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Abstract

In this study, we examine the process of interfirm knowledge transfer in R&D relationships. Based upon an embedded case study, we develop a model for understanding the initiation and evolution of interfirm knowledge transfer. Complementing previous cross-sectional research, this model points to the importance of legal clauses as a formal design alternative to equity governance structures, expectations of a long-term relationship as a specific indicator of trust, and similarity of technological equipment as an important facilitator for acquisition and assimilation of knowledge. This model also indicates that interfirm knowledge transfer is likely to continue in R&D relationships as long as perceived market threats remain limited and perceived technological complementarities remain extensive. In addition, we point to two strategies to organize an R&D relationship such that continuation of interfirm knowledge transfer is more likely to occur.

Keywords: Interfirm knowledge transfer, R&D relationships

In R&D settings, firms increasingly rely on formal links with other organizations to increase their knowledge of innovative technologies (e.g. Faems et al. 2005; Hagedoorn 2002). Although such R&D relationships can lead to successful transfer of codified as well as tacit knowledge (Doz and Hamel 1997), failure rates of such collaborative efforts are said to be high (De Laat 1997). Previous research (e.g. Chen 2004; Lane and Lubatkin 1998; Mowery et al. 1996) has therefore examined the conditions that influence interfirm knowledge transfer in the specific setting of R&D.

While this research offers valuable insights in the effectiveness of interfirm knowledge transfer in R&D relationships, several issues remain. First, these previous studies focus on the relationship between particular conditions and knowledge transfer *outcomes* such as the increase of patent cross-citations between collaborating partners (Mowery et al. 1996) or the perceived increase of a firm's stock of new skills or capabilities (Chen 2004; Lane and Lubatkin 1998). As a result, the actual *process* of initiating interfirm knowledge transfer remains a black box (Inkpen and Pien 2006). Second, because of their mainly cross-sectional nature, these previous studies provide limited insights into how the process of interfirm knowledge transfer evolves over time.

The purpose of this study is therefore twofold: (1) to explore the process of initiating knowledge transfer in R&D relationships; and (2) to investigate how and under what conditions interfirm knowledge transfer evolves once the desired knowledge is transferred. To accomplish these research objectives, we rely on an embedded case study of how one established company over the course of a

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technological trajectory collaborated with three different entrepreneurial partners. Based on these data, we develop a model for understanding the process through which interfirm knowledge transfer in R&D relationships occurs. Further developing the facilitating conditions of knowledge transfer found in previous research, this model points to the importance of legal knowledge-sharing clauses as an alternative to equity governance structure, expectations of a long-term relationship as a specific indicator of trust, and similarity of technological equipment as an important additional facilitator of knowledge acquisition and assimilation. In addition, we newly identify the conditions that influence the evolution of knowledge transfer once the desired knowledge is transferred, referring to perceived technological complementarities and perceived market threats. Finally, we identify and assess two potential strategies to come to sustainable interfirm knowledge transfer in R&D relationships. This study contributes to the alliance literature by taking a process perspective on interfirm relationships, providing new insights into the complexity of knowledge transfer.

Theoretical Background

The Initiation of Knowledge Transfer: Barriers and Facilitating Conditions

Following Hamel (1991), we define interfirm knowledge transfer as a process that consists of two critical steps. First, knowledge needs to be disclosed by the 'expert partner' or the firm that possesses the knowledge. As a second step, the disclosed knowledge needs to be acquired and assimilated by the 'novice partner'. Knowledge acquisition is the process of identifying and evaluating the opportunities and liabilities of disclosed knowledge, while assimilation of knowledge refers to the process of embodying and internalizing the disclosed knowledge (Lane and Lubatkin 1998; Zahra and George 2002). Once knowledge is successfully transferred, the novice partner can start internally exploiting the disclosed knowledge for new markets, products and businesses (Hamel 1991; Zahra and George 2002).

While R&D relationships are increasingly recognized as viable organizational structures for transferring technological knowledge between firms (Doz and Hamel 1997; Mowery et al. 1996), the initiation of interfirm knowledge transfer in R&D relationships may be difficult because of (1) the limited *willingness* of the expert partner to disclose knowledge, (2) the limited *ability* of the novice partner to acquire and assimilate knowledge.

Willingness to Disclose Knowledge

When knowledge is disclosed, the other partner may be induced to abuse it for opportunistic or competitive motives (Hamel 1991; Khanna et al. 1998). For this reason, the expert partner may be hesitant to fully disclose the know-why (i.e. principles underlying the technology), know-how (i.e. procedures required to apply the technology) and know-what (i.e. specific technology configurations that different customers groups may want) (Garud 1997) of the technological knowledge to the novice partner (Larsson et al. 1998). Previous research

(Mowery et al. 1996; Cheng 2004) points to equity governance structure as an important formal condition that mitigates opportunistic abuse of disclosed knowledge. Equity governance structures include joint ventures, minority and majority participations; non-equity governance structures refer to all other cooperative arrangements not involving equity exchange (e.g. co-development agreement, technology sharing agreement) (Tsang 2000). Informed largely by transaction cost economics (e.g. Williamson 1985), the theoretical reasoning for this relationship is that equity governance structures create a mutual hostage situation through ex ante commitments to an alliance, reducing the incentive of the novice partner to opportunistically abuse disclosed knowledge (Dyer and Singh 1998; Williamson 1991). As a result, the expert partner is likely to be more motivated to disclose knowledge.

Several researchers (e.g. Kale et al. 2000; Muthusamy and White 2005), however, criticize the transaction cost economics perspective for being acontextual and ahistorical, ignoring the impact of relational capital on interfirm knowledge transfer. They therefore highlight the importance of trust as a relational condition that motivates disclosure of knowledge. Trust refers to 'a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another' (Rousseau et al. 1998: 395). Here, the theoretical argument is that trust tends to decrease the perceived risk of opportunism, encouraging members of the expert partner to engage in wide-ranging, continuous and intense contact with members of the novice partner (Kale et al. 2000; Muthusamy and White 2005). The study of Chen (2004), reporting a positive relationship between trust and the effectiveness of interfirm knowledge transfer, supports this argument in the specific context of R&D relationships.

Ability to Acquire and Assimilate Knowledge

The second difficulty of knowledge transfer may be situated in the limited ability of the novice partner to acquire and assimilate knowledge (Hamel 1991; Lam 1997; Larsson et al. 1998). Technological knowledge is to some extent tacit and/or embedded within a specific context (Doz and Hamel 1997). However, the more tacit the knowledge, the lower the ability to structure that knowledge into a set of easily communicated rules and relationships (Kogut and Zander 1992; Nonaka and Takeuchi 1996). Valuation and internalization of disclosed knowledge may consequently be hampered.

Existing research points to two organizational conditions that influence a firm's ability to acquire and assimilate knowledge from another firm. A first condition is the similarity of the partners' knowledge bases. Several scholars (e.g. Cohen and Levinthal 1990; Lane and Lubatkin 1998) have stressed that what can be learned from the expert partner is largely determined by what is already known by the novice partner. If the novice partner does not possess some amount of prior knowledge basic to the disclosed knowledge, it will be very difficult to value and internalize it for its own operations (Inkpen and Pien 2006). Effective acquisition and assimilation of disclosed knowledge therefore ask for some overlap in knowledge bases between the involved firms (Cohen and Levinthal 1990). A second condition is the similarity in organizational structures and business practices. The more similar the organizational structures and business practices of expert and novice partner, the more likely the novice partner will possess the necessary knowledge-processing systems to value and internalize not only the codified but also the tacit components of the disclosed knowledge (Inkpen and Pien 2006; Lane and Lubatkin 1998; Simonin 1999).

Lane and Lubatkin (1998) provide empirical evidence for the positive impact of these two conditions on the ability to acquire and assimilate knowledge in the particular setting of R&D. Using a sample of R&D alliances between pharmaceutical and biotechnology firms, they provide evidence that the effectiveness of such alliances in terms of increasing the pharmaceutical firm's stock of knowledge is positively influenced by (1) the overlap between the novice firm's basic knowledge and that of the expert firm; and (2) the similarity of the firm's management formalization, management centralization and compensation practices.

In sum, the above studies refer to equity governance structure, trust, similar basic knowledge and similar organizational structures and business practices as facilitating conditions of interfirm knowledge transfer in R&D relationships. However, as these findings are derived from studies focusing on the *outcomes* of knowledge transfer, the question remains to what extent they also facilitate the *process* of knowledge transfer. As mentioned previously, the first objective of this research is to examine how and under what conditions knowledge transfer in interfirm R&D relationships is initiated.

The Dynamics of Knowledge Transfer: Dissolution or Continuation?

Once the desired technological knowledge is transferred, it remains unclear how the process of interfirm knowledge transfer evolves. Because previous research is mainly cross-sectional in nature, studies provide limited insights into the dynamics of interfirm knowledge transfer. Examining the alliance literature, we further notice that different studies seem to provide contradictory logics, pointing to continuation versus dissolution of knowledge transfer.

Some alliance scholars (e.g. Hamel 1991; Khanna et al. 1998) seem to suggest that, after the novice partner has acquired and assimilated the desired knowledge, knowledge transfer is likely to dissolve. Applying insights from game theory (e.g. Oye 1986) and social exchange theory (e.g. Blau 1964), they argue that, as one partner succeeds in acquiring the desired tangible or intangible assets of the other partner, the expected future pay-offs of the relationship for the former partner are likely to decrease, triggering a shift from cooperative to non-cooperative behaviour.

In contrast, other alliance scholars (e.g. Doz 1996; Larson 1992; Ring and Van de Ven 1994; Uzzi 1997) seem to argue that, when knowledge is successfully transferred from one partner to the other, the incentives to sustain and even expand the collaborative relationship are strong, providing new opportunities for interfirm knowledge transfer. These scholars refer to the dynamics of trust as an explanation in this respect. In line with the trust literature (e.g. Lewicki and Bunker 1996; Jones and George 1998; Ring 1997), they argue that, as partners successfully engage in knowledge transfer, the associated cycles of exchange, risk taking and successful fulfilment of expectations are likely to trigger an increase from fragile to resilient trust levels. In situations of resilient trust, each party's trustworthiness is based on confidence in the other's values, backed up by empirical evidence derived from repeated behavioural interactions (Jones and George 1998). Such resilient trust provides individuals with the assurance that knowledge and information will be used for the greater good and that one need not exercise power or enforce contractual arrangements to protect one's own interests (Ring 1997). As a consequence of such trust dynamics, partners become motivated to expand a single economic transaction to a diverse set of ongoing joint projects and interrelated exchange processes, leading to new opportunities for knowledge transfer (Larson 1992; Ring and Van de Ven 1994).

In sum, while some scholars suggest that knowledge transfer is likely to dissolve because of changes in pay-off structures, other scholars argue that knowledge transfer is likely to continue because of positive trust dynamics. Given these contradictory logics, the second objective of this research is to examine how and under what conditions knowledge transfer evolves over time in interfirm R&D relationships.

Methodology

Research Design

In this study, we adopt an embedded case study approach (Yin 2003), examining three interfirm R&D relationships that were part of the same technological trajectory. This methodology suits our goal of developing a model in an area where little data or theory exist (Yin 2003). In addition, it allows us to perform a comparative analysis of three interfirm relationships, an analysis that facilitates 'analytic generalization' (Parkhe 1993a; Yin 2003). Through selecting interfirm R&D relationships that were part of the same technological trajectory, we minimize the influence of extraneous variation on our research findings (Eisenhardt 1989). The main limitation of our research design is that its generalizability to a larger and more diverse population might be restricted. The value of this research lies instead in its capacity to provide in-depth insights in complex and dynamic processes, which are difficult to reveal by means of more cross-sectional research designs (Larson 1992). In this study, all names of firms, products and individuals are disguised to ensure confidentiality.

Research Setting

In the early 1990s, MAT, a Belgian company working on a global scale with products and systems based on metal transformation and advanced coatings, identified diamond-like coatings as a new promising technology to expand its coating activities. At the end of 2003, one of its divisions, MAT Diamond, succeeded in becoming the leading supplier of diamond-like coatings for a wide array of applications. During the development of this technological trajectory, MAT initiated interfirm relationships with three different partners: USCOAT, RES and FRCOAT (see Table 1). In all three interfirm R&D relationships, the initial objective was the unilateral (i.e. MAT–USCOAT relationship and

Table 1. Overview Interfirm R&D Relationships

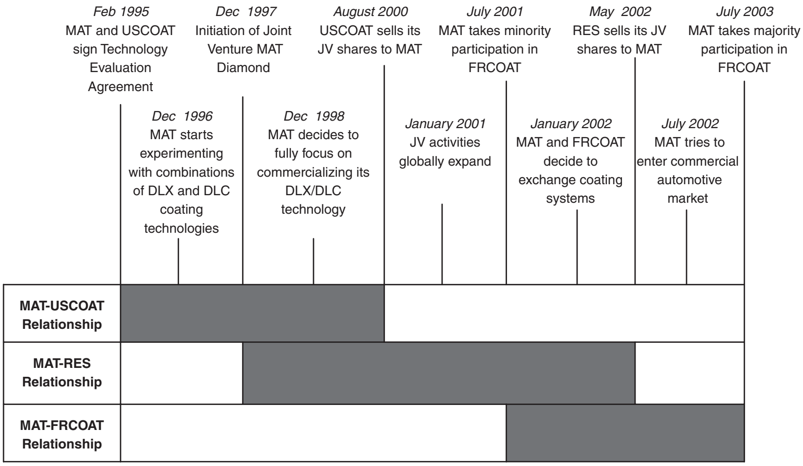
Characteristics	MAT-USCOAT Relationship	MAT-RES Relationship	MAT-FRCOAT Relationship
Description of partners	**MAT**: International group specialized in metal transformation and advanced coatings, located in Belgium		
	USCOAT: High-tech SME specialized in advanced coatings and advanced ceramic materials, located in the US	**RES:** Research institute specialized in advanced materials, located in Belgium	**FRCOAT:** University spin-off specialized in advanced coatings, located in France
Initiation of interfirm relationship	Feb 1995	Dec 1997	July 2001
Initial technological objective of interfirm relationship	Transfer of USCOAT's DLX technology to MAT to explore the feasibility of this technology at MAT	Transfer of RES's DLC technology to MAT to explore the feasibility of this technology at MAT	Transfer of FRCOAT's Advanced DLC technology to MAT to further exploit MAT's DLX/DLC technology Transfer of MAT's DLX/DLC technology to FRCOAT to further exploit FRCOAT's Advanced DLC technology
History of governance structure of interfirm relationship	Feb 1995 – Dec 1997: Contractual agreements Dec 1997 – Aug 2000: Joint Venture (MAT 60%; USCOAT 20%; RES 20%) Aug 2000: MAT buys out USCOAT from the Joint Venture MAT Diamond	Dec 1997 – Aug 2000: Joint Venture (MAT 60%, USCOAT 20%, RES 20%) Aug 2000 – May 2002: Joint Venture (MAT 80%, RES 20%) May 2002: MAT buys out RES from the Joint Venture MAT Diamond	July 2001 – July 2003: Minority participation (MAT holds 48% of FRCOAT's shares) July 2003: Majority participation (MAT holds 90% of FRCOAT's shares)

MAT–RES relationship) or bilateral (i.e. MAT–FRCOAT relationship) knowledge transfer of an existing coating technology from one partner to the other. We should point out that, between 1998 and 2000, USCOAT and RES were minority partners in the same joint venture with MAT. However, we do not consider the interfirm relationship between USCOAT and RES in this study because no knowledge transfer was intended to take place between these two firms.

Data Collection and Analysis

Data on the three interfirm relationships were collected in a retrospective way which allowed for a much more focused data-gathering process (Poole, Van de Ven, Dooley and Holmes 2000). At the same time, unconsciously accepting respondent bias might occur in retrospective studies, leading to confusion about cause-and-effect relationships (Leonard-Barton 1990). To improve the validity of the retrospective reports, we applied a number of strategies. First, we triangulated our data, applying two data sources: interviews and documents (Eisenhardt 1989, Yin 1984). Second, we asked informants to reflect on concrete events rather than past opinions or beliefs to reduce the risk of cognitive biases and impression management (Miller et al. 1997). Finally, we attempted to verify individual reports by asking similar questions to multiple informants.

Figure 1. Chronological Overview of Main Events (Simplified Depiction)



Applying the suggestions of Pettigrew (1990) and Pentland (1999), we made an explicit distinction between three different stages in our theory-building process, representing an evolution of surface levels to deeper levels of data collection and analysis. In the first stage, we conducted unstructured interviews with two MAT managers who were closely involved in all three interfirm R&D relationships. The purpose of these interviews was to obtain initial information about the history and characteristics of the different interfirm R&D relationships (e.g. how successful was the relationship; what major events shaped the relationship; how would the interviewee describe the other organizations). For each interfirm R&D relationship, we also studied relevant documents. In addition to publicly available information (e.g. annual reports, press releases), we gained access to 81 private documents (e.g. contracts, slideshows of technological meetings, minutes of steering meetings) totalling 1731 pages. Based on both interviews and documents, we constructed a graphical representation of the chronology of the major events that took place within each R&D relationship. Figure 1 presents a simplified depiction of this chronology.

In the second stage, we conducted semi-structured interviews (Kvale 1996) with informants from the different organizations involved. Between October 2003 and November 2004, we individually interviewed 19 persons (see Table 2). The interviews were structured along the chronology of the major events, asking respondents to describe these events and the kind of interactions they triggered between the partners. The average length of interview was between one and two hours. The transcribed interviews were sent back to the interviewees for feedback. At this stage, we also re-examined the available documents to verify whether the content of the interviews was consistent with the content of the documents. When discrepancies between these two data sources were observed, we again contacted respondents to ask for additional comments. For each interfirm relationship, a case study report was then written with extensive use of citations from both the interviews and documents to achieve a high level of accuracy (Langley 1999). These reports were sent to one manager of each company; their comments were collected via electronic mail or face-to-face conversations, leading to the final case study reports.

Table 2. Overview of Interviews

Company	Function of Interviewee	Number of Interviewees
MAT	Corporate Manager	2
	Project Manager	2
	Engineer/Technician	2
	Sales Manager	1
	Lawyer	1
RES	Corporate Manager	2
	Project Manager	2
	Engineer/Technician	1
USCOAT	Project Manager	1
	Engineer/Technician	3
FRCOAT	Corporate/Project Manager	1
	Engineer/Technician	1
		19

In the third and last stage, we analysed the case study reports through an inductive approach, relying on an iterative process that coupled within-unit analysis with between-unit analysis (Eisenhardt 1989; Yin 2003). We started by conducting a within-unit analysis for each observed interfirm R&D relationship, focusing on the initiation and evolution of knowledge transfer. After completing the within-case analyses, we compared the findings across the three cases. Based on the identification of similarities and differences across cases, new iterations of within-case and across-case analysis were subsequently initiated. This procedure was repeated until dominant findings emerged. As we analysed our data, we sometimes felt the need to collect additional data. For instance, conducting a first analysis of the data on the MAT–FRCOAT relationship, it was unclear to us why MAT was immediately willing to disclose its coating technology to FRCOAT. We therefore contacted one of the MAT managers involved, asking him the reason for MAT's openness in disclosing knowledge to FRCOAT. When a first draft of this paper was completed, we again conducted feedback interviews with the two MAT managers who were interviewed at the first stage to discuss the content of the study. These feedback interviews proved to be very helpful in fine-tuning our insights as well as testing the internal validity of our findings.

Results

In this section, we turn to our two research questions, examining the initiation of interfirm knowledge transfer and its evolution after the desired transfer is completed. As it is the purpose of this study to inductively develop a model, we provide for each R&D relationship a discussion of the initiation and evolution of interfirm knowledge transfer and its conditions. Table 3 presents the main findings of all three cases.

MAT–USCOAT Relationship

Initiation of Knowledge Transfer

In February 1995, MAT and USCOAT, a US high-tech SME that had developed a pioneering diamond-like coating called DLX, started an R&D relationship by

Table 3. Initiation and Evolution of Knowledge Transfer in Observed Interfirm R&D Relationships: An Overview

Initiation of knowledge transfer during first year of relationship	MAT-USCOAT Relationship	MAT-RES Relationship	MAT-FRCOAT Relationship	
Nature of knowledge disclosure	Feb '95 – Feb '96: Open disclosure of know-what, know-how, and know-why of DLX technology by USCOAT	Dec '97 – Dec '98: Open disclosure of know-what, know-how, and know-why of DLC technology by RES	July '01- July '02: Open disclosure of know-what, know-how, and know-why of DLX/DLC technology by MAT Open disclosure of know-what, know-how, and know-why of Advanced DLC technology by FRCOAT	
Conditions of knowledge disclosure				
Governance structure	Non-equity structure	JV structure	Minority equity structure	
Legal knowledge transfer clauses	Specified in detail	Specified in detail	Specified in detail	
Expected time horizon	Long-term horizon	Long-term horizon	Long-term horizon	
Nature of knowledge acquisition and assimilation	Feb '95 – Feb '96: High ability to acquire and assimilate DLX technology by MAT	Dec '97 – Dec '98: High ability to acquire and assimilate DLC technology by MAT	July '01- Jan '02: Limited ability to acquire and assimilate DLX/DLC technology by FRCOAT Limited ability to acquire and assimilate Advanced DLC technology by MAT	Jan '02 – July '02: High ability to acquire and assimilate DLX/DLC technology by FRCOAT High ability to acquire and assimilate Advanced DLC technology by MAT
Conditions of knowledge acquisition and assimilation				
Knowledge bases	No overlapping knowledge base	Overlapping knowledge base	Overlapping knowledge base	Overlapping knowledge base
Organizational structures and business practices	Hierarchical structure and business practices versus entrepreneurial structure and business practices	Hierarchical structure and business practices versus entrepreneurial structure and business practices	Hierarchical structure and business practices versus entrepreneurial structure and business practices	Hierarchical structure and business practices versus entrepreneurial structure and business practices
Technological equipment	Similar coating systems	Similar coating systems	Different coating systems	Similar coating systems

(continued)

Table 3 *(continued)*

Initiation of knowledge transfer during first year of relationship	MAT-USCOAT Relationship		MAT-RES Relationship	MAT-FRCOAT Relationship
Evolution of knowledge transfer after first year of relationship	**MAT-USCOAT Relationship**		**MAT-RES Relationship**	**MAT-FRCOAT Relationship**
Nature of knowledge evolution	Feb ’96 – Dec ’98: Bilateral disclosure and acquisition/ assimilation of know-what, know-how, and know-why of internal experiments	Dec ’98 – Aug ’00: No interfirm knowledge transfer	Dec ’98 – May ’02: No interfirm knowledge transfer	July ’02 – July ’03: Bilateral disclosure and acquisition/assimilation of know-what, know-how, and know-why of internal experiments
Conditions of knowledge evolution				
Perceived technological complementarities	Extensive	Limited	Limited	Extensive
Perceived market threats	Limited	Limited	Extensive	Limited

signing a technology evaluation agreement. In this agreement, it was stated that the objective of the collaboration was 'to allow MAT an initial opportunity to assess the commercial potential of the Technology [DLX coating] and to determine its interest in pursuing future joint commercial activities with USCOAT' (*Technology Evaluation Agreement*: 1). After signature of the technology evaluation agreement, USCOAT began to disclose knowledge about its DLX technology. Specifically, a number of meetings with MAT engineers were organized, during which 'there was a lot of information exchange [toward MAT engineers] including papers, journal articles and unpublished communications' (USCOAT project manager). These documents contained detailed information about the know-why (i.e. fundamental properties such as 'stability, adhesion, and conductivity of DLX coating'; *USCOAT White Paper* 95–1023: 1–2) and the know-what (i.e. 'coating evaluations of USCOAT's priority accounts'; *USCOAT Market Development Plan for DLX*: 9) of the DLX technology. In addition, MAT's project manager visited USCOAT for one month, allowing him 'to see with [his] own eyes how the coatings were manufactured' (MAT project manager). In other words, USCOAT also disclosed the 'know-how' of its technology. The open disclosure of knowledge was also emphasized in the interviews:

'Despite the risk of withholding information during this initial phase, they [USCOAT] played it openly.' (MAT manager)

'I think we were fairly open.' (USCOAT project manager)

USCOAT interviewees provided two grounds for their openness in disclosing knowledge. First, they referred to the presence of specific contractual clauses in the technological evaluation agreement, regulating how MAT could apply the disclosed knowledge. For instance, the contract stipulated that 'MAT shall not, without the prior written consent of USCOAT, directly or indirectly use or incorporate the technology in connection with any work or project' (*Technology Evaluation Agreement*: 2). According to one USCOAT engineer, such contractual clauses provided 'sufficient legal protection for providing information [to MAT]'. Second, USCOAT interviewees pointed to the expected time horizon of the relationship with MAT. Negotiating with MAT managers, USCOAT's CEO was confident in MAT's willingness to establish a long-term relationship with USCOAT to launch DLX coatings onto the market. This long-term horizon seemed to have a positive impact on their openness toward MAT. A USCOAT engineer, for instance, mentioned that 'we were willing to provide all information because we saw it as a beneficial long-term relationship'.

Next to the high motivation of USCOAT to disclose knowledge, the ability of MAT to acquire and assimilate this knowledge seemed to be extensive. Despite the fact that (1) MAT engineers did not have any experience with diamond-like coatings and (2) partners' organizational structures and business practices were clearly different (i.e. hierarchical structure with highly formalized business practices versus entrepreneurial structure with low degree of business practice formalization), MAT interviewees stressed that that they quickly acquired a feeling for the advantages and disadvantages of the technology:

'We swiftly started understanding what was good about it [USCOAT's DLX technology], what was not good about it, what were the potential opportunities of it.' (MAT manager)

MAT's project manager also mentioned that 'after a few months, we succeeded in internally manufacturing our first DLX samples'. In other words, MAT quickly managed to replicate USCOAT's DLX technology, pointing to successful assimilation of the disclosed knowledge. To explain this high ability to acquire and assimilate the disclosed knowledge, MAT interviewees referred to the presence of similar coating systems at USCOAT and MAT. At the start of their interfirm relationship, MAT and USCOAT had agreed that MAT, experienced in developing vacuum systems, would develop two identical coating systems. One of these coating systems would be installed at USCOAT, while the other coating system would remain at MAT. According to the MAT interviewees, the presence of these similar coating systems was a huge advantage in acquiring and assimilating the disclosed knowledge as it allowed them to 'speak the same language' and 'use similar process parameters'.

Evolution of Knowledge Transfer

After MAT had acquired and assimilated USCOAT's DLX technology, it started to internally experiment with the technology to optimize its feasibility for industrial-wear applications in the European market. At the same time, USCOAT refined the DLX technology for high-end applications in the American micro-electronics market. While disclosure of knowledge had been rather unilateral during the first year (from USCOAT to MAT), we found indications that it started to become more bilateral later on. Meetings were organized between the two partners on a regular basis. In one of the documents, the objective of these meetings was worded as follows:

'The purpose of this meeting is to discuss the technical and commercial issues with respect to the DLX and related technologies. The format is an open dialogue of two partners with similar goals: broad commercialization of the DLX technology.' (Minutes of MAT/ USCOAT Technology/Business Meeting, 4–5 September 1997: 1)

During these meetings, partners openly exchanged the results of their internal DLX experiments. USCOAT, for instance, provided 'results of doping DLX coatings with various kinds of atoms' (USCOAT slideshow Technology/Business Meeting, 20–26 March 1997:33). In a similar vein, MAT presented detailed information about its attempts to 'combine DLX and DLC technologies to improve the hardness of coatings' (MAT slideshow Technology/Business Meeting, 12–13 December 1996: 12). Not only the results, but also the 'process system upgrades' (USCOAT slideshow Technology/Business Meeting, 20–26 March 1997: 26) to execute these experiments were exchanged. Finally, partners also exchanged 'questionnaires for DLX coatings', which both MAT and USCOAT had sent to their potential customers to 'better understand the [customer's] needs and expectations for a DLX coating' (MAT slideshow Technology/Business Meeting, 12–13 December 1996: 6).

In the interviews, two grounds were provided to explain the emergence of such bilateral knowledge disclosure of know-why, know-how and know-what. First, it was stressed that, from a technological point of view, it was interesting to bilaterally exchange information. To be specific, as both partners conducted experiments with the same technology but in different contexts, 'the exchange of information [about the experiments] provided opportunities to know more about how the technology behaved in different contexts' (MAT engineer). Second, it was emphasized that, as partners focused on clearly different applications for different markets, the risk that bilateral transfer of knowledge would bring along increased market competition was limited. A MAT manager, for instance, mentioned that:

'From an American perspective, they looked at high-tech applications, while we focused on wear applications for the European market. In my opinion, this was a good division … If the teams of USCOAT and MAT would have targeted the same markets, they would have contacted the same customers and tried to find solutions for the same applications.' (MAT manager)

We also found indications that the partners' ability to acquire and assimilate the disclosed knowledge remained high. USCOAT engineers, for instance, stressed that 'we internally managed to replicate some of MAT's experiments regarding combining DLX and DLC coatings'. At the same time, MAT turned out to be successful in imitating some of USCOAT's experiments regarding doping DLX coatings.

After experimenting with the DLX technology for two years, MAT became convinced that this technology could offer new industrial applications. At the end of 1997, MAT bought a licence from USCOAT to commercially exploit the DLX technology in Europe and made a proposal to USCOAT to jointly start up a business activity for diamond-like coatings in Europe. In December 1997, the joint venture 'MAT Diamond' was officially launched. At the beginning of the joint venture, USCOAT and MAT continued their bilateral exchange of testing results during regular technical meetings. However, after the first year of the joint venture, the frequency of technical meetings dropped drastically. According to both the MAT and USCOAT interviews, it was MAT that had lost its motivation to engage in bilateral exchange of information:

'We became more reserved concerning [exchanging information about] our [technological] developments.' (MAT manager)

'I think the information was initially very intense and slowed down later on … We no longer knew what was actually done at MAT.' (USCOAT project manager)

MAT interviewees referred to the evolution of the technological activities at both partners to explain their decreased motivation to engage in bilateral exchange of testing results. After the joint venture was initiated, MAT became committed to apply a combination of DLX and more traditional DLC technologies for commercial exploitation of industrial wear applications in Europe. Although USCOAT engineers had been informed about this combined DLX/DLC coating, they did not apply this coating for their commercial development efforts in the American market. An USCOAT engineer stressed that 'our management was not willing to invest in the development of DLC-oriented coatings as USCOAT had recently launched an intensive marketing campaign in the US to promote its DLX technology as an alternative to DLC coatings'. USCOAT consequently remained focused on further developing pure DLX coatings for their blue-sky applications. However, USCOAT's continued experiments with its pure DLX coating were no longer interesting from a technological point of view as they had no relevance for MAT's DLX/DLC development efforts:

'They worked on DLX applications for the electronics industry where you had to put Fluor in the coatings. That was none of our business. There almost was no common ground left.' (MAT engineer)

As a result, MAT engineers became less interested in exchanging technological knowledge with the USCOAT engineers. In 2000, due to internal financial problems, USCOAT sold not only its MAT Diamond shares but also its entire coating division to MAT, representing the end of the interfirm relationship.

MAT–RES Relationship

Initiation of Knowledge Transfer

When MAT decided to start a diamond-like coating business activity in 1997, they asked not only USCOAT but also RES, a Flemish research institute that had developed its own DLC coating and had conducted first production of diamond-like coatings for a limited number of local customers, to become a joint venture partner. In December 1997, a joint venture agreement was signed, stipulating that RES brought its DLC technology and its existing DLC customers into the joint venture in exchange for 20% of the joint venture shares.

Interviewees from both companies stressed that, from the beginning, the disclosure of knowledge from RES to MAT was very transparent:

'Communication from RES to MAT was very open.' (MAT engineer)

'We passed on the complete set-up of the RES process as well as all the process parameters.' (RES engineer)

As in the MAT–USCOAT relationship, technological meetings and visits were organized during which RES engineers provided detailed information about the know-why (i.e. fundamental coating properties and characteristics), know-how (i.e. demonstrations of how coatings are produced) and know-what (i.e. coating evaluations of RES's existing customer base) of the DLC technology to MAT engineers. Again, RES interviewees pointed to specific contractual clauses to explain their openness in disclosing knowledge to the other partner:

'In the JV Agreement, a number of annexes were present that described in detail which technology would be transferred to the joint venture. At that moment, we had just started working on another technology that had some linkages with the DLC technology. Through these annexes we could prevent the disappearance of this technology.' (RES project manager)

Second, RES interviewees referred to the positive expectations that they, as the expert partner, had about the long-term orientation of the relationship with the novice partner (i.e. MAT). The RES project manager, for instance, stated: 'RES believed that this JV could be the start of a close relationship with MAT which, in the long term, would go beyond the scope of the JV.'

In addition to the open disclosure by RES, MAT engineers seemed to have limited difficulties in acquiring and assimilating the disclosed knowledge. For instance, MAT engineers stated that they 'quickly managed to start comparing RES's DLC technology with [their] own DLX/DLC technology' and 'were able to get familiar with the technology.' As in the MAT–USCOAT relationship, MAT interviewees referred to the presence of similar coating systems as a condition that facilitated the acquisition and assimilation of the disclosed knowledge. At the beginning of this relationship, MAT had bought a second-hand coating system from RES and it was 'this coating system [that] allowed imitation of the characteristics of RES's DLC technology' (MAT engineer).

Evolution of Knowledge Transfer

In contrast to the MAT–USCOAT relationship, no technological meetings emerged in which partners bilaterally exchanged information about their internal experiments. Instead, the intensity of communication between engineers of both partners drastically dropped after the first year. Two explanations were provided to explain this evolution. First, it was stressed that MAT engineers were no longer interested in RES's DLC technology. After conducting experiments with RES's DLC technology, MAT engineers quickly concluded that 'this technology turned out to have limited opportunities for industrial commercialization because of scale-up problems' (MAT engineer). As a consequence, 'MAT's technological interest in RES's DLC technology quickly faded away' (MAT manager). Second, it was emphasized that 'MAT was not open about its own internal DLX/DLC experiments' (RES engineer). Asked for their reasons, MAT interviewees expressed their fear that, if RES engineers, being research institute scientists, were to be informed about MAT's technological progress in exploiting the DLX/DLC technology, they would be tempted to talk about it at scientific conferences and workshops, triggering the risk that potential competitors would gain access to sensitive knowledge and could become active in the same markets:

> 'At RES, the risk of leakage of valuable information was large. After all, such scientists are used to giving speeches at conferences and telling everything they know … We did not want other companies to get access to our coatings.' (MAT manager)

It needs to be stressed that, at the start of the joint venture, MAT and RES had signed a separate R&D agreement, which stipulated that MAT had to fund a certain amount of R&D projects at RES during the next five years. The purpose of these projects was that RES would apply its expertise in diamond-like coatings to generate *new* coating knowledge, which could then be transferred to the MAT team. RES therefore started exploring a number of new technological coating opportunities. However, it quickly became apparent that MAT engineers were not really interested in discussing the progress of these explorative R&D projects. To explain this disinterest, interviewees stressed that, as MAT was fully committed to commercializing its own DLX/DLC technology, the motivation to spend time on discussing the potential of alternative technological opportunities was limited:

> 'The MAT people were fully occupied with commercializing their [DLX/DLC] technology. They had to make sure that they had sufficient revenues. Discussing new opportunities was not a priority for them … I remember that we really had to insist on having a meeting during which we could discuss our research.' (RES project manager)

> 'When we started commercializing our technology, our interest in more basic R&D faded away … We [therefore] did not supervise these projects … Regarding the research projects [of RES], there was limited communication.' (MAT engineer)

In 2001, when USCOAT had already left the joint venture, the JV activities were expanding globally. As this expansion required additional financial investments, MAT asked RES to jointly increase MAT Diamond's working capital. However, RES's board of directors was not willing to contribute financial resources to the joint venture. In 2002, MAT chose to buy out RES, making themselves the sole arbiter of MAT Diamond's future. In this way, MAT Diamond, originally a joint venture between three partners, became a fully owned subsidiary of MAT.

MAT–FRCOAT Relationship

Initiation of Knowledge Transfer

From 2000 on, MAT realized that, to stay competitive in this technological domain, it needed collaboration with other partners who possessed complementary coating technologies. In this respect, FRCOAT, a spin-off from a French university that had successfully commercialized a high-quality DLC coating for a particular niche market (i.e. the racing industry), was recognized as an interesting partner. In July 2001, MAT and FRCOAT signed an agreement, stipulating that MAT took a minority interest (47.8%) in FRCOAT. At the same time, the partners signed a cross-licensing agreement, stipulating that each partner disclosed its own coating technology and expertise to the other. Shortly after the agreement was signed, technical meetings and visits were organized in which, according to the interviewees, the project managers and engineers of both MAT and FRCOAT openly disclosed their coating technology:

> 'I did not hide anything about FRCOAT's process. Also the MAT people did not hide anything.'(FRCOAT engineer)

> 'From the start, everything was put on the table.' (MAT engineer)

To explain their openness in disclosing knowledge, MAT interviewees stressed that there was no risk in disclosing knowledge as 'FRCOAT did not have the financial means to abuse such knowledge for competitive reasons' (MAT manager). When we asked the CEO of FRCOAT why he was willing to openly disclose its technology to MAT, he emphasized his confidence in MAT's long-term commitment to the relationship:

> 'What convinced me was the straightforward discourse I had with the people I met [during the negotiation stage] … They clearly communicated that their objective was not to just acquire a technology, but to really commit to a joint project within this technological domain.' (FRCOAT engineer)

Finally, we noticed that, as in the MAT–USCOAT and MAT–RES relationships, contractual clauses were also present that explicitly stipulated how and for which purpose partners could use the disclosed knowledge.

While the disclosure of knowledge seemed to be very open, we found indications that, during the first months of the MAT–FRCOAT relationship, both partners had difficulties in acquiring and assimilating the disclosed knowledge. Although both partners had significant expertise in the field of DLC technology, interviewees from both firms indicated that they initially experienced problems in evaluating and replicating the partner's coating technology. MAT's project manager, for instance, stated that 'initially we were not able to become a natural at FRCOAT's technology'. After six months, the firms therefore decided to install each other's coating systems: a FRCOAT coating system was installed at MAT, while a MAT coating system was installed at FRCOAT. As one FRCOAT engineer expressed, the installation of each other's technological equipment was experienced as a fundamental step in becoming able to evaluate the partner's technology:

> 'For me this [exchange of coating systems] was the fundamental step in the collaboration which meant that both parties really started working with each other's technology … It was a very interesting step because earlier on we thought that it [partner's technology] was very good, but by using the machines we started experiencing problems … In this way it became possible to list the strong and weak characteristics of the partner's technology.' (FRCOAT engineer)

At the same time, a MAT engineer explicitly stressed the importance of this equipment for their ability to imitate the disclosed knowledge:

> 'During the first months, we just visited them [FRCOAT]. We got a lot of information about their machines and technology. However, we gradually realized that getting a large amount of information on a blackboard and looking at how they turn the buttons was not sufficient … After coating systems were exchanged, both partners started experimenting with it. From then on, we became familiar with the technology [of the other partner].' (MAT engineer)

Through experimenting with the coating system of the other partner, engineers were able to develop the necessary know-how in order to understand and use the other partner's technology. In sum, as in the two previous cases, the presence of similar coating systems seemed to be a crucial factor in generating the ability to acquire and assimilate the disclosed knowledge.

Evolution of Knowledge Transfer

After MAT and FRCOAT succeeded in acquiring and assimilating each other's coating technology, they both started to conduct experiments internally with the other partner's technology. MAT engineers, on the one hand, started examining how FRCOAT's advanced DLC technology could help to optimize their own DLX/DLC technology for applications in the commercial automotive market. FRCOAT engineers, on the other hand, experimented with MAT's DLX/DLC technology to improve their own coating technology for its applications in the racing industry. As in the MAT–USCOAT relationship, engineers from both partners had regular meetings in which the set-up, results and customer evaluations of their experiments were openly exchanged and discussed:

> 'Meetings between technical people [of both partners] were very frequent … We had very open discussions with them. There was no confrontation. The experience of everybody was put on the table.' (MAT engineer)

Interviewees stressed that, as both partners were experimenting with the same technologies but for different applications in different markets, it was interesting to exchange this information without being exposed to the risk that it would trigger competitive threats:

> 'They conducted experiments with our technology which we would never think of … This was very interesting.' (FRCOAT engineer)

'The applications of both technologies were quite different. The applications did not focus on the same markets. At that level there were few synergies. But this was also an advantage because it reduced the likelihood of conflict.' (MAT engineer)

In July 2003, the partners agreed to increase MAT's participation in FRCOAT to 90%, representing a quasi integration of FRCOAT into MAT's diamond-like coating business activity, which was still expanding on a global scale.

Discussion

This study aims at contributing to the alliance literature by taking a process perspective on interfirm knowledge transfer in R&D relationships. Relying on the findings of an embedded case study in which one established company collaborated with three different entrepreneurial partners, we present a theoretical model that indicates the conditions facilitating the initiation of interfirm knowledge transfer as well as conditions and strategies impacting on its evolution. This model (see Figure 2) aims to be comprehensive, presenting conditions and strategies discussed in previous research as well as those newly discovered in this study.

Initiating Interfirm Knowledge Transfer in R&D Relationships

The model first identifies the conditions which facilitate the expert partner's willingness to disclose knowledge, the first step of knowledge transfer, followed by those which facilitate the novice partner's ability to acquire and assimilate knowledge, the second step.

Motivation to Disclose Knowledge

Our data indicate that, in interfirm R&D relationships, disclosure of knowledge can be initiated via technological meetings and visits during which engineers of the novice partner receive detailed information about the technology of the expert partner. Two important conditions which facilitate this process emerge from this study: legal knowledge-transfer clauses and expectations of a long-term relationship.

While previous research (Chen 2004; Mowery et al. 1996) has pointed to equity governance structure as a facilitating condition, this study suggests that this formal condition may not be a sufficient nor necessary condition to motivate the expert partner to disclose knowledge. In the two interfirm relationships that possessed an equity structure (i.e. MAT–RES and MAT–FRCOAT relationships), partners had also negotiated detailed contractual clauses, providing a legal framework for the transfer of knowledge. Asked about their willingness to disclose information, interviewees of the expert partner referred to these 'legal knowledge-transfer clauses' rather than to the equity structure. They stressed that the presence of specific contractual clauses protected them against possible opportunistic abuse by the expert partner. In addition, even in the case of the interfirm R&D relationship (MAT–USCOAT relationship), which was governed by a non-equity structure, the expert partner showed a high willingness to openly disclose their technological knowledge from the beginning. Again, interviewees

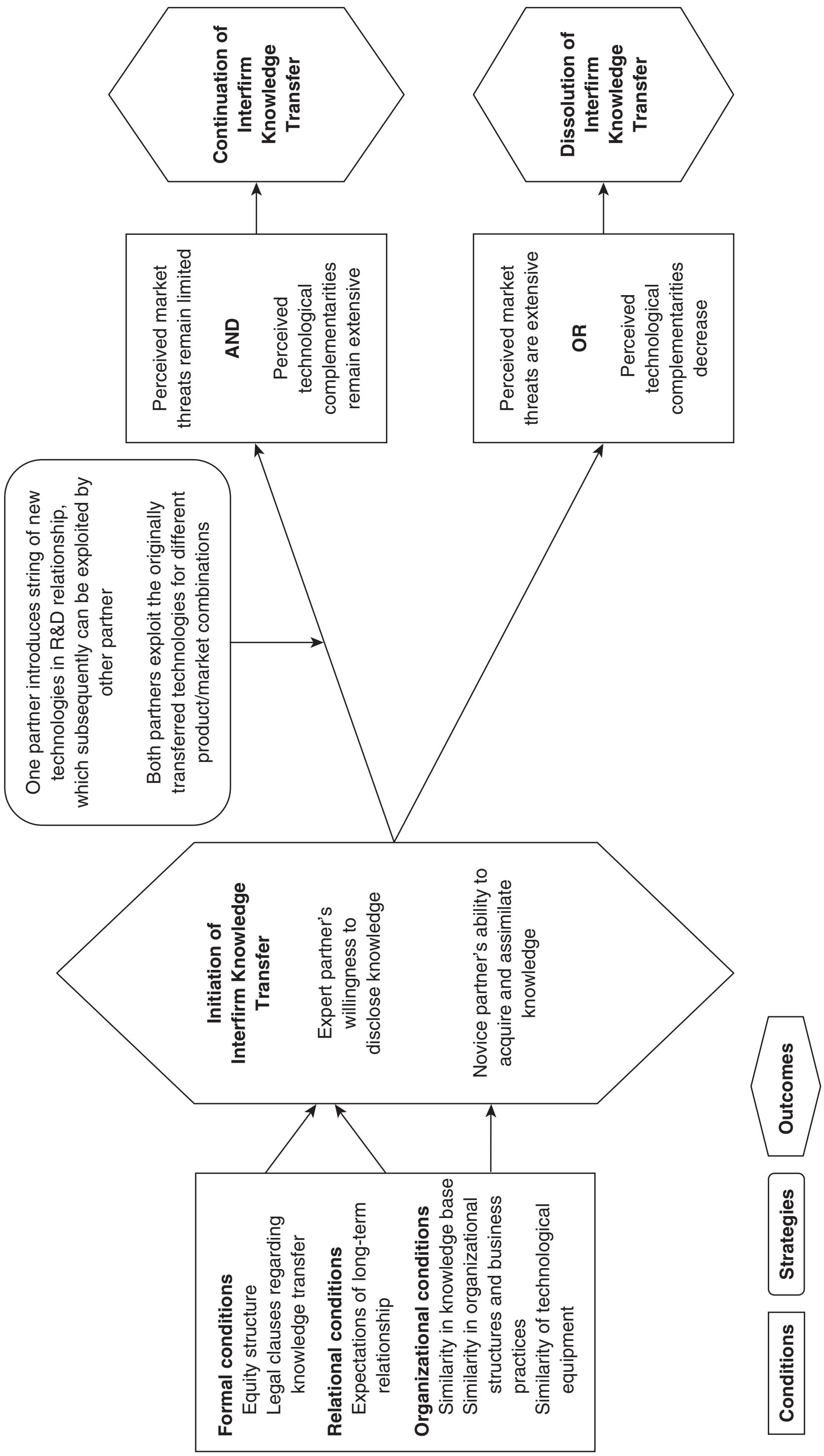


Figure 2. Initiation and Evolution of Interfirm Knowledge Transfer

emphasized the presence of legal knowledge-transfer clauses to explain their transparent sharing of knowledge. These findings are in line with the argument of recent alliance contract researchers (e.g. Reuer et al. 2006) that micro-level governance mechanisms (i.e. specific contractual clauses) can be used as a formal design alternative for macro-level governance structures (i.e. equity ownership structures). Through defining expected behaviours as well as penalties in case of deviation from these behaviours, specific contractual clauses are able to mitigate the risk of opportunism in interfirm relationships. In sum, this study suggests that legal knowledge transfer clauses are an important condition for initiating knowledge transfer in interfirm R&D relationships, even when an equity governance structure is present.

A second important facilitating condition refers to the relational aspect of an interfirm R&D relationship. Previous research (Chen 2004) has identified trust as a relational condition that influences partners' willingness to disclose knowledge in R&D relationships. In accordance with the trust literature (e.g. Cummings and Bromiley 1996; Rousseau et al. 1998), Chen's study (2004) referred to trust in quite general terms as positive expectations of the *intentions and behaviours* of the other partner. In our cases, however, the managers of the entrepreneurial partner pointed to one specific kind of positive expectations to explain their motivation in openly disclosing knowledge: positive expectations of a *long-term duration of the relationship*. These positive expectations about future cooperation seemed to increase the willingness to accept vulnerability, leading to behavioural transparency (Jones and George 1998; Lewicki and Bunker 1996). We therefore interpret the presence of positive expectations of a long-term relationship as a specific indicator of trust that motivates disclosure of knowledge in R&D relationships. Game theorists (e.g. Axelrod 1984; Oye 1986) refer to this bond between the future benefits a firm anticipates and its present actions as the 'shadow of the future'. The longer this shadow of the future, the more likely partners prefer cooperative above non-cooperative behaviour (Parkhe 1993b). It may be that this condition is of particular importance to entrepreneurial companies. In contrast to established companies, entrepreneurial companies are more vulnerable to losing competitive learning races or to being acquired (Alvarez and Barney 2001). We therefore suggest that seeing the benefits of a long-term partnership is crucial for entrepreneurial companies before engaging in risk-taking behaviour such as the disclosure of sensitive knowledge.

Ability to Acquire and Assimilate Knowledge

The second step of knowledge transfer, the acquisition and assimilation of knowledge, manifests itself in our study as an experiential process where engineers of the novice partner evaluate and internalize the technology of the expert partner through conducting experiments with the disclosed technology themselves. We also observed that the presence or absence of similar technical equipment substantially influenced the ability of the novice partner to acquire and assimilate the knowledge that was disclosed by the expert partner. For instance, in the MAT–USCOAT relationship, overlapping knowledge regarding diamond-like coating technology was initially lacking, and the partners had clearly different organizational structures and business practices. While, based on previous research (e.g. Cohen and Levinthal 1990; Lane and Lubatkin 1998; Simonin 1999), one could expect that, in this case, the novice partner's ability to acquire and assimilate knowledge would be limited, we observed a smooth acquisition and assimilation of the technology by the novice partner. Explaining this high ability to evaluate and internalize the disclosed knowledge, interviewees referred to the presence of similar technological equipment as a major facilitator. This same condition was also found in the two other R&D relationships.

Based on these findings, we identify similarity of partners' technological equipment as an additional condition that influences acquisition and assimilation of external knowledge. Nonaka and Takeuchi (1996) as well as Tyre and Von Hippel (1997) already argued that, where users' skills are largely tacit, problem solvers need to observe actual patterns in the operating setting before they can understand and diagnose problems. Likewise, the role of participation — in order for learning to effectively occur — has been stressed by several scholars adopting a situated perspective on learning processes (e.g. Lave 1988; Lave and Wenger 1991). In line with this previous work, the physical environment and more specifically the tools and equipment one is using, can be seen as an inherent part of the setting that allows experiential learning processes to unfold. In other words, the presence of similar technological equipment constitutes an important complement of social interaction, facilitating the acquisition and assimilation of tacit knowledge.

Evolution of Knowledge Transfer in Interfirm R&D Relationships

The model further specifies the evolution of interfirm knowledge transfer in terms of continuation and dissolution as well as the conditions that impact these two possible outcomes. In addition, we identify and assess two strategies that may increase the likelihood of continued interfirm knowledge transfer.

Conditions that Influence Evolution of Interfirm Knowledge Transfer

In two of the three interfirm R&D relationships, partners continued knowledge transfer after the novice partner had acquired and assimilated the technology of the expert partner. In the MAT–USCOAT and MAT–FRCOAT relationships, technological meetings were regularly organized, resulting in bilateral information exchange of internal experiments; however, interfirm knowledge transfer quickly dissolved in the MAT–RES relationship. Our data point to the evolution of perceived technological complementarities between partners as one of the main drivers behind these different dynamics. In the case of dissolution, MAT quickly realized that RES's DLC technology had limited potential value for its DLX/DLC development activities. As a result, perceived technological complementarities between partners decreased, which in turn reduced the motivation of MAT engineers to further engage in technological meetings with RES engineers. In contrast, in the two other interfirm R&D relationships, interviewees stressed that, as each partner experimented with the same technology in different settings, they both continued to generate knowledge that was potentially valuable for the other partner. This sustained presence of technological complementarities motivated continuation of interfirm knowledge transfer during regular technological meetings. The further evolvement of the MAT–USCOAT relationship provides additional support for the importance of technological complementarities. After approximately two years of continued interfirm knowledge transfer in the MAT– USCOAT relationship, the transfer of knowledge gradually decreased. Clarifying this evolution, interviewees of both firms referred to the disappearance of perceived technological complementarities between them. In this case, the technological focus of the partners started to diverge, making it more difficult to find common ground and consequently reducing their motivation to engage in bilateral exchange of information about individual experiments.

While the presence of technological complementarities seems to be a necessary condition to continue interfirm knowledge transfer, our data suggest that it is not a sufficient one. In both the MAT–USCOAT and the MAT–FRCOAT relationships, interviewees pointed to the absence of perceived market threats as an additional condition that seems to be necessary to continue knowledge transfer. It was stressed that, as both partners were focusing on clearly different applications for different markets, the risk of market competition between them was limited, allowing for the continuation of interfirm knowledge transfer. In contrast, market threats were perceived to be present in the MAT–RES relationship. In particular, MAT feared that interaction with the 'scientists' from RES would result in unintended knowledge spillovers to potential customers. These considerations added to the dissolution of the knowledge transfer between MAT and RES.

From these findings, we argue that, in R&D relationships, knowledge transfer is likely to continue between partners if (1) perceived technological complementarities remain extensive *and* (2) perceived market threats remain limited.

Finally, this study suggests that, in contrast to several alliance scholars (e.g. Larson 1992; Ring and Van de Ven 1994; Uzzi 1997) who argue that resilient trust stimulates partners to continue knowledge transfer, resilient trust is not a sufficient condition for the continuation of interfirm knowledge transfer in R&D relationships. For instance, in the MAT–USCOAT relationship, resilient levels of trust emerged both at the managerial level (one MAT manager referred to the emergence of a 'friendship relationship' with the CEO of USCOAT) and the operational level (one USCOAT engineer stressed a 'collegial bond with engineers from the other partner'). However, despite this trusting relationship, MAT's motivation to continue disclosing knowledge drastically decreased once the technological complementarities between the partners diminished. This latter finding corresponds with the argument of Madhok (1995a) that, when a long-term structural disequilibrium in contributions between collaborating partners emerges, the bonding properties of the social dimension (i.e. resilient trust) become inadequate, leading to a reduced willingness to invest time and effort in the relationship. We therefore argue that the presence of resilient trust may not compensate for the disappearance of technological complementarities to continue interfirm knowledge transfer in R&D relationships.

Strategies that Facilitate Continuation of Interfirm Knowledge Transfer

Our model not only identifies two conditions that seem to be important to continue interfirm knowledge transfer, but it also suggests two strategies to organize an R&D relationship such that market threats between partners remain limited and technological complementarities between partners remain present. A first strategy can be found in the work of Alvarez and Barney (2001). Examining multiple alliances between entrepreneurial and established firms, they observed some successful R&D relationships in which a clear division of responsibilities had emerged between the partners. In these cases, the entrepreneurial partner was responsible for continuously developing new technologies that were potentially valuable for the established partner; and the established partner, after acquiring and assimilating these new technologies, was responsible for commercially exploiting them. In other words, the entrepreneurial partner introduced a 'string of new technologies' (Alvarez and Barney, 2001: 145) in the relationship, which subsequently could be commercially exploited by the established partner. We acknowledge that this strategy has huge potential for continuation of unilateral interfirm knowledge transfer. As one partner continuously introduces new technologies in the relationship, technological complementarities between partners are constantly renewed. In addition, as only one partner is responsible for commercializing the technologies, there is no issue of market competition in such relationships.

Alvarez and Barney (2001: 143) recognize that this strategy has one particular limitation: 'the need for large investments in basic R&D at the *entrepreneurial* partner'. Introducing a continuous stream of new technologies requires broad and somewhat diversified investments in basic R&D. However, given the limited financial resources of entrepreneurial companies, such firms may be hesitant to conduct such costly and risky R&D activities. Our data point to a second limitation of this strategy. The MAT–RES relationship indicates that the motivation of the *established* partner to acquire a string of new technologies may be limited. In this case, partners had signed an R&D agreement, stipulating that MAT would fund basic R&D projects at RES. Theoretically, this R&D agreement gave RES the opportunity to come up with a string of new technologies that subsequently could be transferred to MAT. However, because of its focus on obtaining commercial revenues from its existing DLC/DLX technology, MAT was not eager to spend time and effort on discussing RES's initiatives to come up with new technological opportunities. In other words, MAT's intent to acquire and assimilate knowledge about RES's explorative technological efforts became limited due to other priorities (Hamel 1991). As a result, these new R&D projects failed in renewing technological complementarities between RES and MAT.

Next to this strategy of introducing a string of new technologies in the R&D relationship, our own data suggest another strategy to continue interfirm knowledge transfer. We observed that, in the two cases of continuation, both partners internally exploited the initially transferred knowledge for clearly different product/market combinations. As partners focused on different market applications, they perceived limited competitive threats between them. At the same time, the partners' use of the same technology in different settings ensured that technological complementarities remained present. As a result, partners were motivated and able to continue knowledge transfer in terms of bilateral information exchange of internal experiments.

However, we acknowledge that this strategy also faces some limitations. First, partners can only apply this strategy when the technology has the potential to be exploited in different application domains and markets. Second, we observed that, when partners individually exploit the originally transferred technology for different product/market combinations, they are likely to start adjusting the technology through combining it with other kinds of knowledge. As the MAT–USCOAT relationship illustrates, such internal 'knowledge transformation' (Garud and Nayyar 1994) might cause a divergence of technological focus, which subsequently reduces technological complementarities between the partners. Third, we expect that this strategy is only feasible when sufficient entry barriers, restricting the ability of one partner to enter the product/market combinations of the other partner in the future (Robinson and McDougall 2001), are present. If entry barriers are not present, it would be fairly easy for one partner to switch to the other partner's product/market combinations in the future. As a result, partners might remain concerned about competitive risks, discouraging knowledge transfer. In both the MAT–USCOAT and the MAT–FRCOAT relationship such entry barriers were perceived to be present. For instance, in the MAT–FRCOAT relationship, MAT interviewees stressed that FRCOAT was not likely to become active in industrial-wear applications because this entrepreneurial partner could not generate the necessary financial and operational resources to do so. At the same time, FRCOAT interviewees stated that, because of the particular nature of the racing industry, MAT faced huge entry obstacles.

Conclusion

It is widely recognized that the formal design of relationships influences the process of interfirm knowledge transfer. Previous empirical research on interfirm knowledge transfer (e.g. Chen 2004; Mowery et al. 1996; Muthusamy and White 2005) has mainly focused on the distinction between equity and non-equity ownership structures as a formal condition that influences the effectiveness of interfirm knowledge transfer. This study, however, indicates that this well-researched dichotomy of equity/non-equity relationships does not cover the complex and numerous formal design alternatives to motivate disclosure of knowledge in R&D relationships. In particular, our data suggest that R&D relationships which do not possess an equity ownership structure can be as effective in motivating knowledge disclosure as long as detailed legal knowledge-transfer clauses are implemented in the contract. Based on these findings, we encourage scholars to examine the impact of both macro-level (i.e. equity versus non-equity structure) *and* micro-level (i.e. specific contractual clauses) governance mechanisms on the potential for interfirm knowledge transfer.

In addition, this study suggests that managers tend to combine formal *and* relational governance approaches to mitigate the risk of opportunism. While previous research has mainly conceptualized formal safeguards (e.g. legal clauses and/or financial hostages) and relational governance (e.g. building a trustful relationship) as alternative and even substitutive options (Dyer and Singh 1998; Larson 1992; Madhok 1995b), we observed that partners negotiated detailed legal knowledge transfer clauses and, at the same time, spent time and effort in creating positive expectations about long-term cooperation. In our cases, this combinative approach turned out to be very successful in motivating expert partners to fully disclose their technological knowledge. This observation also seems to support recent research (e.g. Klein Woolthuis et al. 2005; Poppo and Zenger 2002), suggesting a complementary relationship between contracts and trust.

This study also provides a richer perspective on the role of relation-specific investments or investments that have limited value outside the interfirm relationship (Dyer, 1997). It contributes to the transactional value perspective (Dyer 1997; Zajac and Olsen 1993) which, in contrast to transaction cost scholars (e.g. Klein et al. 1978; Williamson 1985), emphasizes the value creation properties instead of cost implications of relation-specific investments. In particular, our data indicate that the relation-specific investment of similar technological equipment for transferring knowledge between partners has value-generating properties. This particular type of investment allows creation of a physical environment in which acquisition and assimilation of tacit technological knowledge is facilitated. We therefore argue that, when collaborating partners aim to transfer technological knowledge, the advantages of investing in similar technological equipment (i.e. increased ability to acquire and assimilate knowledge) may outweigh its disadvantages (i.e. additional costs). At the same time, we acknowledge that the presence of similar technological equipment might increase the risk of unintended knowledge spillovers as the partner's ability to evaluate and imitate knowledge is likely to be extensive. Further research examining the advantages and disadvantages of such relation-specific investments in different kinds of collaborative settings therefore seems to be necessary.

A final contribution of this study is related to the stability of interfirm knowledge transfer in R&D relationships. Some alliance scholars (Khanna et al. 1998; Hamel 1991) indicate that, because of changing pay-off structures, interfirm knowledge transfer is an inherently unstable phenomenon. In contrast, other scholars (e.g. Larson 1992; Ring and Van de Ven 1994; Uzzi 1997) suggest that positive trust dynamics motivate partners to expand their relationship, triggering sustained continuation of knowledge transfer. Our study provides a more balanced view on the evolution of interfirm knowledge transfer. On the one hand, our data suggest that, after transfer of the initially desired knowledge, expected future pay-offs of the relationship can remain quite stable. In particular, we found that, as long as perceived technological complementarities remain present and perceived market threats remain limited, the perceived future gains of the relationship are likely to remain positive, allowing for the continuation of interfirm knowledge transfer. These two conditions can be realized through either the strategy of one partner introducing a string of new technologies or both partners exploiting the transferred knowledge for different product/market combinations. On the other hand, our data question the notion of resilient trust as a sufficient condition for continuation of interfirm knowledge transfer. We argue that the long-term social bonding properties of resilient trust may not compensate for short-term disturbances in expected pay-offs, which are caused by decreased technological complementarities and/or increased market threats.

As a final reflection, we point to the need for additional research on the initiation and evolution of interfirm knowledge transfer in other organizational settings. In this study, the observed technological trajectory was one in which interdependencies between the different interfirm relationships remained limited as the core company (i.e. MAT) preferred to maintain bilateral links with the different partners. However, Dyer and Nobeoka (2000) have already pointed to the possibility of applying a more multilateral approach, where interactions among all participating partners are stimulated by the core company. Such alternative approach might require other conditions and processes to facilitate and continue knowledge transfer. We therefore stress the need for additional case studies in other contexts to develop a more general theory on the initiation and evolution of interfirm knowledge transfer.

In sum, this study provided an enriched view on the *process* of interfirm knowledge transfer in R&D relationships. We hope that our suggestions for future research may encourage scholars to continue exploring the process of knowledge transfer in a variety of organizational settings.

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