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International knowledge sourcing and innovation in the Danish wind power industry: an example of multi-locational innovation processes

Anne Nygaard Tanner
Lunds Universitet
CIRCLE
anne.tanner@circle.lu.se

Abstract

Many innovation studies focus on innovation as an outcome measured by patents or innovation statistics and tend to neglect the notion that innovation processes are contingent and unfold over time. This simplistic view of innovation reduces the role of geography to a matter of statistical measures of causalities that frequently seems to favour local over international ties. However, this paper examines how local and non-local knowledge sourcing vary throughout the innovation process and seeks to clarify whether the innovation process can be understood as multi-locational. The paper applies a biographical approach that focuses on the innovation process as it unfolds over time and through space from idea generation through problem solving to implementation. The study finds that patterns of knowledge interactions vary throughout innovation processes, that the core level of innovative activities frequently changes its physical location and that the locality of the firm seems to play a larger role early in the innovation process rather than at later stages.

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Anne Nygaard Tanner, CIRCLE, Lund University

Introduction

For decades there has been an ongoing academic debate about to what degree geographical proximity is important for innovation. The debate has taken its starting point in the dichotomy between local and non-local knowledge sources where the location of the innovating firm(s) denote what is perceived as local and non-local.

On one hand it has been widely argued in literature on clusters (Porter, 1990), regional innovation systems (Cooke, 2001) and 'learning regions' (Maskell and Malmberg, 1999) that firms' co-location can be explained by firms' need to be able to share tacit knowledge and learn from each other since knowledge flows are geographically localized (Audretsch, 1998; Feldman, 1999, 1994; Jaffe et al., 1993; Peter Maskell and Malmberg, 1999; Maurseth and Verspagen, 2002; Morgan, 2004).

On the other hand, a growing number of studies find that firms that are able to acquire knowledge from other firms and organisations over great geographical distances and combine it with their own knowledge assets demonstrate higher innovative performance (Bramwell et al., 2008; Gertler and Levitte, 2005; Niosi and Zhegu, 2005; Simmie, 2003; Tödtling et al., 2012, 2006; von Zedtwitz and Gassmann, 2002).

Theoretically Bathelt et al (Bathelt et al., 2004) have proposed a model that captures this co-existence of local buzz (localized knowledge flows) and global pipelines (extra-regional knowledge linkages), where buzz is associated with tacit forms of knowledge and global pipelines relate to more formalized knowledge types (Feldman and Kogler, 2010). Among others, Amin and Cohendet (2005) question this dual distinction between local and global, where the local is understood as a company's "home base" defined by territorial borders and local ties are stronger and more important than long-distance ties. Amin and Cohendet (2005) on the contrary argue that it is possible to build just as strong ties without physical proximity, through which also tacit knowledge can be shared.

The proximity school (Boschma, 2005; Torre and Gilly, 2000; Torre and Rallet, 2005; Torre, 2008) go beyond the usual dichotomy between local/tacit and global/explicit knowledge and contributes with a deeper understanding of the interplay of different types of proximity dimensions in the facilitation of knowledge creation. Proximity is essential to the innovation process because of its role in facilitating interactive learning and sharing of knowledge (in particular tacit knowledge). A key contribution from the proximity school is that geographical proximity is neither a necessary nor a sufficient condition for learning (Boschma, 2005). Other dimensions of proximity such as organized proximity (Torre and Rallet, 2005) and social, institutional, organisational and cognitive proximity (Boschma, 2005), are either complementary (Torre and Rallet, 2005) overlap (Hansen, 2014), or can substitute (Boschma, 2005) geographical proximity.

The proximity school also recognizes that geographical proximity remains essential for the exchange of knowledge but that this can take the form of temporary geographical proximity (Torre, 2008). In combination with the mobility of knowledge workers or knowledge enablers (Gertler, 2003; Von Krogh et al., 2000), temporary geographical proximity can secure transfer of knowledge between different actors over long distances.

This paper cautiously proposes that the reason for the diverging conclusions in the economic geography literature is that the (geographical) sources of knowledge to innovation varies as the innovation process unfolds over time. To date only a few studies have studied the knowledge and proximity dynamics of innovation processes (Ibert and Müller, 2015; Moodysson, 2008) consequently there is a need to dive into the sub-processes of the innovation process to understand the dynamics of proximity and geographical proximity in particular.

This paper aims to fill this gap by taking a processual approach to innovation in order to investigate how local and non-local knowledge is combined as the innovation process unfold over time. Moreover, as the proximity school propose that knowledge exchange can take place in temporary organized proximity, it is a secondary objective of this paper to clarify whether innovation processes can be conceptualized as multi-locational.

To examine the interplay between local and non-local knowledge sources in innovation processes I apply a biographical approach (Strambach, 2012), which is characterized by its focus on the innovation process itself: the actors involved; the relationships between them; their knowledge contribution; and their geographical configuration (Strambach, 2012).

Empirically, the study investigates knowledge sourcing in innovation processes in the renewable energy sector of wind power. More precisely, this study focuses on the first- and second-tier suppliers to the wind power industry located in Denmark. These firms are often smaller firms emphasising development over research. Consequently, the innovation processes focussed on in this paper resemble those described by Lundvall (Lundvall, 1985) and others, in which firms (typically SMEs) provide specialised products to customers, who are typically large.

The findings show that the spatial configuration of knowledge creation varies as the innovation process unfolds over time. In the initial stages of idea generation the location of the firm and accumulated collective knowledge about the industry is important for identifying customer needs. In the problem-solving stage knowledge creation takes place in face-to-face interaction either at the location of the firm or at the site of key suppliers. At the implementation stage knowledge creation often shift location to the site of producers and customers in order to enable the transfer of tacit knowledge. Hence, the findings propose that the innovation process can be seen as multi-locational which further alters the perception of what is local and non-local knowledge. By detaching the innovation process from the permanent location of the firm this paper facilitates a better understanding of when local and non-local knowledge play a role in the innovation process.

The structure of this paper is as follows. Section two develops the analytical framework that allows analysing proximity dynamics in knowledge creation processes as the innovation process unfolds over time. Section three explains the methodological approach. Section four introduces the wind power industry and analyses the three innovation biographies. Section five discusses the findings, its implications for theoretical understanding of local and non-local knowledge sources in innovation processes and draw up the conclusions.

Theory and background

The analytical framework of the paper seeks to combine three bodies of literature: the economic geography literature on proximity dimensions (Boschma, 2005; Torre and Gilly, 2000; Torre and Rallet, 2005; Torre, 2008), the knowledge management literature on tacit and explicit knowledge (Gertler, 2003; Nahapiet and Ghoshal, 1998; Nonaka and Takeuchi, 1995) and the technology and innovation management literature on processes of innovation (Abernathy and Utterback, 1978; Garud et al., 2013; Van de Ven et al., 1999). The primary focus is on that of combining and exchanging tacit and explicit knowledge and the need for proximity between individuals at different stages of the innovation process.

Proximity Dynamics

Proximity has become a key concept to understand the organization of economic activities and in particular activities of knowledge creation and innovation (Balland et al., 2015; Torre, 2008). It is argued that proximity is important for the innovation process because of its role in facilitating interactive learning. Because of the innate character of knowledge as being essentially tacit it is difficult to access or diffuse without face-to-face interaction. I return to the characteristics of knowledge as tacit and explicit later. First I discuss the most important progress in the proximity literature which has importance for the study of innovation processes.

Most attention has been given to geographical proximity. In literature on clusters (Porter, 1990), regional innovation systems (Cooke, 2001) and 'learning regions' (P Maskell and Malmberg, 1999) it is a key argument that firms benefit from being co-located. In fact, the need to be able to share tacit knowledge and learn from each other is often taken as the main reason for why firms are co-located. Recently this implicit causality has been questioned.

First, it has been argued that geographical proximity is only one of several dimensions of proximity which is important for learning. Boschma (Boschma, 2005) identifies five dimensions of proximity: geographical, social, institutional, organisational and cognitive proximity, which all influence interactive learning processes. Torre and Rallet (2005) have introduced the concept of organized proximity as complementary to geographical proximity.

The concept of organized proximity (Torre, 2008) build on two logics that make individuals capable of exchanging knowledge, also without being physically co-located: the logic of belonging and the logic of similarity. The logic of belonging refers to when two or more individuals belong to the same organisation and hence are trained in the 'routines' (Nelson and Winter, 1982) of the organisation and follow the same behavioural rules (either explicitly or implicitly given). This is what has been called the collective knowledge of an organization, which is knowledge that is fundamentally embedded in the social and institutional practice of a team or an organization (Nahapiet and Ghoshal, 1998). Cooperation and knowledge exchange will thus develop more easily between researchers and engineers that share organizational collective knowledge. The 'logic of similarity' are when two or more individuals are close to each other because they share same system of representations or similar knowledge bases - in short, they are cognitively and socially 'alike'.

The major contribution of the literature on proximity is that geographical proximity is neither a necessary nor a sufficient condition for learning (Boschma, 2005). Organized proximity facilitate learning also over long distances (Torre and Rallet, 2005). This contribution can explain the existence of epistemic communities or communities of practice (Brown and Duguid, 1991).

Another contribution that likewise relaxes the local/tacit and global/explicit dichotomy, is the concept of temporary geographical proximity. Face-to-face meetings can be organized in temporary geographical proximity at fares and workshops or at meetings between collaborative partners to facilitate knowledge exchange (Torre, 2008). One factor that has eased temporary face-to-face meetings between people is the increased professional mobility of people.

Finally the proximity school highlights that proximity dimensions are dynamic and changes with time (Balland et al., 2015; Broekel, 2015; Menzel, 2013), for example the more you collaborate the closer you get thus proximity increases. The dynamics of proximity has been studied in different analytical contexts such as how proximity varies along the industry life cycle (Balland et al., 2013), across knowledge bases (Mattes, 2012) and depending on motives for collaboration (Hansen, 2014). This study adds to this line of study by examining the dynamic changes of proximity throughout the innovation process.

Innovation process

Innovation studies tend to focus rather narrowly on innovation as outputs, e.g., patents, products, innovation statistics, and less on the actual process leading to innovation (Garud et al., 2013; Van de Ven et al., 1999). This limitation reduces the time of innovative activity to a single point in time, often without considering the long process of knowledge generation, problem solving, testing, prototyping, etc. that occurs before any innovation can be developed. A long process that involves the interaction of many different actors. Consequently, the question of proximities is reduced to a matter of statistical (often static) measures of causalities that generate knowledge as follows: Firms in geographical proximity to the source of knowledge are more likely to innovate (e.g., Jaffe et al., 1993), or firms from regions with high levels of social capital are more likely to introduce product innovation (Laursen et al., 2012). Although these insights are valuable and have contributed to better understanding of geography of innovation, they have a tendency to misrepresent the actual role of geographical and organized proximity in innovation processes: how geographical proximate and distant knowledge sources vary throughout the innovation process.

For that reason, it is important to stress that innovation processes are contingent and differ according to economic sector, technological field, type of innovation, historical period and country concerned (Pavitt 2005). Innovation processes develop through time and are extremely uncertain (Dosi, 1988). Although innovation processes typically are goal-driven (i.e., by either a vague or clear idea about an end product), they are fluid processes that can be affected by many different types of firm-internal and firm-external factors. Technically, external or inter-firm knowledge input can fundamentally alter the concept and take the innovation project in a different direction. Managerially, resources can run out. Many innovation projects are therefore uncertain and may be closed down.

There are different ways to characterise innovation processes (Garud et al., 2013; Pavitt, 2005; Utterback, 1971; Van de Ven et al., 1999). However, technological innovation processes are defined for this study rather simply as having three overlapping steps or phases: idea generation, problem solving, and implementation (Garud et al., 2013; Utterback, 1971). This depiction does not involve a linear understanding of innovation; in reality, these stages are difficult to distinguish from one another and frequently are intertwined, and resulting knowledge thus feeds back from later stages to earlier stages and vice versa.

Following the empirical investigations of Utterback (1971) *the idea generation phase* "…is operationally defined to extend from the time of the first thought related to the idea is communicated until a proposal is written or at which the major effort of at least one person is directed toward work on the idea." The idea generation phase contains two elements: 1) the identification of a need and 2) matching the need to a means, such as a technical solution. The *problem-solving phase* extends from the moment the idea is proposed and initial resources have been allocated until the time at which a solution, a model or a prototype is completed. The sub-processes of the problem-solving phase involve identifying sub-problems, specifying technical requirements for solutions, evaluating and deciding on which solution to pursue. Finally, *implementation* is related to manufacturing the solution and bringing the original idea to its first use or market introduction. Implementation considers manufacturing engineering, plant start-up, marketing, production, diffusion, on-going services, etc.

In the following the knowledge creation activities that characterize each phase is explained.

Knowledge Creation

In the knowledge management literature it is common to distinguish between two types of knowledge, explicit and tacit (Nonaka and Takeuchi, 1995). Where explicit knowledge is codified and found in documents, textbooks, databases etc. tacit knowledge is personal, experienced-based knowledge which is difficult to communicate (Gertler, 2003; Nahapiet and Ghoshal, 1998). Tacit knowledge is known as know-how and know-who, where explicit knowledge often is labelled as know-what or know-that (Johnson et al., 2002). Rather than a strict line between tacit and explicit knowledge Nelson and Winter (1982) stress the need to identify the degree of tacitness.

Tacit knowledge is created and accumulated at the individual level through theoretical, practical and experience-based learning (Nonaka and Takeuchi, 1995). However, tacit knowledge also has a social contextual dimension, which differs from the aggregated sum of the knowledge of a group of individuals (Nahapiet and Ghoshal, 1998). Social tacit knowledge is the type of knowledge that is embedded in social and contextual practices which guide the interaction between individuals. It is what Nelson and Winter (1982) define as routines – that is the collective, organizational knowledge which frequently distinguishing the performance-levels of firms (Nahapiet and Ghoshal, 1998).

Individuals are often not aware of this level of social tacit knowledge but reproduce this through their interaction. Organizational collective knowledge is related to the concept of organized proximity and ease communication between individuals.

In this paper it is argued that collective knowledge also exist at the level of industries, and consists of knowledge about other firms' strategies, user needs, current trends (state-of-the-art) and directions in markets and technology development, new and up-coming regulations etc. which is not technical knowledge directly linked to the innovation process but still crucial for successful innovations. Industrial collective knowledge is highly experience-based and accumulated through continuous and strong affiliation to a particular industry. Hence, it is not equally distributed among individuals, but individuals with longer experiences and affiliation to an industry have higher levels of industrial collective knowledge. It is embedded in social, institutional and economic practices, which guide the interaction and transactions between individuals and organisations.

Industrial collective knowledge has strong connotations to the concept of 'buzz' (Bathelt, 2005; Bathelt et al., 2004). However 'buzz' has met a lot of criticism because of its weak definition of forms of knowledge-exchange and the content of buzz (Asheim et al., 2007; Moodysson, 2008). Moreover, the definition of buzz is often defined very broad encompassing almost every knowledge-sharing activity within a spatial boundary. This broad definition juxtapose buzz with concepts of clusters, industrial districts, and innovative milieu (Rodríguez-Pose and Fitjar, 2013) and hence dilute the concept. Some scholars have emphasized that the special feature of buzz is that it is spontaneous, it is rumor-based and characterized as gossip. Moreover buzz is freely available and accessible without any cost (Bathelt 2005).

In particular the latter, that this type of knowledge should be freely available without any cost is highly questionable. On the contrary in this paper it is argued that the collective knowledge about an industry is knowledge that has accumulated in individuals through many years. It has been accumulated over time and is a result of huge individual investments of time in building up relations and a deep know-how and know-who specific to the particular industry. It is highly context dependent and its usefulness depends on social capital and trust embedded in networks and relationships between people and can therefore be difficult to transfer to others (Johnson et al., 2002). Hence, in this paper it is preferred to use the concept of collective knowledge about an industry instead of the concept of 'buzz'.

Since the creation of new knowledge is a vital part of the innovation process it is essential for this paper to understand how new knowledge is created.

Since Schumpeter's (1934) early contribution on this topic it has been widely recognized that knowledge creation happens through two processes: combination and exchange (Nahapiet and Ghoshal, 1998). Combination is the process of either combining known elements in new ways or by developing novel ways of combining elements already connected. The new combination can differ in its disruptive impact and foster either incremental or radical change. When knowledge is known by different individuals, exchange of knowledge is a prerequisite for combining knowledge. Hence interaction between individuals is key to the process of creating new knowledge.

The combination and exchange of knowledge in interactive learning processes often combine both tacit experienced-based and explicit elements of knowledge. As discussed above this exchange of tacit knowledge requires proximity, such as geographical proximity or organized proximity. The question is when in the innovation process face-to-face meetings in temporary or permanent geographical proximity is necessary and when the exchange of tacit knowledge can be orchestrated through organized proximity.

Idea generation and knowledge creation. It is characteristic for the initial idea generation that it is a rather messy process and no one fully understands the idea or emerging body of knowledge (Birkinshaw and Sheehan, 2002). While one element of this phase – the identification of a need – can be quite precisely identified and communicated, the other element about to find a mean to match the need can be very loose and abstract, but still coherent enough to make it to the next stage – the problem-solving phase.

In the idea generation phase, collective knowledge about industry is extremely important in order to understand where there is a need for new innovations. It can be theorized that 'being there' and being part of an industrial agglomeration can have great impact on how easy firms can access industrial collective knowledge (Amin and Cohendet, 2005; Asheim and Isaksen, 2002; Gertler, 1995). Hence, a firm's location may facilitate an easier access to collective knowledge because being located in a 'cluster' will more likely produce more frequent meetings between customers-suppliers, user-producers etc. (Asheim and Isaksen, 2002). Such meetings are often organized and facilitated by existing industrial networks, trade organizations, member based industry associations etc. Other important sources to industrial collective knowledge is frequent customer meetings through salesmen and formal and informal meetings at trade fares.

Table 1: Knowledge creation and proximity dynamics during the stages of innovation

	Idea generation	Problem-solving	Implementation

Knowledge characteristics	▪ Knowledge is fussy ▪ Collective knowledge about the industry ▪ Tacit and explicit knowledge on means	▪ Knowledge is complex and disconnected ▪ Combination and exchange of tacit and explicit knowledge ▪ Production of tacit knowledge through experimentation	▪ Knowledge is complex but connected ▪ Codification of tacit knowledge in requirement specifications ▪ Transfer of tacit knowledge to supplier, producers and users
Proximity	▪ Co-location in clusters is advantageous ▪ Frequent temporary face-to-face meetings	▪ Early development requires geo. proximity (temporary or permanent) ▪ Geo. proximity diminishes concurrently with increased org. proximity	▪ Temporary geo. proximity is important to transfer knowledge to external partners ▪ Organized proximity can secure communication internal in the organization (knowledge enablers)

Problem solving and knowledge creation. This stage involves high levels of interplay between tacit and explicit knowledge. Studies suggest that the tacit dimension is more profound in the problem-solving phase than in other stages of the innovation process (Koskinen and Vanharanta, 2002). This is because it is highly intuitive and experience-based knowledge that is used to identify sub-problems and work out solutions. Due to the complexity of such innovation projects this task is often carried out by a team of co-workers who have different sets of complementary knowledge bases. Similarity in knowledge bases facilitate communication in identifying sub-problems and their solutions. When the solutions are tested out in reality through experimentation and modelling, the individuals involved accumulate new tacit knowledge about the interdependencies and complex interplay between the new combinations of knowledge. Concurrently, problem-solving also involves the codification of knowledge in requirement specifications to potential suppliers and producers. Hence, problem solving is characterized by individuals that by themselves or in teams use tacit experienced-based knowledge to identify sub-problems, develop solutions by combining and exchanging knowledge in new ways and test the new solutions. The latter is often experimental and involves the creation and accumulation of new tacit knowledge (Nonaka and Takeuchi, 1995) in parallel with writing up explicit requirement specifications for what the product and its parts need to meet.

Consequently, in the problem-solving stage it is necessary to create space for ideas to grow (Birkinshaw and Sheehan, 2002) and facilitate the process of building a new concept based on new knowledge combinations and knowledge exchange. It involves high levels of tacit knowledge (previous experiences) and it is here theorized that such knowledge exchange has to be facilitated by either geographical proximity or organized proximity. Moreover, at the very early stage the need for face-to-face interaction is higher than at later stages, when geographical proximity diminishes and can be replaced by organized proximity (Torre, 2008). This is because organized proximity in itself is dynamic and co-evolve as the innovation process unfolds. In particular the logic of similarity – common knowledge base and associated vocabulary – may be lower in the beginning of this process and hence the level of geographical proximity need to be higher.

Implementation and knowledge creation. This stage is about bringing the innovation to its first use and involves manufacturing engineering, production and diffusion. This sub-process often involves a close interplay with suppliers of components, producers of the entire product (if the product is not produced in-house) and the customers who will adopt the new product. For instance, Gertler (1995) shows that the production of new complex production equipment is more likely to be produced successfully when there is a frequent interaction between producer and user but also producer and supplier. Likewise, it has been shown that complex production equipment or machinery is more likely to be adopted successfully, when there is close and frequent interaction between the user and producer (Gertler, 1995).

The newly produced tacit knowledge which has accumulated based on experimentation in the problem-solving stage hence need to be transferred to other parties, such as suppliers, producers and/or customers. Some of this knowledge is translated into explicit requirement specifications other knowledge is so complex that it needs face-to-face interaction between the parties to be transferred.

Firms and industries have developed different routines and strategies for the communication of tacit and codified knowledge at this stage of the innovation process. Large firms tend to have developed knowledge management systems that seek to handle the transfer and exchange of tacit knowledge throughout the innovation process (Birkinshaw and Sheehan, 2002). For example, systems to facilitate the codification of tacit knowledge or knowledge-enablers that circulate tacit knowledge within the organization (Gertler, 2003; Von Krogh et al., 2000). Small and medium sized firms have less formalized support systems for this type of knowledge sharing (Koskinen and Vanharanta, 2002). However in small firms, it is often the case that the same people are involved in the innovation process throughout the whole process from idea generation to implementation which secure continuity. Consequently, the need for transferring tacit knowledge internally in the organization is much smaller because this knowledge is embedded in the individual team-members who are involved in the different stages of innovation.

On the other hand, the lack of a formalized support system for exchanging tacit knowledge imply that no routines or behavioural practice is developed that can assist the process of sharing tacit knowledge with external partners, such as suppliers or customers. Hence it is theorized that these firms rely to a higher degree on co-location either permanent or temporary geographical proximity in order to share the complex and experienced-based knowledge that has been accumulated in the problem-solving stage. Firms can disseminate and share internally developed tacit knowledge to external partners through knowledge-enablers (Gertler, 2003; Von Krogh et al., 2000). That is the circulation of key personnel who can enable the dissemination of tacit knowledge with external partners and at the same time retain the knowledge exchange and feedback to the rest of the team. The knowledge-enabler needs to be geographically close to the external partners, at the site of the producer or customer, hence the innovative activities changes location. Knowledge sharing with the rest of the team-members can be facilitated over longer distances by organized proximity.

Method

This study makes use of a biographical approach that focuses on the innovation processes of suppliers to the wind power industry. Consequently, this study focuses not on a firm's intended procedure in general but on the product development activities and process that occurs within and beyond the borders of the firm. Interviews with those involved in the innovation process were conducted to uncover actors involved, knowledge-relationships between them and geographical configuration (Strambach, 2012).

There are several reasons for the choice of methodological approach. First, the biographical method can focus on distributed knowledge generation activities and their evolution over time without being limited by a certain territorial scope or time-frame. According to Strambach (2012, p. 62), "Knowledge interactions can be mapped regardless of geographical or sectoral scale". Thus, as opposed to other studies in economic geography, the biographical approach does not pre-empt a rigid focus on knowledge dynamics within and beyond one particular region, which is often the case for cluster studies. Instead, it applies a more flexible territorial understanding.

Similarly, methods such as surveys focus only on one point in time, often represented as a three-year period (e.g., in Community Innovation Surveys). The innovation biography method allows working with a flexible time-span because it aims to maintain its focus on how innovation processes unfold in time and space. By focusing on a single innovation process, this method enables the time-space paths of knowledge dynamics to be more flexibly reconstructed than other established data-gathering approaches.

The second advantage of the innovation biography approach is that it yields concrete insights into tangible procedures of new product development without using the observation method (e.g., Garud et al., 2013; Van de Ven et al., 1999), which is extremely time-consuming. Furthermore, the innovation biography method also eliminates the risk of being presented *the ideal situation* of the company or other ex post rationalisations, which can occur when researchers interview managing directors or heads of R&D divisions.

Data collection

The data collection process is balanced between the narrative of the project owner and a focus on the firm's context and its linkages to other partners in the innovation process. For each case the aim is to interview at least two people with a solid understanding of the project, preferably the project owner and an R&D director or a managing director. Table 2 lists the three cases including firm name and titles of interviewees.

Table 2: Cases: Name of firms, innovative event, title of interviewee and interview reference

Firm (name, Dansih town)	Innovation process	Interviewee	Reference
Hempel, Lyngby	**Fast-curing polyurea spartech, Fast-curing paint for wind turbine towers**	Group Wind Power Segment Manager	H1
		R&D Director	H2
		Chief consultant	H3
Liftra, Aalborg	**Blade Dragon, blade installation crane**	Managing Director	L1
		Managing Engineer	L2
Swire Blue Ocean, Copenhagen	**Pacific Orca, windfarm installation vessel**	General Manager & Director	S1
Knud E. Hansen, Helsingør		Senior Naval Architect	S2

Source: Own interviews conducted in Fall 2012

The first part of the interviews is constructed to enable the interviewee to provide an uninterrupted narrative of the focal innovation project. The second part of the interview is structured around a number of questions regarding the relationships to other actors as the innovation process unfolds. For interviews with managing directors or R&D directors, part of the interview is guided by questions about the firm's internal organisation and established procedures for developing new products and about other actions that the firm may take to integrate external knowledge (e.g., hiring skilled staff, licensing patents, or creating strategic alliances).

The interviews were transcribed and coded in Atlas.ti. The coding process followed two approaches: An open-ended process following the issues the interviewee raised, and a more structured approach that followed the phases of the innovation process, types of actors involved and knowledge types and flows.

With respect to the different phases and sub-processes an innovation project passes through from idea generation to implementation, each project has its own logic, which means that the sequence and length of the phases differ and that some phases might be repeated at later stages and hence are coded as development I and development II, for example.

The approximately 100 pages of transcribed interview material reflect the high level of complexity of each innovation process. Thus, it has been necessary to reduce this complexity to a comprehensible interpretation of the data, which has resulted in a mapping of the innovative events (see Figure 1-4) along two dimensions: time and geographical scale. To create these maps, I have been inspired by the figures developed by Simone Strambach and others (see, e.g., Strambach, 2012).

Results

The internationalization of the wind power industry

The development of the wind power industry in Denmark has been labelled *bricolage* (Garud and Karnoe, 2003), which describe a development path characterized by emergent co-shaping by designers and producers, users, evaluators and regulators. The development has since the 1970s been characterized by incremental scaling up of the design while improving it based on input from the many actors involved. It is an exemplary case of entrepreneurial agency distributed across actors (Garud and Karnoe, 2003).

The wind power industry in Denmark has sustained its significant position in world, although the industry has experienced a rapid globalization. In 2011, the global turnover increased to 102.8 bn., and half of the global turnover occurred in Denmark (approx. 52 bn.). Employment in the wind power industry in Denmark was stable in 2009-2011; approximately 25,000 persons were employed by approximately 300 companies, including suppliers, OEMs, engineering consultancies, etc.

Supporting the local dynamics of the wind turbine industry in Denmark includes foreign key players' relocating to the "wind power hub" of Denmark (Andersen and Drejer, 2006). A recent survey of 107 wind power–related companies in Denmark, more than one in four are either wholly or partly controlled by a non-Danish company (Andersen and Drejer, 2012). Although the three types of interrelated industrial activities – sales, manufacturing and employment – have become increasingly internationalised, the wind power industry remains strongly anchored in Denmark and neighbouring countries (Sweden and Germany) mainly because of its long supply-side experience with wind turbine technology and the extensive research conducted at Danish universities and institutes (Andersen and Drejer, 2012; Hansen et al., 2012).

Innovation biographies

The analysis is structured based on the three innovation processes and examines the knowledge creation that takes place through the innovation process. For each analysed innovation process, an innovation biography has been depicted (see Figure 1-3). These figures illustrate different patterns of knowledge creation and knowledge transferring and the change over time with respect to types of actors (customers, suppliers, project owner, etc.), types of knowledge and the geographical dimension.[1] The dark circle in all the figures represents the main level of innovation activities related to the innovation.

Blade Dragon

Blade Dragon is a yoke that enables the installation of blades on rotors at most angles, which can function in wind up to 12 m/s. The yoke can tilt a blade from +30 deg. to -5 deg. and can be used on land and offshore.

Idea generation

The Blade Dragon case is an example of how collective knowledge about the industry plays a crucial role in generating new ideas. It is characteristic for Liftra's innovation processes that all new ideas come from the same person, one of the managing partners, who have close and frequent contact with customers (L1, L2):

> *I am the one who has seen the most. (…) I have been off shore and have seen most turbine factories in Europe for example, and in that way seen and talked to customers and attended all the fairs and heard what problems they have now. I know what issues that need to solved. And then try and see if things can be done smarter … It's not necessarily that they (customers) say, "Can you solve this problem?" But when I listen to them I can hear that we can surely offer a smarter solution … When you look at how they do things today and you think that is a cumbersome way, we can do it in a smarter way? So it is about being out and see what happens and how they do things. And then ask whether we can do it smarter? (*L1: 202-212)

This confirms that for Liftra the most important stimulus for new ideas is external relationships to customers. This collective knowledge of the industry is based on know-who and know-how knowledge which has taken years to build up. It has been accumulated through "being there" and being part of an industry over many years.

In the case of the Blade Dragon the need was formulated by a specific customer, a large wind turbine manufacturer facing challenges in installing wind turbines in a forest without cutting down trees. A solution was to install the blades horizontally, although at the time no crane could perform this

[1] Note that the geographical level 'Denmark & neighbour countries' includes northern Germany and southern Sweden because these are considered part of the centre of gravity of the Northern Europe wind power industry.

operation. When Liftra was presented with this need, one of the managing partners created a rough proposal for the yoke and passed a sketched solution on to one of the engineers in the company.

> *I could see that most of what he suggested… it was not all that could be used. Yes, the concept and the idea that it should be able to turn the blade 360* or turning around its own center of gravity, it was good. So, the concept was good but there was just something about how it could be realized which was not there... So I spent a few months on thinking about this, but we never got an order from the first customer.* (L2, l8-l14)

At this stage no one fully understood the idea (Birkinshaw and Sheehan, 2002) or knew precisely how to come up with a technical solution or, in fact, whether it was practically feasible to create a solution.

Problem solving

The **Blade Dragon** project was developed over two attempts (see Figure 1). The first customer annulled their contract because of disagreements about IP rights, which occurred approximately one year after the project was initiated and temporarily shut down the project. One year later, another customer who had shown interest in the project was contacted, and the project was re-launched.

The main process of identifying sub-problems was undertaken by the managing engineer, who began by spending 1-2 months on the project alone. The initial work was characterised by a lot of thinking in combination with a general scan of the state-of-the-art for each sub-problem. The managing engineer had the full responsibility to develop a functioning concept, and he used a lot of 'pink hours' working on the idea, night and day.

> *I often have many pink thoughts in the evening at home. Especially just when you're about to fall asleep. Can you do such and such? That is usually when something throws off, for my part. That I will get up and draw tomorrow.* (L2, l189-191)

An example of how tacit knowledge 'works in the background' of his consciousness enabling him to focus his conscious attention on solving a specific problem.

After a couple of months, two more engineers were assigned to the project because its complexity and the many calculations that were required to approve the concept were too difficult to be undertaken by one person alone, and they had complementary skills that were needed in the project (L2: l34-38).

One sub-task of the project was to identify a material that could be used to protect the surface of the wind turbine blade when lifting it to the rotor and that simultaneously provided a high level of frictional resistance against the smooth surface of the blade (L2: l31-l43). In this search, they were in contact with suppliers (in many different locations) of such materials to acquire data on frictional resistance. However, because no supplier could provide sufficiently reliable data on their materials to prove its function, the team decided to conduct its own tests.

> "...it is not normal to see friction number of 1 or near 1 (…) it would obviously make it much easier, but we did not really believe it. And when we asked about what would happen if we squeezed on it then they could not respond to it, so we had to run our own test." L2: l45-l47

The three engineers assigned to working on the design and early drawings of the crane were responsible for different subtasks: calculations, hydraulic system, remote control, etc. Based on each team member's individually accrued knowledge bases the team was able to combine and exchange their knowledge to address each sub-problem as well as the complex interplay between them. The team of engineers provided the source for the production of new knowledge (tacit and explicit) in relation to developing, testing, validating and coordinating solutions for each sub-task. In line with Gertler (2003) it was in this part of the innovation process that the team were able to produce tacit knowledge by experiencing how things would work out in practice – learning by doing. This is distinctive for the synthetic mode of knowledge creation which characterize engineering practices (Moodysson, 2008). It is not necessarily important to know why systems work in a specific way, as long as you know how they work.

Testing and validation of the concept was carried out in parallel with codifying the knowledge in specific requirements to suppliers. For each sub-problem, the team specified the solutions to suppliers known to the company from previous projects. In this process, there was little interaction with suppliers; instead, it was a question of delivering components to be part of the final prototype. Hence, this is categorised as knowledge input in Figure 1. In addition, knowledge input from the customer fed into the project through the salesperson, illustrating low levels of interactive knowledge exchange with the customer. Here, the managing engineer explains how the contact with the customer was organized:

> *I think I've been down there 2-3 times for relatively short meetings, a few hours or something. (…) and because we needed a more detailed model of their wing. They were very reluctant to pass that information on to us, because what if we stole their wing… In the beginning, we got the completely wrong wing, because if we stole it ... but that is not so easy to work with.*
>
> *(…)Otherwise we have not really seen them, the German seller has probably spent many hours on the telephone and meetings with them, but he has sort of been our filter.* L2: l146-158

In sum, the problem solving stage was characterised by an internal core of engineers working on solutions for each specified sub-problem resulting in a parallel creation of tacit knowledge (a deeper understanding of the complex interplay between components etc.) as well as codified requirements specifications. The work took place in face-to-face interaction at the work site of the focal company receiving knowledge inputs from suppliers and customer.

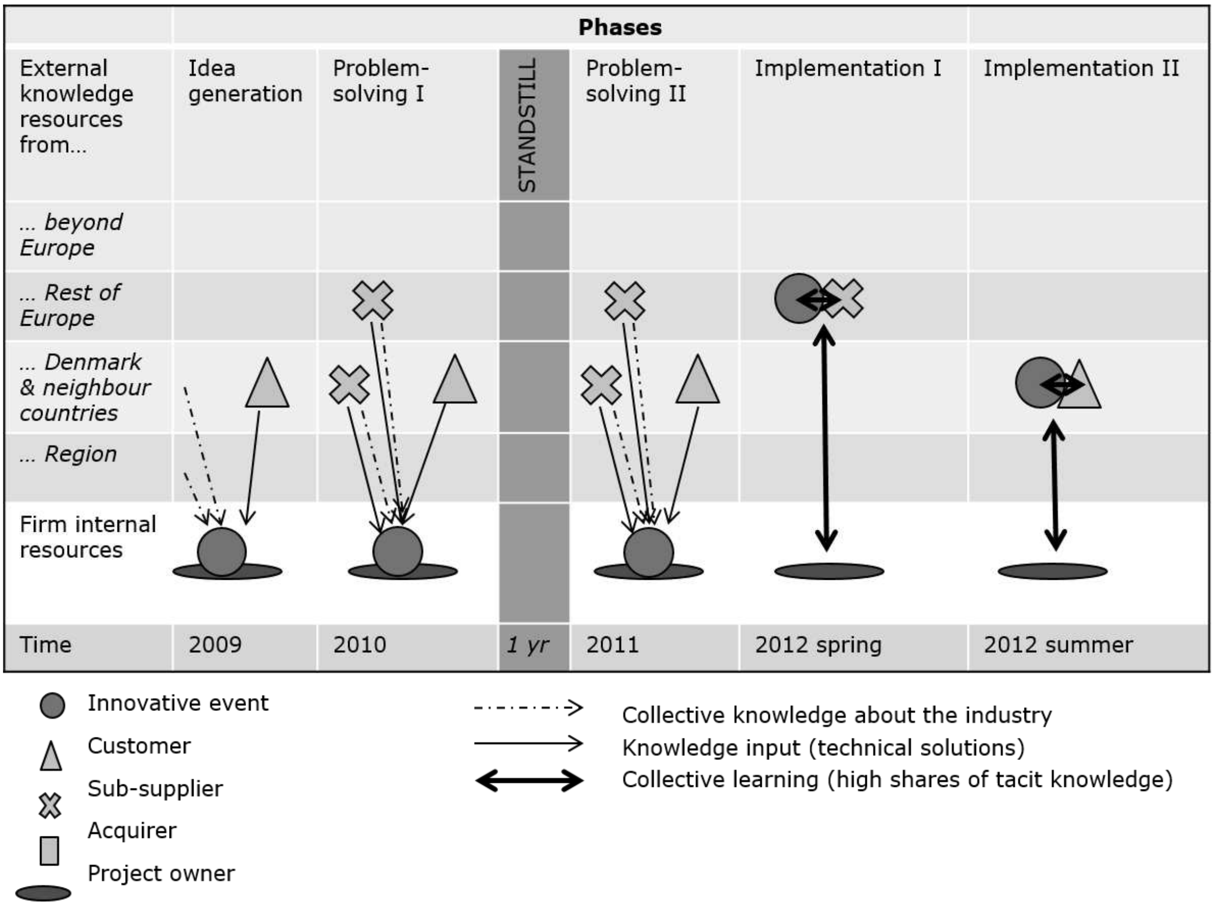

Figure 1: Innovation biography of the Blade Dragon, Liftra A/S

Implementation

A Polish sub-supplier that has been a sub-supplier to Liftra for many years developed the steel construction of the yoke. Liftra had to station an employee at the steel supplier's site for a period of three months to assist developing a prototype.

> *We had a man stationed there for 3 months to make sure they met the deadlines and also to make decisions along the way if the drawings were inconsistent. If there was something on the drawing which was wide of the mark, and they said 'you cannot do this', then he could make the decision and say 'then we do it this way'. Or he called home and said such-and-such. But it was actually him who was responsible for the schedules and for keeping them and also for the quality inspection. The rest of us went down there sometimes, but it was not as often. Maybe it was when some of it was finished or a larger part of it was finished. Or if there were major problems then we also went. L2: l103-l110*

The level of tacit knowledge involved in the physical development process was high and required an employee to be present through the whole development stage, align goals and exchange knowledge between the supplier and the engineering team in Denmark. As such this person became a knowledge-enabler (Gertler, 2003; Von Krogh et al., 2000) between the Danish based company and the Polish supplier. The knowledge-enabler was able to maintain the knowledge flow and continuous learning in the Danish company. Despite the complexity of the knowledge at this stage this person secured learning at the site as well as in the home organisation because of 'organized proximity' – where the logic of belonging and logic of similarity enabled knowledge to be transferred over long distances (Torre and Rallet, 2005). Nevertheless, the handing over of knowledge and the developing of a prototype required temporary geographical proximity (Torre, 2008) with the supplier at a daily basis, and with the developing team when major problems occurred.

The second part of the implementation process of the Blade Dragon (see Figure 1) involved final testing and certification at the customer's site. During this process, the company also chose to station an employee at the physical site of the customer in northern Germany because the complexity of the product and its functioning required the knowledge exchange and transfer to be managed face-to-face. Similar to the first part (production) of the implementation process, the stationed employee at the customer site acted as a knowledge enabler between the home organization and the customer. At the customer site the knowledge-enabler also maintained the contact to certification authorities. Again it was necessary to establish temporary geographical proximity with the customer because of the complexity of the embedded knowledge in the prototype, and again this person was able to function as medium for knowledge transfer between the home organisation and the customer due to organized proximity.

Pacific Orca

Pacific Orca is an offshore construction jack-up for the installation of wind turbines at sea. Safety is enhanced through a 6-leg design that allows the vessel to remain safely standing in the event of a sea bed "punch through" during operations. With a large cargo area and high-capacity deck loading, it can load 12 3.6 MW wind turbines. The innovation project was initiated by the small start-up Blue Ocean Ships A/S, which was acquired by the highly diverse Swire Group during the innovation process.

Idea generation

The original idea behind the Pacific Orca appeared based on informal talks between the managing director, who is a serial entrepreneur, and his cousin, who is an experienced engineer in wind turbine foundations for offshore sites. The latter had gained a thorough understanding of the industry and the gap in the value chain through working and engaging in the industry for many decades. As such he had a high level of industrial collective knowledge about the industry, which is necessary to identify new needs. Together they discussed the unique need in the offshore wind sector for a new vessel.

Development in the wind power industry has generally been characterised by increasing wind turbine sizes[2] and a constant need to reduce costs in offshore installation projects. Consequently, existing installation vessels no longer met the requirements of the industry. Furthermore, extant vessels were not operational in rough seas, leading to a risk of interrupting installation processes, resulting in potentially higher costs.[3]

The managing director followed the call and carried out a strategic analysis through planned interviews with a number of key stakeholders in the industry. It was a clear advantage for the project owner to be located in physical proximity to the Danish offshore wind power industry (S1). Subsequently the project owner identified a specialised supplier, an experienced Danish naval architecture company with specialised local competences in building offshore wind farm installation vessels that could match the identified need.

Problem solving

The specific requirements deriving from the strategic analysis of the need were passed on to the naval architecture company, who designated one person to design the vessel. Figure 2 illustrates how the innovation activities move from the project initiator to the supplier, the naval architecture company. Throughout the problem-solving phase, this supplier came to play a key role in the innovation process as the main provider of technical knowledge and engineering solutions to meet the requirements specified by the project initiator. The process was unusual long because the project initiator was unsure about the precise requirements the vessel had to meet.

The initial idea was to build a vessel that could operate in water depths of 25-30 meters; however, the specifications from the customer were repeatedly up-scaled to meet changes in market development (S2: l150-158). Today, the vessel can operate in water depth up to 60 m. Continuous up-scaling had consequences for the design of the Pacific Orca regarding the type of legs, jacking system and choice of main crane. Operating in such deep water requires truss legs rather than standard plate legs because truss legs are lighter and can resist higher levels of wave impact. However, truss legs and the jacking system required to jack up vessels with truss legs are also more expensive. Moreover, to provide increased safety against leg failure or punch-through, a design with six – rather than four – legs was preferred. Finally, the choice of legs also had consequences for the

[2] In the last 30 years, the size of the wind turbines have increased by a factor of 100 (Islam et al., 2013)
[3] One of the key differences between oil and gas and offshore wind power is that the installation of an oil-drilling rig is a single cost and can be planned depending on weather conditions, whereas the installation of an offshore wind farm is more demanding in time and resources because of the number of turbines that must be installed. For instance, installation cost per turbine is multiplied by the total number of wind turbines, which varies between 80 and 175.

choice of main crane. To provide a safe loading space on the deck, the crane was constructed around one of the legs, and because truss legs have a wider diameter than plate legs, it placed additional requirements on the crane's suppliers. Consequently, the development and design of vessels for wind turbine installation is systemic; it requires coordinating and weighing every choice against the consequences for overall price, safety and usability.

The problem-solving stage was characterised by occasional meetings between the project initiator and the naval architect, where the requirements were discussed. Often the requirements altered from meeting to meeting and hence the whole process was protracted (S2: l274-282). These interactive processes required face-to-face meetings because of the complexity (and tacit knowledge) in the design and sizing of the vessel.

Figure 2 shows that the innovation process consists of two problem-solving periods: one period before the start-up was acquired by Swire and one after. When the new owner entered, the requirements for the vessel changed again, and the possibility of operating in deeper water and the capability of servicing oil-drilling platforms were added (S2: l155-161). Hence, key problem-solving activities were located at the site of the naval architecture company and was carried out in between the meetings. The naval architecture company analysed the state-of-the-art for each individual sub-problem, i.e., cranes, jacking systems, legs, etc.

> *Of course there is also the fact that you are looking at what competitors are doing, and you compare what is available at the market. What type of platforms are available? How are they constructed? What type of legs do they use? That's what we call 'competitor research', right? And that is in a very early design stage that you want to find out what is really state-of-the-art in the market in this area at that particular time* (Swire II, line 303-307).

And in combination with internal competencies he specified the technical requirements that could meet the sub-problems. In this process, knowledge inputs from sub-suppliers (specialised world players located across Europe and the USA) of jack-up systems, cranes, thrusters, etc. played an important role.

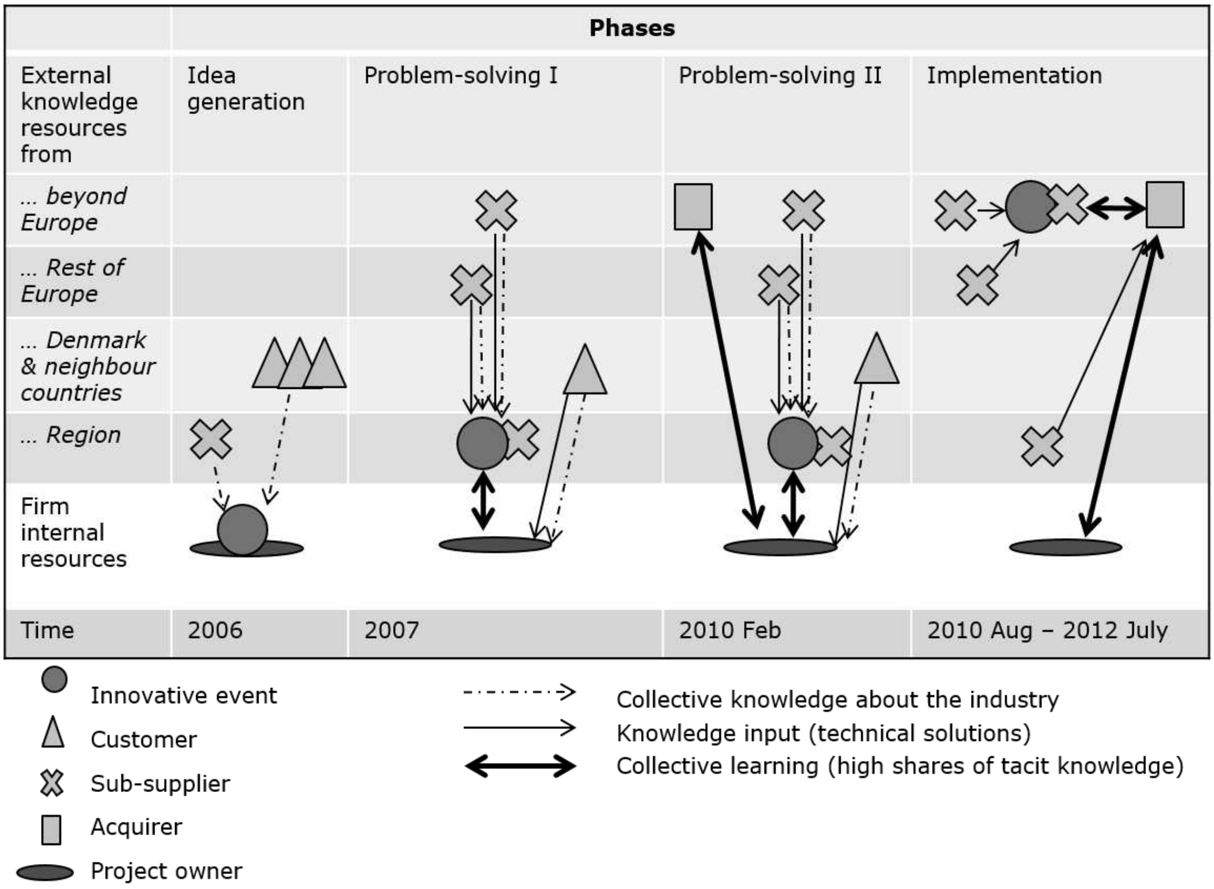

Figure 2: Innovation biography of Pacific Orca, Swire Blue Ocean

During the problem-solving phase, the naval architecture firm tested and validated their choices through both internal and external testing, which resulted in new (tacit and explicit) knowledge. The internal testing procedure consisted of advanced computations and computer-based simulations. They also relied on external testing, such as large-scale testing in wind tunnels and water tanks undertaken by local and specialised consultancy firms (S2: l463-496).

The choice of which solutions to implement was made in the first problem-solving phase in collaboration with the project initiator. In the second problem-solving phase, these decisions were made by the acquirer after evaluating the opinions of the project initiator and the naval architecture company. However, final decisions on sub-suppliers of components and equipment were typically made by the shipyard based on a 'makers list' provided by the naval architecture company.[4]

[4] Knud E. Hansen's role as commissioned designer of the vessel provides them limited influence on the final choice of suppliers. Instead, the shipyard was provided with the specifications and designs of the vessel together with a 'makers list' of suppliers for all the different components meeting the requirements. The shipyard typically negotiates the final price and negotiates requirements directly with suppliers.

Implementation

Swire Blue Ocean placed its order at Samsung Heavy Industries in Korea to build the **Pacific Orca** in August 2010 and the ship was delivered in July 2012. Again, the innovative activities changed site, from the naval architecture firm to the Samsung shipyard. The shipyard took over the detailed drawings at the time they signed the contract. This means that the shipyard is responsible for all changes that appear as a result of the selected suppliers (S2: l419-428).

During this process, Samsung was in close contact with Swire's technical department who sometimes mediated the contact with their subsidiary, Swire Blue Ocean (the original project initiator), when they had to adjust the design or were in doubt about the reasoning of previously made decisions. The initial conveying of the technical drawings to Samsung shipyard as well as contract negotiations happened at face-to-face meetings between Swire and Samsung. Most of the later communication took place over long geographical distance.

The shipbuilding industry differs from the Blade Dragon case because at this stage, tacit knowledge is to a much higher degree formalized and codified in drawings and specifications of the vessel. This is because large companies have systematized processes of knowledge transferring between units and their external knowledge transferring (Birkinshaw and Sheehan, 2002), the specific practice developed in shipbuilding and because of the role played by classification companies. Before the shipyard take on the drawings these have to be approved by a classification company and again when the shipyard has made the detailed production drawings the classification company has to approve them. The classification company also has a surveyor physically located at the shipyard to monitor the production process, such as the welding and overall quality (S2: l445-452).

While Swire, the parent company, took over the shipbuilding function in collaboration with the shipyard, Swire Blue Ocean concentrated its efforts on marketing and building up a sustainable organisation that could run the operation of the Pacific Orca including services, managing contracts, etc.

Fast-curing Polyurea

Fast-Curing Polyurea is a fast-curing paint that can be applied in one coat directly to metal and touched within one hour. The project focuses on making a one-coat, direct-to-metal product that can be applied to a new type of wind turbine tower. The tower is made in sections and is line produced, which drives the need for a fast-curing product that can be applied in one coat.

Idea generation

The third case differs somewhat because the original idea was initiated in one of the company's other market areas. Hempel distinguishes between three market segments: industry, marine and wind. The idea behind developing a *fast-curing polyurea* originated in the industry segment approximately a decade prior to initiation of the current innovation project. At that time, the idea was developed based on a wish to meet future demands of the industry segment, hence industrial collective knowledge about current and future needs in the industry segment. For quite some time, the project was a "garage project"; R&D employees worked on it when regular projects did not need their full attention. However, in this early phase, the project was never realised because one of the key ingredients in the paint was protected by a patent owned by a large chemical company and the production cost would thus be excessively high. When the current project was initiated, the patent was set to expire; consequently, it was worth initiating negotiations on the price, which made the economics of the project more promising.

The idea for the current project originated from a customer request and was mediated through one of Hempel's salespersons. When the customer request was presented to the R&D division, they matched it with the 10-year-old "garage project" (H3).

Problem-solving

The first problem-solving phase had the character of a 'garage project', during which internal employees worked on solving sub-problems. These employees drew heavily on their practical experience from the steel and iron industry. In addition, knowledge input from European suppliers of materials (on binding agents and epoxies) played a role in the first development phase, as well as initial interest from a northern European customer (see Figure 3).

In the second problem-solving phase, the specifications for the paint became more difficult because the project changed character following interest from a new customer. The fundamental idea of a fast-curing polyurea remained, but the specifications changed from a two-layer to a one-layer paint, to a faster drying time (max of 1 hour) and to incorporating corrosion protection that could withstand the outdoor elements for at least twenty years. To ensure they could deliver, most of the problem solving occurred internally before negotiations with the customer began. Continuous internal testing of the required level of corrosion protection and curing was a crucial part of the problem-solving phase. And it was through these tests and practical experimentations that new knowledge was created.

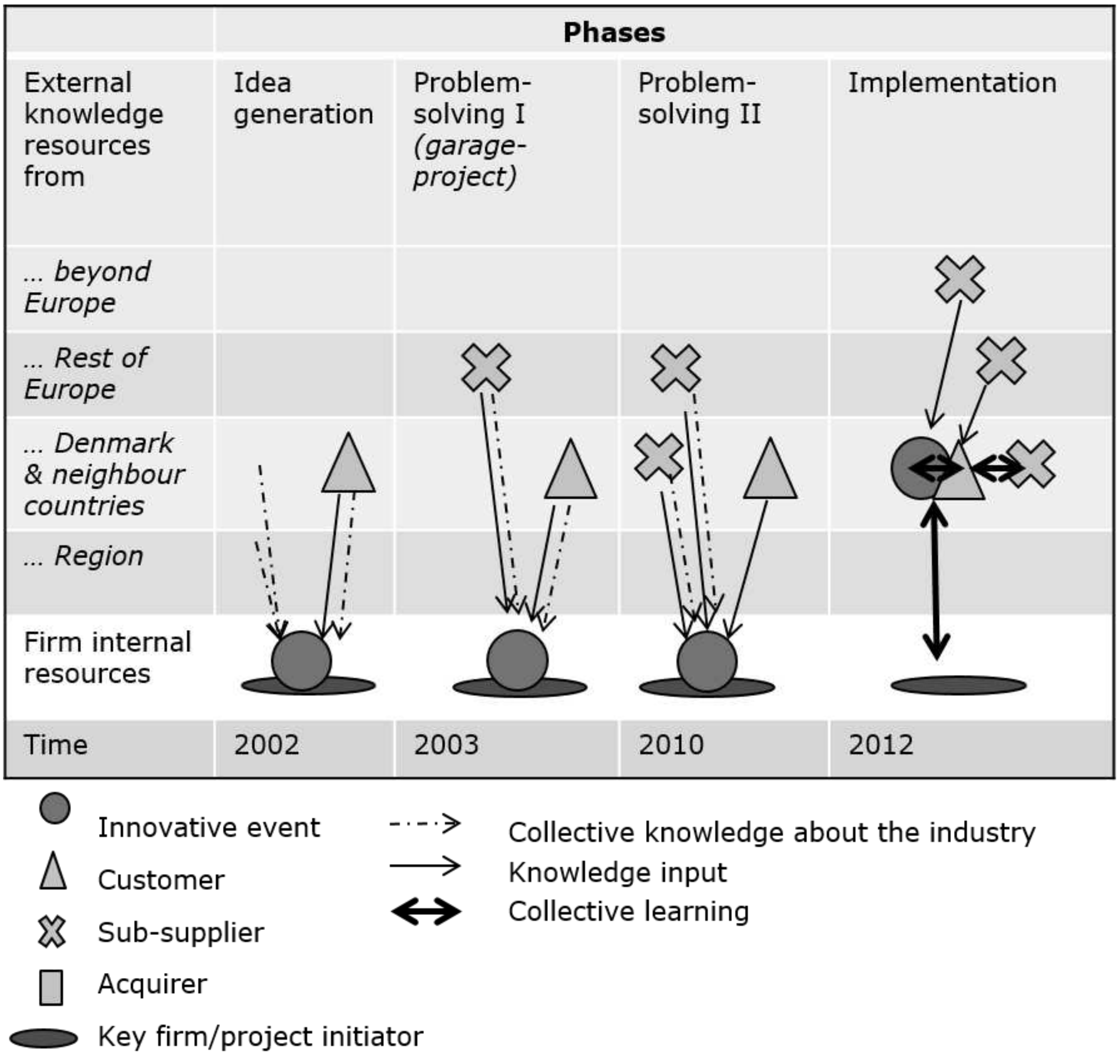

Figure 3: Innovation biography of the fast-curing polyurea, Hempel A/S

Implementation phase

The fast-curing polyurea was first applied manually at a prototype tower at one site in Denmark (Esbjerg) before the implementation process was moved to the customer's production line at another site in Denmark (Nyborg). At this location, the challenge was to automate the application process because the customer was accustomed to powder-based paint, and the new product is a wet paint. This change involved knowledge input from a number of suppliers, such as the application system and kiln-and-washing appliance suppliers. However, at the same time, this process of delivery involved enormous knowledge sharing that required temporary geographical proximity between the employees from the companies involved.

Thus, the implementation phase in the case of the fast-curing polyurea involved relocating the innovation activities to the site of the customer's production facility. It further involved combining chemical engineering knowledge with industrial and production facility experience. The R&D

manager explains why they have both technicians and chemists sited at the customer's production facility for the months it takes to implement the new production line.

> *First, we have some technicians we call coating advisors, who are out there on the spot to help. And second, we have our chemists who have developed the product on the site as well. When it is a new production line like this one, then the chemists are also there to see what is going on. So, it's like a collaboration between people who are experienced in being at workplaces where you apply paint, they can see something, and then our chemists who can see something else because they know what is in the paint, so they know what to adjust to improve the product* (H2: l223-229).

The company also hired an external consultant (former Hempel employee) who was familiar with the specific painting equipment that was installed at the customer's factory. His job was to ensure that the suppliers of the painting appliance equipment had implemented the correct programming, among other things. His former affiliation to Hempel made communication and knowledge sharing easier due to organized proximity. The result is a mix of suppliers working together with experts from the project initiator at the site of the customer to adjust the product, as illustrated in Figure 3.

Summary and conclusion

The analysis of the three innovation processes reveals different patterns of knowledge interactions and different patterns for the spatial configuration of knowledge creation between project owners, customers and suppliers throughout the innovation processes. The discussion focusses on three key findings: the mobility of innovation related activities, different strategies to diffuse knowledge between partners and the role of social tacit knowledge about the industry in generating new ideas.

The most striking finding is that the main level of innovation activities in all three events changes location at least once during the innovation process. With respect to Pacific Orca (see Figure 2), the main level of innovation activities changed site from the location of the project owner to the site of the key supplier (the naval architecture firm) in the problem-solving phases and again to the shipyard in the implementation phase. With respect to both the Blade Dragon (see Figure 1) and the fast-curing polyurea (see Figure 3), the main innovation activities changed location in the implementation phase. In the former case, the site changed twice: first to the construction site of the supplier in Poland and then to the customer's site in northern Germany. In the latter case, the location of the main innovation activities changed to developing the automated application process at the customer's site.

Thus, geographical proximity – understood as face-to-face meetings between individuals – is important for sharing tacit knowledge but is not limited to the location where the tacit knowledge is produced. For example, in the implementation phase, the delivery to the customer involves sharing of tacit knowledge that requires temporary geographical proximity – as in the cases of the Blade

Dragon and the fast-curing polyurea. Similarly, to incorporate the knowledge of specialized suppliers in the problem solving and implementation phases, the main level of activities move to the suppliers' location in the Pacific Orca and Blade Dragon cases. Consequently, this study indicates not only that innovation processes unfold over time and involve different types of actors but also that the core level of innovation activities relocate to physical sites that may be geographically far from the source of knowledge production.

This finding confirms similar findings in the previous literature, indicating that it is important for firms' innovativeness that they are capable of approaching and acquiring knowledge from geographically distant locations (Bramwell et al., 2008; Gertler and Levitte, 2005; Niosi and Zhegu, 2005; Simmie, 2003; Tödtling et al., 2012, 2006; von Zedtwitz and Gassmann, 2002). It also extends this work by providing a more detailed understanding of how the innovation process is flexible in its geographical configuration and can be perceived as multi-locational because of the mobility of innovation related activities. In other words, this understanding of firms relocating components of innovative activities to different regions, countries or continents and still being capable of transferring and sharing tacit knowledge is important to bear in mind when analysing how firms approach and acquire international knowledge in the innovation process. Hence, the static type of knowledge provided by some research that firms rely on international knowledge sourcing in the innovation process tells us little about how, where or when a firm approaches and acquires such knowledge (see also Ibert and Müller, 2015).

Secondly, the analysis reveals that the three cases differ with regard to the mode of mediating the tacit knowledge that has been produced in the problem-solving phase. In the case of Blade Dragon and the fast-curing polyurea knowledge produced in the problem-solving phase were transferred by letting the individuals who were responsible for the problem-solving tasks be involved in the implementation stage as well. Knowledge was thus embedded in the individual project worker. However, in the ship-building industry the handling of and handing over of knowledge that was generated in the problem-solving phase is more systematized. There are standardised ways of codifying tacit knowledge in detailed explicit drawings, requirement specifications and makers lists, which can be handed over to the shipyard. The difference could be explained by the sizes of the companies since the latter approach is similar to the handling of tacit knowledge in large multinational companies (Birkinshaw and Sheehan, 2002). On the contrary it is often common that smaller organisations handle the "diffusion" of tacit knowledge differently, where the engineers who develop the solutions and hence produce tacit knowledge about how to develop the product are the same responsible for the implementation – the creation of a prototype.

Finally, another finding relates to whether the location of the firm influences the innovation process at all. In all three cases, the process of identifying a need and matching it with a solution benefits from being located close to the wind power hub in Northern Europe. Additionally, in all three cases, the initial ideas originate from customer needs located in 'Denmark & neighbouring countries'. Although the projects have this in common, how project owners have achieved knowledge about customer needs has varied from a strategic examination to a more spontaneous approach in which customer needs are identified coincidentally (such as through salespersons). Nevertheless, knowledge of market trends, customer needs and possible technological solutions has, in all three cases, been accumulated as a result of being part of an industrial agglomeration of wind-power related companies and participating in fairs and industry meetings and through close customer contact. In the case of the Pacific Orca, this knowledge came around more accidentally in an informal talk between the project owner and a relative, who had built up this insight from being active in the industry for decades.

Thus, the locality of the firm seems to be extremely important for generating new ideas and initiating innovation processes. Through connections and linkages to the wind turbine industry the individuals who identified the ideas had built up social tacit knowledge or collective knowledge about the industry. Without ties to customers and in-depth knowledge of customer needs, value chain dynamics and the development and direction of the industry, the project owners would most likely not have originated the ideas leading to the innovation projects. Knowledge of the industry has thus accumulated through former collaborative ties, informal talks at fairs and conferences and from "being there" and being part of an industry for years. It is this accumulated knowledge of the industry and an understanding and anticipation of current and future needs that caused the companies to initiate the development of new products. Nonetheless, the locality of the firms seems to be less relevant at later phases of the innovation process.

As discussed above, the analysis shows that, at later stages of the innovation process, firms must be more flexible in how their knowledge work is organised and, in fact, must be capable of operating at different locations throughout the innovation process.

Conclusion

This paper set out to develop a better understanding of how local and non-local knowledge sourcing vary throughout the innovation process. By applying a biographical approach (S Strambach, 2012), the paper followed the knowledge creation in three innovation processes as they unfolded over time and through space. The analysis sheds new light on three aspects: 1) how patterns of knowledge interactions vary throughout the innovation process, 2) how the core level of innovative activities changes physical site during the process of innovation, and 3) how the location of the firm seems to play a larger role early in the innovation process rather than at later stages.

The reach of the conclusion is of course limited in terms of generalisation because the analysis only builds on three innovation processes. However, the analysis produces qualitative insight into the process of innovation, uncovering how these examples rely on many different configurations of spatial knowledge dynamics, including knowledge social tacit knowledge about the industry, formalised knowledge inputs and collective learning processes. This analysis has asked a different set of questions and has consequently shed new light on how the importance of geographical proximity varies across the different phases an innovation process passes through.

The findings imply that innovation policy should be designed to support companies working across regional and national borders. Lots of policy, particularly regional innovation policy, has been preoccupied with creating and supporting cluster dynamics by building up local networks between companies. However, as this study shows it is just equally important to build up international knowledge networks to successfully innovate, hence, innovation policy must not forget the international dimension. This also includes creating favourable framework conditions for the support of different types of knowledge sharing mechanisms such as labour mobility and strategic alliances.

A natural question arises regarding whether these findings are equally valid for other industries or technologies, or whether these findings are unique to the wind power industry because of the very large-scale innovations that characterise this industry. Further studies must decide whether this finding is unique to the wind power industry or whether similar patterns for knowledge interactions can be found in other industries. For example, it would be worth considering repeating studies in other types of industries, such as creative industries or more science-based industries, which would likely show different patterns of interaction in innovation processes.

Similarly, it would be of great interest to be able to test these results on larger, more generalizable data sources (e.g., surveys). In particular, it would be of interest to examine whether the local level of knowledge interactions is more important in phases involving the generation of new ideas than in later phases of the innovation process. Such studies would be of great academic value if they could provide general support for the idea that different geographical levels have varied significance throughout the innovation process.

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