EUROPEAN PLANNING STUDIES, 2018
VOL. 26, NO. 5, 877–894
https://doi.org/10.1080/09654313.2018.1427700

Routledge
Taylor & Francis Group

Proximity and modes of innovation – evidence from two agricultural engineering industries in north-west Germany

Dominik Santner

Centre for Regional and Innovation Economics (CRIE), Faculty for Business Studies and Economics, University of Bremen, Bremen, Germany

ABSTRACT

Recently, policymakers realized the important role of traditional industries for regional development. However, traditional policies of the last decades mainly focussed on science-intensive high-tech industries. Therefore, it is important to understand, how traditional industries innovate and renew themselves. One of the most notable recent strands of literature distinguishing between the characteristics of high- and low-tech industries is the one on modes of innovation. However, another very important approach related to innovation and regional development, the proximity literature, has only partly discussed in relation to innovation modes. This paper seeks to contribute to this issue by focussing on two traditional agricultural engineering industries from north-western Germany that experienced processes of renewal in the first years of the twenty-first century. It is shown that these industries followed very different developments and utilized different forms of proximities in this process in very specific ways.

ARTICLE HISTORY
Received 15 December 2015
Revised 7 January 2018
Accepted 9 January 2018

KEYWORDS
Modes of innovation; proximity; STI; DUI; CCI; agricultural engineering

1. Introduction

Traditional regional innovation policies of the last decades often tended to concentrate on high-tech industries and the role of regional research infrastructures. However, more recently, scholars realized that many regional economies lack a sufficient research infrastructure and depend on traditional, often low-tech industries (Cooke, 2013). The issue has been put on the political agenda within the RIS3 strategy of the European Union. Thus, European policymakers decided to empower traditional industries through the support of their innovation activities.

In general, economic geographers widely agree that the degree of cognitive, social, institutional, organizational and geographical proximities (Boschma, 2005; Nooteboom, 2000) has a direct influence on collaborative innovation activities and learning.

However, innovation in differently structured industries (e.g. high- vs. low-tech) differs. For example, Mattes (2012) described the role of different dimensions of proximities in industries with different knowledge bases.

Recently, the literature on modes of innovation (Isaksen & Karlsen, 2012; Jensen, Johnson, Lorenz, & Lundvall, 2007) developed a more pronounced picture of innovation

CONTACT Dominik Santner dsantner@uni-bremen.de Centre for Regional and Innovation Economics (CRIE), Faculty for Business Studies and Economics, University of Bremen, Wilhelm-Herbst-Str. 12, 28359 Bremen, Germany

activities in differently structured industries. It distinguishes between a science–technology–innovation (STI) mode, which is characteristic for science-based industries, a doing–using–interacting (DUI), which is often applied in low- to medium-tech industries like food or engineering, and combined and complex innovation (CCI) mode, which combines and entangles DUI and STI innovation. Some authors introduced the issue of proximity to this discussion (e.g. Fitjar & Rodríguez-Pose, 2013). However, an encompassing conceptualization of this topic is still missing.

This paper seeks to shed light on this topic by discussing theoretically and empirically the changing roles of proximities in evolving and renewing traditional industries characterized by different modes of innovation. It is based on two qualitative case studies from the agricultural engineering context of north-western Germany, including the farm trailer and the stable technology industries. Both industries traditionally followed DUI mode innovation, share an overlapping regional and industrial context, and both industries experienced advanced technological changes and innovation in the early twenty-first century. Nevertheless, changes in innovation modes differ between the two case studies. While many firms in the farm trailer industry switched to a fully developed CCI mode of innovation, central actors of the stable technology industry diversified into the related sector of biogas technology following a DUI strategy. Both cases differ in terms of the relevant forms of proximity involved. Therefore, a theoretical and an empirical research question arise: How do agents utilize different forms of proximities in different innovation modes in the event of cluster renewal? What conclusions can be drawn from the empirical cases for the literature on regional industrial renewal?

The remainder of this paper is as follows. Section 2 is introducing the modes of innovation literature, while Section 3 is discussing the role of proximities for different modes of innovation. Section 4 is offering an overview of the methodology and the broader context of the case studies. Sections 5 and 6 describe and discuss the case studies. Finally, Section 7 is drawing some conclusions.

2. Modes of innovation

Traditionally, the literature on innovation distinguishes between, firstly, R&D and technology-driven innovation (e.g. Audretsch & Feldman, 1996; Cantwell & Iammarino, 1998; Maclaurin, 1953), and secondly, interactive, institution-driven innovation which is often created 'on the job'. While the first is strongly based on knowledge codified in books, articles and other sources of written data, the second relies to a stronger degree on so-called tacit knowledge (e.g. individual experiences). The ability to learn from a specific source depends on the absorptive capacity of the learning agents (Cohen & Levinthal, 1990). Or in other words, on the question whether the learning agents already know enough to be able to understand what they are trying to learn. Learning is potentially most effective if both partners are from thematically related but still not the same cognitive contexts (Frenken et al., 2007). Absorptive capacity building and collective learning can be potentially self-enhancing as they increase the attractiveness of a firm to potential partners (Brunswicker & Vanhaverbeke, 2015; Dahlander & Gann, 2010) and may unfold systemic effects within regional innovation networks (Menzel & Fornahl, 2010; Ter Wal & Boschma, 2011).

Learning and absorptive capacity are core concepts of the literature on modes of innovation. Thus, this theory strand is related to other space-based concepts like the knowledge bases literature (Asheim & Coenen, 2005; Cooke, Laurentis, Tödtling, & Trippl, 2007) as well as the literature on regional innovation systems (RIS) (Cooke, 2001; Cooke, Gómez Urnaga, & Exteberria, 1997). Jensen et al. (2007) differentiate between the STI and the DUI modes. The STI mode refers to firms that rely on scientific search and use and produce R&D-related codified knowledge. They mainly use know-what and know-why types of knowledge (Jensen et al., 2007). This kind of knowledge can easily be reproduced and used by everyone who understands the scientific code regardless of the location or the social background. It is typical for industries with an analytical (meaning science-based) knowledge base (e.g. pharmaceutics). However, synthetic (meaning engineering-based) knowledge may also play a role in form of applied research (Isaksen & Karlsen, 2012). Knowledge is created in firm-owned R&D departments or acquired through interactive linkages to universities, R&D organizations and other scientific agents (so-called STI agents) in a learning-by-searching mode. Mostly, basic scientific knowledge (in contrast to applied scientific knowledge) cannot be commercialized directly. There exists a relatively high potential that STI mode firms create radical and sophisticated innovation. However, pure STI mode innovation patterns are at best rare as most firms also innovate application oriented.

The DUI mode refers to firms that rely mostly on tacit knowledge and thus, a synthetic or symbolic (meaning aesthetic-based) knowledge base (e.g. from engineering or creative sectors). Knowledge is mostly of a know-how and know-who character (Jensen et al., 2007). Most innovation is incremental and associated with refinements of existing technology and practice. It is created by experienced employees on-the-job and very often induced by market-demands in tight interaction with customers, suppliers and, more seldom, competitors (so-called DUI partners). This represents a learning-by-doing, using and interacting mode. Thus, radical innovation is much less likely in these industries. However, new products can be more often easily commercialized than in the case of STI mode innovation. Furthermore, some authors point to the possibilities for more sophisticated innovation if interaction involves partners from broader contexts, like, for example, from related industries (Herstad et al., 2015).

Jensen et al. (2007) show in their empirical study from Denmark that firms relying on both modes, STI and DUI, seem to be on average more innovative than firms that widely rely on just one of both. Similar findings have been concluded from Portugal (Nunes, Lopes, & Dias, 2014), Belarus (Apanasovich, Heras, & Parrilli, 2016), China (Chen, Chen, & Vanhaverbeke, 2011), Austria (Trippl, 2011) and the Basque Country (Parrilli & Heras, 2016). However, the effectiveness of a combined STI–DUI innovation mode may vary between industries and cultural–institutional contexts (Apanasovich et al., 2016; Chen et al., 2011; Parrilli & Elola, 2012). In line with these observations, Isaksen and Karlsen (2012) formulated a third mode, the CCI mode. CCI refers to firms that apply both STI and DUI style innovation. According to Isaksen and Karlsen (2012) combining STI and DUI is not a trivial task as both modes are based on different types of learning. Thus, CCI firms rely on a much broader absorptive capacity. They recombine resources and knowledge in a much more complex way than DUI or STI firms. CCI firms effectively need to develop their core competences and technology platform to be able to learn from both STI (universities and research centres) and DUI partners (clients, suppliers and competitors).

3. Modes of innovation and proximity

As mentioned earlier, interactive learning and innovation strongly rely on the ability of agents to find and understand relevant knowledge. Economic geographers widely agree that absorptive capacity building through learning depends on different kinds of proximities. Boschma (2005) distinguishes five forms of proximities. Firstly, cognitive proximity describes the degree of similarity between two agents' industrial-thematic and technological knowledge. Interactive learning is most effective if cognitive proximity is large enough to learn something new, but not too large, so that one still understands, what the opponent is dealing with (Frenken et al., 2007). Secondly, social proximity refers to a shared social context and background of two agents. It has the potential to create mutual trust, which can help to establish new contacts. Third, institutional proximity is associated with a shared institutional context of values, expectations and norms. It can help to establish common routines of social practice but may also lead to the technological lock-in of industries (Grabher, 1993). Fourth, organizational proximity describes a common organizational context (for example subsidiaries of a company). Finally, geographical proximity is connected to physical distance and may unfold an indirect effect as it can promote and enable interaction through visibility and accessibility.

These forms of proximities are not static. They may change over time and vary according to each specific situation. Economic agents can make strategic decisions to create a more favourable degree of proximity (Balland, Boschma, & Frenken, 2015). For example, the degree of cognitive proximity can be enhanced through learning. Social proximity can be created through the decoupling of social ties from one context to another. Other processes include institutionalization (institutional proximity), the integration of firms and employees through mergers and acquisitions or hiring (organizational proximity) and spatial agglomeration (geographical proximity).

In this sense, the roles and effects of different forms of proximity vary between industrial contexts and evolve over time. Therefore, first attempts to include the issue in the debates on knowledge bases (Mattes, 2012) and innovation modes (Fitjar & Rodríguez-Pose, 2013; Herstad et al., 2015; Trippl, 2011) have been conducted. This section discusses which conclusions regarding the role of proximity can be drawn from this literature. They are summarized in Table 1.

STI mode innovation is associated with scientific principles of knowledge creation (Jensen et al., 2007). Thus, it mainly involves agents such as universities, research facilities and science-based industries such as pharmaceuticals. Scientific knowledge tends to be sophisticated but is also often codified. It is mainly associated with more radical and technological forms of innovation (product and process innovation), rather than

Table 1. Modes of innovation and proximities.

	STI	DUI	CCI
Relevant partners	Mainly STI partners	Mainly DUI partners	STI and DUI partners
Proximities			
Cognitive	Fundamental	Fundamental	Fundamental
Social	Negligible	Helpful	Helpful
Institutional	Important	Very important	Very important
Organizational	Very important	Possibly helpful	Helpful
Geographic	Negligible	Helpful	Helpful

non-technological forms like organizational innovation (Apanasovich et al., 2016). Codified knowledge is easy to learn and accessible if one knows the principles of the respective scientific discipline. Fitjar and Rodríguez-Pose (2013) state that interactive learning of STI mode firms strongly depends on cognitive and organizational proximities. STI mode collaboration with scientists from firm-internal R&D departments or external partners from universities and other R&D organizations demands a high degree of coordination. Cognitive proximity to R&D organizations enables those collaborations as the knowledge on the key principles of a scientific discipline is fundamental for STI learning. Organizational proximity through hiring or mergers and acquisitions offers a better control over otherwise easily transmittable codified knowledge. For the case of Norwegian firms, Herstad et al. (2015) find empirical evidence that recruitment from STI agents increases the probability of a firm to develop technical inventions. Thus, the organizational incorporation of STI agents (through mergers and acquisitions) and personnel (through hiring) possibly can enhance the absorptive capacity of the firm itself. Other forms of proximity seem to be less relevant for STI mode innovation. Fitjar and Rodríguez-Pose (2013) expect geographical proximity to be less valuable due to the codified character of knowledge. However, empirically, they find evidence that collaboration with STI agents is slightly more likely to lead to innovation if the collaborating agents are situated in a shared regional context. Mattes (2012) comes to very similar conclusions for firms with analytical knowledge bases. In addition, she states that institutional proximity may be supportive as a shared institutional context may provide the ground for sophisticated learning. Furthermore, interactive STI mode learning is often based on contracted research (Trippl, 2011), which helps to provide a common institutional ground for complex R&D activities. Finally, Mattes (2012) believes that social proximity probably plays a more insignificant role as access to codified knowledge is generally not dependent on social contacts.

In contrast to STI mode innovation, proximities partly have a different effect on DUI mode innovation. It is traditionally perceived by economic geographers to be more sensitive to geographical proximity as learning of tacit knowledge (like individual experiences) depends on face-to-face interaction. However, industry standards in mature DUI industries may reduce the need for intensive face-to-face interaction and in some industries like the Austrian automotive sector (Grillitsch & Trippl, 2014) the sufficient degree of geographical 'proximity' between collaborating DUI partners may be situated on the scale of neighbouring nation-states. Geographical proximity can foster interaction but also raises the risk of cognitive lock-in due to too narrow collaboration networks (Grabher, 1993). However, Fitjar and Rodríguez-Pose (2013) also state that geographical proximity can be compensated by other forms of proximity and Boschma (2005) states that it is neither necessary nor sufficient for any interactive innovation efforts. Mattes (2012) believes that, alongside with social proximity, geographical proximity plays a supportive role in innovation in industries with a synthetic knowledge base. In contrast, Fitjar and Rodríguez-Pose (2013) find empirical evidence that collaboration with DUI partners is more likely to lead to innovation if these partners are located outside the own regional context. They explain this instance by the tendency for lock-in in geographical proximity. Mattes (2012) also states that cognitive and institutional proximity are the most important forms to stimulate interactive innovation and economic prosperity in industries with a synthetic knowledge base. Interaction with clients and suppliers, based on tacit knowledge is strongly dependent on a mutual understanding of problems (thus, cognitive proximity).

A shared institutional context in terms of values and routines may support this. Thus, trust (and therefore social proximity) may be more important than institutional proximity in certain forms of DUI mode learning. Organizational proximity is perceived to play a less significant role for DUI mode firms as mergers and acquisitions do in most cases not offer a better degree of control over tacit knowledge. For example, Herstad et al. (2015) find empirical evidence that recruitment from DUI agents is less effective because tacit knowledge of new employees cannot be easily integrated into the firms' own routines. However, they also observe that, if DUI recruitment comes from related industries, it helps to strengthen a firm's organizational knowledge base and processing routines and may thus enhance the likelihood of innovation. Thus, more sophisticated innovation may also be possible in DUI mode if sufficiently cognitive proximate collaboration partners are involved or acquired.

The role of proximities in CCI mode innovation has been less widely discussed in the literature. However, due to the assumptions formulated by Isaksen and Karlsen (2012) some expectations can be drawn. The recombination of STI and DUI knowledge in CCI mode innovation requires a much broader absorptive capacity of the firms. Thus, one can expect most forms of proximities to play a more or less significant role. Like in the case of STI and DUI mode innovation, cognitive proximity is most central to interactive learning and innovation. However, firms need to be able to build cognitive proximity to a much more heterogeneous set of agents. Thus, they have to be able to recombine different modes of learning (doing–using, searching, interacting with partners with heterogeneous partners) and knowledge (know-what, know-why, know-how and know-who). The complex character of interactive innovation activities in the CCI mode is dependent on a supporting institutional infrastructure. The building of such an institutional environment that enables firms to recombine DUI and STI knowledge and that offers an infrastructure for joint collaboration of DUI and STI agents is one of the most important and demanding tasks for successful CCI mode innovation.

Geographical and social proximity can be supportive but are not always necessary. Isaksen and Karlsen (2011) state that a broad RIS in terms of supporting political and academic structures is helpful for CCI mode innovation but can be at least partly substituted by knowledge links to extra-regional partners. Organizational proximity may also be supportive as it can provide similar benefits as in STI and DUI mode interaction patterns. However, depending on the specific innovation output, control over codified knowledge flows may be helpful but much of the often applied scientific knowledge can be expected to be acquired through collaboration efforts with firm-external scientific partners, especially if the innovating firm traditionally had a stronger synthetic knowledge base. Thus, organizational integration can help to foster innovation when firms strategically integrate formerly independent firms or hire specific personnel to enhance their absorptive capacity to be able to learn from new STI or DUI partners.

Regarding the discussed literature review, two possibilities arise. Firstly, firms may start to incorporate STI knowledge, resulting in a more CCI innovation mode. And secondly, firms may continue to rely on a DUI mode but manage to incorporate knowledge from DUI partners that are sufficiently cognitive proximate, like from related industries.

4. Methodology and background of the case studies

For this research, 33 semi-structured qualitative interviews were conducted between 2012 and 2015 within the context of a research project and a Ph.D. thesis. Of these interviews, 23 interviews were conducted with stakeholders from organizations that actively developed technological innovation in the past: 12 companies of the stable technology industry, 8 companies from the farm trailer industry, the COALA research centre, which also develops farm trailer and farm vehicle-related technology, and 2 biogas companies without a direct organizational connection to the two other industries. The remaining 10 interviews were conducted with industry experts with in-depth knowledge of the case studies from non-innovating organizations (academia, chambers of handicrafts, etc.). Relevant interview partners were identified in the first explorative interviews with some of the industry experts, through the analysis of secondary sources like trade fair participant lists and company data banks, and after the mentioning of firms in previously taken interviews. Interview partners from firms included CEOs, high-ranked managers and heads of product development departments. Except for one interviewee, all of them were occupied by their company for five years or longer, or, as in the case of younger companies, since the establishment of the firm. Industry experts came from different contexts, including academia, trade organizations, administration and interest groups. All interview partners, besides two industry experts, came from the regional context of north-western Germany.

The interviews lasted generally between 60 and 75 minutes. Interviewees from firms were mainly asked about the development of the firm in the last 15 years prior to the interview with a strong focus on innovation efforts and collaboration activities.[1] Industry experts were mainly asked about the general development of the observed industries.

The analysis of the interviews followed a qualitative interpretation and was based on the theoretical assumptions drawn from the literature on dynamic proximities (e.g. Balland et al., 2015). Processes of changing cognitive proximity were identified if an interviewee stated processes of collaborative learning (distinguished between STI and DUI type of learning). Social proximity dynamics were associated with decontextualizing social relationships (meaning, activating and using social relationships for innovation that have been created in a different social or professional context). Institutional proximity shifts were assumed if processes of common institution building were mentioned. The formation of organizational proximity was associated with processes of (mainly strategic) hiring of skilled staff or mergers and acquisitions. And finally, geographical proximity changes were associated with statements regarding changes of an agent's physical location.

The two case studies include the farm trailer industry broadly centred on Osnabrück and the stable technology industry broadly centred on Vechta (see Figure 1). They share a common and overlapping regional, and thus, social and partly institutional, context. Both industries are often treated as parts of the larger agribusiness context (Davis & Goldberg, 1957). The north-west is one of Germany's most productive agricultural regions in terms of both crop and livestock farming. Furthermore, the region is home to several significant producers of processed food. Firms from the whole value chain of food production can be found in the region. The agricultural engineering industries are perceived to be part of this value chain. However, this

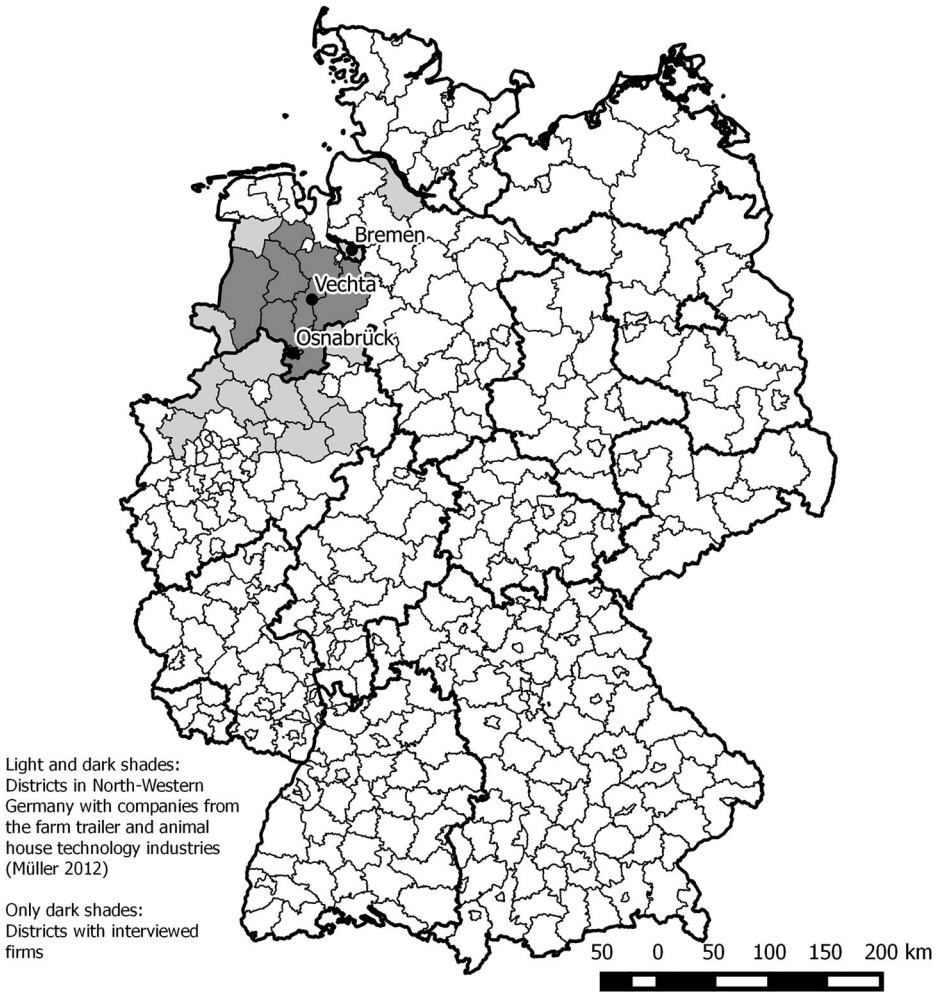

Figure 1. The investigated region within Germany.

study investigates the two case studies separately, as their value chains and innovation networks are widely independent of each other (crop vs. livestock value chains) and show different characteristics.

The farm trailer and stable technology industries can be traditionally perceived as low-tech industries. For decades, the firms from both industries traditionally used to follow a classical DUI innovation mode with strong ties to clients (farmers) and suppliers, often in geographical and social proximity, firm-internal incremental innovation through learning-by-doing and important established institutional arrangements. Informal institutional settings have developed between clients and suppliers to ease and enable collaboration. Even today, incremental refinements follow these patterns. However, in both case studies events and developments of more sophisticated innovation occurred during the early twenty-first century that are characterized by different modes of innovation and shifts in the relevance of different forms of proximity.

5. The farm trailer industry

Producers of the farm trailer industry can be found in several regions of Germany. However, the region of north-western Germany centred on the city of Osnabrück, including parts of western Lower Saxony and northern North Rhine-Westphalia shows the highest concentration of these firms in Germany (Krawczyk & Nowak, 2009). Notable firms include Claas, Amazone, Grimme, Krone, Lemken and others. Furthermore, specialized suppliers from contexts such as tyre making, specialized computer control systems and others can be found in the region. The firms of the north-west are widely specialized in trailers and self-propelled vehicles, while tractors are not produced in the region.[2]

Recently, the innovation activities of many firms changed from a DUI to a more CCI mode character. Since the 1990s, the global farm vehicle sector was, as many industries of that time, characterized by the increased introduction of modern information and communication technology (ICT; e.g. onboard computers, sensors, robotics, etc.). ICT is beyond the traditional technological scope of most producers of farm vehicles and the personnel of most firms did not have relevant ICT-related skills. Thus, many firms needed to build their cognitive and absorptive capacities to become able to understand, use and develop upon this new type of technology. In 2003, the global industry standard ISOBUS was introduced. This was an event that boosted this development. ISOBUS is a standard for the communication of soft- and hardware of tractors and trailers and enables the direct communication of vehicles from different producers. Even though this trend is more of a global character, the firms of the farm trailer industry of north-western Germany managed to start a development with an explicit regional character. Two strongly interrelated processes are associated with this. Firstly, in 2007 the interdisciplinary research centre COALA (Competence Of AppLied Agricultural engineering) was founded at the University of Applied Science of Osnabrück by several scientists who have worked at this university and in this field before. COALA combines competences from agricultural engineering, crop research and other disciplines. It was founded upon the motivation of the scientists but also due to the strong demand for sophisticated engineering development by local firms. The second event that played a significant role was the foundation of Competence Centre ISOBUS (CCISOBUS[3]), which is also located in Osnabrück. CCISOBUS is a collaboration network of farm vehicle producers, specialized suppliers of ISOBUS technology and COALA that seeks to develop and refine the ISOBUS standard. Most of the members of CCISOBUS are situated in north-western Germany but within the last years the network increasingly expanded and included partners from different regional and national contexts.

This development was characterized by shifts in the importance of different forms of proximity to innovation activities in the farm trailer sector of north-western Germany. These are very much in line with what has been formulated as an expectation for CCI mode innovation in Section 3. Cognitive proximity to collaboration partners still plays a significant role in innovation. However, it now depends on a broader cognitive capacity as, in addition to the traditional DUI partners (e.g. clients), who still often formulate the specific application problem, much of the innovation is conducted in collaboration with the STI-partner COALA to find sophisticated solutions, as the CEO of a smaller farm trailer business states for the case of the innovation process of a sensor:

> […] in the fields one often has the problem that when one tries to spread manure it is unclear whether it is running or not. You do not fertilize the ground when the hose is clogged. A farmer asked us if we can find a solution for this problem. […] We asked several research organizations and then we ended up with Professor [X] from Osnabrück. He thought about it and said: 'We will find a solution.' And so they did.

Even though some of the larger firms of the industry have established their own R&D departments, much of ICT-related technology development is done in close collaboration with the researchers of COALA and specialized ICT and ISOBUS-related suppliers. Especially, smaller producers of farm vehicles that do not have the internal capacities to develop sophisticated ICT-related technology strongly rely on the work of the researchers of COALA. Learning-by-searching as well as know-what and know-why become increasingly important for the innovation processes in the farm trailer industry, even though much of it is not conducted by the firms themselves but by researchers from COALA.

The role of institutional proximity is also increasing. The process of technological upgrading through the introduction and development of ICT is strongly linked to the CCISOBUS network and the refinement of the industry standard ISOBUS. The increased complexity of collaboration efforts and the collectively perceived necessity to develop the technology in a standardized way strongly relies on the existence of a profound institutional setting that enables single firms to develop novelty more easily and in a way that is offering better possibilities for commercialization. CCISOBUS is offering the framework for the development of joint institutions based on CCI mode innovation.

Learning and absorptive capacity building through hiring of skilled staff (formation of organizational proximity) play a central role in the case of CCI mode innovation of the farm trailer. The University of Applied Science in Osnabrück (including COALA) has established as an important source of human capital for farm trailer producers:

> We [COALA] are strongly intertwined with the region's industry. We provide the necessary education and many of our graduates, and even former employees directly find a job in the farm vehicle industry, especially the one here in the region.

Graduates are an important source for sophisticated application-oriented scientific knowledge that enables firms to enhance their absorptive capacity. Many graduates already cooperate with their future employer within the context of their bachelor or master thesis. Thus, they are often already familiar with the firms and their routines. Another source for human capital is university start-ups that form within the close spatial and organizational context of COALA and which are sometimes directly or indirectly acquired by firms through hiring of key personnel, as stated by the CEO of a start-up company, which spun-off from the University of Applied Sciences in Osnabrück:

> My partner and I had been worked at the university here before in a research project. We decided to found our business to continue the work from that project. Professor [Y] asked us to move to the office here in Osnabrück to be able to continue the cooperation. In the end, we highly profited from this close proximity to the university and also to [farm trailer company Z] that also participates in this project. In the end, this cooperation was very positive for us. […] Recently, my partner was hired by that company. He couldn't refuse this offer. But he is still shareholder of our business.

Social and geographical proximities are, as expected, helpful but not of a very central character. COALA emerged within the same geographical context as the farm trailer industry.

Joint application-oriented collaboration of firms with the researchers of COALA strongly profits from spatial proximity and frequent interaction. Standard development (ISOBUS) shares characteristics with incremental innovation as frequent interaction in close spatial and social contexts promotes a joint technological development (and possible lock-in). Nevertheless, in recent years the CCISOBUS network expanded and increasingly and successfully included firms from other parts of Germany and even Europe. In these cases, social and geographical proximity within a common regional context was successfully substituted by the more important cognitive proximity within the shared industrial context.

Concluding, compared to the traditional DUI mode, the shift to the CCI mode of innovation in the farm trailer industry was characterized by three main changes regarding the role of proximities in innovation processes. Firstly, cognitive proximity remained highly relevant but needs now to rest on a much broader cognitive foundation as firms need to be able to absorb STI knowledge as well. Secondly, this integration of new knowledge does not only rest upon inter-organizational communication and collaboration but also relies on organizational proximity as firms increasingly hire specialized personnel from the context of academia. This process is central, as hiring of skilled personnel (e.g. absolvents from COALA) is a main mechanism for most of the firms to increase the absorptive capacity in order to be able to efficiently cooperate with partners like COALA and specialized ICT providers. And thirdly, the role of social, institutional and geographical proximities remained important but shifted in relation to the new constellations within the CCISOBUS network. For example, as Fitjar and Rodríguez-Pose (2013) observed for Norway, extra-regional ties with DUI partners and inter-regional ties to STI partners enhance the probability of innovation, as in the first case spatial distance lowers the risk for lock-in and in the second case spatial (and social) proximity may help to bridge the cognitive distance. The CCISOBUS network pretty much develops into this direction, especially in respect to the central role of intra-regional STI-ties. Extra-regional DUI-ties, however, became more important especially in the later stage of the development when the CCISOBUS network increasingly incorporated extra-regional agents, and thus, shifted its boundaries beyond the regional scope. Thus, the network may have the potential to remain innovative in the future if these intra- and extra-regional ties can be continuously utilized for innovation processes.

However, Fitjar and Rodríguez-Pose (2013) believe that DUI collaboration has only a positive effect if it is occurring with partners along the value chain, like customers and suppliers. However, the CCI mode innovation of the farm trailer industry is very much built upon collaboration between competitors and proved to be very successful. This has two reasons. Firstly, the target of the collaboration is to develop the common ISOBUS standard within a shared and established product field (the farm vehicles). This kind of innovation shares characteristics of incremental innovation. Nevertheless, the individual innovations are far beyond incremental, as many innovations target totally new application fields and technology solutions. This is related to the second reason: Collaboration with competitors is embedded into a more complex innovation network that also includes certain specialized suppliers and COALA. Thus, the case shows that collaboration with competitors may lead to sophisticated innovation activities within a CCI innovation mode. Collaboration with competitors proved to lead to sophisticated innovation as it was recombined with knowledge from other STI and DUI partners.

6. The stable technology industry

The development of the stable technology industry was of a pretty much different character. Today, north-western Germany and especially the region around the city of Vechta is one of the most important clusters of companies producing technology used within stables (especially pigs and poultry). Intensified livestock farming and stable technology production used to be highly advanced relatively early in the region. Today, the technology includes a broad set of applications, including feeding technology, egg collection, climate technology, manure treatment and disposal, as well as technology regarding caging, breeding, animal entertainment and the like. ICT skills were incorporated pretty early by many firms since the 1970s. Today many firms can rely on their own competences regarding ICT in stable technology. Stable technology, and especially stable design (the assembling of the components to a full stable), share a lot of similarities with project-oriented industrial plant engineering.

In contrast to the farm trailer industry, the animal house technology sector in the region is strongly dominated by a single stable designer, namely Big Dutchman, even though other notable stable designers such as WEDA and Schulz exist. Components are mostly produced by independent and often highly innovative suppliers, of which many also are located in the region. Besides the production of machinery and electronics, specialized suppliers from the plastics, metal and concrete sectors are located in the region.

As stated earlier, innovation in the stable technology industry is mainly of a DUI mode character and incremental. However, in the early years of the twenty-first century, some companies diversified into the field of biogas technology and biogas plant manufacturing. These include the two stable designers Big Dutchman and Schulz with own subsidiaries as well as a joint venture of the stable designer WEDA with Stallkamp, a supplier from the stable technology context. Biogas technology itself was developed in a separate sector since the 1980s. It gained momentum with the enactment of the Erneuerbare Energien Gesetz (EEG; Renewable Energy Act) in 2000 and its strongly biogas-supportive amendment of 2004. The EEG is a law offering favourable feed-in tariffs for renewable energies. The enactment of the law did not only foster economic growth of original biogas firms but also created a favourable condition for stable technology firms to diversify into this field. Stable designers were able to do so as they benefited from several aspects. Firstly, biogas and stable technologies are targeting the same group of clients (farmers) and early biogas plants were generally designed to digest manure. Thus, the operation of a biogas plant became highly interesting for livestock farmers. According to Müller (2012), stable designers could profit from their familiarity with farmers as clients and their experiences with environmental and building laws in the countryside. Furthermore and not trivially, stable design and technology as well as biogas plant manufacturing rely on very similar technological principles, as both use similar process and control systems and stable designers are generally familiar with the influence of acids and manure on material and surfaces as well as the handling of semi-liquid substances. Thus, one can describe both technologies as being related, as one stakeholder of a stable design firm states:

> [Biogas technology and our original competences] are similar. […] We also already had these experiences with disposal products like manure, because in the first years one mainly fermented disposal products in the biogas plants.

In contrast to the development of the farm trailer industry, the diversification of the stable technology industry was not characterized by a shift to a CCI mode. Biogas technology is characterized by DUI mode innovation in a pretty similar way as stable technology and clients (meaning farmers) are the main source for innovation input, as has been stated for example by one firm:

> [Regarding the issue of biogas technology], in 2001 clients came to us and asked if it is possible to deliver control and pumping technology for biogas plants. This was the starting point for us to cooperate with company X which has competences in fermenting containers.

The diversifying firms quickly adapted the new technology to their established working routines and value chains. With the enactment of the EEG, biogas technology was already widely a fully developed technology. Due to the strong technological relatedness of the two technologies, stable designers could quickly rely on their established routines. Nevertheless, the event and early process of biogas diversification was characterized by certain shifts regarding the role of different forms of proximity to the innovation process. These include mainly shifts in the role of cognitive and organizational proximities. DUI mode interaction along the value chain with clients and suppliers remained also for the biogas context the most important collaborations for innovation activities. Collaborations with STI partners are not regarded as very important for own innovation activities for both, the stable and the biogas context.

In the case of stable technology and biogas, firms had to build their cognitive capacities to be able to understand, use and develop biogas technology. As mentioned, this process was supported by the fact that stable and biogas technologies are technologically related and also target an overlapping group of clients. Nevertheless, stable designers could not develop these skills by themselves but had to search for specific knowledge sources. This learning occurred mainly through the forming of more organizational proximity (mainly through acquisitions and hiring). Firms such as Big Dutchman and Schulz acquired formerly small independent biogas firms to get access to this strategic knowledge. In the case of Weltec knowledge access was gained without acquisition but through the creation of a joint venture of the stable designer WEDA and the producer of fermenting containers Stallkamp. Hiring of qualified personnel was another important strategy for diversifying stable designers. After this initial process of diversification, the diversifying firms could quickly reproduce their routines to the biogas context. The established spatial, institutional and social context of the existing stable technology industry widely offered the necessary and supporting degree of geographical, social and institutional proximities for this diversification process.

In contrast to the case of the farm trailer industry and the argumentation by Fitjar and Rodríguez-Pose (2013) (intra- or even extra-regional), knowledge ties to STI partners were irrelevant in this process. Thus, the diversification of the stable technology industry was not associated with a shift to a CCI mode. However, even the role of knowledge ties to DUI partners was limited to the pre-existing relationship with the farmers. Knowledge acquisition was mainly built upon recruitment and acquisitions from the technologically related biogas context. As Herstad et al. (2015) state, recruitment from DUI contexts can lead to product innovation if it comes from related industries. One can expect acquisitions of formerly independent small firms to have a very similar effect. Recruitment (and acquisition) from related industries may result only in a limited degree of change compared to

real CCI mode innovation, but it can be easily adopted as existing routines are reproduced. Ter Wal and Boschma (2011) state that the reproduction of successful routines to a new spatial context represents one of the dynamic capabilities of cluster agents that enables them to renew a cluster. However, there exists no reason why this potentially positive effect should be limited to the geographical dimension. The successful reproduction of existent routines into new thematic contexts, as in the case of stable design routines reproduced in the biogas context, proved to be supportive of innovation activities by these firms. Thus, the case of biogas diversification represents a case where DUI mode innovation led to product innovation beyond the pre-existent cognitive horizon of the innovating firms. Nevertheless, the process remained widely based on processes of incremental innovation. Knowledge ties with other partners inside and outside the region are, compared to the farm trailer case, relatively weakly developed for the development of biogas technology. Furthermore, the process was mainly driven by political intervention and the EEG. Thus, the industry is at risk of being highly prone to technological lock-in and a loss in future innovativeness. However, besides these aspects, the case shows that technological renewal and reorientation in DUI mode industries is possible.

7. Concluding remarks

This paper discussed the role of different forms of proximity for sophisticated product innovation in different modes of innovation. It took a focus on engineering-based firms from the context of two agricultural engineering industries of north-western Germany.

In the introduction, a relatively widely formulated research question was formulated. It deals with the question of how sophisticated product innovation takes place in engineering-based industries and what role different proximity constellations play in these processes.

The results regarding the role of proximities are summarized in Table 2. As can be seen, in both cases similar types of proximities played a central role in the renewal processes. Especially, and unsurprisingly, the creation of cognitive proximity to agents from the new technological context is a critical event. Furthermore, in both cases the creation of organizational proximity through hiring or acquisitions is a main strategy.

Table 2. Role of proximities for innovation in the case studies.

	Farm trailer ICT upgrading	Stable design biogas diversification
Mode	CCI	DUI
Relevant partners	STI-partner COALA, competitors, clients/suppliers	Clients/suppliers, agents from related biogas context
Proximities		
Cognitive	Enhancement of cognitive proximity to formerly technologically unrelated ICT-context (STI-context)	Enhancement of cognitive proximity to technologically related biogas context (DUI context)
Institutional	Institutionalization of new technology in CCISOBUS-innovation network	No explicit institutionalization of biogas technology on the regional level; adaptation to national institutional framework
Organizational	Creation of organizational proximity for competence building mainly through hiring from academia/COALA	Creation of organizational proximity for competence building through hiring and acquisitions from related biogas sector
Geographical/social	Helpful, especially in early phase of CCISOBUS-network formation	Helpful in early phase, especially in relation to regional farmers as test users

Geographical and social proximities were supporting forces in the early formation phases of both case studies. However, the processes are not as similar as it seems, as the type of knowledge that had to be incorporated differs significantly. Stable designers could focus on their pre-existing skills and thus learned and organizationally acquired from a technologically related context, while farm trailer producers had to establish ties to a technologically unrelated context. Therefore, the creation of institutional proximity in a newly formed innovation network was much more important in the farm trailer case than in the case of stable designers who could widely reproduce their old routines without the need for a new regional institutionalized innovation network. Thus, it is not that different modes of innovations seem to rely on different forms of proximities but it is more like that different modes of innovation involve different processes to utilize these different types of proximities, dependent on the specific constellations of knowledge involved.

Proximities matter in cluster renewal and transformation processes. And different modes of innovation involve different strategies of the involved agents. Further research should take a stronger focus on this interrelationship of innovation modes and proximities. Several open questions remain open that may be targeted in future research. For example, even though this paper started to comprehensively discuss proximity in the context of innovation modes, still little is known about the right degree of proximity. As, for example, Broekel and Boschma (2012) found out, the positive or negative effect of cognitive proximity on interactive innovation efforts is not linear but follows the pattern of an inverted U-shape. Thus, there seems to exist a 'best' degree of cognitive proximity that lies in between 'too similar' and 'too different'. So far, it remains unclear how this effect is related to innovation in STI, DUI and CCI modes.

Finally, the case studies also show that modes of innovation are not static and that firms may develop towards a changing innovation mode. Firms may slowly change their innovation mode as in the case of the farm trailer industry. This is associated with changing roles of proximities. The proximity concept by itself has recently been reinterpreted in a more dynamic way (Balland et al., 2015). This aspect could be a part of future research.

The comparability of the two case studies is supported by the fact that both industries share a common agribusiness background in an overlapping regional context. However, both industries followed quite different development paths, which also adds a limiting aspect. While the farm trailer industry mainly followed a (technologically sophisticated) process of specialization in ISOBUS technology within the pre-existing context of farm vehicle production, the stable technology industry followed a diversification strategy into a new market, even though the technological changes were much less complex in this case. Therefore, firms in both cases experienced quite different challenges. The main challenge for farm trailer firms was to incorporate new technological knowledge. However, this challenge was quite manageable for most firms like COALA and the University of Applied Sciences in Osnabrück acted as powerful suppliers of this kind of knowledge. In contrast, the main challenge for stable designers was to deal with the institutional conditions of the renewable energy regime. This task was not trivial and associated with processes of institutional misalignments.

Nevertheless, with respect to recent policy programmes, having a more pronounced and detailed understanding of innovation processes in traditional industries is of high

value. Offering satisfying conditions that enable firms to make use of the knowledge of their collaboration partners can be a powerful policy tool when it is targeted on the specific innovation mode the firms apply or seek to apply. As can be seen from the two case studies, this is highly industry specific. The two empirical cases superficially seem to share a lot of similarities in terms of their agribusiness context and their location within the, more or less, same region. Furthermore, both industries are engineering based and have a tradition of DUI mode innovation. However, the recent innovation strategies of both industries differ a lot and both industries experienced quite different industry dynamics in the early twenty-first century (specialization vs. diversification). Thus, regional innovation policymakers should be aware that seemingly similar industries may need very pin-pointed support in the creation and support of cluster and network activities or the support of the region's research infrastructure. Therefore, when it comes to the political support of traditional industries, the old warning that there exists no ideal type of innovation policy that 'fits all' (Tödtling & Trippl, 2005) should be remembered.

Notes

1. The addressed topics include general information on the interviewee and the firm; targeted markets; products and services provided by the firm; the general development of the company; the role of specific events on the firm's development; skills and recruitment of specialized staff; the way how innovation is generally conducted by the firm; recent and future product and service innovation; the quality of the innovations (incremental, new to the firm or new to the market); the relationship to customers, suppliers, competitors, research organizations and other agents and their roles for the firm's innovation activities; the role of policy; financing of innovation activities; membership in networks and interest organizations; perception of the development of the own industry in general and within the own regional context.
2. Claas produces tractors at other sites.
3. Another official acronym is CCI which is not used in this paper due to the risk for confusion with the combined and complex mode of innovation (CCI).

Acknowledgements

The author thanks all interview partners for participating in the study. Furthermore, he thanks two anonymous referees for their comments that helped to improve this paper a lot. An earlier version of this work was presented at the IINO seminar in Bremen 2015. The author thanks the participants of this seminar for fruitful comments.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by Deutsche Forschungsgemeinschaft [grant number HA 3179/6-1] and European Science Foundation [grant number 10-ECRP-07].

ORCID

Dominik Santner http://orcid.org/0000-0002-3330-9894

References

Apanasovich, N., Heras, H. A., & Parrilli, M. D. (2016). The impact of business innovation modes on SME innovation performance in post-Soviet transition economies: The case of Belarus. *Technovation*, *57–58*, 30–40. doi:10.1016/j.technovation.2016.05.001

Asheim, B. T., & Coenen, L. (2005). Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research Policy*, *34*, 1173–1190. doi:10.1016/j.respol.2005.03.013

Audretsch, D. B., & Feldman, M. P. (1996). R&D spillovers and the geography of innovation and production. *The American Economic Review*, *86*, 630–640. http://www.jstor.org/stable/2118216?seq=1#page_scan_tab_contents

Balland, P.-A., Boschma, R., & Frenken, K. (2015). Proximity and innovation: From statics to dynamics. *Regional Studies*, *49*, 907–920. doi:10.1080/00343404.2014.883598

Boschma, R. (2005). Proximity and innovation: A critical assessment. *Regional Studies*, *39*, 61–74. doi:10.1080/0034340052000320887

Broekel, T., & Boschma, R. (2012). Knowledge networks in the Dutch aviation industry: The proximity paradox. *Journal of Economic Geography*, *12*, 409–433. doi:10.1093/jeg/lbr010

Brunswicker, S., & Vanhaverbeke, W. (2015). Open innovation in small and medium-sized enterprises (SMEs): External knowledge sourcing strategies and internal organizational facilitators. *Journal of Small Business Management*, *53*, 1241–1263. doi:10.1111/jsbm.12120

Cantwell, J., & Iammarino, S. (1998). Mncs, technological innovation and regional systems in the EU: Some evidence in the Italian case. *International Journal of the Economics of Business*, *5*, 383–408. doi:10.1080/13571519884459

Chen, J., Chen, Y., & Vanhaverbeke, W. (2011). The influence of scope, depth, and orientation of external technology sources on the innovative performance of Chinese firms. *Technovation*, *31*, 362–373. doi:10.1016/j.technovation.2011.03.002

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, *35*, 128–152. doi:10.2307/2393553

Cooke, P. (2001). Regional innovation systems, clusters, and the knowledge economy. *Industrial and Corporate Change*, *10*, 945–974. doi:10.1093/icc/10.4.945

Cooke, P. (2013). *Towards DUI regional innovation systems*. Papers in Evolutionary Economic Geography # 13.21. Utrecht University.

Cooke, P., Gómez Uranga, M., & Exteberria, G. (1997). Regional innovation systems: Institutional and organizational dimensions. *Research Policy*, *26*, 475–491. doi:10.1016/S0048-7333(97)00025-5

Cooke, P., Laurentis, C. D., Tödtling, F., & Trippl, M. (2007). *Regional knowledge economies: Markets, clusters and innovation*. Cheltenham: Edward Elgar.

Dahlander, L., & Gann, D. M. (2010). How open is innovation? *Research Policy*, *39*, 699–709. doi:10.1016/j.respol.2010.01.103

Davis, J. H., & Goldberg, R. A. (1957). *A concept of agribusiness*. Boston: Graduate School of Business Administration, Harvard University.

Fitjar, R. D., & Rodríguez-Pose, A. (2013). Firm collaboration and modes of innovation in Norway. *Research Policy*, *42*, 128–138. doi:10.1016/j.respol.2012.05.009

Frenken, K., Van Oort, F., & Verburg, T. (2007). Related variety, unrelated variety and regional economic growth. *Regional Studies*, *41*, 685–697. doi:10.1080/00343400601120296

Grabher, G. (1993). The weakness of strong-ties: The lock-in of regional development in the Ruhr area. In Grabher, G. (Ed.), *The embedded firm: On the socioeconomics of industrial networks* (pp. 255–277). London: Routledge.

Grillitsch, M., & Trippl, M. (2014). Combining knowledge from different sources, channels and geographical scales. *European Planning Studies*, *22*, 2305–2325. doi:10.1080/09654313.2013.835793

Herstad, S. J., Sandven, T., & Ebersberger, B. (2015). Recruitment, knowledge integration and modes of innovation. *Research Policy*, *44*, 138–153. doi:10.1016/j.respol.2014.06.007

Isaksen, A., & Karlsen, J. (2011). Organisational learning, supportive innovation systems and implications for policy formulation. *Journal of the Knowledge Economy*, *2*, 453–462. doi:10.1007/s13132-011-0063-6

Isaksen, A., & Karlsen, J. (2012). Combined and complex mode of innovation in regional cluster development: Analysis of the light-weight material cluster in Raufoss, Norway. In Asheim, B. T. & Parrilli, M. D. (Eds.), *Interactive learning for innovation: A Key driver within clusters and innovation systems* (pp. 115–136). Basingstoke: Palgrave Macmillan.

Jensen, M. B., Johnson, B., Lorenz, E., & Lundvall, B. Å. (2007). Forms of knowledge and modes of innovation. *Research Policy*, *36*, 680–693. doi:10.1016/j.respol.2007.01.006

Krawczyk, O., & Nowak, C. (2009). *Die Agrartechnik-Branche im Osnabrücker Land – Regionalwirtschaftliche Bedeutung im überregionalen Vergleich*. Niedersächsisches Institut für Wirtschaftsforschung NIW – Studie im Auftrag der Wirtschaftsförderungsgesellschaft Osnabrücker Land mbH (WIGOS).

Maclaurin, W. R. (1953). The sequence from invention to innovation and its relation to economic growth. *Quarterly Journal of Economics*, *67*, 97–111. doi:10.2307/1884150

Mattes, J. (2012). Dimensions of proximity and knowledge bases: Innovation between spatial and non-spatial factors. *Regional Studies*, *46*, 1085–1099. doi:10.1080/00343404.2011.552493

Menzel, M.-P., & Fornahl, D. (2010). Cluster life cycles—dimensions and rationales of cluster evolution. *Industrial and Corporate Change*, *19*, 205–238. doi:10.1093/icc/dtp036

Müller, H. (2012). *Die Agrar- und Ernährungswirtschaft vor neuen Herausforderungen – eine Konzeption zur aktiven Gestaltung von Zukunft im Nordwesten Niedersachsens* (Ph.D. thesis). University of Vechta.

Nooteboom, B. (2000). *Learning and innovation in organizations and economies*. Oxford: Oxford University Press.

Nunes, S., Lopes, R., & Dias, J. G. (2014). *Firm performance and modes of innovation*. DINÂMIA/CET-IUL Working Paper No. 2014/01. doi:10.7749/dinamiacet-iul.wp.2014.01

Parrilli, M. D., & Elola, A. (2012). The strength of science and technology drivers for SME innovation. *Small Business Economics, 39*, 897–907. doi: 10.1007/s11187-011-9319-6

Parrilli, M. D., & Heras, H. A. (2016). Sti and DUI innovation modes: Scientific-technological and context-specific nuances. *Research Policy*, *45*, 747–756. doi:10.1016/j.respol.2016.01.001

Ter Wal, A. L. J., & Boschma, R. (2011). Co-evolution of firms, industries and networks in space. *Regional Studies*, *45*, 919–933. doi:10.1080/00343400802662658

Tödtling, F., & Trippl, M. (2005). One size fits all? Towards a differentiated regional innovation policy approach. *Research Policy*, *34*, 1203–1219. doi:10.1016/j.respol.2005.01.018

Trippl, M. (2011). Regional innovation systems and knowledge-sourcing activities in traditional industries—evidence from the Vienna food sector. *Environment and Planning A*, *43*, 1599–1616. doi:10.1068/a4416