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Exploring preconditions for open innovation: Value networks in industrial firms

Ulrika H. Westergren *, Jonny Holmström [1]

Department of Informatics, Umea University, 901 87 Umea, Sweden

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ABSTRACT

The open innovation model embraces the purposive flow of internal and external ideas as a foundation for innovation and network formation. While the open innovation paradigm has been successfully applied in high-tech settings, there is a lack of research on adopters of open innovation in other settings. We describe a case study conducted in a process industry setting, focusing on the LKAB mineral group as it makes a transition from a closed to a more open innovation context by adopting remote diagnostics technology. This process has resulted in the creation of new value networks. By tracing the reasoning behind the organizational transformation and studying the technology used to carry it through, we seek to explore the preconditions for open innovation and provide insight into the role of IT in the process. Our findings show that adoption of the open innovation model is grounded in developing organizational environments that are conducive to innovation, including expertise in creating a culture for knowledge sharing, building a trustful environment, and a resourceful use of IT.

1. Introduction

Contemporary industrial firms are under pressure. While they once took pride in producing sought-after, superior quality products and exporting them for profit, manufacturers are now being overtaken by firms located in high-tech, low wage nations where products of comparable quality are produced at much lower costs (Banker, Bardhan, Chang, & Lin, 2006; Houseman, 2007). In order to regain its competitive advantage, industry must re-invent itself by looking for alternative approaches to value production. One approach is to

* Corresponding author. Tel.: +46 90 786 74 67; fax: +46 90 786 6550.
E-mail addresses: ulrika.westergren@informatik.umu.se (U.H. Westergren), jonny.holmstrom@informatik.umu.se (J. Holmström).
[1] Tel.: +46 90 786 97 66; fax: +46 90 786 6550.

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improve the effectiveness and efficiency of production, partly by organizational re-structuring, but also by investing heavily in new information technology (IT) to develop industrial processes. By using IT to monitor the production line, the process can be speeded up and made more efficient, more streamlined, and more cost-effective. To this end the evolution in remote sensing technology holds particular promise as it enables firms to monitor complex processes from a distance. Remote sensing has to date received some, but not sufficient, attention within our field, for example through the work of Zuboff (1988), who studied the use of smart machines within the pulp- and paper industry, Puri (2007), with his work on the use of GIS in India, and Østerlie, Almklov, and Hepsø (2012) who studied undersea oil well maintenance. These researchers have all shown how the use of IT creates possibilities for knowledge generation. As industries now embrace the use of remote sensing, they come into close contact with the technological potential for boundary-spanning activities (Jonsson, Holmström, & Lyytinen, 2009), hence providing the firms with an opportunity for both internal and external process innovation and new ways of value creation. As such, the current industrial use of remote sensing opens up the field of research, from a focus on knowledge systems to value creation and innovation.

The procurement and employment of new information systems are not the only things that industrial firms have done to remain competitive. They are simultaneously stimulating innovation by rethinking and reshaping their original forms and external boundaries, moving toward a networked environment in line with the current global trend of interorganizational collaboration (Chesbrough, 2003, 2006). Since the 1980s, there has been a persistent decline in conventional business practices such as mergers and acquisitions and reliance on venture capital as the number of new interorganizational collaborative schemes has increased (Xie & Johnston, 2004). Research has shown how organizations strive to create added business value through actively seeking cooperation and co-dependency in the pursuit of mutually beneficial behavior (Gallivan, 2001; Swan, Newell, Scarbrough, & Hislop, 1999; Swan & Scarbrough, 2005; Van de Ven, 2005). The increased globalization, widespread use of new technology, and pressure to be on-line, flexible, and efficient has resulted in the formation of strategic alliances, joint-ventures and partnerships, and a steadily increasing flow of interorganizational knowledge (Chesbrough, 2006; Inkpen & Tsang, 2005; Kling & Jewett, 1994; Newell & Swan, 2000; Wigand, Picot, & Reichwald, 1997). By engaging in an interorganizational network, firms gain access to new knowledge, resources, markets and technologies (Hislop, Newell, Scarbrough, & Swan, 2000; Inkpen & Tsang, 2005). This movement toward an open, networked environment, is captured in the open innovation model proposed by Chesbrough (2003, 2006). The model focuses on the possibilities and limitations associated with organizational transformations involving moving from a more closed environment where innovation is done in-house to a more open environment where innovation is done in collaboration and through the flow of internal and external ideas. However, firms involved in such enterprises risk the outflow of internal core competence, which could make them more vulnerable to competitors. The necessary openness is both a strength and a potential weakness, and the changing boundaries and the process of creating and maintaining partnership relationships over time thus have to be properly managed in order to maximize potential value and decrease potential risks (Vanhaverbeke, 2006).

This paper discusses LKAB, Sweden's largest iron ore mining company, and their struggle to remain competitive by engaging in an interorganizational network and thus moving from a predominantly closed environment to a more open one. By tracing the reasoning behind the organizational transformation and studying the technology used to carry it through, we seek to *explore the preconditions for open innovation and provide insight into the role of IT in this process*, thereby developing this open innovation perspective theoretically as well as illustrating it empirically. This research expands the study of innovation by exploring the underlying dynamics and trust in open innovation networks. Our findings show that network ties provide value that is augmented or hampered by the role that trust plays in such networks. Thus, this study introduces trust as an underappreciated but potentially highly valuable source of value in open innovation networks.

There have been recent calls from other researchers to increase the amount of IS research conducted at the industry level (Chiasson & Davidson, 2005; Crowston & Myers, 2004). Although mining was one of the first industries examined by IS researchers (specifically, Enid Mumford in the 1960s), it has not been considered in many recent studies. Acknowledging that information technology has permeated all aspects of industrial organizations, these areas offer rich opportunities for the IS field to develop its knowledge and broaden its relevance (Chiasson & Davidson, 2005). Due to their systematic, strategic, and innovative use of IT, and their commitment to an open innovation network, LKAB provides an opportunity to study the impact of technological and organizational changes on the mining industry as they take on their competitors.

The section immediately after this gives an overview of related research on innovation networks and trust. This is followed by a description of the research methodology. The actual case study, including the empirical data obtained during our interviews at LKAB and MCC is then presented and analyzed. The paper ends with conclusions and suggestions for future research.

2. Related research

While much research attention has been aimed toward networked innovation models, less attention has been directed toward the preconditions for their establishment. In order to understand the mechanisms behind innovation networks, it is helpful to examine previous research done within this area. This section also includes a discussion of trust and shows how different researchers have provided valuable insights that have furthered our understanding of the concept. The innovation network model presupposes a trustful relationship between the actors involved in an innovation partnership. To this end, a detailed exploration of trust as a precondition for the innovation network model is necessary for the successful deployment of the model in contemporary business relationships.

2.1. Innovation networks

Previous studies on innovation have highlighted the roles of networks and linkages. The networked model of innovation has drawn attention to the interactive character of the innovation process, suggesting that innovators rely heavily on interactions with other actors, such as lead users and suppliers, as well as a range of institutions inside the innovation system (Brown & Eisenhardt, 1995; Szulanski, 1996; Von Hippel, 1988). Much of the existing discussion on innovation focuses on static individual or organizational characteristics, and many existing process models are linear in nature. Additionally, many authors focus on one specific type of innovation such as administrative, technological, product, or process innovation (Rogers, 1995; Van de Ven, Polley, Garud, & Venkataraman, 1999). However, Van de Ven et al. (1999) proposed a model that presents innovation as a complex, non-linear, dynamic process, and the open innovation model is in many ways a continuation of that dynamic model.

The focus on openness and interaction in studies of innovation reflects a wider trend in studies of firm behavior that suggest that the network of relationships between the firm and its external environment can play an important role in shaping performance. For instance, Powell (1990) investigates interorganizational collaboration in biotechnology and assess the contribution of collaboration to learning and performance, showing that firms embedded in networks are likely to have greater innovative performance. Moreover, Chesbrough's open innovation model (Chesbrough, 2003, 2006; Chesbrough & Rosenbloom, 2002) suggests that the advantages that firms gain from internal R&D expenditure have declined. At the center of the open innovation model and other similar conceptualizations of innovation is how firms use the ideas and knowledge of external actors in their innovation processes. In sum, these studies illustrate the importance of open behavior by firms seeking innovative opportunities and suggest that this behavior may be responsible for differences in the performance of different organizations. While the open innovation paradigm has been successfully applied in high-tech settings, where it has been shown to have relevance for our understanding of innovation processes (Chesbrough & Kardon Crowther, 2006), there is a lack of research into adopters of open innovation in other settings.

The traditional view of the industrial firm has strong ties to the closed innovation paradigm or the vertical integration model, where an organization's research and development activities are considered strictly internal processes that should be guarded from external influence. Under this model, ideas should be produced in-house and the only way to market them is through the originating firm (Chesbrough, 2006). Internal processes, here defined as those inherent to the customer organization, exist in a separate context from external processes (i.e. processes pertaining to the service provider) and the two do not mix. In contrast, the open innovation paradigm involves on using both internal and external knowledge to accelerate internal innovation. Chesbrough (2006, p.4) notes: "*Open innovation processes combine internal and external ideas into architectures and systems. Open innovation processes utilize business models* *to define the requirements for these architectures and systems. The business model utilizes both external and internal ideas to create values, while defining internal mechanisms to claim some portion of that value.*" This suggests that the innovating firm actively partakes in the value creation process together with external partners, using the business model as an innovation intermediary.

The open innovation model draws upon previous research done within the innovation area. Considerable work has been done on strategic alliances (Gulati, 1998), open source software (Von Hippel & Von Krogh, 2003), and the relationship between geographic location and knowledge exchange between firms (Jaffe, Trajtenberg, & Henderson, 1993). However most of these previous works focused on how organizations can make use of external knowledge and paid little or no attention to positive and purposive outbound flows of internal knowledge. Dyer and Hatch (2006) have shown that organizations can gain competitive advantages by developing their network of relationships, as this enables interorganizational knowledge sharing. Open innovation presupposes collaboration and knowledge flows between organizations. Although open innovation has mostly been analyzed at the level of the innovating organization, the network level is implicit in the business model (Vanhaverbeke, 2006). As a result, the earlier recommendation to "ally with caution" has transformed into "manage your inter-organizational value network" (Maula, Keil, & Salmenkaita, 2006).

As organizations turn to each other in order to create possibilities for innovation, different ties are established at both an organizational and an individual level. Simard and West (2006) make a distinction between formal and informal, and also deep and wide organizational ties. They state that formal ties, which are based on formal contracts between organizations, also lead to the formation of informal ties, often in the form of friendships between company staff, and vice versa: informal friendships can lead to more formal collaboration. Deep ties refer to strong ties between organizations, which are often enhanced by geographical proximity and dependent on trust. Wide ties may be weak, but may join disparate networks and provide fertile ground for innovation. Furthermore they draw upon previous research (Baum, Calabrese, & Silverman, 2000; Powell, 1990) and show that: "firms involved in multiple types of ties are more innovative than organizations that engage in a single type of tie, since different types of ties can transfer different types of knowledge" (Simard & West, 2006, p. 6). Deep ties may offer stable, yet redundant, knowledge that is already known to the firm, while wide ties may offer new knowledge, but which might be difficult to capture. Formal ties involve knowledge paths that are regulated on an organizational level, while informal ties create knowledge flows between individuals (Simard & West, 2006). Thus, we conclude that open innovation is centered on the concept of knowledge flows between firms and individuals, and different types of network ties provide a variety of ways in which knowledge can be both created and communicated.

We have seen that in the movement from a closed to an open innovation environment there are several questions that arise and concerns that have to be addressed. One such question is the role of technology both in making the transition and in sustaining the interorganizational ties that are created in the innovation network. Further areas of concern are the nature of the emerging networked relationship, the management of network ties and the importance of trust in this process. In order to highlight the important issues that are connected to the process of changing the logic of innovation from closed to open we have provided a summary of our conceptual framework in the table below (Table 1):

2.2. The trust aspect

As IT-related processes move beyond the organizational level, network theory can be applied to understand their adoption in networks. The application of network theory has allowed researchers to incorporate both network levels and organizational levels of analysis to provide a more thorough understanding of intricate dual-level processes that intertwine between the firm and the network in which the firm is embedded (Ford & Mcdowell, 1999; Rampersad, Quester, & Troshani, 2010). In addition, researchers have used the network approach to explore dynamic processes; networks can be viewed as instances of interaction between organizations (Etzkowitz & Leydesdorff, 2000). Network constructs including trust, commitment and communication efficiency have been recognized as key factors for technology adoption in networks (Rampersad & Troshani, 2010).

Innovators are interlinked in networks based on 'swift trust' and embedded in a dense network of interactions (Brown & Duguid, 2000). Trust is thus a critical part of the process of developing

Table 1
Conceptual framework for firm innovation logic transformation.

Area of concern	Innovation logic	
	Closed innovation	Open innovation
Locus of innovation	Innovation process internal to firm. Focus on having the best people working for you.	Innovation process result of a mix of internal and external contribution and a mix of various types of ties. Focus on having the best network working with you.
IT	Proprietary, belonging to innovating firm.	Shared, either the actual object of innovation (e.g. Open source software) or providing common platform for network participants.
Interorganizational relationships	Contractual, short term, hierarchical.	Trust-based, long term, networked.
Management strategy	Staying in control.	Balancing trust and risk.

interorganizational relationships (Warne & Holland, 1999) and considered to be essential to the success of interorganizational systems (Ibbot & O'Keefe, 2004). Indeed, organizational relationships where the objective is to pursue mutually beneficial goals only exist where trust is well developed. Furthermore, they are focused on cooperation and collaboration rather than domination and control (Oliver, 1990; Williams, 1997). Consequently, a lack of trust is among the most frequently cited reasons for failures in organizational cooperation (Williams, 1997). Mishra (1996) defines trust as "…one party's willingness to be vulnerable to another party based on the belief that the latter party is 1) competent, 2) open, 3) concerned, and 4) reliable". These four dimensions form an overall trust construct, and a low level of trust in any one of the dimensions offsets a high level of trust in any of the other dimensions. That is, it is the combination of these four dimensions that determines the general level of trust that one party has for another. Another way of looking at trust is presented by Lee, Huynh, and Hirschheim (2008), who developed a trust-based relationship research model to assess perceived outsourcing success. Their specific goal is to "understand outsourcing success in terms of (1) mutual trust with its temporal dimension of initial trust and initial distrust, and (2) knowledge sharing with the moderating effect of mutual dependency". Their model is based on four factors: initial trust, initial distrust, knowledge sharing, and mutual dependency. They show that mutual trust between the customer and service provider is important for knowledge sharing and outsourcing success and that initial trust is a contributing factor in the perception of mutual trust from the customer's perspective.

One way to classify trust is to distinguish between what is called personal trust, which is trust developed in close relationships, and trust in abstract systems, which can be trust in society and the rules and norms it is made of or trust in abstract technology. Giddens (1990) emphasizes the significance of "access points" for the development of trust in abstract systems. Moreover, he states that individuals that occupy certain roles within an organization represent access points at which trust can be built up and maintained. Trust in abstract systems is considered to be less psychologically satisfying than its interpersonal counterpart. To this end, Giddens argues that people seek others to rely on and place trust in because interpersonal trust is anchored in human nature whereas system trust is not. Network trust is a kind of "system trust" that is based on the existence of abstract regulatory mechanisms (Giddens, 1990).

Giddens bases his definition of trust on his discourse on modernity, where his basic premises are that the dynamic, transformative character of the modern world has led to the transformation of intimacy and the increase of high risk environments (Giddens, 1990). According to Beck (1992) we are now living in a risk society where we neither understand nor control the course of events. Consequently, trust becomes a way of handling the complex environments generated by modernity. This is also a major point in the work of Luhmann (1988), in which trust is explicitly treated as a means of reducing complexity. Luhmann (1995) discerns between confidence and trust, and states that the latter is the product of a consciously made choice; that is, to trust is to consider the alternatives available, and to acknowledge the risks involved, and to make a rational decision, based on that information. In addition, Luhmann (1995, p. 96), draws on Deutsch (1958) and states that "Moreover, trust is only possible in a situation where the possible damage may be greater than the advantage you seek". For Giddens (1990) trust is a continuous state, based on contingency, and related to the absence of time and space, and not a specific and conscious choice. Nevertheless, both authors stress that trust and risk go hand in hand and that one should always be considered in relation to the other. This is also a key concept for Sztompka (1999) who claims that trust and risk are intrinsically associated; without risk, there is no need to trust.

Trust has become a rather fashionable research topic, and its pervasive role in information systems research is related to the emergence of interorganizational partnerships that are enabled by new IT and rely on trusting relationships between the involved parties. However, while trust is widely acknowledged as being important for the efficient operation of interorganizational business arrangements, the formation of trust remains challenging.

3. Method

3.1. Research site

LKAB is an international high-tech mineral group that operates mines, processing plants, and harbors in Sweden and Norway. The company has about 3500 employees. Over the last ten years, it has invested in remote-controlled operations, reducing both the need for manpower and the hazards associated with underground mining; to facilitate this, it has installed sensors along the entire production line. The remote monitoring systems are used to provide maintenance staff with early indications of equipment failure, and to allow production staff to control the quality of both the product and the process. In addition, the company increased its spending on equipment monitoring and preventive maintenance from 3 million SEK in 2003 to 11 million SEK in 2004. Finally, it opened itself up for collaboration by creating a joint-venture company with two of its long-term business partners, Sandvik and SKF. The new company, Monitoring Control Center (MCC) specializes in advanced equipment monitoring. By using MCC and their expertise in remote machine monitoring as a foundation for innovation, LKAB seeks to fully exploit the advantages of a more open business model that embraces knowledge inflows while contributing to the overall good of the network. LKAB's transformation from a traditional closed industrial setting where innovation was handled in-house to a networked environment based on remote monitoring technology (i.e. technology with an intended local *and* remote presence) provides a rich opportunity for studying the preconditions for open innovation.

The collaboration with MCC represented the first time that LKAB had given another company access to internal process data from strategically important machines that are crucial to its production process. LKAB, which initiated the establishment of MCC in 2003, owns 20% of the company and was its first customer. MCC's business concept is to provide advanced condition monitoring of machinery and equipment all over the world.

3.2. Data collection and analysis

Data was collected by the first author through a mixture of semi-structured interviews and document reviews (Yin, 2003). In total, we performed 43 interviews with 35 different people representing four organizations. For a list of respondents, see Appendix A. A majority of the interviews were conducted on site, giving us a firsthand account of the respondents' working environments. Eight interviews were done by phone. The interviews had a structured part involving questions related to our readings of internal reports, and an unstructured part with follow up questions emerging from previous interviews and meetings. When examining progress reports and other documents from internal meetings, data was coded into categories concerning expectations and experiences of the collaboration.

The data were gathered, analyzed, and discussed with the participants within an interpretivist paradigm. This interpretivist approach, with its goal of revealing the participant's views of reality, allowed the underlying reasons for actions in innovation practice to be elicited. The interviews, which were audio recorded and transcribed, were between 45 and 120 min long and conducted by the first author. With respect to the use of theoretical constructs to guide theory-building research, we worked within the conceptual framework presented in the literature review. Such a framework becomes a “researcher's first cut at making some explicit theoretical statements” (Miles & Huberman, 1994, p. 91).

While early identification of possible constructs allows them to be explicitly used in the interview context (Eisenhardt, 1989), it is equally important to recognize that the identification of constructs is tentative in theory-building research. We found this to be true as new factors were found during data collection that needed to be added to the analysis, for example pre-existing relationships between people from the different organizations and how they affected trust relations. In studies of this kind, it is important to determine when to stop conducting interviews. Ideally, researchers should stop adding cases when theoretical saturation is reached (Eisenhardt, 1989). Theoretical saturation is the point at which learning becomes minimal because the researchers are observing phenomena seen before (Glaser & Strauss, 1967). In practice, we decided to stop conducting interviews once we reached a point at which new interviews were not adding to what we already knew.

In addition to the interviews, we collected more than 20 documents relevant to the present study, including the original business plan for MCC, organizational charts, annual reports, special reports, administrative documents, and the LKAB staff magazine. We followed an iterative coding process that involved identifying the emerging concepts, examining empirical evidence for support, consolidating similar concepts to create more refined ideas, and collecting more data until theoretical saturation was reached. Our data analysis was based on open, axial and selective coding as suggested by Strauss and Corbin (1990). The analysis was conducted using the Atlas.ti software package, which is designed for managing complex data and supporting qualitative analysis. Our research centered on exploring preconditions for open innovation and the role of IT in that process, and with that in mind, we first identified a number of codes, each supported by two or more text segments in the data set, during the open coding stage. In line with the theoretical constructs that we drew upon for guidance, we traced the movement from closed to open innovation, the attempt to balance internal and external processes, and the process of managing trust and risk. In order to capture the role of IT, we also coded text whenever IT was mentioned (see Table 2 for the coding logic of the open coding stage).

During the axial coding stage we consolidated codes that were conceptually similar. This resulted in the emergence of three themes related to the preconditions for open innovation: the importance of technology, the formation of the network, and the creation of trust. Finally, during the selective coding, we strove to integrate the identified codes and formulate a storyline that offered a coherent and insightful account of the innovation practices. Following an initial coding effort, additional data collection and coding efforts were made until theoretical saturation was reached. To verify the plausibility of the identified concepts, we further reviewed the data set for corroborative evidence to ensure the validity of our findings (Miles & Huberman, 1994).

4. Results

4.1. A focus on technology

Preventive maintenance is a fairly new concept within LKAB. The maintenance unit, which is responsible for keeping machines such as mills, crushers, and conveyors up and running, previously relied on its employees' personal skills and senses, i.e. their individual ability to detect and correct any errors or problems that arose. Today, these machines are instead monitored via various sensors and IT-applications, which continuously log process data and passing it on for analysis. By using real time data logging and remote diagnostics systems, one can monitor each machine's current status and detect unusual patterns of behavior or early signs of equipment failure. The expected outcomes from using remote diagnostics technology include a reduced number of unplanned production stops and a more efficient production process. These are of great

Table 2
The coding logic of the open coding stage.

Theoretical constructs	What construct captures	Code	Questions asked while coding
Locus of innovation	Movement from closed to open innovation.	LoI_Open LoI_Closed	How is innovation conceptualized?
Interorganizational relationship	Balancing internal and external processes.	IoR_Internal IoR_External	What is the nature of the interorganizational relationship?
Management strategy	Managing trust and risk.	MS_Trust MS_Risk	What are the management strategies for handling the interorganizational relationship?
IT	Conceptualization of IT.	IT	What is the role of it?

strategic importance to LKAB because increasing up-times confers a competitive advantage. Moreover, unplanned maintenance stops are extremely costly and so the goal is to minimize them. According to LKAB's Service Director:

> "*Three more days of production will have paid off the entire investment in preventive maintenance and then some.*"

This way of performing maintenance means that the maintenance worker no longer has to be on site to monitor equipment and changes the time frame for maintenance work. With methods such as vibration analysis, an erratic behavior can be detected months before it causes a problem for the actual machine. This gives the maintenance unit ample time to prepare for a planned maintenance stop, instead of responding to a breakdown after it has happened.

LKAB is also investing a lot of money in sensor technology. Over the past 20 years, they have increased the number of measuring parameters from three to 33. They have also increased the number of points of measurement from about 100 to more than 15 000. Currently, LKAB is collecting and storing data from all parts of the production process. Various sensors are dispersed across the production line, where they log machine data such as temperature, oil pressure, and vibrations. Such data can be highly sensitive because it reveals all the details of the production process and has therefore traditionally been kept in-house in closed systems. Some data analysis is performed, but mostly data is simply collected because the technology is available, and in the hopes that it might prove useful in the future. By turning to technology, LKAB expects to be less reliant on skilled individuals and to instead gain collective knowledge that will be stored within the maintenance system.

LKAB's technology strategy is focused on investing in and making use of new solutions rather than developing them in-house. This is regarded as a very important strategic move according to the Service Director, who says:

> "*This is an extremely important change in the LKAB mentality. Earlier we thought that anything in-house was so special and everything had to be specifically made for LKAB because we thought of ourselves as an extremely specific organization.*"

Basic machine knowledge should reside within the company, but developing new technology is not part of LKAB's primary focus. LKAB's Service Director says:

> "*We are not going to be experts at constructing these highways, we are going to be experts in using them and getting the information that we want. Sometimes we adjust the system to LKAB, sometimes we adjust LKAB to the system.*"

By choosing to maintain a narrow view and understanding of technology, LKAB makes it possible for other actors to contribute with their expertise. However, there is also a risk associated with turning to technology. The LKAB project manager states that:

> "*The things that give us the most trouble are the ones that we know the most about. The worst-case scenario from a knowledge perspective is when things work. Then no one will know what to do when there is a problem.*"

An LKAB division manager notes:

> "*We trust technology, but sometimes you can take it too far. There is a danger of having less engaged and informed staff members; if you trust technology too much, you stop walking around the processing plants.*" (Hydraulics group leader)

4.2. The innovation network

MCC was formed in 2003 as a joint venture between LKAB, Sandvik, and SKF. Sandvik is a world-leading manufacturer of drilling and excavation machinery, tools and service for the mining and construction industries, and SKF is a leading global supplier of products, solutions and services relating to rolling bearings, seals, mechatronics, and lubrication systems. The three companies own 20%, 12.5%, and 67.5% of MCC respectively. LKAB had several reasons for forming MCC and establishing the network. The decision to create a joint venture was inspired by the ongoing maintenance makeover, where heavy emphasis was placed on creating a systematic, preventive, and structured maintenance organization. Instead of limiting themselves to re-organizing the internal maintenance unit, LKAB decided to use the potential embedded in its relationship with its two major business partners — Sandvik, who had delivered a lot of the equipment used in LKAB's mines and processing plants and SKF, who had developed an advanced solution for remote equipment monitoring. This network was to be used as a foundation for maintenance process innovation. The three firms were all expecting to gain something from joining the network and creating MCC. Sandvik would use MCC to get access to equipment data and advanced measurements that could be used for product development purposes:

> "*Our aim was to develop a logic that may not be present today around how to translate machine data into conclusions about how to plan and evaluate the need for machine maintenance.*" (Sandvik's representative to MCC's board)

SKF obtained the opportunity to put their remote monitoring system to use through MCC and develop both methods and technology while trying them out in a real setting. The SKF representative to the MCC board states:

> "*We saw the opportunity to adapt our vibration analysis methods for the mining industry, where we had not done so much of that before.*"

By letting MCC handle data monitoring and analysis, LKAB saw an opportunity to better structure their maintenance organization. They also saw the possibility of saving time, cutting costs, and getting to know the plants better through monitoring and subsequent analysis of machine data. In return, LKAB opened up its organization to MCC and gave them full access to the machines and technological infrastructure.

LKAB saw the creation of MCC as an added-value project, a joint venture that would bring new job opportunities to the region and increase their revenue. Since MCC's main focus is on the remote monitoring and analysis of machine data, it can pool collective knowledge to specialize in this area, which was not possible when the competence resided within individuals spread across the different production units at LKAB. LKAB's manager of maintenance development says:

> "*Someone who also has to focus on other things can never excel in any one given area.*"

In keeping with this, several LKAB employees stated that moving the competence from the internal organization to the external service provider increased the overall level of competence. Another benefit is that MCC's staff is constantly available with access to backup. Initially, LKAB was MCC's only customer, but the company was set up on the premise that it should actively seek others, in which they ultimately proved successful. The innovation network encouraged this planned expansion as they hoped that it would lead to a sharing of costs and also increase the level of competence within MCC as it learned from other organizations and would bring that knowledge back to the three owners. This was a specific strategy used by LKAB:

> "*LKAB told us initially that what we learn and develop at LKAB, we should bring with us out in the world to sell to our other customers. And what we learn from our other customers, should then be brought back to LKAB.*" (SKF representative)

This would have been impossible had MCC been created as an internal service division within LKAB, as its knowledge would have remained in-house without external influences.

Having MCC as an external partner has proven beneficial in other ways, as LKAB has discovered that MCC's opinions and analyses have more leverage with LKAB's own maintenance staff than internal directives. In addition, several division maintenance managers state that they use the reports and documentation from MCC to exert pressure on their own organization, particularly when asking for more money and inspiring their staff to develop their skills.

Following the reasoning of Simard and West (2006), there are four different types of ties that may co-exist within an innovation network; formal, informal, deep, and wide ties. The relationship between LKAB, SKF, Sandvik and MCC is based on formal ties as there is a formal contract regulating the joint venture, but the relationships that have emerged between company workers can be classified as informal as friendships are established over time. The ties between the four firms are deep, and there have been intentional efforts to establish trust. At the same time, all of the four participants exist within other networks and arenas and thus bring with them wide ties that may be beneficial to this innovation network. Thus, although the joint venture is based on formal and deep ties, all four types of ties co-exist within the network.

4.3. A strategic move toward trust

When MCC was formed, LKAB recruited some of their own maintenance staff and transferred them to the new firm. A trusted LKAB employee was made CEO. This was also a strategic step toward establishing interorganizational trust as it is considered easier to trust someone you already know. This also becomes apparent while talking to LKAB's Service Director. In describing MCC's CEO, he says:

> "*[He] is in such control… he will surely make more money than we have imagined.*"

The majority of MCC's employees had previously worked for LKAB. This picture has changed somewhat today, but there are still very close ties between the two organizations. The same line of reasoning was used when choosing potential network partners:

> "*We have built a relationship for almost one hundred years […] That is what makes SKF one of the interesting partners in such an endeavor; one trusts us.*" (SKF representative)

There was also a strict business contract written to regulate the joint-venture, and LKAB has a designated person who is in charge of the contract with MCC to ensure that they deliver what they have promised. However, LKAB's Service Director states that it was impossible to cover all aspects and claims that there was no choice but to trust the other parties:

> "*We have to stay focused, so we just have to trust.*"

All organizations stress that the trust between them is essential to the functioning of the network:

> "*If you don't have trust, you will have nothing.*" (SKF Representative)

This trust encompasses both trust in people and trust in technology. MCC has access to data that reveals LKAB's business secrets and should not end up in the wrong hands. Interpersonal relations are considered to be very important. LKAB staff stress that their contact person from MCC has to be someone one can talk to, who will stop and have a cup of coffee, and who can explain the technology in use. One maintenance worker said:

> "*We are a bit suspicious… however as long as they are here, we don't believe there will be problems; we can discuss matters directly with them.*" (Maintenance Worker L21)

In addition, MCC is expected to have an inspired and engaged workforce, with a detailed knowledge of LKAB. A constant dialogue, availability, and visibility are regarded as being very important in furthering the relationship.

MCC is seen as a potentially positive influence on LKAB's staff because it helps people to focus on preventive maintenance and can show how the use of technology can improve maintenance work. The collection and analysis of data lie at the heart of condition monitoring, and are done using information technology. Both LKAB and MCC staff argue that the trust in this technology is created by personal trust. However, once established, trust in technology can stand alone. There are regular meetings between LKAB and MCC during which common business is discussed. One of their more recent discussions focused on judging risks, a topic closely associated with the use of technology. The ability to collect and analyze data over time makes it possible to see ongoing trends and make predictions about the future. MCC uses this methodology to follow up on problems with bearings that will eventually cause equipment failure. The tricky part is judging the risk; once an error has been detected, how long should the actual machine be kept up and running before maintenance is performed? There are no definite answers to that question, but MCC uses a combination of probability and consequence to judge risk. The general idea is that if the probability of a breakdown occurring is low, but the consequences of such a breakdown are severe, the risk could still be considered high and MCC would alert LKAB, who will probably take action. Similarly, if the probability of a machine breakdown is high, but the consequences are minimal, the situation might be considered low risk. LKAB would still be alerted, but would probably not do anything with the information. By making correct predictions, MCC establishes trust in technology. However, incorrect predictions present a risk of generating distrust in technology and also personal distrust. One service technician described a situation where there was a difference in opinion between an LKAB maintenance worker and the MCC service technician regarding the status of a certain machine, and noted that:

> "*If you have a problem with someone once and it turns out you are the one who was in error, it takes a very long time to repair that relationship.*" (Service Technician 2)

This reflects how error detection is enacted in a social context where trust is a critical, yet fragile social glue. In this context, it is interesting that even though they can actually perform a lot of the work from a distance using remote technology, an MCC technician needs to show up on site regularly in order to be considered trustworthy.

In the beginning some of LKAB's maintenance staff was highly skeptical of the technology that MCC uses to monitor the machines. They were used to using their senses to detect errors and to making regular inspection rounds to see if anything looked, smelled or sounded wrong. In contrast, the methods used by MCC are so sophisticated that they can predict a machine breakdown a year before it actually takes place. Many LKAB workers were therefore initially skeptical of MCC's reports and did not listen to their warnings, as the machines had seemed to be in good working order on the last inspection. However, with the support of LKAB's maintenance managers, MCC has had the chance to prove that their analyses have been on target, by letting a machine run until it breaks down and then picking it apart and analyzing the cause. An LKAB division manager states:

> "*I have seen many examples of them [MCC] finding errors, so now I trust them.*" (Division Manager L12).

MCC has also spent a lot of time on site, talking to LKAB's staff, showing up for coffee and discussing technology. An LKAB maintenance worker said:

> "*What is important is personal contact, that you can discuss things. You have to get to know each other and improve your relationship. Just sending us monthly reports and e-mail is not the same thing at all.*" (Maintenance Technician L14)

Moreover, they have provided some courses on vibration analysis, which is the main method they use to detect errors, and made a conscious effort to show curves and diagrams on the computer screen and explain what they indicate. This strategy has been very successful and has gradually built up trust in both people and technology. Both LKAB and MCC state that this has been crucial in strengthening relations between the two organizations. Although the relationship is regulated by contracts, mutual trust has proven to be central to its success. As trust has been established, staff members from both organizations have tended to work more as a team instead of as separate entities, which has led to more cooperation and collaboration, and a higher level of knowledge sharing.

With the aim of increasing transparency between the organizations, LKAB has set out to create a common platform where information is shared so that knowledge is recycled back to LKAB from MCC. In return, MCC is given full access to LKAB's machinery, maintenance system, and technological infrastructure, which they can use to try out new technology and develop their methods of analysis. There is an effort to make informed decisions based on data analysis:

> "*Condition monitoring in itself is not going to help anyone, that is, one cannot simply measure. When one measures, and knows, and has the time to do something about it, then one can take calculated risks.*" (LKAB Service Director)

Both organizations believe that investment in IT will increase interaction and provide a basis for improved co-operation. IT is present not only in the remote diagnostics technology that is used to collect data, but also in the new maintenance system where data is stored and readily accessed, and in the computer programs that are used for data analysis. By turning to technology, LKAB expects to become less reliant on skilled individuals and instead gain collective knowledge that is stored within the maintenance system. This may seem to be a rational decision, but what will it mean to undertake technology-driven development without maintaining expertise with that technology in-house and instead relocating those skills to the external organization? An LKAB project manager discusses this in some detail and states:

> "*We have to constantly and continuously raise the level of education of our staff members. The problem is not educating people and having them leave. The problem is having the uneducated people stay.*"

LKAB needs to keep a close watch on their technology strategy so that they do not end up with a high-tech organization but low-tech workers.

5. Discussion

As the importance of innovation grows, so does the need to understand it well. Reviews of the literature concerning the adoption of innovation demonstrate that successful adoption requires the management of ideas, practices, behaviors, and structures, with the aim of bringing these different aspects of organizational and program structures into alignment (Rogers, 1995; Van de Ven, 1986). While existing research on open innovation has provided insights into how both technologies and social networks must change as firms move from a closed to an open innovation paradigm, the literature is silent on the nature of the relationship between technology and social networks. Our findings show how the move toward an open innovation environment was made possible through the ways in which trust in people (e.g. the social network) made trust in technology possible. In doing so, we provide insight into how technology and social networks are co-dependent. In our research, we have used the trust aspect of open innovation to guide research and analysis. Much of this trust aspect is drawn from Giddens' (1990) descriptions of the ways in which trust is shaped or framed by social institutions and enacted by organizational members. He observed that over time, people have used many resources, including technologies, to build trust. In this section we argue that the adoption of the open innovation model is grounded in developing organizational environments that are conducive to innovation, including expertise in creating a culture for knowledge sharing, building a trustful environment, and a resourceful use of IT.

5.1. Openness and interorganizational knowledge sharing

The open innovation paradigm described by Chesbrough (2003, 2006) focuses on the purposive flow of internal and external knowledge between organizations. Ideas are insourced and outsourced with the aim of setting the stage for technological innovation. The basic premise for this business model is that organizations benefit through collaboration and openness. Innovation is not restricted to products; it also includes techniques and processes (King et al., 1994), and as projects grow in complexity, knowledge cannot and should not be restricted to what is available in-house. As a consequence, innovation value networks are formed. As noted by Van de Ven (2005, p. 373): "Technological innovation is fundamentally a collective action process of building an infrastructure that reduces the time, costs, and risks for each participating member […] Developing and commercializing these new products and services require resources that are beyond the capabilities of any one firm". In LKAB's case, the innovation network consists of itself and two of its partners, Sandvik and SKF, and is embodied in the creation of MCC. All of these organizations are in turn linked to other organizations in various network constellations. The creation of the network has enabled interorganizational knowledge sharing and technological innovation. MCC uses remote diagnostics technology to monitor LKAB's equipment. This is a new method for condition monitoring, which was previously done by technicians using only their senses and experience. By engaging in the innovation network, LKAB gets access to new tools and techniques but also provides a forum for technology development and innovation. Sandvik, the equipment provider, learns about their own products by taking part in MCC's analyses and reports and are able to use that information for product development. SKF in turn, has a unique opportunity to try out new technology in a real setting over a long period of time.

Knowledge flows are crucial and essential for open innovation processes (Chesbrough, 2003, 2006; Simard & West, 2006). These flows may take different form depending on the network ties present. Formal and deep ties may provide strong, easy and long term access to knowledge, but the knowledge itself may be redundant and therefore of less value to the firm. Informal and wide ties on the other hand, may provide knowledge that is both new and fairly easy to access, but harder to capture (Simard & West, 2006). In this case all four types of network ties co-exist within the network, creating grounds for various types of knowledge flows. It has been shown that knowledge flows more readily between entities that are in close geographic proximity (Jaffe et al., 1993). Creating knowledge clusters in a specific geographical location is therefore an integral part of open innovation as it provides deep and strong ties between firms (Simard & West, 2006). This has also been a deliberate strategy at LKAB, whose contract with MCC stipulates that the service provider cannot move its headquarters from its current location. Geographical proximity brings new job opportunities to the region, and causes knowledge to be contained. Wide ties, on the other hand, ensure that the knowledge does not become stale and static, and an important concept in the creation of the joint venture was the transferral of knowledge into the network, by virtue of participating firms having ties with other firms in other constellations. Another deliberate move to create knowledge flows and to profit on wide ties was made by stating early on that MCC should quickly find other customers and bring back the knowledge gained in those new relationships to benefit the network as a whole. Thus, in order to increase the flow of knowledge and to benefit from both internal and external ideas, both deep and wide ties were encouraged and established.

In a similar manner, there was a conscious effort to establish both formal and informal ties as the joint venture and the work of MCC were regulated by formal contractual agreements, but the relationships between both firms and individuals were created by informal personal connections. This mix of formal and informal ties helps create a dual knowledge flow of both internal knowledge to the external network, and external knowledge to the internal network. In addition, new knowledge was created. On the creation of MCC, specific knowledge was initially transferred from LKAB to the new company, but the introduction and use of new technology have created new knowledge, both internally and externally. In an attempt to insource knowledge, LKAB has contracted MCC to give courses on their primary monitoring method, vibration analysis. They have also stressed the importance of visibility; making sure that MCC technicians and LKAB staff meet regularly in informal settings so that knowledge exchange can take place.

When considering the different ties present within this open innovation network, it is clear that the variety of ties and the expectations and possibilities connected to them present a multitude of opportunities for knowledge creation and both inbound and outbound knowledge flow. However, this case also shows that the efficient circulation of knowledge is ultimately dependent on trust. In the words of Kim and Mauborgne (1998, p. 323): “Without individual's voluntary will to cooperate, firms cannot effectively build their collective wisdom that is critical to succeed in this knowledge economy […] Trust and commitment are essential attitudes here. In their absence, the behavior of voluntary cooperation is hardly obtainable”. In light of this, we shall therefore delve deeper into the concept of trust.

5.2. Openness, trust and risk

Although the benefits of trust in interorganizational exchanges are well established and verified in the empirical literature, we know relatively little about its role in innovation processes. Such understanding is important not only from a normative perspective – when and how should we expect trust to affect innovation processes – but also from a theoretical perspective. According to Sztompka (1999), trust and risk are intrinsically associated; without risk, there is no need to trust. Sztompka's definition of trust reflects the close relationship between trust and risk: “trust is a bet about the future contingent actions of others” (Sztompka, 1999, p. 25). The “others” in Sztompka's case might be individuals, organizations, or technologies.

Defining trust in this way provides a means for us to understand the important link between the concept of trust and the challenges associated with living in a risk society. The notion of the risk society builds on the argument that modern societies encounter many more risks than previous ones (see e.g. Giddens, 1990, 2002). While traditional societies encountered risks from potential natural disasters, modern society – due to the advance of technology – faces additional risks that do not stem from nature. In addition, modern societies are built upon the notion of the disembedding of social relations, where relationships are lifted "from local contexts of interaction and their restructuring across indefinite spans of time-space" (Giddens, 1990, p. 21). This creates an element of uncertainty and points to the necessity of trust, which is seen as a fundamental property of disembedding: "All disembedding mechanisms [...] depend upon trust" (Giddens, 1990, p. 26).

Furthermore, Giddens (1990, p. 88) distinguishes between trust in abstract systems and trust in persons. The former takes the form of a faceless commitment "in which faith is sustained in the workings of knowledge of which the lay person is largely ignorant". Trust in persons is a facework commitment "in which indicators of the integrity of others are sought". System trust becomes localized through personal relations in the form of access points which tie actors into trust relations. Although Giddens' analysis concerns the structures within modern society as a whole, we find that it can be applied to the case of open innovation, which is contingent upon the restructuring of social relations across time and space. In our research, we find that as organizations seek new ways of innovation, they allow for the outflow of internal processes, which in turn leads to the relinquishing of control and the placing of trust in an abstract system, i.e. the open innovation network. They do this by establishing personal trust, embodied in this case by the close relationship between LKAB and MCC, the latter of which serves as the access point for the three owner organizations. A key factor in the success of the network between LKAB, Sandvik and SKF is the centrality of MCC, a physical place with real people where the network comes to life. Dialogue, availability, and visibility are the means by which trust is created and upheld.

Inherent to trust is the notion of risk, and while personal trust creates system trust, the opposite also holds true: when the system fails, personal trust is damaged. In the case of LKAB and MCC, we note that by making correct predictions, MCC established trust in technology; inaccurate predictions present risks of both technology distrust and also personal distrust. However, making correct predictions is not enough to uphold trust over time if there is a lack of personal trust. This again shows the significance of access points, and the vulnerability associated with them. A lot of focus has been put on the risk of potential knowledge-drainage as organizations engage in partnerships where knowledge is moved from within the organization to an external partner. There is also the risk of actual knowledge loss as LKAB turns to technology instead of relying on individual's skills and use of the senses. The objective of establishing continuous equipment monitoring via remote diagnostics systems is to minimize the number of unplanned stops. However, the success of these instruments might lead to over-confidence in the system, and a decrease in personal knowledge and responsibility as LKAB's maintenance staff will be exposed to fewer machine break-downs. This risk must be handled by incorporating reciprocity into the relationship, whereby the involved parties have a responsibility to give something back to one another.

Knowledge, in this sense, has been transferred from the internal LKAB staff to the external MCC staff, but as it still exists within the network, it can benefit all actors. With the support of LKAB's managers, MCC has sought to recycle knowledge and prove that their analyses were accurate by alerting LKAB of an error but then letting the machine run until it broke down in order to be able to pick it apart and analyze the cause. MCC has also spent a lot of time on site, talking to LKAB's staff, explaining their methods and discussing technology. This has made staff members of both organizations work more as teams instead of separate entities. Our research thus provides support for Lee et al. 's (2008) claim that interorganizational knowledge sharing requires mutual trust. Furthermore we find that maintaining trust is a way to contain risk. Existing research shows how open innovation alliances blur firm boundaries and create mutual dependencies between previously independent actors. A distinctive characteristic of open innovation alliances is that partners have to deal not only with the uncertainty in their environment but also with the uncertainty arising from each other's behavior. We contribute to this stream of research by empirically showing how trust brings about benefits by attenuating the effects of uncertainty in open innovation alliances. This finding underscores the potential benefits of investing in trust when behavioral uncertainty is considerable in open innovation alliances, and also suggests that trust can support open innovation processes by allowing partners to realize their potential synergies.

5.3. Openness and the enabling role of technology

The use of IT is a fundamental part of the communications and exchanges that occur when organizational members engage in interactions with others, be they members of the same organization or people from the outside. Whether as a situated individual or a larger group, the social actor may be simultaneously representing that self, or the larger organization, depending on which affiliations pertain. As organization members, people routinely perform socially embedded actions, and IT is increasingly enabling these interactions.

Sztompka (1999, p. 20) argues that when we say we trust a technology, we are really saying that we trust the people behind the technology: "Intuitively we feel that trust must be vested in people, rather than natural objects or events. Even when we seemingly confer trust on objects, for instance when saying 'I trust Japanese cars,' 'I trust Swiss watches,' or 'I trust French rapid trains,' we in fact refer to humanly created systems and are indirectly placing trust in the designers, producers, and operators whose ingenuity and labor are somehow encrypted in the objects."

Although trust in technology is important for the running of contemporary organizations, the people behind the technology remain key agents in establishing that trust. This has also been the case with LKAB, as MCC's staff members have come to serve as access points through which faceless commitments are re-embedded, creating trust in the abstract technologies that were at first regarded with skepticism. In doing so, MCC becomes the guarantor of the quality of the technology, and as such assumes the role of (and the trustworthiness accredited to) designers, producers and operators. In such an environment where trust is crucial, the interactions that organizational members engage in produce a situation where they cease to only represent themselves or their organization and also come to represent the people behind the tools and techniques they are using. This multitude of roles and their possible consequences is something that should be taken into consideration when engaging in a partnership based on trust.

This case study further shows that interactions occur on many levels. Giddens (1990) makes the distinction between system trust, which is sometimes labeled as trust in abstract principles, and trust in persons. These two trust constructs are in constant interplay. As we examine the case of LKAB and its partners, we find that this division can be applied in various ways. First we have the network level, where LKAB, Sandvik, and SKF have formed an open innovation network. MCC becomes the access point for the network. System trust in this sense is trust in the structure of the network, and personal trust is trust in the individual organization, in this case MCC. However, when we move down to the organizational level, and examine the relationship between LKAB and MCC, the system trust is the trust placed within the individual organization and the technology that is put in use, and the personal trust pertains to the individual staff members. It is important to keep these different levels of analysis in mind when discussing open innovation and the networks that are formed. Open innovation has previously mostly been analyzed at the level of the innovating firm (Vanhaverbekei, 2006). Using trust as a framework, we can expand that analysis to include the network level as well.

6. Conclusions

By tracing the reasoning behind an organizational transformation process involving a transition from a closed to a more open innovation environment, and by studying the technology used to carry it through, we have sought to explore the preconditions for open innovation and provide insight into the role of IT in this process. To shed light on the issue, we performed a case study at LKAB as it formed an open innovation network and created MCC together with Sandvik and SKF. By focusing on preconditions, we have added to the existing discussion on open innovation and its possible outcomes. Moreover, we have focused on the mining industry and thus extended the open innovation model to a setting that has previously had little attention from open innovation researchers. More specifically, our conclusions are threefold:

First, our findings show how the idea of openness has a positive influence on interorganizational knowledge sharing. Our case specifically illustrates the ways in which the organizations continuously seek to find new arenas in which knowledge exchange can take place. The open innovation model is centered around the notion of purposive internal and external knowledge flows. To this end, it is critical to examine network ties and trust constructs in order to analyze open innovation and its relationship to interorganizational knowledge sharing at both the organizational and the network levels.

Second, our findings illustrate how trust and risk are intrinsically associated, and in particular how open innovation projects tend to increase their co-dependencies. We found that interorganizational knowledge sharing requires mutual trust, and that maintaining trust is a way in which the organizations can contain risk. Adding to the research on network ties, where the presence of a variety of ties has been positively associated with open innovation, this research presents empirical evidence that the role of trust in network ties is crucial for open innovation milieus.

Third, our findings show how information technology can be an enabler for social action, and to this end any openness in the organizing practices has to be successfully enabled by technology. In particular, our findings show that both technologies and social networks must change as firms move from a closed to an open innovation paradigm. Our findings provide insight into how technology and social networks are co-dependent as the move toward in open innovation environment was made possible though the ways in which trust in people (e.g. the social network) made trust in technology possible. As enabling technology, IT is a fundamental part of the communications and exchanges taking place in and between organizations. IT will interact closely with systems of trust and these systems will have significant implications for the adoption, understanding, and use of technology. Trust in technology as an enabler of social action is important for the running of contemporary organizations, but the people behind the technology remain key agents in establishing that trust. This paper shows how the trust aspect can push researchers to consider IT use within complex organizational settings, enabling insights that may not have been possible with other organization-level models. We argue that trust is a key precondition for openness in organizational life and must be understood better if we are to understand the promises and perils of open innovation.

Taken together the aforementioned conclusions – related to the ways in which the idea of openness is expressed in relation to interorganizational knowledge sharing, in relation to trust and risk, and in relation to the enabling role of technology – present us with critical preconditions for open innovation projects. Our findings show that adoption of the open innovation model is grounded in developing organizational environments that are conducive to innovation, including expertise in creating a culture for knowledge sharing, building a trustful environment, and a resourceful use of IT.

Appendix A. List of interviews

This is a list of the interviews performed at MCC, SKF, Sandvik and LKAB between 2003 and 2011. LKAB operates in three different locations, and consequently there are MCC staff members at all three locations as well. The different locations are denoted L1, L2, and L3 in the tables.

Table 1: MCC

2003	Consultant responsible for drawing up the original MCC business plan
2004	CEO 1
2006	Service Technician 1 (L1)
	Service Technician 2 (L2)
	Service Technician 3 (L3)
	Development Engineer
	Condition Monitoring Group Manager
	CEO 1
2008	CEO 1
2009	CEO 1
2010	CEO 2 (new, former CMG Manager)
	Service Technician 3 (L3)
2011	CEO 2

Table 2: Sandvik and SKF

2009	Sandvik: MCC Board Member
	SKF: MCC Board Member

Table 3: LKAB

	LKAB Location 1 (L1)	LKAB Location 2 (L2)	LKAB Location 3 (L3)
2003	Service Director	Maintenance	
	Technician L21		
	Project Manager	Maintenance Technician L22	
	Leader of the Hydraulics Group		
2004	Technology Division Manager	Maintenance Technician L21	
		Maintenance Manager L21	
2006	Manager Maintenance Development	Maintenance Technician L22	Maintenance Technician L31
	Division Manager L11	Maintenance Technician L23	Maintenance Technician L32
	Service Director	Maintenance Manager L21	Maintenance Technician L33
	Maintenance Technician L11		Division Manager L31
	Maintenance Technician L12		Production Manager L31
	Maintenance Technician L13		Maintenance Manager L31
	Division Manager L12		
	Division Manager L13		
	Maintenance Technician L14		
	Maintenance technician L15		
	Maintenance Technician L16		

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