Learning and Innovation in Inter-Organizational Relationships and Networks

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Publication date:
2006

CentER

Discussion Paper

No. 2006–39

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March 2006

ISSN 0924-7815

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Revised version, March 2006

Summary

This paper gives a survey of insights into inter-firm alliances and networks for innovation, from a constructivist, interactionist perspective on knowledge, which leads to the notion of 'cognitive distance'. It looks at both the competence and the governance side of relationships. Given cognitive distance, organizations need to align cognition sufficiently to enable the fast and efficient utilization of opportunities from complementary capabilities. This, I propose, is done by means of a culturally mediated 'organizational cognitive focus'. The problem with that is that it yields a greater or lesser organizational myopia that, for the sake of innovation, needs to be complemented by means of outside relations with other firms, at larger cognitive distance. Hence the importance of networks for innovation. On the governance side, the paper gives a review of relational risks and instruments to manage them. Next to the effects of cognitive distance, the paper analyses the effects of density and strength of ties in innovation networks, concerning both competence and governance.

JEL code: D23, L14, L22, L24, O31, O32, Z13.

Key words: Inter-organizational relationships, networks, competence, governance, innovation, cognitive distance.

Introduction

Increasingly, it has been recognized that firms need outside relationships for innovation, in the development of new products, production processes, markets, or forms of organization, and for learning, in the development of new competencies. That is the subject of the present chapter. The subject is covered by a large literature (Lundvall 1988, Porter 1990, Hamel & Prahalad 1990, Hamel 1991, Kogut & Zander 1992, Nooteboom 1992, Hagedoorn 1993, Hagedoorn & Schakenraad 1994, Nooteboom 1999, Ahuja 2000, Rowley et al. 2000, Hagedoorn & Duysters 2002, Duysters & de Man 2003). The basic idea that for innovation firms need to open up to outside relationships, which goes back at least as far as Lundvall (1988), has recently received a new buzz-word label of 'open innovation' (Chesbrough 2003).

In innovation, it is useful to distinguish between exploitation, with incremental improvements on existing dominant designs, and exploration, with radical breakthroughs that develop into new dominant designs (March 1991). On the firm level exploration may, for example, be operationalized as patents in patent classes in which the firm did not have patents before (e.g. in Nooteboom et al. 2005). On an industry level, exploration may be operationalized as an innovation 'new to the world', as is the custom in innovation statistics. In learning, it is customary to distinguish between learning by communication, i.e. the acquisition from others of knowledge that is already available, and 'experiential learning' that may generate new knowledge by discovery or invention. Similar to the distinction between exploitation and exploration, the literature on organization yields the distinction between

'single-loop' and 'double-loop' learning (Argyris & Schön 1978). The former preserves a mental frame, basic design, logic or architecture, while the latter breaks through to novel basic principles. A fundamental, key question is how the latter may emerge from the former, or how exploitation may lead to exploration (Nooteboom 2000).

For outside means and conditions for innovation, not only alliances are relevant, but also conditions of national innovation systems (NIS) and conditions of location ('externalities'), in regional innovation systems (RIS). There are large literatures on both, but these will not be included in the present chapter, which focuses on inter-firm relationships. Inter-firm relationships for learning and innovation clearly go beyond inter-organizational dyads, to include network effects, i.e. effects of the structure and strength of ties between firms, and interactions between structure and strength. That is included in the present chapter, and on that subject also there is a large literature (e.g. Granovetter 1973, Burt 1992, Powell & Smith-Doer 1994, Powell et al. 1996, Uzzi 1996, 1997, Koza & Lewin 1998, Oliver & Ebers 1998, Ebers 1999, Ahuja 2000, Rowley et al. 2000, Rothaermel 2001, Duysters et al. 2001, Beerkens 2004, Nooteboom 2004a).

The purpose of the present chapter is to give a survey of this complex field of alliances and networks for innovation, without being able to claim a complete survey of its vast literature, with an emphasis on a coherent causal analysis that integrates at least some of the many factors that have been found to play a role. In particular, it will look at issues of both competence, which are clearly central in innovation and learning, which is about developing competence, and governance, concerning the management of relational risk, which cannot be ignored (Williamson 1999, Nooteboom 2004b). For example, the role of network structure cannot be properly understood in looking only at either competence or governance. Density of ties, for example, may obstruct the flexibility and variety needed for learning, but may also be needed for trust, reputation or shared norms for the sake of governance.

The chapter employs multiple perspectives, from economics, sociology and cognitive science. Economics is needed for considerations of efficiency, sociology for interaction, and cognitive science because learning is, after all, the central issue.

The chapter proceeds as follows. First, it summarizes the constructivist, interactionist view of knowledge employed in this chapter. That is a crucial step. According to that view, cognition is based on categories that re constructed in interaction with the world, particularly interaction between people. Since people construct their cognition along different life trajectories, through different environments, they differ in their cognition to the extent that those paths are different. In other words, there is greater or lesser 'cognitive distance' between people (Nooteboom 1992, 1999).

Second, this chapter looks at the implications for the firm, from the perspective of both competence and governance, and its need for outside relations, from a competence perspective. Given cognitive distance, organizations need to align cognition sufficiently to enable the fast and efficient utilization of opportunities from complementary capabilities. This, I propose, is done by means of a culturally mediated 'organizational cognitive focus'. The problem with that is that it yields a greater or lesser organizational myopia that, for the sake of innovation, needs to be complemented by means of outside relations with other firms, at larger cognitive distance (Nooteboom 1992). Hence the importance of networks for innovation.

Third, this chapter looks at the governance side of relations, in a review of relational risks and instruments to manage them. One relational risk results from resource dependence on partners, some of which may result from relation-specific investments in the relationship, as argued in transaction cost economics (TCE). While TCE neglects innovation, it will be argued that under innovation, additional kinds of relation-specific investments arise, in building mutual understanding across cognitive distance, and in building relation-specific trust.

Fourth, this chapter analyzes in more detail the sources of novelty in IOR's, in particular the role of variety and cognitive distance, as both an opportunity, for competence, and a problem, for both competence and governance. Here, it also analyses the effects of density and strength of ties in innovation networks, concerning both competence and governance. The chapter closes with an indication of lines for future research.

Cognitive construction

Since organizational learning pertains to cognition, it stands to reason that we should look to cognitive science for requisite insight. Here, a possible misunderstanding of terminology should be eliminated from the start. In this chapter, the terms 'knowledge' and 'cognition' have a wide meaning, going beyond rational calculation. They denote a broad range of mental activity, including proprioception (grasp, touch, grip, etc.), perception, sense making, categorisation, inference, value judgments, and emotions.

Concerning competence and knowledge I adopt a 'situated action', 'constructivist' view of cognition, as most authors do in the literature on organisational cognition and learning (for surveys, see Hedberg 1981, Cohen & Sproull 1998, Meindl, Stubbard & Porac 1998). 'Situated action' entails that knowledge and meaning are embedded in specific contexts of action, which yield background knowledge, as part of absorptive capacity, which cannot be fully articulated, and always retain a 'tacit dimension' (Polanyi 1962). This view is also adopted, in particular, in the literature on 'Communities of practice' (COP, Brown & Duguid 1991, 1996, Lave & Wenger 1991, Wenger & Snyder 2000). According to a social constructivist view of knowledge, people

1. *construct* their cognitive categories, or mental models, by which they perceive, interpret and evaluate phenomena,
2. *in interaction* with their physical and, especially, their social environment.

The resulting mental frameworks constitute 'absorptive capacity' (Cohen & Levinthal 1990). People can turn information into knowledge only by assimilating it into those frameworks, and thereby they shape and mold it. Consequently, to the extent that people have developed their cognition in different environments or conditions, they interpret, understand and evaluate the world differently (Berger & Luckmann 1966). As a result, there is greater or lesser 'cognitive distance' between people (Nooteboom 1992, 1999).

The constructivist view goes back to the work of Piaget and Vygotsky, in developmental psychology, and the 'symbolic interactionism' of G.H Mead (1934), in sociology, and has later been called the 'experiential' view of knowledge (Kolb 1984) and the 'activity' view (Blackler 1995). More recent work in neural science is providing further scientific underpinnings of the constructivist perspective, by showing how it works in terms of the development of neural structures, in what is becoming known as the perspective of 'embodied cognition' (Damasio 1995, 2003, Edelman 1987, 1992, Lakoff & Johnson 1999). A key characteristic of embodied cognition is that it sees cognition as rooted in brain and body, which are in turn embedded in their external environment. This is consistent with the 'situated action' perspective indicated above.

A cognitive view of organizations and IOR's

Economic theories of organization, in particular transaction cost economics (TCE), look at organisations as systems for governance, to reduce transaction costs, by means of incentives, monitoring and control. However, professional work requires considerable autonomy for its execution and is hard for managers to monitor and evaluate. Rapid innovation increases

uncertainty of contingencies and makes formal governance, especially governance by contract, difficult to specify, which increases the need for collaboration on the basis of personal trust. If specification of detailed contracts is nevertheless undertaken, it threatens to form a straightjacket that constrains the scope for innovation. Furthermore, the attempt to use contracts to constrain opportunism tends to evoke mistrust that is retaliated by mistrust, while in view of uncertainty there is a need to use trust rather than contract.

Beyond governance, there are implications for competence. If the situated action view of competence is true, then canonical rules, i.e. all-encompassing and codified rules, for executing work are an illusion, since they can never cover the richness and variability of situated practice, which require informal improvisation and workarounds that have a large tacit component that cannot be included in codification of rules, as recognized in the literature on COP (Brown & Duguid 1991). The proof of this lies in the fact that 'work to rule' is a form of sabotage.

Using the perspective of embodied cognition, the view in this chapter is that organization functions primarily as a cognitive 'focusing device', for reasons of both competence and governance. In order to achieve a specific joint goal, on a higher level than basic needs, the categories of thought (of perception, interpretation and value judgment), of the people involved must to some extent be aligned (Kogut & Zander 1992, Nooteboom 1992, 2000). Alignment entails that cognitive distance must be limited, to a greater or lesser extent.

The main purpose of organizational focus is to reduce cognitive distance, in order to achieve a sufficient *alignment* of mental categories, to understand each other, utilise complementary capabilities and achieve a common goal. Note that, given the wide notion of cognition used here, focus has perceptual, intellectual and normative content. It includes views of how people 'deal with each other around here'.

To achieve such focus, organisations develop their own specialised semiotic systems, in language, symbols, metaphors, myths, and rituals. This is what we call organisational culture. This differs between organisations to the extent that they have different goals and have accumulated different experiences, in different industries, technologies and markets. Organisational culture incorporates fundamental views and intuitions regarding the relation between the firm and its environment ('locus of control': is the firm master or victim of its environment), attitude to risk, the nature of knowledge (objective or constructed), the nature of man (loyal or self-interested) and of relations between people (rivalrous or collaborative), which inform content and process of strategy, organisational structure, and styles of decision-making and coordination (Schein 1985).

Organizational focus also has functions of selection and adaptation. In selection, it selects people, in recruitment but often on the basis of self-selection of personnel joining the organization because they feel affinity with it, and adaptation, in the socialisation into the firm, and training, of incoming personnel.

Elements of this idea of organization are not new. It connects with the idea, in the organisation literature, that the crux of an organisation is to serve as a 'sensemaking system' (Weick 1979, 1995), a 'system of shared meaning' (Smircich 1983) or 'interpretation system' (Choo 1998). I propose that this yields a more fundamental reason for firms to exist than the reduction of transaction costs, although transaction costs are also part of the story (Nooteboom 2000). In a firm, people need to achieve a common purpose, and for this they need some more or less tacit shared ways of seeing and interpreting the world and regulating collaboration.

Note that the notion of organisational focus does not entail the need for people to agree on everything, or see everything the same way. Indeed, such lack of diversity would prevent both division of labor and innovation within the firm. As discussed in Nooteboom (1999) there is a trade-off between cognitive distance, needed for variety and novelty of cognition, and

cognitive proximity, needed for mutual understanding and agreement. In fact, different people in a firm will to a greater or lesser extent introduce elements of novelty from their outside lives and experience, and this is a source of both error and innovation (Dimaggio 1997). Nevertheless, there are some things they have to agree on, and some views, often tacit, which they need to share, on goals, norms, values, standards, outputs, competencies and ways of doing things.

An implication of the notion of a firm as a focusing device is that the need to achieve a focus entails a risk of myopia: relevant threats and opportunities to the firm are not perceived. To compensate for this, people, and firms, need complementary sources of outside intelligence, to utilise 'external economy of cognitive scope' (Nooteboom 1992). This yields a new perspective on inter-organisational relationships, next to the usual considerations, known from the alliance literature. This perspective is consonant with the notion of double embeddedness, indicated before, of minds in organisation, and organisations in outside networks. It also fits well with the prevalent idea in the literature on innovation systems that innovation derives primarily from interaction between firms (Lundvall 1988).

Concerning the boundaries of the firm, the present theory yields a prediction that is opposite to that of classical transaction cost economics, and which is particularly relevant in innovation. With increasing uncertainty, in terms of volatility of technology and markets, firms should not integrate activities more, as transaction cost theory predicts, but less, because the need to utilise outside complementary cognition is greater. The argument from TCE was that under uncertainty one needs the greater power of management by fiat within a firm, to monitor behaviour and resolve conflicts. Here, the counter-argument is that under the volatility of innovation the risk or organizational myopia is greater and hence there is a greater need for outside complementary cognition, with 'external economy of cognitive scope'. The prediction of less rather than more integration under uncertainties of innovation has been confirmed empirically by Colombo & Garrone (1998), who found that in technologically volatile industries, as measured by patent intensity, the likelihood of alliances rather than mergers and acquisitions is higher than in the absence of such volatility.

Implications of the theory for the size of the firm, and for differences between large and small firms, are beyond the scope of the present chapter.

Relational risk

Even when the focus is on competence, as here, in the study of learning and innovation in IOR's, issues of governance, concerning relational risk, cannot be ignored, because innovation has implications for forms of governance, which in turn have implications for the content, strength and structure of ties between firms. For a discussion of governance we must first turn to the risks that governance aims to control.

There are two fundamental kinds of risk: of holdup and of spillover. As defined in TCE, the problem of hold-up results from dependence, in the form of switching costs: if the relationship breaks, costs have to be incurred anew. Switching costs are caused, in particular, by investments that are specific to the relationship.. Next to the types of specific investment recognized in TCE (in location specificity, tangible asset specificity, and human asset specificity), in innovation specific assets are needed to develop mutual understanding, under conditions where knowledge is in flux, and to build up personal trust, under conditions where uncertainty precludes governance by contract and reputation mechanisms are not yet in place, while both may be highly relation-specific.

In relationships, one may also lose a hostage, mostly in the form of sensitive information, particularly in innovation. There are also opportunity costs: the loss of the value that the current partner offers relative to the next best alternative. This depends on the availability of

alternative partners, or the possibility of conducting an activity oneself, and the extent that the partner offers something unique.

Spillover risk entails that knowledge that constitutes competitive advantage, as part of core competence, reaches competitors and is used by them for imitation and competition. That is of particular relevance in innovation. The risk may be direct, in the partner becoming a competitor, or indirect, in networks, with knowledge spilling over to a competitor via a partner. In the past, many firms have been overly concerned with spillover risk. First of all, one should realise that to get knowledge one must offer knowledge. The question is not how much knowledge one loses, but what the net balance is of giving and receiving knowledge. Second, when knowledge is tacit it spills over less easily, or is more 'sticky' (Utterback 1981, von Hippel 1988, Brown & Duguid 2001) than when it is documented. However, even then it can spill over, for example when the staff or the division in which the knowledge is embedded are poached, or when the staff involved have more allegiance to their professional colleagues, also in rival firms, than to the interests of the firm (Grey & Garsten 2001), or professional vanity leads them to divulge too much in meetings with outside colleagues. Furthermore, the question is not whether *information* reaches a competitor but whether he will also be able to understand it, i.e. turn it into *knowledge*, and to turn that it into effective competition. For this he needs to understand it, and his absorptive capacity may not enable that (Cohen & Levinthal 1990). There may be 'causal ambiguity' (Lippman & Rumelt 1982). Next, he will need to effectively implement it in his organization. And finally, if by that time the knowledge has shifted, spillover risk drops out.

Governance

In the IOR literature there is a big and ongoing debate on the question to what extent governance is a matter of control, on the basis of the deterrence of opportunism, or can go beyond that, in trust based on solidarity or benevolence. According to TCE, it is impossible to reliably judge possible limits to other people's opportunism, and therefore trust does not yield a reliable safeguard (Williamson 1975: 31-37). If trust goes beyond calculative self-interest, it yields blind, unconditional trust, which is not wise and will not survive in markets (Williamson 1993). From a social science perspective, many others take the view that trust is viable, without necessarily becoming blind or unconditional (Macauley 1963, Deutsch 1973, Granovetter 1973, Ouchi 1980, Gambetta 1988, Bradach and Eccles 1989, Helper 1990, Hill 1990, Bromiley and Cummings 1992, Murakami and Rohlen 1992, Dyer and Ouchi 1993, Ring and Van de Ven 1992, 1994, Gulati 1995, McAllister 1995, Chiles and McMackin 1996, Noorderhaven 1996, Nooteboom et. al.1997, Das & Teng 1998, 2001, Nooteboom 1999, 2002). A committed partner does not immediately exit from the relationship in case of unforeseen opportunities or problems, but engages in 'voice' (Hirschman 1979, Helper 1987).

What are the sources of collaboration? On what basis do people rely on each other? Reliance may have rational reasons and psychological causes, and combinations of them. The psychological causes go beyond the present chapter. For rational reliance it is important to know what reasons people may have to act in a reliable fashion, i.e. to act to the best of their competence to satisfy expectations. Adapting a scheme proposed by Williams (1988), Nooteboom (2002) proposed the scheme of reasons for intentional reliability that is specified in Table 1. Note that instruments and concepts from TCE have been built in. While governance goes beyond control, it still includes it.

Table 1 about here

Reasons for reliability are split in two ways. One split is between micro, particularistic, relation-specific reasons, and macro, universalistic, institutional reasons, outside the relationship. The second split is between extrinsic self-interested motives, by which a trustor can try to control a trustee, and more intrinsic motives, whereby the trustee may feel little inclination towards opportunism, from a motivation to act loyally or benevolently. This distinction between self-interested motives, which yield a basis for control, and motives to act benevolently, which go beyond control, plays an important role in the trust literature, as indicated.

According to Table 1, control on the basis of self-interest has two forms. One is to limit opportunities for opportunism, in constraint of action, by legal enforcement (macro) or hierarchical direct control (micro). The second is to use incentives, on the basis of reputation (macro) or the trustee's own material interest in the relation, on the basis of trustor's value to him, or costs of switching to a different relationship, or a risk of losing a hostage (micro). The role of hostages is adopted from transaction cost economics (TCE). Hostages may take the form of strategically sensitive information (that the trustor may threaten to divulge to trustee's rivals), minority shareholding, or staff seconded by the trustee to the trustor (who may be poached if the trustee misbehaves). Other-directed reasons include institutions in the form of values and norms of decent conduct, identification with a community (macro), empathy or identification within a relationship (Lewicki & Bunker 1996) and routinized conduct (micro). Empathy may carry an affect of solidarity, and identification tends to carry an affect of friendship or comradeship, or at least a sense of shared destiny. Not mentioned in Table 1 is the possibility of using trusted third parties for intermediation or arbitration (Simmel 1950, Shapiro 1987, Nooteboom 2002).

The context of innovation makes special demands, and imposes limits, on the configuration of instruments. The high uncertainty involved in, especially radical, innovation, entails that the specification of contracts is problematic, and can constrain the scope of innovation when imposed anyway. Hierarchical control also is problematic because monitoring is problematic, due either to the high level of professional labour involved, when the level of technology is high, or the condition that knowledge is typically highly tacit in innovation, or the condition that knowledge can be greatly in flux, in innovation, or all three in combination. Under the high flux of knowledge and entry and exit of players that is typical of especially early stages of radical innovation, reputation mechanisms and reliable third parties (reliable in both competence and fairness) may not yet be in place. If all those instruments from Table 1 are unavailable, one is left with the sources of benevolence, on the basis of institutionalized ethics or personalized trust. However, such generalization would be too hasty. What instruments are available depends on details of ties and structure of the network, to be analyzed later in this chapter.

Sources of learning and innovation

Here, the focus is on learning in the sense of discovery or invention, which is connected with innovation. Especially from an evolutionary perspective on innovation (Nelson & Winter 1982), heterogeneity or variety is a crucial source of innovation, and this has been taken up in the alliance literature (Stuart & Podolny 1996, Almeida & Kogut 1999, Rosenkopf & Nerkar 2001, Fleming 2001, Rosenkopf & Almeida 2003, Ahuja & Katila 2004). However, that literature does not explain how, precisely, heterogeneity produces innovation. Furthermore, heterogeneity in networks has two dimensions that are seldom explicitly distinguished. One is the number of firms involved, and the pattern of ties between them, and the other is the

difference, in particular cognitive distance, between them. Between firms, in contrast with people, cognitive distance is the difference between the cognitive foci of firms, with two main dimensions of technological knowledge/competence and moral principles for internal governance.

A large steam of literature has indicated only the problems rather than also the benefits of such cognitive distance. In a study on alliance formation in the semi-conductor industry, Stuart (1998) argued that the most valuable alliances are those between firms with similar technological foci and/or operating in similar markets, whereas distant firms are inhibited from cooperating effectively. In a similar vein, the diversification literature argues that most is to be learned from alliance partners with related knowledge and skills (Tanriverdi & Venkatraman 2005), or from areas that firms already possess capabilities in (Penner-Hahn & Shaver 2005). In a survey of key customer relations of 180 young technology-based firms, Yli et al. (2001) hypothesized that relationship quality, in terms of goodwill trust and shared norms and reciprocal expectations would have a positive effect on knowledge acquisition, but found a significant negative effect. In the literature on international business also, a pervasive view is that cognitive distance is a problem to be overcome. Johanson & Vahlne (1977, 1990) employed the notion of 'psychological distance', which is seen as having an adverse effect on cross-cultural communication. When learning is discussed, in that literature, it is mostly seen as learning to cope with transnational differences, by accumulating experience in cross-border collaboration (e.g. Barkema et al. 1997), rather than taking those differences as a potential source of learning to change home country products or practices.

Nooteboom (1999) proposed an interaction between the advantages and disadvantages of distance, as follows. The ability to understand each other (in absorptive capacity) and to collaborate declines with cognitive distance, whereas the novelty value of the relationship, i.e. its potential to generate Schumpeterian novel combinations, increases with distance. If the two effects are linear with respect to distance, and if learning or innovation performance of the relationship is proportional to the mathematical product of novelty value and mutual absorptive capacity, the result is an inverted-U shaped performance as a function of distance, as illustrated in Figure 1.[1] This implies an optimal cognitive distance, which is large enough for partners to offer each other something new, but not so large that they cannot understand each other or come to agreement.

Figure 1 about here

In Figure 1, the downward sloping line of absorptive capacity is not fixed. It is subject to an upward shift, as a function of the accumulation of knowledge in relevant fields and experience in IOR's. That yields a shift to higher optimal cogntive distance.

Wuyts et. al. (2005) put the hypothesis of optimal cognitive distance to two empirical, econometric tests. The first test was conducted on a combination of the basic hypothesis of optimal cognitive distance with the second hypothesis that cognitive distance decreases with increased frequency and duration of interaction. As argued by Gulati (1995) and others (Simmel 1950, McAllister 1995, Lewicki & Bunker 1996), familiarity may breed trust, which is good for governance. However, it may also reduce variety of knowledge, which is bad for innovative performance. This yields the hypothesis of an inverted U-shaped relation between radical technological innovation and the extent to which firms ally with the same partners

[1] In figure 1, the vertical axis may be a single one, of percentages, if we define absorptive capacity as the percentage of knowledge that can be absorbed and novelty value as the percentage of novelty. Then innovative performance, as the product of absorption and novelty, also results as a percentage.

over time. That hypothesis was tested on data on vertical alliances between biotech and pharma companies, and was supported.

In fact, the derived hypothesis is subject to nuance. If two partners have access to other, non-overlapping partners, so that they are continually being refreshed with new, non-overlapping knowledge, cognitive distance between them is maintained, so that the relationship may remain innovative even when it lasts long. This is, in fact, the point, or part of the point, of Burt's (1992) notion of bridging structural holes.

The second test by Wuyts et al. was conducted on a combination of the basic hypothesis of optimal cognitive distance with a second hypothesis that the likelihood of a collaborative alliance increases with the expected performance of collaborative innovation. This yielded the derived hypothesis that the likelihood of an alliance for innovation has an inverted U-shaped relation with cognitive distance. That hypothesis was tested on data on horizontal alliances in ICT industries. Cognitive distance was measured by differences in degrees of specialisation in different dimensions of technology, inferred from patent data. Partial support was found. Technology-related measures of cognitive distance were not found to have any significant effect, but several indicators of differences in firms' organisational characteristics proved to have the expected inverted U-shaped effect. Several considerations were offered to explain why organisational aspects turned out to be more important than technological ones in ICT industries.

Nooteboom et al. (2005) conducted a more complete empirical, econometric test, on the basis of a large set of data on inter-firm alliances over a ten-year period, in a variety of industries. Cognitive distance was reduced to technological distance, which was measured on the basis of correlation between profiles of technological knowledge composed from patent data. Innovative performance was measured as new patents, in successive years, with a distinction between exploratory patents, in patent classes that are new to the firm, and exploitative patents, in patent classes in which a firm already has patents. Absorptive capacity was made endogenous, in that the downward sloping line of absorptive capacity (cf. Figure 1) was taken as a function of technological capital, accumulated from past R&D, measured by the variety of accumulated patents. The hypothesis of performance as an inverse-U shaped function of cognitive distance was confirmed, including the further hypotheses that optimal distance is higher for exploration than for exploitation, and that technological capital has a positive effect on absorptive capacity. The effect for exploration can de attributed to a higher slope of the novelty line, in Figure 1: in exploration the positive effect of cognitive distance on novelty value is higher. The effect of past R&D can be attributed to an upward shift of the line for absorptive capacity.

As expressed, but only in part, by the declining line of absorptive capacity and ability to collaborate, cognitive distance has implications for governance. Cognitive distance hinders monitoring and control of opportunism. Furthermore, to bridge cognitive distance, firms need to make investments in mutual understanding that are to a greater or lesser extent specific in the sense of transaction cost economics, particularly in exploration. As noted before, according to transaction cost logic such specific investments contribute to dependence and risk of *hold-up*. Also, again by transaction cost logic, if collaboration requires a relation-specific investment in mutual understanding, such investment will only be elicited if partners expect the relationship to last sufficiently long to recoup that investment.

Networks

Inter-firm relations go beyond dyads. There may be multiple participants and indirect linkages in networks. Those have implications for the value, risk and governance of relations. One may value a partner not for himself but for the access that he provides to others. In an alliance, one

may need to assess the risk that the partner may be taken over by a competitor, possibly in an indirect way, in which he takes over a majority shareholder of the partner (Lorange and Roos 1992). Spillover risk can be indirect, through partners to competitors. If one already has many partners, adding a new one might raise spillover risk for existing partners. The literature yields some puzzles concerning networks.

One stream of literature on networks suggests that players who span 'structural holes' can gain advantage (Burt 1992). If individuals or communities A and B are connected only by C, then C can take advantage of his bridging position by accessing resources that others cannot access, and by playing off A and B against each other. As a result, the third party is maximally powerful and minimally constrained in his actions. This yields Burt's (1992) notion of *tertius gaudens,* indicated earlier by Simmel (1950).

A central debate in the network literature is, or used to be, whether in networks for innovation ties should be sparse and weak (Granovetter 1973, Burt 1992), or dense and strong (Coleman 1988). The argument in favour of sparse and weak ties is that in frequent and intense interaction between many actors, in a dense structure, much of the information circulating in the system is redundant. If A is connected to B, and B is connected to C, then A does not need a direct connection to C because he can access information from C through B (Burt 1992). The cost of redundancy, in setting up and maintaining ties, increases with the strength of ties. Thus, according to Burt (1992), efficiency can be created in the network by shedding redundant ties and selectively maintaining only a limited set of ties that bridge 'structural holes'. Then, time and energy are saved for developing new contacts to unconnected nodes. Apart from efficiency, bridging structural holes also provides advantages of 'brokerage'. Also, strong, i.e. intense and long lasting ties, can lead to reduced variety and hence reduced potential for learning (Burt 2000). Or, in other words, and more precisely, strong ties can lead to too little 'cognitive distance' (Nooteboom 1999). Originally (Granovetter 1973), density and strength of ties were conflated, while later it was recognised that they represent separate features (Burt 1992). It is conceivable that sparse ties may be strong and that dense ties may be weak (Reagans & McEvily 2003). Indeed, the present chapter will give illustrations of that.

According to Coleman (1988), by contrast, dense and weak ties ('cohesion' or 'network closure') facilitate the role of social capital such as the build-up of reputation, trust, social norms, and social control, e.g. by coalition formation to constrain actions, which facilitate collaboration.

In this debate the empirical evidence is mixed. McEvily and Zaheer (1999) found evidence against redundancy in an advice network, for the acquisition of capabilities. Ahuja (2000) found evidence against structural holes, for innovation in collaboration. Walker et al. (1997) found evidence in favour of cohesion, for innovation in biotechnology. In view of these apparently inconsistent findings, subsequent studies have taken a 'contingency' approach (Bae & Gargiulo 2003), investigating environmental conditions that would favour the one or the other view (Podolny & Baron 1997, Ahuja 2000, Rowley et al. 2000, Podolny 2001, Hagedoorn & Duysters 2002).

In fact, this apparently contradictory evidence is not surprising. The two opposite claims concerning density and strength of ties may well both be true. As noted by Burt (2000, quoted also by Rowley et al. 2000: 373): '.. the closure and hole arguments are not as contradictory as they might seem .. The ambiguity stems in large part from the different roles that social capital plays in the study populations'. More precisely, I propose here, they simply represent different aspects of collaboration: a competence dimension, in terms of the access to new knowledge, the combination of complementary competencies, joint production of new knowledge, and the creation of Schumpeterian 'novel combinations', and a governance dimension of managing relational risks of opportunism and spillover or loss of appropriability

of returns on innovation. Concerning competence, particularly in exploration of novel opportunities, one may need weak ties, in the bridging of structural holes. For governance, one may need cohesion. This was also Ahuja's (2000) argument: structural holes are less likely to be beneficial when overcoming opportunism is critical for success. When combining competence and governance perspectives, there are arguments both in favour and against density and strong ties, in innovation and knowledge transfer (Uzzi 1996, 1997).

Another cause of the ambiguity of outcomes in empirical studies lies in the neglect of the content of ties (Gilsing & Nooteboom 2005). Hansen (1999) made a distinction between acquiring knowledge about and knowledge from others, i.e. between the identification of the location and usefulness of knowledge, and the transfer or sharing of knowledge. He, and earlier Uzzi (1997), argued and found empirical evidence that strong ties promote the transfer of complex knowledge, while weak ties promote the transfer of simple knowledge.[2]

Following sections give more recent results concerning the effects of network structure and strength of ties, which help to resolve some of the puzzles.

New developments

Gilsing & Nooteboom (2005) offer several new hypotheses as modifications and additions to the extant literature on the effects of network structure and strength of ties. First, let us consider network structure. A first hypothesis is that networks for radical innovation or exploration (March 1991, Nooteboom 2000) require density of ties. There are three arguments from considerations of competence. First, under the radical uncertainty of exploration it has not yet been established what knowledge, and hence what sources, are relevant. As a result, one has to hedge one's bets concerning what sources to tap, including sources that may turn out to be irrelevant. This is an argument for *redundancy in type of sources*. Second, there is high volatility of existence and network membership of firms, so that firms that give access to knowledge now may not exist tomorrow. As a result one has to hedge one's bets concerning what firms will remain in existence. One may need to maintain a tie with C even if one also has a tie with B who also has a tie with C, to cover for the risk that B drops out for access to C. This is an argument for *redundancy in ties.* Third, under the conditions of a large variety of knowledge, or potential knowledge, in exploration, with large cognitive distances, one may need a third party to help understand a given party, by supplementing one's absorptive capacity, or to check the accuracy of information. This is an argument for *redundancy for triangulation*. The argument that density enables triangulation was proposed earlier by Rowley et al. (2000). However, they argued that it was most important in exploitation, while Gilsing & Nooteboom argue that it is most important in exploration.

Fourth, there is an argument by default: in exploration *costs of redundancy matter less*. They are typically smaller and less relevant than in exploitation. Under exploration, (specific) investment in a tie tends to be *smaller*, in mutual understanding, designing and executing experiments, building and testing prototypes, in comparison with investments for exploitation, such as investment in scaling up, efficient production systems with corresponding division and coordination of labour, distribution channels, brand name, and the like. Note that there is room for contingency here. In some industries, such as aerospace, prototyping and testing may require investments that are as high, or even higher, than for production. Second, costs are *less relevant*. As the innovation literature argues, in exploration competition is aimed at technical and commercial viability, while low cost emerges as a competitive advantage only later, after the market has materialised and price competition increases from new entrants who

[2] Hansen (1999) associated simple knowledge with codified knowledge (information) on opportunities regarding where specific knowledge was located and by whom. Complex knowledge was associated with more tacit knowledge on in-depth technological issues.

jump on the bandwagon of new market success (Abernathy 1978, Abernathy & Utterback 1978, Abernathy & Clark 1985).

There are also arguments in favour of density from considerations of governance. As indicated before, the literature (Coleman 1988) proposes that density favours the functioning of social norms, social control, coalitions, sanctions, and reputation mechanisms. These mechanisms of social control are particularly needed in exploration, in view of the limited feasibility of contractual control, due to uncertainty concerning the content and conditions of a contract and limited ability to assess and control contract compliance. On the other hand, from a governance perspective density also brings risks. Having a partner who has multiple partners increases his opportunities for switching, which may increase his hold-up power, with more 'opportunities for opportunism'. Density also opens up more avenues for spillover, which may increase risk of loss of competitive advantage. However, as argued by Nooteboom (1999), in radical innovation change of knowledge may be so fast that spillover risk becomes negligible. Hold-up risk from multiple partners is limited if it is balanced, i.e. if all actors have such multiple partnerships, as tends to be the case in a dense network.

Concerning other features of network structure, stability of the network should be low, reflecting frequent exit and entry of network participants, for the sake of novel combinations (see the simulation model in March 1991). Moreover, under such conditions of radical innovation, with uncertainty concerning what elements will emerge and survive in what configuration, centralization is less relevant. Centrality may also yield an obstacle to re-configuration of ties, in attempts to maintain the power invested in established, centralized positions.

For more incremental innovation, in exploitation, the arguments concerning network structure go in the opposite direction. The cost of redundant ties matters since competition has shifted to price, and the size of costs is likely to be high. Since it is now clear what knowledge is relevant, who has it, and network membership is more stable, there is less need to hedge bets by redundancy of ties. Since knowledge is more stable and diffused there is less need for triangulation. Concerning governance, reduction of uncertainty allows for more governance by contracts, lessening the need for dense ties for the sake of a reputation mechanism. As a result of the emergence of dominant designs and the stabilization and diffusion of knowledge, network stability can be larger, and centrality in the network may be needed for efficient coordination in division of labour, in hub-and-spoke type structures. This depends on industry contingencies. Centrality or some density is needed, in particular, if technology is systemic, to ensure that the different components of the system remain in tune with each other (Langlois & Robertson 1995).

Now, let us consider tie strength. According to Granovetter, in personal networks there are four dimensions of tie strength: 'amount of time, emotional intensity, intimacy (mutual confiding) and reciprocal services' (Granovetter 1973: 1361). Gilsing & Nooteboom (2005) proposed the following, modified dimensions: scope of shared activities, i.e. the range of issues incorporated in the tie, frequency of interaction, duration of the relationship, trust and openness, and the extent of formal, contractual control. The scope of a tie refers to its content. Scope may refer to width and depth of knowledge shared, but also to different contents of knowledge, concerning technology, materials, sources, markets, government regulations, finance, accounting, and gossip on the technical or intentional reliability of potential or actual partners.

The following hypotheses were proposed for exploration networks. Duration should be low, since long duration would conflict with the need for network flexibility, for the sake of Schumpeterian novel combinations, and is likely to lead to too much reduction of cognitive distance as a source of innovation. Then high frequency of interaction is needed as an alternative way to recoup the specific investments relevant in exploration. High frequency is

also consistent with the speed of developments associated with radical innovation. The limited viability of contracts in exploration, due to uncertainty, and the need to share tacit knowledge, in intensive and frequent interaction, plead for high trust and openness and low contractual control. The wide range of uncertainty that characterizes exploration, and the importance of reputation mechanisms, argued before, plead for a wide scope of ties.

Again, the hypotheses concerning networks for exploitation go in the opposite direction, although there are industry contingencies. In exploitation specific investments tend to be larger, with a longer economic life, requiring longer duration of relationships to recoup investments, while longer duration is less of a problem due to less volatility and the emergence of dominant designs in technology and organization. Dominant designs and codification and wider diffusion of knowledge yield less need for a high scope and high frequency of interaction. Due to less uncertainty contracts are more feasible, and they are more needed because due to lesser scope and frequency of interaction trust and openness are less, and due to lesser density of networks, argued before, reputation mechanisms are weaker.

Beyond the industry case studies of Gilsing & Nooteboom (2005), Gilsing et al. (2006) tested network effects on innovation in an econometric model, using the same data used by Nooteboom et al. (2005) for testing the inverse U-shaped effect of cognitive distance, discussed earlier. In this model in addition to the effect of cognitive distance, effects were added of network density and centrality of a firm in the network. Here, the same approach was used as in Nooteboom et al. (2005), in the sense that separate effects were hypothesized on absorptive capacity and novelty value. In line with the logic of structural holes from Burt (1992), network density was hypothesized to have a negative effect on novelty value. In line with the logic set out above, density was hypothesized to have a positive effect on absorptive capacity. For centrality of the firm 'betweenness centrality' was taken, which measures the extent that a firm lies on shortest paths between other firms, and thus occupies a position at a 'crossroads'. Note the difference here between cognitive distance between any two firms, and 'social distance' as the number of firms on the shortest path between any two firms. The hypothesis was that betweenness centrality has a positive effect on novelty value, with the firm able to cross information from many, also socially distant sources, and a negative effect on capacity to absorb such variety of information.

Discussion

In the model of Nooteboom et al. (2005), in addition to the inverse-U shaped effect of cognitive distance on innovation, illustrated in Figure 1, particularly for explorative innovation, and a positive effect of technological capital, accumulated from past R&D, on absorptive capacity, an additional, unexpected effect was found. Technological capital turned out not only to have a positive effect on the intercept of the line for absorptive capacity, as illustrated in Figure 1, but also to have a negative effect on the slope of the novelty line. This indicates an effect of *decreasing* returns to learning, or 'boredom effect', in the sense that the more one knows, the further away one has to go, at larger cognitive distance, to still *find* something new. This, then, comes in addition to an effect of *increasing* returns to knowledge, in the sense that the more one knows the easier it is to *absorb* something new. The upshot is that at very high levels (width and depth) of accumulated knowledge it is difficult for an organization to find outside sources of further new knowledge, and outside collaboration then focuses on relations at small cognitive distance, to exploit the large knowledge potential within the firm. This is illustrated in Figure 2, which reproduces the interaction of effects of cognitive distance and knowledge capital, according to the estimated model, for the range of observations in the study. The figure shows that for the highest observed level of technological capital optimal technological distance is zero.

Figure 2 about here

Concerning the effects of structure and strength of ties, while the two can and should be distinguished, there is interaction between them (cf. Rowley et al. 2000). For example, for governance one can use contracts or trust/openness (in tie strength), or, alternatively, density for the sake of social control (structure). Another example is that when specific investments are needed, to recoup those one needs either high frequency or long duration (strength), while the latter entails a certain stability of the network (structure). Here elements of structure and strength can substitute for each other. This gives an opportunity to reconcile the otherwise contrary effects of 'weak ties' vs. 'closure'.

What is the empirical evidence, in the extant literature? Rowley et al. (2000) made the customary hypotheses that in exploration density and strength of ties are negatively related and in exploitation are positively related to performance, and they concluded that '..our results do not strongly support the theoretical arguments regarding the main effects of strong ties or density …'. They did find evidence for the interaction effects between tie strength and structure. Hagedoorn and Duysters (2002) found a positive effect of 'multiple, redundant ties' under exploration and Beerkens (2004) found empirical evidence for dense ties in exploration in three industries: chemicals, cars, and pharmaceuticals. Gilsing & Nooteboom (2005), in two qualitative case studies of exploration and exploitation in multi-media and biotechnology, found considerable evidence in favour of most of their hypotheses, contrary to previous literature, but not for all. Here, the focus is on the anomalies and their interpretation.

Most of the anomalies were in exploration in biotechnology, in interaction between small biotech firms and universities. One of the theoretical arguments was that in exploration knowledge is more tacit, which complicates knowledge diffusion and the build-up of a joint understanding (competence), and also limits the use of contracts for formal control (governance). However, it turned out from the biotechnology case that while in exploration knowledge was indeed highly tacit in the exploration *process*, exploration *outcome* was highly codified, which, counter to the assumption, enabled governance by formal contracting and monitoring. Another empirical anomaly in biotechnological exploration was the moderate centralisation of the network structure, and the narrow scope of ties. The explanation of the latter lies in the highly science-based nature of biotechnology, which makes the role of universities and research institutes a more central one and eliminates the need to explore subjects related to organisation, production, marketing and distribution. The most important anomaly in biotechnological exploration was that network structure was stable and, correspondingly, ties had long duration. However, closer analysis showed a structure that did satisfy theoretical considerations, but in an unforeseen way, in a dual, 'small world'-like structure, with a dense and stable core community 'at home', yielding high absorptive capacity with respect to less durable ties to such communities elsewhere. In this way, the potential for inertia in long local ties was compensated by continual influx of novelty from more flexible outside ties.

In exploitation in multimedia, anomalies were: fairly high density and frequency of interaction. Related to that, governance can still be informal and trust-based, and serve as a complement to formal control. This deviation from hypotheses may be attributable to the fact that in the integration of a systemic technology some exploratory activity was still going on, in exploitation, which put limits on the codifiability of knowledge. Then, also in a setting of exploitation, high frequency is warranted and governance needs to be of a more informal type.

An important characteristic of knowledge that varied between both industries was the extent to which it was systemic versus stand-alone knowledge (Teece 1986). This yields an important feature of the content of ties. This issue has received limited attention in the

literature on networks and alliances (but see Teece 1986, Langlois and Robertson 1995). It yields important, relatively new insights. In multimedia, high density was needed to preserve systemic integrity of the emerging technological architecture while the combination of high frequency, short duration, wide scope and informal governance created cognitive diversity. In other words, stability in structure was needed in view of the systemic nature of technology, while potential disadvantages of that were compensated by features of the ties.

In sum, how structure and strength of ties enable and constrain learning and innovation in inter-firm networks depends on the extent to which knowledge is tacit versus codified as well as on the degree to which it is systemic or stand-alone. When knowledge and technology are systemic, this can require frequent interaction and informal governance even towards exploitation. Also, while knowledge can be tacit in exploration, the results of exploration can be codified, allowing for contractual control even in exploration. The most important conclusions perhaps is that in exploration local stability and density of structure, with ties of long duration, can be complemented by more sparse and flexible outside ties, in a small-world structure.

The findings seem in line with the findings by Beerkens (2004) on the role of redundancy in networks in exploration and exploitation in chemicals, cars and pharmaceuticals. The findings concerning the interaction between structure and strength of ties is in line with the findings of Rowley et al. (2000). The results on industry effects are in line with a recent study by Hagedoorn et al. (2005), who found that understanding the phenomenon of repeated ties, as a dimension of tie duration, requires a careful consideration of the specific industrial context. Overall, the analysis yields some explanations of the ambiguity of empirical results in previous literature, as discussed in the introduction. The analysis shows that for this it is important to look at the interaction of structure and strength of ties from the perspective of both competence and governance.

There are also interaction effects between cognitive distance, network density and centrality of a firm. The hypotheses of Gilsing et al. (2006) concerning combined effects were almost completely confirmed. The model implies interaction effects. High cognitive distance or high centrality, both yielding high novelty value but low absorptive capacity, can be compensated with high network density to repair absorptive capacity. Alternatively, high centrality, yielding much novelty but a danger of information overload, may be complemented with alliances with firms at small cognitive distance to help absorb it.

Some of the effects, according to the model estimate, are given in Figures 3 and 4. The graphs cover the range of observations.

Figure 3 about here

Figure 3 shows that within the range of observations, at mean network density we find that if betweenness centrality is high, yielding problems of absorptive capacity, one cannot afford to also have large technological distance to direct partners, which would compound the problem.

Figure 4 about here

Figure 4 shows that even at the mean level of betweenness centrality one needs a certain amount of network density to yield requisite absorptive capacity, and an intermediate (not too high) level of technological distance is best at all levels of network density.

Conclusions and research agenda

There is a vibrant activity of ongoing research of innovation in IOR's, in which the literatures on inter-firm alliances, with an emphasis on strategic behaviour of firms, and the literature on networks, with an emphasis on structural effects, are coming together in the study of strategy in networks. That constitutes progress. Important for innovation is the distinction, in recent research, between two dimensions of variety: number of actors and the structure of ties between them, and cognitive distances between them. Related to this is the distinction between cognitive distance, between any two firms, and social distance, defined as the number of intervening firms on the shortest path between the two firms.

A shortcoming in much research still is the neglect to combine issues of competence and governance. That combination is needed to understand the otherwise contradictory results concerning positive and negative effects of network structure and strength of ties. For example, network density may have a negative effect on variety of knowledge and a positive effect on governance by means of reputation and coalition formation. For innovation, ties may need to be weak in duration, size of specific investments and formal contracting, but strong in frequency and scope of interaction, and in trust.

The combination of competence and governance is also of great importance for policy. Focus only on governance can eliminate the variety and flexibility needed for innovation, while focus only on innovation can create havoc with firm interests, in unforeseen relational risks. Another point that is important for policy concerns trade-offs between variety and homogeneity and between stability and change. Variety, in numbers and cognitive distance, is beneficial for radical innovation, but a certain homogeneity and cognitive proximity is beneficial for collaboration. Hence one should make trade-offs and look for optimal variety and distance. Similarly, a certain flexibility and variability of relations is needed for innovation, but also a certain stability, to elicit and enable investments in mutual understanding and trust. Hence one should make trade-offs here as well, in looking for optimal rather than maximal flexibility.

Another lesson, related to the combination of competence and governance, concerns the interaction between structure and strength of ties. Problems resulting from policy measures taken in the one may be compensated by measures taken in the other. There is also interaction between cognitive distance, density of networks and centrality of firms. For example, positive effects on novelty value combined with negative effects on absorptive capacity for cognitive distance and centrality may be compensated by positive effects on absorptive capacity for density. These results have important policy implications for firms. There is no one best network or one best position in a network. The research discussed in this chapter opens up a repertoire of strategies for innovation, in combinations and trade-offs between effects on innovative performance of decision variables concerning the choice of network structure (density), position (central or peripheral), (different dimensions of) strength of ties, and cognitive distance.

Another lesson concerns contingencies of industry, in relation to contingencies in type of technology (systemic, stand-alone), type of knowledge (more or less tacit), and the different effects of tacitness of knowledge concerning products and tacitness in knowledge concerning production.

Following up on the research that combines effects of network structure and strength of ties, and interaction between the two, and on research on effects of cognitive distance, network density and centrality in a network, and interactions between them, a challenge now is the complex task of combining all these factors.

Following up on the research on the effect of the duration of a tie, a challenge is to include the modifying effect of exclusiveness of the relationship, e.g. in terms of non-overlapping ties with other firms that the two firms may have, as a source for revitalizing the relationship. This would combine the effect of duration with the notion of bridging a structural hole.

A particularly interesting avenue for further research appears to lie in the notion of 'small worlds' (Watts 1999). There is empirical evidence, and theoretical argument, in favour of dense and stable local communities, with strong ties, for the sake of high collective absorptive capacity, which have more sparse, weak and flexible ties with more distant communities, to provide requisite variety for novelty.

More attention is required for triads. On the whole, the literature has tended to focus on either two actors (dyads) or many (networks). While some attention has been given to triads, they have remained under-researched (Madhavan et al. 2004). Burt's (1992) studies of bridging structural holes, and studies of roles of third parties or go-betweens (Shapiro 1987, Nooteboom 2002) entail three parties, but there the third party takes up a special intermediary position external to the relation between the other two actors. Simmel's (1950) more extensive analysis of triads, in which any two can form a coalition against the third, who may then switch from the position of *tertius gaudens* emphasized by Burt to a problematic position of being caught 'in the middle' (Krackhardt 1999). As shown by Simmel, in triads any one of the three can help to solve problems between the other two, and there may be effects of rivalry between two in gaining favour from the third, etc. This could yield a source of inspiration for more extensive analysis of triads. The importance of triads goes beyond governance, and has implications for competence. This was already part of the earlier analysis: in a closed or transitive triangle, where each has a tie to the other two, two sides may triangulate their understanding of the third. There are also spillover effects. If A has a tie with B and B has a tie with C, and C is a potential competitor of A, then knowledge transferred from A to B may spill over to C, and for A's control of spillover it matters a great deal whether or not A also has a tie with C. These are just some indicative examples of the importance of triads.

Knoke & Chermack (2005) showed that there is not only the issue whether ties are uni-directional or symmetrical, which tends to be neglected, but also to what extent ties are acknowledged. A may claim a tie to B, as recipient or sender, which is not acknowledged by B. This can have important implications that seem to have been wholly neglected.

Finally, there may be useful spillover from insights from inter-organizational relations to relations between units within organizations.

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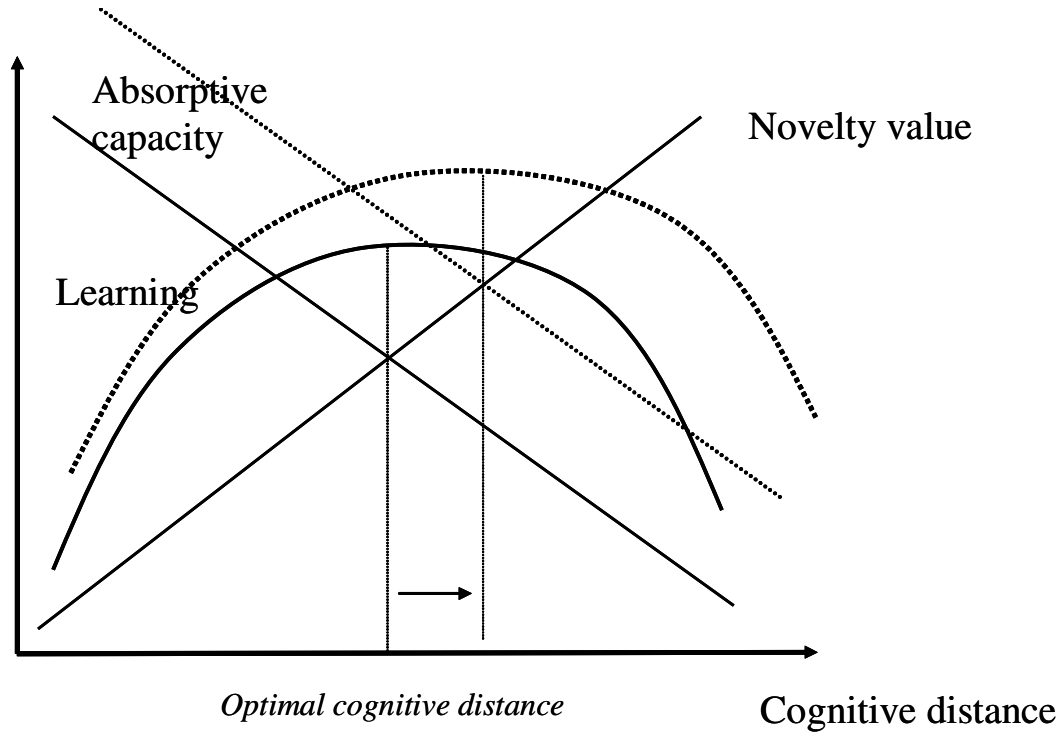
TABLE 1
Sources of (Intentional) Reliability

	macro; universalistic institutional	micro; particularistic, relation-specific organizational
self-interest opportunity control	contracts, legal enforcement	hierarchy, managerial 'fiat',
incentive control	reputation	dependence: unique partner value, switching costs, hostages
other-directed benevolence	social/moral values/norms of proper conduct, sense of duty, bonds of kinship	empathy, routinization, identification, affect, friendship

Source: adapted from Nooteboom (2002).

Figure 1: Optimal cognitive distance



Source: Nooteboom (1999)

Figure 2 Exploration performance as a function of cognitive distance and technological capital (Source: Nooteboom et al. 2005)

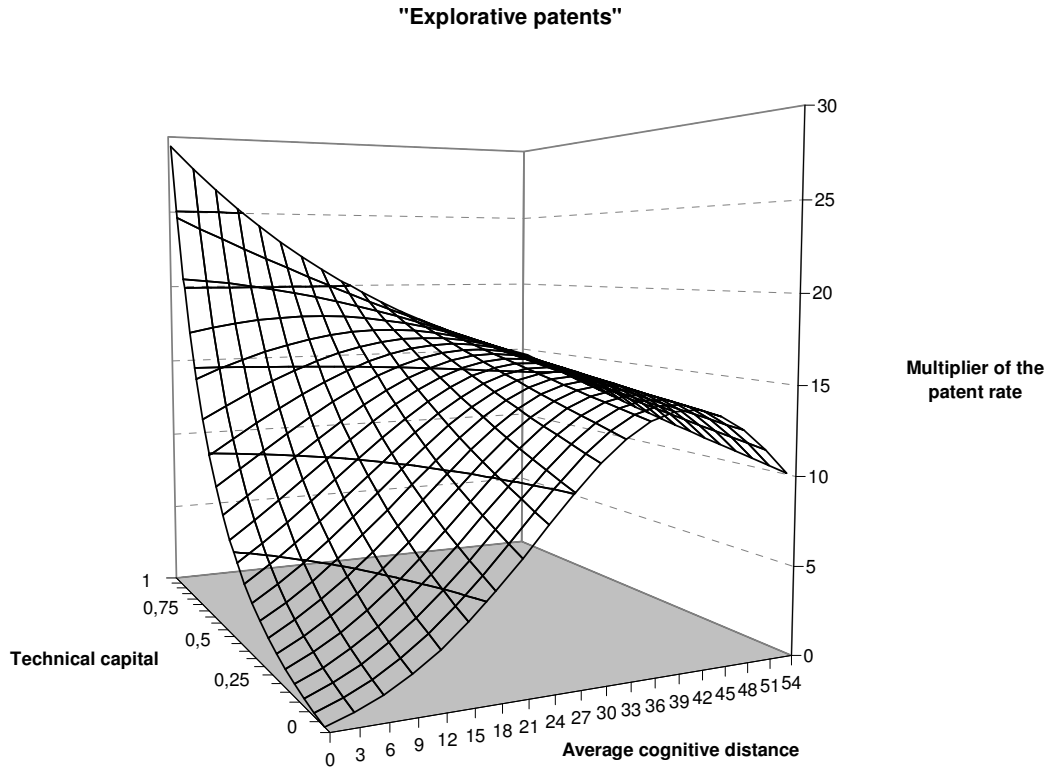


Figure 3 Exploration performance as a function of betweenness centrality and cognitive distance, at mean network density (Source: Gilsing et al 2006)

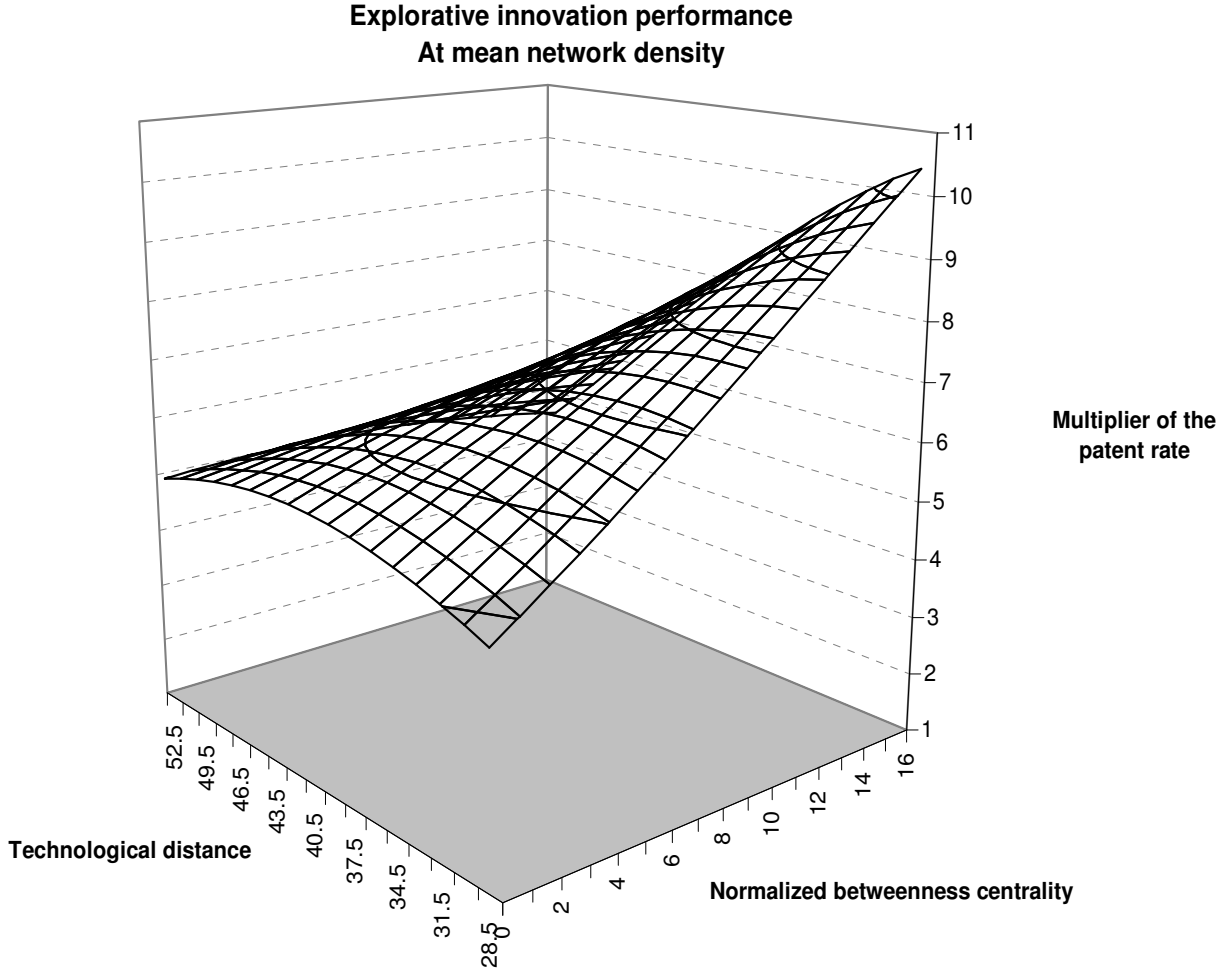


Figure 4 Exploration performance as a function of network density and cognitive distance, at mean betweenness centrality. (Source: Gilsing et al 2006).