nakamura *et al*., 1996), but also on other theories such as attention based theory (Laursen and Salter, 2006), or social network theory (Rindfleisch and Moorman, 2001). And finally, their research has revealed mixed results, ranging from positive (Kotabe and Swan, 1995; Nakamura *et al*., 1996; Baughn *et al*., 1997), via inverse U-shaped relationships (Simonin, 1999; Ahuja and Katila, 2001; Nooteboom, 2004; Laursen and Salter, 2006; Cowan and Jonard, 2009), to negative relationships (Lane and Lubatkin, 1998; Inkpen, 2000; Rindfleisch and Moorman, 2001), between knowledge distance and innovation performance. Table 1 provides an overview.

Table 1 Research on knowledge base distance

Source	*Method*	*Industries*	*Knowledge base*	*Effect proposed*	*Results*
Cantwell and Colombo, 2000	Empirical: 68 firms	IT	Technological knowledge	The relationship between knowledge overlap and innovation performance is inversely U-shaped	Empirical support
Liyanage and Barnard, 2003	Empirical: 65 firms	Biotech	(scientific), Technological knowledge	The relationship between knowledge overlap and knowledge integration (resulting in innovation performance) is inversely U-shaped	Empirical support
Mowery *et al*., 1998	Empirical: 151 joint ventures	All over	Technological knowledge	The relationship between knowledge overlap and the likelihood of the alliance (chances of innovation performance) is inversely U-shaped	Empirical support
Oxley and Samson, 2004	Empirical: 208 alliances	Telecom equipment, electronics	Technological knowledge	The relationship between knowledge overlap and the probability of broad alliance scope is positive	Empirical support
Schoenmakers and Duysters, 2006	Empirical: 171 parent firms	All over	Technological knowledge	The relationship between knowledge overlap and learning performance (resulting in innovation performance) is inversely U-shaped	Empirical support
Ahuja and Katila, 2001	Empirical: 72 leading firms	Chemicals	Not specified	The relationship between knowledge distance and innovation performance is inversely U-shaped	Empirical support
Baughn *et al*., 1997	Conceptual	All over	Not specified	The relationship between knowledge distance and knowledge protection is positive	Explicitly conceptualized
Cowan and Jonard, 2009	Conceptual	Not specified	Not specified	The relationship between knowledge distance and the expected benefit of the alliance is inversely U-shaped	Explicitly conceptualized
Grant and Baden-Fuller, 1995	Conceptual	All over	Not specified	The relationship between knowledge overlap and integration of organizational structures is inversely U-shaped	Explicitly conceptualized
Hamel, 1991	Empirical: 9 alliances	All over	Not specified	The relationship between knowledge distance and knowledge integration is negative	Side–focused
Inkpen, 2000	conceptual	All over	Not specified	The relationship between knowledge distance and knowledge integration is negative	Explicitly conceptualized
Kotabe and Swan, 1995	Empirical: 905 new product innovations	All over	Not specified	The relationship between knowledge redundancy and innovation performance is negative	Empirical support
Lane and Lubatkin, 1998	Empirical: 31 alliances	Pharmacy biotech	Not specified	The relationship between knowledge distance and knowledge integration is negative	Side–focused
Laursen and Salter, 2006	Empirical: 2,707 firms	Manufacturing	Not specified	The relationship between knowledge distance and innovation performance is inversely U-shaped	Empirical support
Nakamura *et al*., 1996	Empirical: 41 subsidiaries	Manufacturing	Not specified	The relationship between different but complementary knowledge bases and new knowledge integration is positive	Side–focused
Nooteboom, 1999	Conceptual	All over	Not specified	The relationship between knowledge distance and new knowledge integration is inversely U-shaped	Explicitly conceptualized
Rindfleisch and Moorman, 2001	Empirical: 106 U.S. firms	Not specified	Not specified	The relationship between knowledge redundancy and innovation performance is positive	Empirical support
Simonin, 1999	Empirical work: 147 multinationals	Not specified	Not specified	The relationship between knowledge distance and knowledge integration is inversely U-shaped	Side–focused

In summary, the literature most clearly specifies technological knowledge and posits that it is the most important reason why firms team up with each other (Vanhaverbeke *et al*., 2002). However, this overlooks the role of other knowledge such as managerial knowledge in fostering the innovation process (Sammarra and Biggiero, 2008). In this study, we simultaneously consider technological and managerial knowledge base distance. Thus, we supplement the research that has contributed to our understanding of technological knowledge distance between collaborating partners. Past research has specified and recognized three types of knowledge as relevant in innovation alliances: Technological, managerial, and market knowledge (Sammarra and Biggiero, 2008). Market knowledge is not part of our study and we acknowledge this as a limitation.

Many researchers agree on the importance *of technological knowledge* for innovation performance (Cohen and Levinthal, 1990; Faulkner, 1994; Bettis and Hitt, 1995; Cantwell and Colombo, 2000; Howells *et al*., 2003; Petersen *et al*., 2005; Schoenmakers and Duysters, 2006). Technological knowledge includes scientific, applied, and experimental knowledge, and is necessary for the execution of product and process development (Liyanage and Barnard, 2003; Sammarra and Biggiero, 2008). Managerial knowledge includes operational and applied knowledge and refers to knowledge necessary to efficiently coordinate organizational resources and processes (Joshi and Sarker, 2007; Easterby-Smith *et al*., 2008; Sammarra and Biggiero, 2008). It comprises formal organizational structures that encompass hierarchical systems of divisions and functions, together with the permitted information flows (Gupta and Govindarajan, 1991). Informal organizational structures also reflect unrecorded valid rules and fully functional problem-specific networks, as well as dynamic interaction, which is critical if tasks are to be performed (Wang and Ahmed, 2003). These informal structures pertain to relationships between employees, which provide important context knowledge of actual organizational activities that 'materialize only when esoteric experiential problem-solving knowledge is required. Once the problem is dealt with, they dissolve again, leaving hardly a trace upon the formal organization' (Rochlin, 1989: 161). Furthermore, organizations are seen as cultural units (Brown and Duguid, 1991) and managerial knowledge also includes knowledge of the organizational culture, which is essential for interacting appropriately in given environments and situations. Culture is frequently described as values shared by its members (Cullen *et al*., 2004), and scholars find evidence of organizational members' homogeny, which is also known as cultural force (Martin, 1992; Tsoukas, 1996). Culture includes the individual organizational population, organizational backgrounds, social norms, practices, rules, policies, etc. (e.g., Hofstede and Hofstede, 2005). In turn, these societal-level properties influence individuals' attitudes and behaviors, as well as the functioning of small (e.g., teams) and large collectives (e.g., business organizations).

Knowledge base distance

When firms enter development alliances, they seek to combine their knowledge for the purpose of developing an innovative product, software, or process (Miotti and Sachwald, 2003). Before entering an alliance, the components of the firms' knowledge bases may include different pieces of knowledge and information. For example, while firm A possesses technological knowledge of sensors' reaction times, firm B's technological knowledge may include knowledge of real-time systems. Scholars recognize knowledge of the importance of base distance. Specifically, they believe that the distance between development partners' knowledge bases influences the likelihood of forming an alliance (Mowery *et al*., 1998), the value of integrating organizational structures (Grant, 1996), the degree of organizational learning (Hamel, 1991; Nakamura *et al*., 1996; Baughn *et al*., 1997; Lane and Lubatkin, 1998; Nooteboom, 1999; Simonin, 1999; Inkpen, 2000; Liyanage and Barnard, 2003; Schoenmakers and Duysters, 2006), as well as the joint innovation performance (Kotabe and Swan, 1995; Cantwell and Colombo, 2000; Ahuja and Katila, 2001; Rindfleisch and Moorman, 2001; Cowan and Jonard, 2009). These authors define knowledge base distance as the degree to which firms possess dissimilar types of information. Other researchers have an opposing view; they refer to a knowledge base overlap (i.e., commonality, redundancy, relatedness, and familiarity) in their studies (Kotabe and Swan, 1995; Mowery *et al*., 1998; Cantwell and Colombo, 2000; Rindfleisch and Moorman, 2001; Oxley and Sampson, 2004; Schoenmakers and Duysters, 2006). They define knowledge base overlap as the degree to which firms possess similar types of knowledge and information.

Concerning the partially contradictory findings presented by existing studies, we concentrate on the content-related components of a knowledge base rather than on its knowledge characteristics (such as knowledge's degree of tacitness). With this differentiated component view, we strive to separately identify the component-specific effect of partners' knowledge distance on innovation performance. Therefore, in this study, the development partners' knowledge distance is the degree to which the content of a specific knowledge component differs before the development project starts.

In the following section, we present our hypotheses, building on existing literature as well as the theoretical frames of the transaction cost and knowledge-based theory.

Hypotheses

The effect of technological knowledge distance on innovation performance

The knowledge-based theory suggests that firms collaborate for innovation to access idiosyncratic resources. And frequently, firms collaborate with partners that have resources they lack (Grant, 1996; Gulati *et al*., 2000; Ireland *et al*., 2002). Accordingly, a collaboration can be perceived as a collection of heterogeneous resources with a potential source of competitive advantage (Ireland *et al*., 2002).

There are arguments that, on the one hand, suggest a large distance of collaborating firms' technological knowledge is beneficial for collaborative innovation performance. Allies obtain novel input from each other and the broader set of knowledge (e.g., Kotabe and Swan, 1995; Nakamura *et al*., 1996) can be used to create new knowledge to be harnessed for innovation (Kanter, 1988; Hargadon and Sutton, 1997; Leonard-Barton and Sensiper, 1998; Taylor and Greve, 2006). Hence, they collaborate with a development partner whose technological knowledge base is clearly different to their own. In addition, different perspectives and solutions may produce innovative answers to problems (Nakamura *et al*., 1996), and research has shown that successful product innovations frequently originate from outside the industry (Calantone *et al*., 1988; Kotabe and Swan, 1995). Furthermore, knowledge base distance prevents the alliance partner from absorbing knowledge uninvited, which is important for protecting a firm's valuable technologies (Baughn *et al*., 1997; Oxley and Sampson, 2004). On the other hand, absorptive capacity theory suggests that firms need common knowledge, that is, the partners' technological knowledge needs to relate to a firm's existing technological knowledge (Lane and Lubatkin, 1998; Mowery *et al*., 1998; Simonin and Ruth, 1998; Inkpen, 2000), due to the fact that this enables the partners to assess and integrate new knowledge into their knowledge base (Cohen and Levinthal, 1990).

Consequently, studies proposed and find almost unitary empirical evidence to support an inverted U-shaped relationship between technological knowledge base distance and innovation performance (Grant, 1996; Nooteboom, 1999; Simonin, 1999; Ahuja and Katila, 2001; Laursen and Salter, 2006; Cowan and Jonard, 2009).

In summary, if partners' technological knowledge is too similar, it could lack the desired complementary effects and there is little point in sharing (Schoenmakers and Duysters, 2006). If it is too large, the partners will struggle to integrate this distant knowledge for innovation benefits (Grant, 1996; Dyer and Singh, 1998; Nooteboom, 1999). We therefore agree with Cantwell and Colombo (2000: 141) that, in the case of technological knowledge, it is optimal for partners to have a 'sufficient degree of complementarity in their technological competencies, which in turn provides a greater motive for cooperation and a greater ability to benefit from such alliances, owing to the existing possession of absorptive capacity in the relevant area.' We therefore hypothesize:

> **Hypothesis 1:** The degree of technological knowledge distance has an inverted U-shaped relationship to innovation performance.

The effect of managerial knowledge distance on innovation performance

From an alliance transaction cost perspective, joint innovation endeavors benefit from minimized transaction costs of the collaborating firms. Accordingly, allies would aim at minimizing the sum of its transaction costs, such as coordination costs incurred in coordinating actions through integrated decision networks and associated communication patterns (Jarillo, 1988; Gulati and Singh, 1998; Barringer and Harrison, 2000; Ireland *et al*., 2002). However, joint development projects must deal with different organizational structures and cultures. And in the context of an alliance, managerial alliance knowledge reflects the collaboration's particular characteristics (e.g., Von Hippel, 1994; Hoang and Rothaermel, 2005). Accordingly, knowledge of each other's formal organizational structures, such as reciprocal regulatory approvals (Powers and Wilson, 2010), causes less interpersonal tension, and allows partners to collaborate more smoothly; namely it helps each partner to act efficiently in, or in conjunction with, the other's system (Spender, 1996; Von Krogh *et al*., 2007). For example, knowledge of the relevant decision makers in the partner firm enables firms to attain quick and valid decisions (Saxton, 1997). In order to assure an efficient collaboration, both partners should therefore understand their divisions and functions' hierarchical systems (Gupta and Govindarajan, 1991). Further, joint knowledge of the new product development process is beneficial for innovation performance, because it provides an essential structure for coordinating the partners' development work (Cooper, 1990).

Decision making occurs along formal and informal organizational processes (Miles and Snow, 2001; Von Krogh *et al*., 2007) and '[i]n many cases, tacit knowledge is shared via informal organizational structures' (Duysters and Heimeriks, 2002: 9). Hence, Ring and Van de Ven (1989) point to the significant role of informal connections across organizations when transacting. Organizational members who have informal ties are likely to share an understanding of each other's behavior and share opinions, which in turn influences their actions (Coleman *et al*., 1966). When alliance partners are familiar with each other's informal organizational structures, they can address the right people, interlink experts concerning specific tasks, and select appropriate interaction activities. In turn, insufficient knowledge of informal organizational structures leads to more complex and time-consuming inquiries, which hampers innovation performance (Hansen, 1999; Miles and Snow, 2001; Wang and Ahmed, 2003; Škerlavaj *et al*., 2010).

Often, partners with different organizational cultures may collaborate for joint innovation (Sivadas and Dwyer, 2000). These differences might occur as a result of dissimilar histories, and are characterized by specific norms, value systems, and emotions (Hofstede and Hofstede, 2005). Such values' differences can lead to conflict and contrary behaviors, and might therefore prevent effective progress on a good project (Urban and Hauser, 1980). This might negatively distract the team from the development work and cause transaction cost. Knowledge of the partner's organizational culture – which is different from necessarily having the same culture, but comprises understanding each other's culture – prevents cultural conflicts, provides conflict solutions, and minimizes transaction cost, because accurate and efficient interaction is possible (Hurley, 1995; Koc, 2007). This, in turn, facilitates joint innovation performance.

Furthermore, innovation always bears uncertainties with regard to potential changes in technologies, competition, and customer needs (Ruekert and Walker, 1987; Song and Xie, 2000). These uncertainties require not only managerial knowledge but also joint managerial knowledge for close cooperation between the parties, in order to accomplish the project objectives (Moenaert and Souder, 1990; Song *et al*., 1998; Rindfleisch and Moorman, 2001). Overall, we recognize the importance of a small managerial knowledge distance for collaborative innovation performance. We therefore propose:

Hypothesis 2: The degree of managerial knowledge distance has a negative relationship to innovation performance.

Method

Research setting

To test our hypotheses, we examined 53 inter-organizational development projects conducted by 60 firms. In each project, two different firms collaborated. They belong to the automotive supplier industry and are located in Switzerland, Germany, and Austria. To explain our setting, we provide Table 2 (with fictitious firm names) and deploy a metaphor: 60 people (firms) get married (ally for joint development projects). In each wedding (project), two people (firms) get married (ally to conduct a project). One person (firm) would take the role of husband (Partner A) and one the role of wife (Partner B). Assuming a perfect world, we would have 60 people (firms) forming 30 couples. However, our sample contains 53 couples (projects) because in our imperfect world, people (firms) marry (ally) several times. In the illustrative example of Table 2, Mr Boehr as a man (Partner A) would first marry Ms Steeltex. Perhaps Mr Boehr gets divorced or his wife dies. He marries a second time, to Ms Ivesan.

Table 2 Research setting

Project	*Partner A*	*Partner B*
1	Aluwarner	Knoff
2	Boehr	Steeltex
3	Boehr	Ivesan
⋮	⋮	⋮
53	Blosa	GFK

In our sample, each alliance's objective was to collaboratively develop an innovative and complex technical product, software, or process. Owing to their innovative nature, the products, software, or processes were unusual in terms of buyer-supplier collaborations (Inkpen, 2000). We only included projects that had been completed within the past three years. Hence, the respondents, who were chosen for their ability to provide inside information, could still recall information related to the relevant development projects (they could, for example, check survey studies), which allowed us to measure the innovation performance. Furthermore, we included both partners in order to receive unbiased data; however, we assigned one firm as the knowledge sender and the other as the knowledge recipient.

Data collection

The selection of the projects was aided by an existing database of development projects, complemented by secondary data from media releases on the subject of development cooperation. We contacted the R&D managers of the projects telephonically to obtain project details, on the basis of which we assigned the specific development partners as Partner A and Partner B. We then contacted multiple respondents to collect data on projects reported by the firms reported as having been completed within the past 36 months. Specifically, we contacted Partner A's project leader and at least four randomly selected Partner A team members, as well as Partner B's project leader. The respondents' participation was strictly voluntary, and all respondents were assured of complete anonymity. All respondents received a link to their personalized and standardized online questionnaire via email. The role respondents played in the project determined the type of questionnaire. The number of team members who answered depended on the response rate and project size. However, both partner firms always answered. We received 159 valid responses, constituting 53 data sets. The response rate of the firms requesting a link to the particular questionnaire was 88%, resulting in a final sample of 60 firms.

Measures

All constructs considered in this investigation refer to the new product development (NPD) project as the unit of analysis. Because a joint project is the expression and realization of an alliance between two partner firms, all measures were specified at the project level. We followed the steps recommended by Churchill (1979) as well as Nunally and Bernstein (1994) during the measure development procedures. To achieve content validity, we used construct definitions and measures gleaned from the literature whenever possible. The constructs: innovation performance, degree of modularization, and partner firm's absorptive capacity investigated were assessed using multiple questionnaire items. All questions in this study, besides antecedents and project outcome (i.e., products, processes, or software) were measured using a 5-point Likert-type scale, ranging from (1) 'totally disagree' to (5) 'totally agree.' To answer the questions concerning the antecedents, the respondents had to quote percentages. All questionnaires were administered in German. Translations are included in Appendix A.

Dependent Variable

We derived four items from Gemünden *et a*l. (2005) to cover the innovation performance technology and market dimension (four-item scale, Cronbach's $\alpha = 0.87$, 5-point rating scale). Accordingly, we introduced one item in which we checked for new technological principles integrated into the newly developed product, process, or software. We investigated whether the firms' customer satisfaction had improved and checked for improved market position resulting from the newly developed product, process, or software.

Antecedents

The technological knowledge distance (two-item scale, Spearman Brown formula $r_{xx} = 0.81$, quotation) was one of our model's antecedents. We determined this to check the level of knowledge required from the partner with regard to technologies and products. This factor is formed by two items. To test for reliability, the Spearman Brown formula, commonly recommended for two-item factors, was applied (Hulin, 2001). The respondents provided percentages by rating their partner's knowledge required for the project as either entirely irrelevant or completely relevant. The same approach was used to evaluate managerial knowledge distance (three-item scale, Cronbach's $\alpha = 0.84$, quotation). We examined the knowledge required from the partner regarding formal/informal organizational structures and the partner firm's culture. The answers indicated the partner's knowledge distance with regard to content from the recipient firm's perspective.

Control variables

Since modularization allows alliance partners to develop separate modules independently, it reduces the need for intense interaction and a shared knowledge base between the partners (e.g., Nakamura *et al*., 1996; Baldwin and Clark, 2000; Cowan and Jonard, 2009). To control for this, we developed the construct degree of modularization (three-item scale, Cronbach's $\alpha = 0.84$, 5-point rating scale). The first item builds on research by Ethiraj and Levinthal (2004) and measures strong functional dependence during development. The other two items were derived from the work by Baldwin and Clark (2000) and control the importance of the partner's contributions to the joint product development. In addition, these items control whether the partners obtained specialized expertise during development. Because the firm's experience in dealing with external knowledge transfers also has a significant impact on innovation performance (e.g., Szulanski, 1996), the partner firm must be able to evaluate and assimilate such external knowledge into its existing practices (Liyanage and Barnard, 2003). To control for this, we developed the construct partner firm's absorptive capacity (three-item scale, Cronbach's $\alpha = 0.77$, 5-point rating scale). This construct was derived from the work of Fosfuri and Tribó's (2008) and investigates the partner firm's experience of implementing knowledge, acquiring outside knowledge, and searching for external knowledge sources.

The construct validity assessments as well as the correlations of the study variables are shown in Table 3.

Intentional trust – the acceptance of the subjective probability that the partner will not utilize opportunities opportunistically – is seen to be a very important precondition for alliance success, because it enables an increase in mutual learning (Boutellier *et al*., 1998; Nooteboom, 1999; Schoenmakers and Duysters, 2006). Alliance partners that trust each other are also more willing to openly exchange important ideas and information (Gulati, 1995; Inkpen, 2000). We therefore controlled for trust, which may impact innovation performance. Given that the data sets originate from different development projects with different project objectives, we also controlled for project outcome (i.e., product, process, or software).

Table 3 Construct validity assessments and correlations

	Variable	Mean	SD	Items	Alpha	1	2	3	4	5	6
1	Trust	4.04	0.61								
2	Project outcome (product, process, software)	2.32	0.92			0.117					
3	Degree of modularization	4.00	0.77	3	0.835	−0.014	0.038				
4	Partner firm's absorptive capacity	4.02	0.77	3	0.768	−0.084	−0.447***	0.136			
5	Innovation performance	3.33	0.73	4	0.873	0.210	−0.169	0.106	0.187		
6	Technological knowledge distance	29.81	16.44	2	0.813+	−0.063	−0.072	0.175	−0.011	−0.294*	
7	Managerial knowledge distance	34.65	19.09	3	0.835	−0.115	0.051	0.133	0.055	−0.465***	0.320*

*** = significant at the 0.01 level (two–tailed).
** = significant at the 0.05 level (two–tailed).
* = significant at the 0.1 level (two–tailed).
+ = Spearman Brown formula.

Table 4 Constructs and respondents

	Variables	Respondents	
		Partner A	Partner B
Dependent variable	Innovation performance	Project leader	
Antecedents	Technological knowledge distance		Project leader
	Managerial knowledge distance		Project leader
Controls	Trust	1 to 4 team members	
	Degree of modularization	Project leader	
	Partner firm's absorptive capacity	Project leader	
	Project outcome (product, process, software)	Project leader	

Multiple informants

To ensure content validity and to avoid common source bias, data from different respondents were used to measure the variables. While Partner B's project leader was assigned the questionnaire with the independent constructs: knowledge distance regarding managerial knowledge (KDmK) and knowledge distance regarding technological knowledge (KDtK), Partner A's project leader was asked to evaluate innovation performance (dependent construct). We held that trust could best be evaluated by affected participants and therefore asked Partner A's project team members to evaluate the open knowledge exchange with their partner. We also questioned different team members so as to avoid single source bias (Sproull, 1995). The remaining controls were evaluated by Partner A's project leader. Table 4 provides an overview of the model constructs and the various respondents.

In terms of trust, we questioned several of Partner A's team members working on the same project. Given the respondents' ratings, we used the multiple item estimators for within-group interrater agreement (r_{wg}) (James *et al*., 1984). George and Bettenhausen (1990) recommend an r_{wg} greater than, or equal to, 0.70 because this is considered an indicator of good agreement within a group. The intra-group reliability of this scale was 0.78, which further legitimizes the aggregation of the individual team member scores. As a result, we aggregated these data by calculating the arithmetic mean.

Data analysis

All analyses were conducted at the project level ($N = 53$). First, we conducted exploratory factor analyses to assess whether all predicted items pertain to the same latent construct, as noted. Because all items scored high on the factors (> 0.77), we used them for a two-step hierarchical moderated regression analyses to test our hypotheses (Cohen *et al*., 2003). We also verified the normality of our residuals, because this is required for regression analysis (Field, 2009). To address concerns of multicollinearity between the main effects with their corresponding interaction term, we used Cronbach's transformation. Hence, the variables were centered to their means (Jaccard and Wan, 1996). In model 1, we performed a regression analysis of the effect of the control variables (i.e., trust, the degree of modularization, the partner firm's absorptive capacity, and the project outcome) on innovation performance. In model 2, we entered the direct effect of KDmK on innovation performance to test Hypothesis 1. In the regression approach, the relationship between KDtK and innovation performance is formulated as linear. In order to test the inverted U-shaped effects

Table 5 Regression analysis

Dependent Variable	*Innovation performance*			
	Model 1		*Model 2*	
	Coefficient	*S.E.*	*Coefficient*	*S.E.*
(Constant)	–2.28E–15	0.132	–2.60E–15	0.102
Controls				
Trust	0.249*	0.134	0.247**	0.105
Project outcome (product, process, software)	–0.144	0.149	–0.085	0.115
Degree of modularization	0.073	0.137	0.028	0.110
Partner firm's absorptive capacity	0.214	0.160	0.241*	0.123
Independent variables				
(Technological knowledge distance – mean)^2			–0.330**	0.110
Managerial knowledge distance			–0.460***	0.107
R^2	0.14		0.52***	
adjusted R^2	0.07		0.45	
change in R^2	0.14		0.37	
F value	2.01		8.18	
change in F	2.01		17.7	

*** = significant at the 0.01 level (two–tailed) $N = 53$.
** = significant at the 0.05 level (two–tailed).
* = significant at the 0.1 level (two–tailed).

predicted by Hypothesis 2 while avoiding multicollinearity, we transformed this independent variable into the variable KDtK_meansquared (Haida and Muto, 1994) computed as:

$$\text{KDtK\_meansquared}_j = (\text{KDtK}_j - \text{mean}_{\text{KDtK}})^2$$

We subsequently also entered this variable into model 2. The collinearity statistics calculated for the regression analyses show no distortion of the results due to correlation between the independent variables (the variance inflation factor is 1.1).

Findings

Table 5 illustrates the regression model based on the dependent variable innovation performance. It summarizes the results attained by entering the control variables (Model 1), followed by the antecedents (model 2). We expected an inverted U-shaped relationship between KDtK and innovation performance in Hypothesis 1. Considering the results of model 2, we find that the transformed variable KDtK_meansquared is significantly related to innovation performance ($\beta = -0.33$, $p < 0.01$, two-tailed). Hence, Hypothesis 1 is supported by our data. In Hypothesis 2, we predicted a negative relationship between the KDmK and innovation performance. The regression analyses results strongly support this ($\beta = -0.46$, $p < 0.01$, two-tailed). In addition, model 2's result support some control variables. Consequently, trust is significant, and partner firm's absorptive capacity is marginally positive in relation to innovation performance ($\beta = 0.25$, $p < 0.05$, two-tailed, and $\beta = 0.24$, $p < 0.1$, two-tailed).

Discussion

Theoretical contributions and implications

Alliance researchers have attempted to determine the degree of the development partner's knowledge distance that enhances innovation performance (e.g., Kotabe and Swan, 1995; Cantwell and Colombo, 2000; Ahuja and Katila, 2001; Laursen and Salter, 2006). They can be assigned to two research groups: (1) Those who used knowledge bases as inventories of generic knowledge not specifying contents and reporting contradictory results; and (2) Those who specify content, in other words, technological knowledge and finding consistent results, that is, a moderate degree of knowledge distance as most valuable (Mowery *et al*., 1998; Cantwell and Colombo, 2000; Liyanage and Barnard, 2003; Schoenmakers and Duysters, 2006). This suggests that a firm's knowledge base comprises different content-specific components that are important for development alliances, whereas are independent of particular project objectives or partners' attitudes. (Faulkner, 1994; Liyanage and Barnard, 2003). Hence, a more complete conceptualization of knowledge needs to incorporate heterogeneous taxonomic components. Based on Sammarra and Biggiero's (2008) knowledge classification, we extend existing research on technological knowledge distance by specifying and considering the distance of an ally's managerial knowledge distance.

Analyzing data from 53 inter-organizational development projects, we find support for our Hypothesis 1 by finding that KDtK has an inverted U-shaped relationship to innovation performance. Thus, we confirm prior research results (Mowery *et al.*, 1998; Cantwell and Colombo, 2000). We also find, in support for Hypothesis 2, that a small KDmK yields better performance. Thus we lend theoretical and empirical support to work by Rindfleisch and Moorman (2001), Zollo *et al.* (2002), and Hoang and Rothaermel (2005); the latter argue: The refinement of organizational interfaces and the development of organizational decision making as well as conflict resolution routines should enhance subsequent alliance performance (Hoang and Rothaermel, 2005). In particular, we show that the knowledge-based and transaction cost theory help us better explain the effects of technological and managerial knowledge distance between development partners on collaborative innovation performance.

In addition, we find that two control variables have a positive impact on innovation performance: First, trust has a positive impact on joint innovation performance. Therefore, our findings support the work of Gulati (1995) and Boutellier *et al.* (1998). The partners need to trust that everyone involved is working towards the same goal and to the best of their abilities. This aids an open exchange of ideas and information needed for innovation performance. Second, the partner firm's absorptive capacity enhances innovation performance. Our data therefore support the findings by Fosfuri and Tribó (2008), who emphasize firms that are experienced in searching for, transferring, and implementing knowledge into their organizations are also more capable of knowledge exchange than firms with less experience in these areas. Consequently, more experienced firms stand a greater chance of successful innovation.

We also contribute to the emergent literature on partner selection (Emden *et al.*, 2006). Alliance researchers agree that the selection of a development partner is critical with regard to the distance between their knowledge bases (e.g., Gulati, 1995; Deeds and Hill, 1996; Lane and Lubatkin, 1998; Schoenmakers and Duysters, 2006). Decisions can be made more effectively if there is a better understanding of how they relate to collaborative innovation performance. Further, our work complements research on the knowledge-based theory (e.g., Asheim *et al.*, 2007; Corrocher *et al.*, 2007; Escribano *et al.*, 2009) by expounding a knowledge base's content-specific components required for joint development. Carefully considering the individual contributions of knowledge components to collaboration, it bears much better fruit than 'content-free' approaches to knowledge (Spender and Grant, 1996; King and Zeithaml, 2003).

Furthermore, our findings support the existing literature on absorptive capacity, which argues that a too large knowledge distance between partners results in absorption of each other's know-how (e.g., Cohen and Levinthal, 1990). We also corroborate the literature on new product development that shows that firms can improve their innovation performance by leveraging others' knowledge through collaboration and knowledge transfer (Kogut and Zander, 1992; Van Wijk *et al.*, 2008).

Managerial implications

Our findings draw managers' attention to several aspects of partner selection for joint innovation performance. First, the study's results indicate that a moderate technological knowledge distance is best. The partner should ideally operate in different (for new knowledge) but related fields (for knowledge integration reasons). Second, this study indicates that managerial knowledge is indispensable for successful joint innovation. Hence, mutual knowledge of the partner firms' formal and informal organizational structures and cultures enable the collaborators to operate efficiently, avoiding costly conflicts or additional barriers, thus producing optimal results. Further, knowledge of a partner's formal and informal structures as well as organizational culture increases over time (Gulati, 1995). We therefore hold that optimal results can be attained by selecting a partner for innovation projects, with which the firm is already familiar. Overall, from the partner selection perspective, our research suggests that it is important to carefully evaluate potential partners' knowledge portfolio in relation to the focal firm's knowledge portfolio before choosing partners.

Limitations and future research

The limitations of this study lead to a number of promising opportunities for future research. While we have evaluated alliances' knowledge base distance with regard to technological and managerial knowledge, *market knowledge* is not part of our study, and we acknowledge this as a limitation (Sammarra and Biggiero, 2008). In addition, we did not take into account knowledge characteristics, such as tacit or explicit (Nonaka, 1994), since our study assumes that these characteristics are equally distributed across the identified knowledge base components. Future research could examine whether this assumption is reliable, or if knowledge characteristics moderate the relationships of identified knowledge components to innovation performance (Hamel, 1991; Nooteboom, 1999; Simonin, 1999; Cowan and Jonard, 2009).

The empirical test of our research model is clearly limited to the context of development partnerships in the automotive supplier industry. Given that development projects are applied in different contexts, we recommend that future studies apply our model to other industries. By definition, inter-organizational development projects involve at least two organizations, which often exist in a situation of power asymmetry (Easterby-Smith *et al.*, 2008). Power relationships, along with trust, risk, and social ties, are key factors that could moderate the effects of knowledge base distance on innovation performance. Further research is required in this regard.

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Appendix A Measurement of the dependent construct, the antecedents, and the controls

Antecedents	Items
Technological knowledge distance[a]	When running the NPD project, you needed relevant knowledge from your partner. How much knowledge did you need? 1) Knowledge of the technologies (e.g., nanotechnology) 2) Knowledge of the products (e.g., steering column)
Managerial knowledge distance[a]	When running the NPD project, you needed relevant knowledge from your partner. How much knowledge did you need? 1) Knowledge of the partner's formal organizational structures (e.g., hierarchy and functions) 2) Knowledge of the partner's informal organizational structures (e.g., informal networks) 3) Knowledge of the organizational culture (e.g., social norms, rules, and policies)

[a]Scale format: percentages.

Dependent construct	Items
Innovation performance	The new product/software/process . . . 1) . . . followed a new technological principle. 2) . . . created a totally new customer benefit. 3) . . . improved our market position. 4) . . . improved the partner's market position.

[a]Scale format: 1 = totally disagree, 5 = totally agree.

Controls	Items
Trust[a]	Important ideas and information were openly exchanged between the alliance partners.
Project outcome[b]	What was the outcome of the joint development project?
Degree of modularization[a]	1) Functionally, our partner and we depended strongly on the development tasks. 2) The partner's contribution was very important for the joint development. 3) Developing this component generated specialized expertise for both partners.
Partner firm's absorptive capacity[a]	1) We have done NPD projects in collaboration with other firms in the past, during which we successfully implemented the partner's knowledge in our firm. 2) We have done NPD projects in collaboration with other firms in the past, during which knowledge transfer was a critical success factor. 3) In the past, we also searched for specific outside know–how carriers (e.g., domain experts).

[a]Scale format: 1 = totally disagree, 5 = totally agree.
[b]Scale format: 1 = process, 2 = software, 3 = product.