Balancing diversity in innovation networks

Trading zones in university-industry R&D collaboration

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Abstract

Purpose – Although the potential of innovation networks that involve both university and industry actors is great variances in cultures, goals and knowledge poses significant challenges. To better understand management of such innovation networks, the authors investigate different strategies for balancing diversity. The paper aims to discuss these issues.

Design/methodology/approach – In this multiple case study, the authors draw on network and trading zone theory to examine the strategies of four research centers that govern university-industry innovation networks.

Findings – The authors provide empirically grounded descriptions of strategies for balancing diversity in innovation processes, extend previous theorizations by suggesting two types of trading zones (transformative and performative), and identify four strategy configuration dimensions (means of knowledge trade, tie configuration, knowledge mobility mechanisms and types of trust).

Research limitations/implications – Further research is needed on transferability of results when, e.g. cultural collaboration and communication patterns change, and performance implications of different configurations. The research provides conceptual tools for future research on the impact of different diversity strategies.

Practical implications – The findings point to the importance of identifying desired types of innovation outcomes and designing the appropriate level of diversity. To implement the selected strategy, managers need to configure communication channels and strength of relationships, establish associated capacity for knowledge transfer and build appropriate levels of trust.

Originality/value – While extant research has provided a solid understanding of benefits from diversity in boundary spanning innovation processes, this paper outlines strategies for managing associated challenges.

Keywords Diversity, Open innovation, Innovation management, Innovation networks, The medici effect, Trading zone

Paper type Research paper

1. Introduction

While research and practice has shown that innovation processes can benefit from diversity, how to design and orchestrate effective collaboration between heterogeneous actors remains an open-ended issue (Hargadon and Sutton, 1997; Chesbrough *et al.*, 2008; Levén *et al.*, 2014). Contemporary firms operate in dynamic technological environments with rapidly rising costs for research and development (R&D) and shortened product and technology lifecycles (Chesbrough *et al.*, 2008; Sandberg, 2014). As a consequence, firms are increasingly streamlined in their operations and have

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typically developed boundary spanning collaborations for knowledge creation (Jonsson *et al.*, 2009). This shift, often described as a movement from closed to open innovation (Chesbrough, 2003, 2006), allows firms to systematically explore a broad range of innovation sources (West and Gallagher, 2006). Open innovation advocates argue that there are particular benefits in combining competencies from academic and industrial sources in networks of innovators (Chesbrough, 2003; Levén *et al.*, 2014). By participating in such innovation networks, universities can receive financial benefits, generate valuable research findings and contribute to economic growth (Etzkowitz and Leydesdorff, 2000; Lind *et al.*, 2013). Some of the potential benefits for a firm participating in innovation networks include a reduction of R&D costs, improved time-to-market and new technological opportunities (Chesbrough *et al.*, 2008). Prior research suggests that innovative breakthroughs often happen at the intersection of fields (Johansson, 2006; Hargadon and Sutton, 1997) when innovators manage to connect fields, problems, or ideas that seemed unrelated. The argument that diversity drives innovation has been referred to as the "Medici effect" – suggesting that innovation stem not from particular fields, but rather from combinations of knowledge and experiences across contexts (Johansson, 2006). But while recent studies have pointed to the growing relevance of external sources of innovation in the context of university-industry relationships, the dynamics in these relationships remain poorly theorized. In particular, discrepancies in incentives pose significant collaboration challenges and accentuate differences between pursuing cutting-edge research and offering expertise to industrial partners (Perkmann and Walsh, 2007).

Although the potential benefits involved with the dynamic diversity in innovation networks are substantial, several key challenges make collaboration between heterogeneous actors challenging. First, there is an inherent conflict in the conditions that facilitate network stability and those that spark innovation. Innovation is facilitated by freedom, political support and open communication, whereas network stability and boundary spanning collaborations often are built on well-defined situations where contracts are needed in order to avoid suspicion of disloyal behavior (Linnarsson and Werr, 2004; Dhanaraj and Parkhe, 2006). Second, collaboration between disparate actors inevitably involves the issue of trust, both in terms of loyalty and competence (Newell and Swan, 2000; Hardwick *et al.*, 2013). Hence, the network must find ways to deal with appropriability and capability assurance. Third, in order to combine their specific knowledge base in innovative ways, network participants need to establish communication channels. They need to create ways to cooperate despite holding different understandings, motives and communication patterns (Galison, 1999). Once knowledge is generated in the collaboration, it needs to be transferred, translated and transformed into practical, commercially viable solutions (Carlile, 2004). Despite the rich literature on boundary spanning innovation, we have very little systematic knowledge of how innovation networks are constructed and orchestrated in terms of diversity.

Building on research that suggests that a firm's collaboration management capability can be a source of competitive advantage (Ireland *et al.*, 2002) and that integrating knowledge across boundaries is an essential characteristic of innovation (Burt, 1992; Hargadon, 2002), we seek to understand these challenges and how they are resolved in practice. In doing so, we employ two complementary theoretical perspectives. First, we conceptualize innovation networks involving university-industry actors as trading zones. Trading zones are interdisciplinary partnerships in which parties face communication barriers but still manage to communicate. Actors engaging in trading zones might not only differ in their understanding of the exchange but also in its purpose (Kellogg *et al.*, 2006). Trading zones can be classified based upon how co-operative the partnership is and how homogenous the end state is (Collins *et al.*, 2007). Different types of trading zones present specific challenges as well as suggested strategies for enabling more successful communication. These include the use of boundary objects (Carlile, 2002; Carlile, 2004), boundary practices and processes (Wenger, 1998), and knowledge brokers (Brown and Duguid, 1998). Second, we examine tie configurations through network theory. On an individual level, strong ties are the relationships we have with our close friends and weak ties are the relationships we have with our acquaintances (Granovetter, 1983). While strong ties support extensive communication and reinforce understandings, weak ties have been shown to stimulate the exchange of knowledge and values between groups (Granovetter, 1973, 1983).

Against this background, we investigate the research question:

RQ1. How can innovation networks configure strategies for diversity?

This question is not only interesting in terms of exploring network dynamics, an area of inquiry raised by a number of scholars (Tushman, 1977; Burt, 1992; Hansen *et al.*, 1999), but also has practical implications for firm-level outcomes. We examine the research question in the context of research centers hosting innovation networks that build on university-industry collaboration. Such collaboration involves highly disparate actors and hence both great challenges and opportunities. We explore the evolution of network relationships and the antecedents and consequences of those relationships. We base our investigation on the assumption that viewing innovation networks as trading zones can support our understanding of them. The notion of trading zones, in this context, refers to the ways in which diverse groups can interact across boundaries by agreeing on the procedures surrounding the exchange rather than on issues pertaining to the meaning of the exchange. We present a case study of four research centers with a history of participating in innovation networks. Based on a cross-case analysis, we present key issues related to idea generation, problem solving and results delivery. Also, we identify specific strategies used to effectively coordinate efforts.

In the following, we first review existing literature about innovation in general and innovation networks in particular. Second, we describe in detail the theoretical framings with which we study university-industry collaboration in innovation networks: trading zones and strength of ties. Third, we outline the research approach, the rationale underlying it and details regarding data collection and analysis. Fourth, we offer a detailed account of the issues and strategies found for managing these networks. Finally, we discuss the contributions of our research and conclude with suggestions for future research and practical management of collaborative innovation efforts.

2. Diversity in innovation networks

2.1 Innovation networks

Contemporary organizations increasingly leverage external knowledge sources in their innovation processes (Chesbrough *et al.*, 2008). Innovations often arise from re-combination of existing methods, components or sub-systems in novel syntheses (Arthur, 2007). Opportunities for such re-combination arise through interactions with distinct contexts where technology or knowledge is applied to similar, but yet divergent, problems (Hargadon, 2002). To increase both the quantity and quality of such interactions firms engage in various types of boundary spanning processes. One way of organizing boundary spanning innovation processes that has drawn particularly large interest is in the context of inter-organizational innovation networks. During the last decades such collaborations has been researched under labels such as open innovation (Chesbrough *et al.*, 2008), ecosystems (Adner, 2006) strategic networks (Gulati *et al.*, 2000), value networks (Kothandaraman and Wilson, 2001) and alliances (Sampson, 2007). While the spark in interest from both practitioners and researchers provides evidence of potential advantages in boundary spanning innovation processes, we still have limited understanding of how to manage them (Dhanaraj and Parkhe, 2006; Lundberg, 2013; Levén *et al.*, 2014).

Organizations differ in their network management capability and these differences may be a source of organization-level competitive advantage (Dyer and Singh, 1998; Ireland *et al.*, 2002). The ability to manage boundary spanning collaborations effectively has been described as a capability that enables a firm to integrate, build and reconfigure internal and external competences to address rapidly changing environments (Teece *et al.*, 1997). Although research indicates that such networks can provide an efficient mechanism for learning and innovation (Rowley *et al.*, 2000), these collaborations have not always been successful. In fact, recent studies suggest that diversity of knowledge, experiences and perspective does not necessarily translate into innovations and that outcomes are dependent on types of ties between actors in these networks (Tortoriello and Krackhardt, 2010). In particular, outcomes from innovation networks are closely related to amount of stability, trust and knowledge mobility.

Successful innovation networks manage to balance dichotomies between diversity and stability in established structures. Innovation network success depends in part on the capability to design and orchestrate relationships between participating actors (Ireland *et al.*, 2002; Dhanaraj and Parkhe, 2006). There is a fundamental tension between innovation on the one hand, and forming close relationship in innovation networks on the other (Bidault and Cummings, 1994). While innovation underscores the importance of flexibility and change, stability and continuity is key for boundary spanning collaboration (Linnarsson and Werr, 2004). Analysis of innovation network stability is hence a key activity in designing these collaborations.

In order to create a dynamic and creative collaboration environment actors also need to develop trust, both in terms of non-opportunistic behavior and competence (Newell and Swan, 2000). Since network structures blur firm boundaries and create mutual dependence between previously independent firms (McEvily *et al.*, 2003), a distinctive characteristic of networks is that partners have to deal not only with the uncertainty in their environment but also with uncertainty related to each other's behavior. An important concern with innovation networks is thus that misunderstandings or conflicts between actors can result in a breakdown of the collaboration (Zaheer *et al.*, 1998). Trust helps defuse such conflicts since trusting partners are more likely to interpret each other's actions in a manner conducive to the stability of the relationship.

Knowledge mobility is the main product of interactions in networks and also a precursor to innovation output (Dhanaraj and Parkhe, 2006). Transferring knowledge across boundaries requires absorptive capacity, i.e. the "ability to identify, assimilate, and exploit knowledge from the environment" (Cohen and Levinthal, 1989, p. 569). At the individual unit level, network position and absorptive capacity has been found to be significantly related to the level of innovation output (Tsai, 2001). A common identity among members in the networks has also been found to increase knowledge mobility since it increases motivation to participate in interactions and willingness to share experiences (Dhanaraj and Parkhe, 2006). Furthermore, social structures in the network impacts knowledge mobility (Brown and Duguid, 2001). As innovation often emerge in unpredictable ways, and informal communication and common practices are essential for knowledge transfer, open forums and informal communication channels are key ingredients of well functioning innovation networks (Tsai and Ghoshal, 1998).

2.2 Balancing diversity

The fundamental logic behind organizing innovation in boundary spanning networks is to leverage benefits associated with diversity. There is however a fine line between diversity, which provides creative and dynamic perspectives, and disconnectedness due to lack of shared knowledge, incentives and identification. Balancing the tension between dynamic diversity and efficient stability in established structures requires careful consideration. In particular, such considerations are essential for university-industry innovation networks since they involve multiple communities of practice (Brown and Duguid, 2001).

Solutions generated from problem-oriented R&D do not constitute innovations until implemented in practice. Innovation involve three phases: generating new ideas, solving problems and implementing solutions in practice (Myers and Marquis, 1969). Each phase is linked with its specific coordination, communication and decision challenges. According to Tushman (1977), the generation of ideas involves external stimuli, problem solving is related to coordinating internal efforts while implementation demands the orchestration of both. Knowledge that is to be transferred from the idea generation phase is often complex, since neither domain-specific experiences nor analytical abilities are easily codified. Also, domain-specific knowledge is, by definition, dependent on its context. In the problem solving and implementation phases, actors also face the challenge of how to actually change existing practice as a result of the innovation (Carlile, 2004). To analyze how diversity can be balanced in university-industry innovation networks we examine communication processes among heterogeneous communities and the role of structures in knowledge transfer, throughout these three phases.

2.2.1 Trading zones. The notion of trading zones was first introduced into studies of collaborative research efforts between heterogeneous communities by Peter Galison (1997, 1999). Galison studied how groups of physicists collaborated, despite differences in purposes, norms, understandings and meanings, without coming to global understandings of these issues. A defining characteristic of trading zones is the problem of communication between communities (Collins *et al.*, 2007). What is striking in Galison's use of the term is how stability and common understanding of exchanged objects is not viewed as a necessity for collaborative efforts. As described by Kellogg *et al.* (2006, p. 39), the absence of shared understanding implies a performative view of exchange between communities:

> Engaging in a trading zone suggests that diverse groups can interact across boundaries by agreeing on the general procedures of exchange even while they may have different local interpretations of the objects being exchanged, and may even disagree on the intent and meaning of the exchange itself.

Collins *et al.* (2007) proposed a general model of trading zones based on two dimensions (figure 1); on the vertical axis, they placed the extent to which power is used to enforce trade; on the horizontal axis, they showed a distinction as to whether or not a new homogeneous culture is created. Based on these characteristics, they presented four different types of trading zones: inter-language, fractionated, subversive and enforced. In the inter-language type of trading zone, collaborative trade efforts result in a shared language. This happens when languages are mixed to the degree that a new one arises, a Creole. The subversive type is a one-way directed influence, where one of the original cultures or languages gradually becomes dominant, such as the position of English as the dominant language of science. In the enforced type of trading zone, trade is imposed on one of the cultures and it takes place without any substantial cultural change. In the upper right corner, where cultures remain heterogeneous and trade is enacted through collaboration, we find the fractionated trading zone. Here, fractions of cultures become the medium for trade, either through the exchange of objects (boundary objects) or through language (interactional expertise).

Expanding their theorizing Collins *et al.* (2010) has suggested that trading zones are dynamic entities that can evolve between the general states outlined in Figure 1. The collaborative and heterogeneous characteristics of university-industry collaboration lead us however to propose that most collaboration between university and industry entities in innovation networks takes place in fractionated trading zone. While some use of power might be present in different phases of collaboration (e.g. managers making strategic decisions and steering through incentives such as research funding), we expect the homogenous/heterogenous culture distinction to be more important for the trading zones in university-industry innovation networks.

Collaboration in the fractionated trading zone is supported by boundary objects and development of interactional experts (Collins *et al.*, 2007). Boundary objects are physical artifacts or representations that "have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation" (Star and Griesemer, 1989, p. 393). Interactional experts hold or acquire knowledge of the involved cultures and, to some degree, mediate differences. Collaborations that are based on interactional expertise are by their very nature challenging and serendipitous, as they require considerable efforts on the part of at least some participants (Collins *et al.*, 2010, p. 21).

2.2.2 Tie configuration. The configuration of ties between actors has been shown to play an integral role in the diffusion of knowledge between actors (Granovetter, 1973, 1983; Krackhardt, 1992). Strong ties are often found in homophilic (love of the same) relationships where they are manifested through extensive communication, trust and shared values (Tallon *et al.*, 2002). Weak ties, on the other hand, are more prone to link

Use of power	Culture: Homogeneous	Culture: Heterogeneous
Collaboration	Inter-language Collaborative trade results in a shared language.	Fractionated Fractions of cultures becomes the medium for trade either through objects (boundary objects) or through language (interactional expertise)
Coercion	Subversive One culture or language gradually becomes dominant.	Enforced Trade is imposed without substantial cultural exchange.

Figure 1.
A general model of trading zones by Collins *et al.* (2007)

individuals and groups that hold differing understandings and cultural values (Granovetter, 1983). Strong and weak ties thus promote different types of communication and diffusion. Capaldo (2007) suggested that innovation is promoted by weak ties on a network level, while firms benefit from strong relationships with their core partners. Such a pattern indicates that the more explorative work benefits from weak ties while exploitation calls for strong ties. Further, the type of knowledge exchanged, in terms of tacit or codified and systemic or stand-alone, will have an impact on the innovation outcomes from different collaboration designs (Gilsing and Nooteboom, 2005). Hansen (1999) examined the role that the strength of ties between units plays in the search and transfer phases of innovation for complex and non-complex knowledge within units of an organization. Complex knowledge is non-codified and/or dependent, e.g. not easily transferred, while non-codified knowledge is closely related to the notion of tacit knowledge. An example of levels of dependency is how software can either be deeply integrated with its surroundings and thus non-transferable (dependent) or stand-alone and easily used in other settings (non-dependent). Hanson concluded that weak ties are beneficial to the search for knowledge but, in combination with complex knowledge, create transfer problems.

Innovation networks between universities and industry involve knowledge transfer between actors with communication problems. An important issue for establishing successful trading zones is to adapt the tie configuration to the type of knowledge that is to be transferred. For example, whether or not the problem description and solution are easily codified affects which type of strategy might be employed with the partner. Non-codifiable problems and/or solutions will force actors to manage either of these issues related to the search or transfer of knowledge. Strong ties might be a hindrance to the search for knowledge but they limit transfer problems, whereas weak ties advantage the search process but cause transfer problems and thereby higher demands for the creation of boundary objects or interactional expertise. These relationships are illustrated in Figure 2.

While strength of ties has been discussed extensively in the innovation literature, recent studies suggest that the impact of tie configuration is complex and that qualitative differences between ties affect innovation outcomes (Tortoriello and Krackhardt, 2010). Specifically, bridges across community boundaries consisting of Simmelian ties, i.e. ties between parties connected to one other that are also both connected to another, third party, have been found to positively impact innovation

KNOWLEDGE / TIE STRENGTH	Strong	Weak
Non-codified, dependent	Low search benefits, moderate transfer problems	Search benefits, severe transfer problems
Codified, independent	Low search benefits, few transfer problems	Search benefits, few transfer problems

Source: Hansen (1999)

Figure 2.
Search and transfer effects associated with four types of knowledge complexity and tie strength

outcomes (Tortoriello and Krackhardt, 2010). The transition from two parties connected through a tie (i.e. a dyad) to three is particularly valuable since it alters impact of self-interest, reduces bargaining power of individual entities, and, facilitates conflict resolution (Krackhardt, 1999).

To examine how diversity is balanced in university-industry innovation networks, trading zones and tie configuration will be applied as analytical tools in these three processes – idea generation, problem solving and implementation – in R&D center's boundary spanning operations.

3. Research method

University-industry R&D centers and participating actors constituting innovation networks involve highly disparate actors, hence they present great promises and significant challenges (D'Este and Patel, 2007; Perkmann and Walsh, 2007). The salience of diversity-related challenges and opportunities suggest that management of these R&D centers compose a suitable research context for examining design and orchestration of diversity in innovation networks (Flyvbjerg, 2006). Relationships between universities and industrial firms are mediated by a complex set of overlapping interactions and institutions (Salter and Martin, 2001), where the dual goals of making an impact in industry as well as in the academic world is a complicating factor. In fact, some research has suggested that university research rarely translates into new products or services for industrial organizations (Pavitt, 2001). Collaboration between heterogeneous actors from universities and industries often involve complicated knowledge sharing, as each partner has their own nomenclature, demands and expectations on innovation (Holmström and Boudreau, 2006). Extensive fieldwork on the socially situated nature of knowing has led to a broad recognition that knowledge sharing is a complex process that goes beyond the mere transfer of abstract bodies of knowledge (Suchman, 1987; Boland and Tenkasi, 1995; Hutchins, 1995). As such, we examine the role of diversity in innovation networks led by university-based R&D centers.

Our research was carried out in the form of a case study that examined collaborative IT innovation efforts between universities and industry actors. A case study is "a research strategy which focusses on understanding the dynamics present within single settings" and "typically combines data collection methods such as archives, interviews, questionnaires and observations" (Huberman and Miles, 2002). The case study approach can be applied to either single or multiple cases. Our research is grounded in a multiple case study of four distinct R&D collaboration selected from a screening process involving in total 12 R&D centers in the IT domain at the universities of Umeå (five), Luleå (five) or both of them (two).

Our data collection and analysis involved four major activities. First, we interviewed key informants from the twelve different R&D centers that we had identified as significant within IT-related collaborative innovation at the two universities. From these centers, we collected background information on their management models, innovation processes and outcomes. Semi-structured interviews with managers of university-affiliated centers lasted approximately one hour. The interviews were recorded, fully transcribed and conducted by the first author. The interviews covered questions regarding all phases of the innovation process. In addition, documents were collected and analyzed. We used ATLAS.ti, software to structure and code the transcribed interviews.

Second, based on our initial analysis we selected four innovation networks, with distinct diversity configurations in terms of knowledge types and number of participating actors, to study in more detail. Our selection was theoretically informed as we were looking for deep insight into problems and solutions rather than a representative sample (Yin, 2003). We invited informants and relevant industrial actors to a seminar where preliminary findings were presented and discussed. Managers from three out of the four centers participated (the manager of the "Project Portfolio" center could not attend).

Third, we analyzed the four cases using within-case and across-case analysis. Our data analysis can be characterized as inductive thematic analysis, as described by Braun and Clarke (2006). For each case, we described the research center's management model, innovation processes and network outcomes. Analyzing across cases, through the lenses of trading zone and strength of ties, we identified specific strategies used to coordinate efforts. Applying trading zones' as analytical lens, we identified issues related to the innovation process as well as strategies that were used to enable communication. With respect to the configuration of ties, we considered the relationships between the three partners in the university-industry network.

Fourth, follow-up interviews with representatives from each center were conducted, transcribed and used to fill in existing gaps. Finally, written summaries of each center were created and a cross-case analysis conducted. These steps are summarized in Table I.

4. Results

This section offers an account of the four R&D centers and innovation networks in which they engage, their management models, innovation processes and outcomes. As illustrated in Table II, these R&D centers vary greatly in terms of types of knowledge traded and tie configurations. Consequently, they face different challenges and problems in their operations.

Phase	Description	Data collected	Data analysis
1. Exploring the research context	Initial interviews conducted and analyzed in order to increase understanding of the research context	12 interviews with managers from different centers, public and internal documents collected	Transcribed interviews and documents coded, first summary of each center and report developed
2. Learning from experiences	Initial report presented and experiences discussed with stakeholders from academy and industry in a workshop. Four centers chosen for in-depth analysis	Notes on discussions taken separately by two of the authors	Notes and perspectives were later compared and discussed
3. In-depth analysis	Collected material from the four centers analyzed, case descriptions written, gaps identified	–	Material from workshop, interviews and documents regarding the four centers analyzed and case descriptions written. Gaps in material identified
4. Validating findings	Follow-up interviews conducted	Four interviews conducted (recorded and transcribed)	New interviews analyzed and gaps in case descriptions covered

Table I.
Research report

In the following, we explore the R&D centers in detail. First, we describe them individually and we present a cross-case analysis.

4.1 The cross-industry center

Management model. The Cross-Industry Center is a collaborative center that brings together industrial user organizations (i.e. plant owners) with business-related problems to solve, product owners and researchers to develop new IT solutions, based on industry needs. The researchers represent fields such as computer science and electrical engineering, applied physics and electronics and information systems, temporarily working together on projects as needed. Plant owners are typically manufacturing organizations such as paper and pulp companies and mining companies who wish to innovate their processes and improve efficiency. While the center collaborates with some system suppliers, the majority of product owners involved in their projects are component suppliers. The center mainly deals with innovation projects, with a focus on producing non-codified knowledge and regional growth through commercial development. The projects involve creation of products such as engineering prototypes, assisting new companies to succeed in the R&D phase and creating new spin-off companies.

The center was established in 2004 and has since grown to involve 64 industry partners and 46 researchers. The center can be described as a grid of loosely coupled actors that takes part in some collaborative events at the center level, such as workshops and presentations, while the actual collaborative practices take place in projects that are formed with a smaller number of selected actors with larger degrees of similarities from the network. The center is managed by a board of directors, executive management group and a research management team. The fourth author serves as part of the executive management group while the second has been on the research management team. Key personnel for the center include the project officers who participate in industry visits, listen to the explicit wishes of the product owners and facilitate the matching of skills and techniques between researchers and plant owners.

Innovation processes. To encourage collaboration, the Cross-Industry Center arranges forums so that the actors can meet, present their competencies and challenges and discover matching innovation partners. To establish project feasibility and determine whether there is the potential for innovation, partners can propose pre-study projects lasting between one and three months and costing between 200,000SEK and 400,000SEK in total. If successful, the pre-study is turned into a proper project.

R&D Center	The Partner Center	The Project Portfolio Center	The Network Center	The Spin-Off Center
Number of organizations in the alliance	1	9	64	n/a
Type of knowledge	Dependent	Non-codified	Varying	Codified and independent
Application area	Forestry machines	Product innovation methods in large-scale firms	IT in processing industries	Medical technology

Table II. Overview of R&D centers

Another way in which projects are initiated is through the matching of problems with solutions by the project officers:

> From the beginning, we thought that everything would come from the industry, but that's not the case. Rather, ideas comes from all three types of actors. Both [project officers] have become key figures there since they spend a lot of time with the industry. They have very good dialogue and many times they are the ones that hear about the needs and see that this is something we can solve. (Cross-Industry Center Manager).

Involving the product owner early on in the innovation project is seen as critical. Usually, the product owner involved in the projects will be component suppliers rather than system suppliers. These component suppliers are smaller firms (as compared to system suppliers) with shorter development cycles, allowing for exploratory projects that can be implemented locally. The product owners are interested in participating because they have limited R&D centers of their own and appreciate the access to the resources at the university. Also, even if the researchers and those with the problems to solve can implement solutions in practice, neither one is interested in developing the product further. Thus, the supplier not only contributes with resources and know-how in terms of problem solving, but also secures the proliferation of successful solutions.

In some cases, the researchers analyze the processes, identify problems and recommend theoretically informed solutions. In other cases, the researchers are actively involved in developing new technologies such as IT support for mining prospecting, embedded systems and a simulation tool for chemical processes. Product owners translate the ideas from the innovation projects into a new context. The product owners are either system suppliers or component suppliers that own, maintain and develop the product. The main responsibility for implementing the innovation falls to these product owners and, if there is a wider commercial potential, they make sure that the product is sold in other markets. While boundary objects, such as prototypes, are used, the dynamic mix of actors in the projects requires interactional expertise in order to match actors and translate problem comprehension and abstract competencies.

Network outcomes. From 2005 to 2009, the Cross-Industry center has been able to launch 86 project activities, including 61 pre-studies and 25 projects. From these, the network has produced 19 new products, four new IT companies and 29 installations in process and manufacturing industries. Taking a university perspective, the network has resulted in 81 research publications and 44 new project activities.

Figure 3 illustrates the collaborative efforts of the Cross-Industry Center.

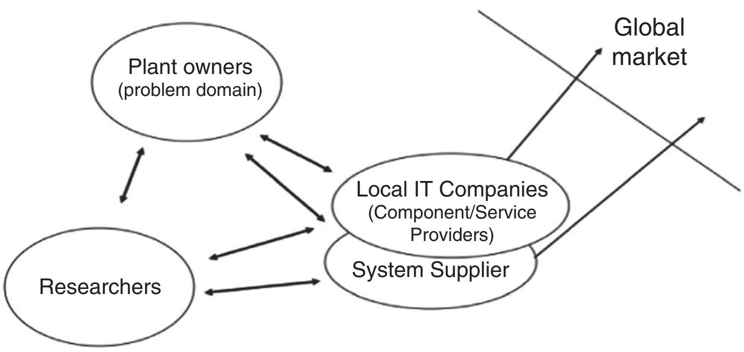

Figure 3.
The cross-industry center

4.2 The Partner Center

Management model. The Partner center works with technological issues related to steering, design and interfaces in production machines within the forestry, mining and process industries. The center consists of researchers who learn about industry needs from an institute consisting of forest companies as well as one global manufacturer of machines for mechanized logging. The Partner center was founded in 2001 as an initiative from a global manufacturer of forest machinery and an institute formed by large forest companies. The center is managed by a research director and an executive board, consisting of representatives from the forest industry, the aforementioned manufacturer and the university. There are 16 affiliated researchers across two universities, working in the areas of computer science and automated control engineering. A total of 25 companies have participated in activities arranged by the Partner center. Throughout the center history, the projects have focused on different areas. For example, in 2005, efforts were focused on improving cranes in forestry environments and autonomous navigation. In 2009, the program was expanded with efforts directed toward sensor technology and the visualization of vehicle simulations. The majority of projects do however involve some kind of collaboration with an important system supplier.

Innovation processes. Compared to the Cross-Industry Center, the Partner center has fewer projects but they last longer. This is partly related to the size of the network, but it is also a strategic choice to have longer project life spans. Projects typically last at least a year and sometimes up to five years. Researchers are expected to innovate a specific component or function of the machine and demonstrate a working prototype. Student-based engineering projects are often created with a focus on generating a prototype. This is a way of providing feedback to the companies quickly. Demonstrations of research also serve as generators of new projects, as they function as a stimulus for discussions:

> We work with prototypes that show the functionality that they want […] It is something we need to do for the companies, they see the use of coming back to us with feedback that stimulates new research (*Partner center Manager*).

Most of the project ideas come from industrial actors, mainly the system supplier. A scarcity of knowledge trade between actors is seen as a problem for the center. While the researchers might solve the problems described, the possibility for cross-fertilization is reduced. The limited number and heterogeneity of actors also creates a lack of influx of ideas from both practical contexts and other research areas. During the R&D cycle, researchers do not typically involve either the manufacturing company or the institute. There is a limited interaction with the machines in order to allow researchers to perform experiments:

> They have continuous contact by phone with [system supplier] about the machines so that they can perform experiments. In the new lab, they also provide training for the researchers so that they get to drive the machines (*Partner center Manager*).

The strong and exclusive ties to the system supplier, and the dependent type of knowledge involved, require innovations to be implemented by that firm. Subcontractors do not have the know-how to implement the innovations by themselves and the complex type of knowledge is hard to implement by the researchers themselves:

> The researchers would not stand a chance commercializing these results. You cannot build a new machine by yourself, there's so much other technology that needs to be integrated (Center manager).

Since the machines are quite sophisticated, the changes that will make the most impact will require a shift in practice. The innovations created by the center change both technical components and established practices. Implementing this type of radical innovation implies a radical shift within the practice of both forest companies and system supplier. The center thus struggles with the practical implementation of their findings. One proposed strategy for reducing these obstacles was to work closer with those who will actually use the implementation by creating Simmellian ties:

> Future action: form a consortium of forest companies, machine manufacturers and suppliers that should realize a prototype and perform tests in order to evaluate and improve the system (Official report).

Clearly, these recommendations represent a view where the implementation of results is left to industrial actors. This practice has been consistently followed since the center's founding: industrial actors approached the university and proposed an initiative for improving applied research within the area. Thus, implementation of knowledge was largely left to these actors. The strong position of system suppliers also affects the extent to which their component suppliers can implement innovations. Most of the suppliers are very dependent on the system/machine producer, giving that company a gatekeeper role:

> We have got a mission to transform the competency and knowledge to the companies, this is a question of packaging and presenting research in a way that they can understand, not a scientific paper that is totally incomprehensible to someone that hasn't got a Ph.D. in the subject. Making prototypes for these companies means that they see how it can be used and get an interest in using it in their business and also provide us with feedback (*Partner center Manager*).

Network outcomes. From 2001 to 2009, the center produced 22 peer-reviewed publications by 18 researchers. The center has developed a couple of promising prototypes but no project has resulted in a commercial solution. While there are some projects and research still running, the center is not operational today (Figure 4).

4.3 The Spin-Off Center

Management model. The Spin-Off Center brings together researchers from different disciplines, working within the application area of medical technology. The aim is to bring university research to new product ideas that can be used within health-care systems. The Spin-Off Center was founded in 2000, after a central level initiative from

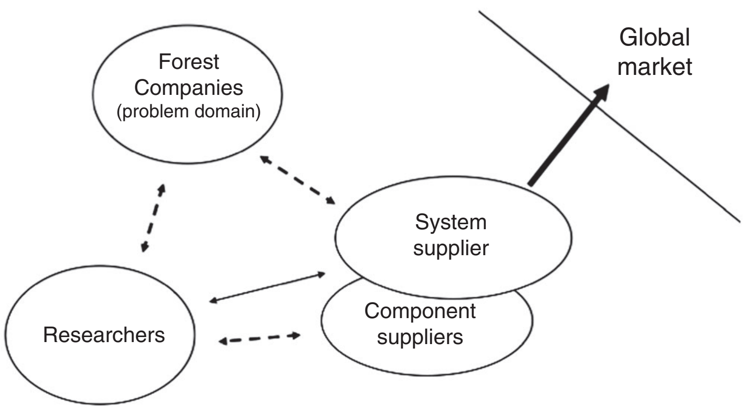

Figure 4.
The partner center

the university, aimed at achieving synergies between various research environments working within the same problem domain. Funding opportunities from the European Union required a critical mass of collaborative research within the field. At the same time, there was also a perceived need among researchers to collect the research in this field into a more structured model, with a platform for researchers, industry and practitioners. Today, the center has 23 projects involving seven departments. While the Center strives to conduct excellent research, funding organizations largely measure their performance on commercial aspects. This is one reason why they have started a business development company.

Innovation process. The center normally does not actively participate in the idea generation phase; instead, researchers develop a project proposal and then apply for the project to be considered. This proposal is then reviewed for both scientific and commercial merits. Project length is dependent on funding, but normally lasts five to six years. The project managers meet once every month to share experiences and discuss current events. According to the managers, these meetings result in new ideas and knowledge diffusion. The center has also recently suggested the possibility of funding pre-studies of interesting ideas. In order to increase the number of partner companies, workshops are held twice a year, where the research portfolio is presented to industry. However, so far this initiative has received limited interest.

While the center works actively with both companies with a problem to solve, and product owners to improve existing products and practice, most of this collaboration consists of input in the form of personnel for the projects. The collaboration with industry actors can for example be realized through access to equipment or knowledge and input in the form of personnel working within projects.

Considering the performance indicators, it is not surprising to find that the project portfolio contains mostly applied research; however, basic research is also prevalent. This mixture enables the center to apply for funding from a bigger range of actors and the basic research also creates input for future projects that are more applied in nature and thus closer to commercialization.

The center has started a business development company that is responsible for the commercialization of findings. The main part of the company is owned by the researchers involved in the projects, and the business model focuses on creating spin-off companies based on their patents. The business development company helps with the patent process and also in turning these patents into practical solutions. The researchers that own the business development company have signed a contract transferring their right to the findings to the company. When the business development company leaves the founding company, the researcher(s) receives 50 percent of the profit, the company 43 percent and the center 7 percent.

Network outcomes. Research in the projects has resulted in more than 100 journal publications, five new companies and nine patents. The management model has also been an inspiration for creating similar environments at three other universities in Sweden (Figure 5).

4.4 Project portfolio center

Management model. The Project Portfolio Center was started in 2007 and was awarded funding for a ten-year period. The center works together with eight partners on developing new simulation-driven design methods and IT-based supervision of products in use. The aim is to create innovations that allow partners to improve

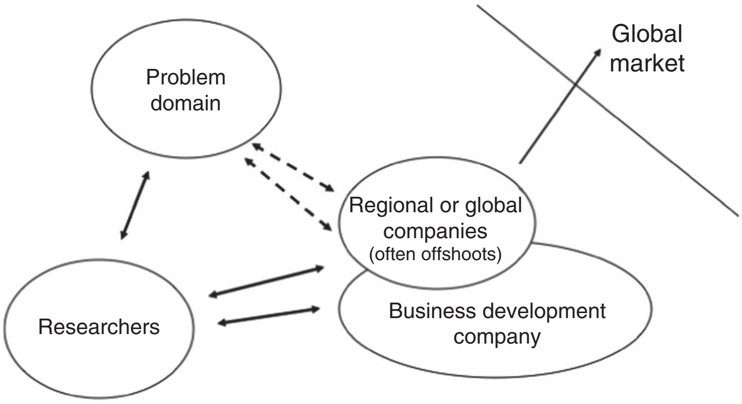

Figure 5.
The spin-off center

product development and move toward a position where suppliers sell functionality instead of products. The partner's application areas range across industries such as airplane engines, cars and mining. Six different departments from the university are involved in working on nine different projects that are divided into two different work packages. There is also an additional work package that analyses the results generated in projects in order to support aggregated knowledge generation.

Innovation process. Before the actual center started, an extensive amount of work was carried out in conjunction with industry partners to identify problems that seemed promising both from an academic and practical perspective. After the initial screening, pre-studies were conducted in order to test the feasibility. This initial phase sets the stage for the projects that are then developed along the way as knowledge is generated.

The center works closely with the industry partners involved in the problem-solving phase. A prerequisite was that partners would put resources into the projects themselves. This is done by involving both their personnel and equipment in the projects. Also, the center hosts a series of workshops aimed at improving the understanding of problems and plausible solutions. Collaboration during the problem-solving phase is a conscious strategy employed by the center, as they put it themselves: "Industry stakeholders (users) are continuously kept 'in the loop' and we aim to 'think together' rather than only dividing work between academia and industry" (Written presentation from the center).

The main way of implementing results is by improving a partner's practices. The strategy is one of "building a community with supporting methods that facilitate on-going utilization, rather than after-the-fact 'packaging' of results" (*Center manager*). This is done through prototyping, workshops and meetings. The key practical results at this stage are methods for product and service delivery, identification of new application areas and a computerized model through which the center claim that partners can determine "the readiness level of total offers." Since most of the results are focused on methods and/or context-specific IT support, the main way to commercialize results is through their use within the partnering firms. As an alternative for innovations that are possible to commercialize, the center has together with involved partners created a holding company. If that company does not want to utilize the findings they are released to another university owned holding company for commercialization together with the involved researchers.

Network outcomes. Practical implementations of findings include new product development methods within one partnering firm, a new idea generation method at another and a prototype computer model by which it is possible to predict the readiness level of offers. In terms of research results, the center has reported that it has produced 150 publications (Figure 6).

4.5 Cross-case analysis

Considering the differences in the nature of research between the centers, it comes as no surprise that interactions with external actors vary greatly. Table III summarizes the ways in which in the centers activate actors in their innovation networks in the various phases, and, the methods applied to do so.

Based on the analysis of these innovation networks, we suggest that the trading zones vary according to at least four dimensions: means of trade, tie configuration, type of trust and knowledge mobility mechanisms. We also propose the transformative and performative trading zones as two idealized models of innovation networks with large degrees of diversity. The transformative is enacted through interactional expertise. It is relationship based and since actors invest in the innovation process before an output has been reached, they need to trust the other parties' competency. Furthermore, knowledge mobility is based on shared parts of identity and social structure where unforeseen interactions take place. The performative trading zone is instead enacted mainly through trade of boundary objects that can be exchanged without demands on any close relationship. As trade mainly happens when innovative outputs have been reached, competence is not an issue, instead actors desires trust in ability and willingness to transfer opportunities to appropriate value. Finally, knowledge mobility is mainly based on the recipients' ability to leverage the packaged knowledge, i.e. their absorptive capacity (Table IV).

As suggested by our analytical framework, the centers make use of both boundary objects and interactional expertise. E.g. the Cross-Industry Center uses project officers, who help match researchers' competencies to industry problems, to increase their interactional expertise. All of the centers also work with prototypes as boundary objects in order to facilitate knowledge sharing. Another example of trade with boundary objects is how the Spin-off center uses patents as carriers of knowledge. These patents are well suited for implementation in commercial contexts and the ways in which they are put into use is not necessarily aligned with the researchers' understanding.

The tie configuration, in terms of the set of actors participating in the innovation process, varies a great deal between the centers. While some focus on building stronger

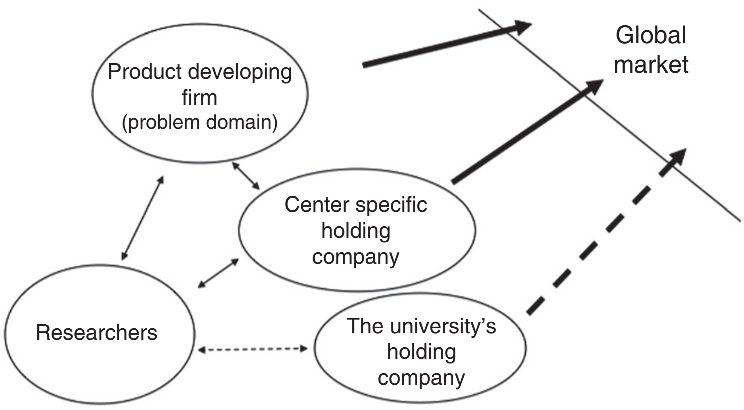

Figure 6.
The project portfolio center

Table III. Summary of configurations

Phase	The Network Center	The Partner Center	The Spin-Off Center	The Project Portfolio Center
Innovation process 1: *Idea generation*	*Actors involved* Problem originator One system supplier Component suppliers Researchers Project officers	*Actors involved* System supplier Component suppliers Researchers	*Actors involved* Researchers	*Actors involved* System suppliers Researchers One Problem originator
	Methods applied Industry visits by designated personnel and researchers Forums where all actors interact Forums where certain industries interact Pre-studies	*Methods applied* Industry visits by center manager and researchers	*Methods applied* Ideas from previous research and collaboration used for project proposals	*Methods applied* Ideas from previous research and collaboration condensed into pre-study proposals that are tested/verified in collaboration with partner
Innovation process 2: *Problem-solving*	*Actors involved* Researchers Problem originator System supplier Component supplier	*Actors involved* Researchers	*Actors involved* Researchers To a small degree, system suppliers	*Actors involved* Researchers System supplier One problem originator

(*continued*)

Phase	The Network Center	The Partner Center	The Spin-Off Center	The Project Portfolio Center
	Methods applied	*Methods applied*	*Methods applied*	*Methods applied*
	Analyzing practices and problems on site, recommending actions for suppliers and problem originators	Prototypes developed based on some interaction between system supplier and researchers, feedback gained from demonstrations	Research conducted in laboratory settings	Studies of industry actors practice in lab environment and in real settings
	Prototypes developed by researchers, sometimes in collaboration with suppliers			Tools developed by researchers based on problem description
Innovation process 3: *Implementation*	*Actors involved*	*Actors involved*	*Actors involved*	*Actors involved*
	Problem originator Component suppliers and sometimes system suppliers	System supplier Researcher	Business development firm System supplier	System suppliers
	Methods applied	*Methods applied*	*Methods applied*	*Methods applied*
	Products developed by component suppliers sometimes system supplier) taken to local market (problem originator) and sometimes the global market	Findings might be implemented in the system supplier's product	Knowledge implemented into patents (and brought into the market by interested partner firms or sold on the global market	Methods and tools implemented within collaborating firm

Table III.

relationships throughout the innovation phases, others base their exchange on transaction like ties. For example, the number of actors and their involvement in the projects varies greatly between the Spin-Off Center and the Partner center. One reason for this is that they are working with different types of knowledge and addressing different types of challenges. For the Partner center, knowledge is non-codified and very much dependent on the project environment. The strong ties to one actor imply dependency on that partner for new knowledge to be implemented in practice and thus become an innovation. For the Spin-off Center, where industry partners are less involved in the actual idea generation and problem-solving phase, the main challenges have to do with finding suitable industry partners. The knowledge is codified and non-dependent, which allows packaging in the form of patents, as such, trade does not necessitate strong ties. Also, researchers with experience of the problem domain decrease the center's dependency on the originators of the problem.

The networks also differ in terms of mechanisms for knowledge mobility, while transformative trading zones require some degree of shared identity and social structure the performative trading zone relies on absorptive capacity. For the Cross-Industry Center, knowledge mobility challenges are mainly related to matching problems with competencies. In order to moderate the matching of problems, the center makes use of interactional expertise and stimulates trading by arranging regular forums for interaction. Also, while the center is based on weak ties, it stimulates knowledge trading within the projects by demanding participation of the problem originators, suppliers and researchers. Thus, actors engage in sense-making actions throughout the projects. The inclusion of suppliers also stimulates identity creation as actors collaborate on boundary objects in terms of the solution that will hopefully be taken to the market. The Partner center works with knowledge that is dependent on its implementation context; the strong ties to the system supplier allow for knowledge trade in terms of problem understanding and problem solving. The main tool for trading is the use of prototypes. However, the ties also result in a decreased influx of competencies and might therefore decrease the ability to produce more radical solutions. The biggest problem they face is, however, in terms of knowledge implementation since there is more or less only one way that findings can be implemented in practice and that is through the system supplier. In other words, the center suffers from dyadic ties and has not managed to create Simmelian ties, despite holding such ambitions. Since implementation of findings is dependent on a high degree of absorptive capacity, trade with other actors has not happened to any substantial degree.

5. Discussion

While prior research has emphasized the notion of collaboration management capability for creating and sustaining competitive advantage (Dyer and Singh, 1998; Ireland *et al.*, 2002), empirical work is this area has been scarce (Rothaermel and Deeds, 2006). To this end, we

Dimension	Transformative trading zone	Performative trading zone
Means of trade	Interactional expertise	Boundary object
Tie configuration	Relationship based	Transaction based
Main knowledge mobility mechanisms	Identity and social structure	Absorptive capacity
Key type of trust	Competence	Appropriability

Table IV. Trading zones in innovation networks have presented a study of university-industry R&D collaboration, investigating *RQ1* Having conducted a cross-case analysis, our study confirm the observation made in extant research that the role of diversity is critical for innovation (Granovetter, 1973; Hargadon, 2002; Johansson, 2006). We contribute to this discourse by: pointing to the need for strategies to balance diversity in innovation processes; extending current theorizing by identifying two types of trading zones; and suggesting four design dimensions for how to manage collaboration in highly diversified innovation networks.

It has been widely discussed in innovation literature that when innovation networks combine insights across disciplines, path-breaking innovation is likely to happen. Our findings suggest that while this argument – often described as the "Medici effect" (Johansson, 2006) – holds some truth, a key challenge is to balance diversity in innovation networks. Diversity, and bridges across structural holes in networks, allows knowledge and solutions to be transferred, and potentially transformed (Burt, 1992; Hargadon, 2002). Nevertheless, diversity also convey challenges for communication and collaboration, for instance reinforcing the tension between stability and dynamics (Linnarsson and Werr, 2004), reducing trust (Newell and Swan, 2000), and creating new challenges in transferring, translating and transforming knowledge (Carlile, 2004). Both opportunities and challenges associated with diversity were present in all four examined innovation networks, as reflected in Table III a large number of strategies for balancing diversity were employed. The overall finding in our analysis is that a large degree of diversity holds great innovation potential, but also requires a high level of commitment and patience from network participants. We argue that the more innovation networks are able to discover and exploit opportunities, the higher the performance of the network. In particular, network relationships can be both beneficial and detrimental to the discovery and exploitation of opportunities. The effect depends on the configuration of openness, trust and mechanisms for knowledge transfer.

We identified two distinct types of trading zones: the transformative and the performative. These two types of networks vary in terms of four dimensions: their means of trade, tie configuration, main knowledge mobility mechanisms and type of trust dependency. The transformative trading zone relies heavily on interactional expertise, is relationship based, leverages identity and social structure as main mobility mechanisms, and requires trust in trading partners' competency. The performative trading zone, on the other hand, relies instead mostly on boundary objects, is transaction based, necessitates absorptive capacity in trading partners, and requires appropriability-related trust. While the performative trading zone is designed for the exploitation of knowledge diversity, the transformative trading zone's characteristics lead to more explorative ends. In the performative trading zone, parties exchange knowledge without engaging in negotiations regarding problem definitions, innovation processes or how technological innovations might affect practice once implemented. Such trade typically involves codified knowledge, inscribed into boundary objects such as patents, prototypes and weak ties between parties and it does not, in any substantial way, affect the end state of the trading zone. In terms of the taxonomy described by Collins *et al.* (2007, 2010), the trading zone remains fractionated since the exchange does not substantially affect the culture of the involved parties. In the transformative type, the parties do, however, engage in negotiations to achieve a shared understanding of problem definitions, competencies, how innovation activities are conducted and how implementing technological innovation might affect practice. The transformative trading zone involves exchange of non-codified knowledge, as such interactional expertise is needed to facilitate trade. Due to the character of exchange, the trading zone typically evolves toward a more homogenous end-state as parties gain an increased understanding and establish routines for how to interact (Collins *et al.*, 2010).

In the transaction-based networks trust mainly becomes an issue in terms of appropriability, while in relationship-based networks actors must ensure the competency of collaborators before investing too much in innovation processes. An example is how firms leveraging patented innovations from the Spin-off center, mainly is concerned with costs for ensuring sole access to findings. In other instances, when the innovation activities are more tightly linked to processes and the commercializing part invests more resources in earlier phases, trust in the ability to innovate becomes essential.

The need for interactional expertise for successfully enacting and re-enacting the transformative trading zone was particularly prevalent in our results. Also, our findings suggest that interactional expertise mainly supports idea generation while boundary objects are essential for solution implementation in the innovation process. While boundary objects are efficient, their use is limited to codified knowledge. The need for trust between parties is closely linked to the overall purpose of the network; if the purpose is to establish a performative trading zone, trust can be managed through contractual agreements. If the purpose instead is to establish a transformative trading zone, the innovation network needs to establish trust in both the participating parties ability and the collaboration model.

6. Conclusions

Innovation networks involving disparate actors have drawn a great deal of attention and been applied in a wide range of industries. Despite a strong appreciation of the importance of cross-boundary knowledge transfer for innovation (Burt, 1992; Hargadon, 2002; Chesbrough, 2006; Johansson, 2006), we know little of how innovation networks, involving a diverse set of actors, are managed in practice. This paper aimed at increasing our understanding of how diversity-related challenges and opportunities can be managed and how strategies affect the innovation potential in these innovation networks.

The implications for research lie primarily in three areas. First, our study builds on the appreciation of heterogeneity in innovation processes and contributes to the literature on innovation networks through empirically grounded descriptions of the importance of balancing diversity according to opportunities and challenges. While diversity has been found both to have positive impact on output from innovation networks (e.g. Johansson, 2006; Nieto and Santamaría, 2007) and convey challenges (e.g. Newell and Swan, 2000; Carlile, 2004; Linnarsson and Werr, 2004), we still know little of the mechanism for balancing this duality. We provide a cross-case analysis of four research centers that orchestrate innovation networks, and we describe the design of diversity-related strategies in boundary spanning collaborations. Second, we have explored two distinct types of trading zones: the performative and the transformative. In the performative trading zone, collaboration is mainly designed with exploitation in mind and exchange is conducted through boundary objects. Since the parties do not engage in substantial negotiation of differences in understanding, the end-state of the trading zone remains heterogeneous. In the transformative trading zone, parties engage in collaboration with a more explorative mindset. Since much of the exchange consists of non-codified knowledge, interactional expertise is essential for the trade. A substantial degree of engagement between the parties results in increased understanding of the other parties. Hence, the trading zone evolves and becomes gradually more homogenous. Our conceptualization of trading zones extends previous theorizations (Galison, 1999; Collins *et al.*, 2007, 2010) and provides analytical tools for further validation, refinement and adaptation to the innovation network context. Third, collaboration management capability has been shown to affect innovation outcomes (Dyer and Singh, 1998; Ireland *et al.*, 2002) but our understanding of its generation and implementation in practice remains limited. We identified four design dimensions for configuration of innovation networks according to the overall purpose and desired levels of diversity in the collaborations: their means of trade (i.e. interactional expertise or boundary object), tie configuration (relationship based of transaction based), main knowledge mobility mechanisms, and type of trust dependency (competency or appropriability). These dimensions can provide a starting point for research on long-term implications of different diversity strategies on innovation outcomes.

This study provides descriptive results by examining implemented strategies for diversity, and outlines analytical tools for future research on this important topic. Limitations and venues for future research include transferability of results to contexts with, e.g. other levels of trust, hierarchies and communication patterns. For example, the university-based setting and cultural aspects might have affected the level of trust among actors in our study. Further research is also needed on the long-term evolution of trading zones examining issues such as if the innovation potential reduces as actors in the transformative establish a more homogenous perspective on innovation processes. Finally, future research is needed on performance implications of various strategy configurations to validate and extend our study.

There are a number of practical implications from our analysis. Orchestrators need to understand both motives for participating in the network and the desired type of innovations and knowledge generation. They should carefully consider if they are mainly striving for explorative purposes (the transformative trading zone) or exploitation (the performative) and adapt levels of diversity, type of relationship, and collaboration configurations accordingly. In general, clearly defined and stable problems call for a performative trading zone whereas the transformative can provide more value when problems are ambiguous and dynamic. An important challenge for the networks is to establish trust between the parties, both in terms of loyalty and competency (Newell and Swan, 2000). Due to the deeper involvement, the transformative trading zone is significantly more dependent on trust in the network than the performative zone is. While disloyal behavior can be regulated by restricting the number of parties in the network, or through careful use of contracts, such strategies are likely to limit the innovation potential (Linnarsson and Werr, 2004). Establishing trust gradually, by limiting knowledge trade to smaller projects at the beginning of an innovation network, seems to be a successful approach. Further, designating substantial resources to establishing communication channels and negotiating understandings of the purpose and structure of networks can improve trust, both in collaboration models and participating actors. Innovation networks need to align knowledge transfer mechanisms with their purpose and overall configuration. Performative trading zones that deal with codified knowledge can, for example, rely on trade through boundary objects such as patents or prototypes. Transformative trading zones with a high degree of openness involve transfer of non-codified knowledge, which can be stimulated through interactional expertise held by, e.g. brokers in the network.

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