Cluster Renewal – Complex Processes in Two Agricultural Engineering Clusters of North-Western Germany

vom Fachbereich Wirtschaftswissenschaft der Universität Bremen
zur Erlangung der Würde eines
Doktors der Wirtschafts- und Sozialwissenschaften (Dr. rer. pol.)
genehmigte Dissertation

vorgelegt von

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Tag des Verteidigungskolloquiums:	23.08.2017

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am Fachbereich Wirtschaftswissenschaft (FB 07) der Universität Bremen

Contents

List of Abbreviations

AEF	Agricultural Electronics Foundation
CAP	Common Agricultural Policy
CCI	Competence Centre ISOBUS (chapter 2; *see also* → *CCISOBUS*); combined and complex innovation (chapters 1, 4 and 5)
CCISOBUS	Competence Centre ISOBUS (chapters 1, 4 and 5; *see also* → *CCI*)
CLC	cluster life cycle
COALA	Competence Of Applied Agricultural Engineering
CRIE	Centre for Regional and Innovation Economics
DFG	Deutsche Forschungsgemeinschaft
DIL	Deutsches Institut für Lebensmitteltechnik
DMK	Deutsches Maiskomitee
DOI	Digital Object Identifier
Dr.	Doctor
DUI	doing-using-interacting
ed.	edition/editor/editors/edited
EEG	Evolutionary Economic Geography (chapters 1, 2 and 5); Erneuerbare Energien Gesetz (chapters 3 and 4; *see also* → *REA*)
e.g.	exempli gratia
ESF	European Science Foundation
esp.	especially
et al.	et alii/et aliae
etc.	etcetera
e.V.	eingetragener Verein
GBA	German Biogas Association
ha	hectare
ICO	InnovationsCentrum Osnabrück
ICT	information and communication technology
iino	Institut für Institutionelle Ökonomik und Innovationsökonomik
ISIC	International Standard Industrial Classification
ISOBUS	brand name of a data bus for agritechnical purposes
ISPA	Institut für Strukturforschung und Planung in Agrarischen Intensivgebieten
JEL	Journal of Economic Literature
kW	kilowatt

LU	livestock unit
mbH	mit beschränkter Haftung
MLP	multi-level perspective
MW	megawatt
NACE	Nomenclature statistique des activités économique dans la Communauté européenne
Nawaro	nachwachsende Rohstoffe
NieKE	Niedersächsisches Kompetenzzentrum Ernährungswirtschaft
NIW	Niedersächsisches Institut für Wirtschaftsforschung
No.	number
NSI	national system of innovation
p.	page
PD	Privatdozent
PhD	philosophiae doctor
pp.	pages
Prof.	Professor
R&D	research and development
REA	Renewable Energy Act (chapters 1, 2 and 5; *see also* → *EEG*)
RIS	regional innovation system
StÄBL	Statistische Ämter des Bundes und der Länder
STI	science-technology-innovation
tech. rep.	technical report
TIS	technological innovation system
vs.	versus
WIGOS	Wirtschaftsförderungsgesellschaft Osnabrücker Land
WING	Wissenschafts- und Informationszentrum Nachhaltige Geflügelwirtschaft
WZ	Klassifikation der Wirtschaftszweige

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Preface

The Centre for Regional and Innovation Economics (CRIE) at the University of Bremen was just newly founded when I started my work there in February 2011. I remember that on my first working day furniture and computers have been delivered. The working group was really nice and welcoming from the beginning but the formal working conditions were unfortunately bad. Due to uncertain funding I only got repeatedly working contracts for just a few months. However, Dirk, my boss and supervisor repeatedly helped me to renew my contract and at some point in time in summer 2011 he asked me if I was interested to work in a project on cluster life cycles. I quickly agreed and was really interested in the subject as it offered me a chance to work in a recent core field of evolutionary economic geography research. In October 2011 I started to work in this project and from that day the broader topic of my PhD thesis was defined.

The next three years were a very interesting time as I got the chance to work in an international working group with some well-known researchers of the field of economic geography including Franz Tödtling, Björn Asheim and many more. Furthermore, I got the chance to get in touch with two quite different but interesting contexts. On the one hand, I could participate in very interesting academic conferences. On the other hand, I got insights into the world of an industry that is based on a rural and agricultural context: the agricultural engineering industry this thesis is based on. In this time I developed the first ideas on what today is my PhD thesis. However, one experience of this time is that writing such a thesis is not a trivial thing. It needs a lot of work, time and endurance to find the own research field and to develop own ideas.

Even though most of this work is definitely in the responsibility of the PhD student, it would not be possible without the help and support of other people. Thus, I would like to express my gratitude here. First of all I would like to thank Dirk Fornahl, my boss and supervisor who gave me the chance to work in his working group by offering me the PhD position in early 2011 and who always found new possibilities to prolong my contract. Furthermore I would like to thank him for the frequent possibilities to talk about the thesis and other scientific issues in a friendly atmosphere. Thank you also for the good time at the CRIE.

Secondly, I would like to thank Robert Hassink who has been my de jure superior during the time of the cluster life cycle project as the project was allocated at the University of Kiel, even though my office remained in Bremen. Robert became the second supervisor of my thesis. Thank you also for the friendly and helpful comments on my work at various occasions in the last years. At this point I also want to thank his secretary Heidi

Seeliger who helped me a lot with the bureaucracy of Kiel University, an issue that is really helpful if one is sitting far away in Bremen.

A person who was directly involved in my way to my PhD was the supervisor of my diploma thesis Thomas Brenner from the University of Marburg. He helped me during the time between my diploma and my start in Bremen to find a job in academia. Thank you very much for this.

Furthermore, I also want to thank my dear colleagues at the CRIE for the good working climate and the small supports during all of the time. Special thanks go to Isa who duteously read all the texts I wrote within the last years and gave me helpful comments on both, the subjects as well as English orthography and grammar. But I also want to thank all the others: Antje, Biene, Cathrin, Florian, Katharina, Kolja, Lennard, Nils, Noreen, Rodrigo, Will and all the student assistants. Thank you all for the good working atmosphere and the good time. Here I also want to address special thanks to the student assistant Alexander for the transcription of a large amount of the interviews.

Many thanks go furthermore to all other persons who gave helpful comments on my work during the last years at conferences or other occasions as well as to all persons who participated in my study as interview partners. Special thanks go to Prof. Dr. Hans-Wilhelm Windhorst and Dr. Henning Müller, two central industry experts who were very helpful to build contacts to other interview partners.

Last, but not least, I want to thank all the dear persons of my private life who supported me during the last years in one way or the other. Special thanks go to my family, especially my mother, my stepfather, my father and my stepmother. I also want to thank all my dear friends, especially those who share the experience of writing a PhD thesis and can understand both the sorrows and moments of achievement that are part of the PhD process.

Dominik Santner
Bremen, November 2016

Information on this publication

Information in English

This publicised version of the thesis differs from the original version that has been subject to the doctorate evaluation process. In the appendix, the original version included the complete interview transcripts and the respective audio files on a DVD.

Parts of this information are subject to secrecy interests of the interviewed firms and experts. In accordance with the chairman of the PhD examination board it has been decided to exclude this information from the published version of the thesis. In addition, markers linking referred interview sequences in the text to specific sentences in the interview transcripts, have been removed to ensure the interviewees' interests. In each other aspect the published version of the thesis equals to the original version.

For any questions, do not hesitate to contact the author per email or visit the CRIE homepage for other contact information: dsantner@uni-bremen.de / www.crie.uni-bremen.de.

Information auf Deutsch

Diese Publikation der Dissertation unterscheidet sich von der im Promotionsverfahren vorgelegten Originalversion. Die Originalversion enthält im Anhang eine DVD mit den detaillierten Interviewtranskripten sowie den entsprechenden Audiodateien.

Teile dieser Informationen sind Gegenstand von Geheimhaltungsinteressen der interviewten Firmen und Experten. Mit Genehmigung durch den Vorsitzenden der Prüfungskommission wurde daher beschlossen, diese Informationen nicht in die Publikationsversion zu übernehmen. Zudem wurden Marker, welche Interviewzitate im Text mit Sequenzen in den Transkripten verbinden, entfernt, um die Interessen der Interviewpartner zu wahren. In allen weiteren Aspekten entspricht die veröffentlichte Version der Originalversion der Dissertation.

Fragen können natürlich gerne per Email an den Autor dieser Arbeit gerichtet werden. Alternativ finden Sie weitere Kontaktmöglichkeiten auf der Homepage des CRIE: dsantner@uni-bremen.de / www.crie.uni-bremen.de.

1 Introduction

1.1 Cluster renewal and the case of agricultural engineering in north-western Germany

Firms, like any other form of social organisation, change and develop over time. They may prosper, face periods of economic struggle or develop technologically through learning, invention and innovation. As economic action involves interaction with other agents like clients, suppliers, competitors, researchers or politicians, networks of strongly and repeatedly interacting agents can be expected to co-evolve over time, resulting in collective development patterns. During the last decades economic geographers stressed the role of a common geographic context for these kinds of development. Firms and agents of the same industry or a shared value chain often co-locate in so-called industrial districts or regional industrial clusters (e.g. Marshall 1920; Porter 1990; Porter 1998). Co-location has been traditionally perceived to be supportive for collaborative interaction of innovating agents. Especially firms from the engineering and creative industries that rely on tacit knowledge can strongly benefit from spatial proximity (Mattes 2012). It can help to support and initialise collaboration among firms and agents. Thus, geographical proximity can enable and increase the likelihood of collaboration that benefits from other forms of proximity like cognitive or institutional ones (Boschma 2005).

More recently, the development patterns of regional industrial clusters have been conceptualised in cluster life cycle approaches (CLC) and related models (e.g. Maskell and Malmberg 2007; Menzel and Fornahl 2010; Ter Wal and Boschma 2011; Martin and Sunley 2011). These models show that, after an initial phase of cluster formation and growth to a critical mass, clusters tend to stabilise for a longer period of time. In this time, firms seek to exploit scale economies. The technological design of the product portfolio of cluster firms has been standardised and firms innovate widely incrementally. However, sometimes clusters change more radically. In such an event, a significant number of cluster firms introduces new technology that strongly differs from the firms earlier cognitive scope. Firms enter new technological terrain which may help them to improve their existing products and services or their production processes significantly. New technology can be used to develop strongly enhanced versions of existing products. For example, the firms of the farm trailer cluster of north-western Germany began to build enhanced farm vehicles based on modern information and communication technology (ICT) in the early 21st century. In other cases, firms may use their technological knowledge to enter new markets. For example, firms from the stable technology cluster in north-western Germany started to diversify into the technologically similar field of biogas plant manufacturing during the last two decades. Processes like those in the two examples can be called cluster renewal. They are characterised by significant cluster-internal shifts in the technological scope of firms and the collaboration network between them. The issue of cluster renewal is not new to the academic discourse. Nevertheless, certain questions on the nature of cluster renewal have been, so far, not sufficiently answered in the literature. The central aim of this thesis is thus to shed light on the factors and processes of cluster renewal.

The theoretical starting point of the thesis is the mentioned CLC literature (e.g. Maskell and Malmberg 2007; Menzel and Fornahl 2010; Ter Wal and Boschma 2011). The issue of cluster renewal is generally an integrative aspect of those concepts. Thus, in this literature some very specific assumptions on cluster renewal have been formulated. In general, this literature assumes that cluster-specific change and renewal has to be widely explained by factors that come from the cluster itself. These include aspects like agent-specific capability building and systemic knowledge diffusion and utilisation processes within the cluster network. Internal dynamics are widely driven by synergies within a regionally, socially and cognitively narrow cluster context. However, the significant role of external knowledge pipelines is also acknowledged, but its relevance remains explained by the actions of adaptation and learning of cluster agents themselves. The external environment has thus only widely a passive role in these concepts.

This focus on cluster-internal drivers in the CLC literature has recently been criticised by Martin and Sunley (2011), as will be explained in more detail in the next section. They advocate for a more open conceptualisation of cluster dynamics that includes explanatory factors for change from the cluster-external industry-specific and unspecific environment which are connected to the cluster-internal dynamics. These aspects are tackled in this thesis through the application of two theoretical concepts that have been, so far, barely been connected to the CLC literature: firstly, the literature on geographies of transitions (Coenen et al. 2012; Truffer and Coenen 2012; Raven et al. 2012; Binz et al. 2014; Murphy 2015) that offers explanatory power to the nature of the interrelationship of the cluster with its technologically and geographically external environment; and secondly, the modes of innovation literature (Jensen et al. 2007; Isaksen and Karlsen 2012), which highlights industry-specific differences of interactive innovation activities and thus contributes to a better understanding of case-specific development patterns.

Empirically, the thesis takes its focus on north-western Germany, roughly between the urban centres of the Ruhr to the south and Hamburg and Bremen to the north, in western Lower Saxony and northern North Rhine-Westphalia. In this region a strong agriculture-based regional economy has developed during the last century, the so-called agribusiness industry. Part of this industrial complex are two agricultural engineering clusters. These two clusters represent the case studies this thesis is built upon. One of these clusters is specialised on farm trailer production, while the second one produces pig and chicken-related stable technology. In north-western Germany, regional farmers and entrepreneurs repeatedly created innovations and entered new economic activities over the last decades. Thus, the history of the agribusiness industry in the region is marked by a number of renewal processes. Historical examples include the introduction of the chicken cage that enabled industrial chicken farming in the 1950's and 60's and the beginning of salad and berries cultivation since the 1960's and 70's (Windhorst 1975). Most recently, the latest renewal processes have been connected to macro-economic trends like globalising markets and the introduction of information and communication technologies (ICT) to almost any segment of the modern industrial economy. These trends contributed to the renewal processes within the two agricultural engineering clusters, which are investigated in more detail in this thesis.

The rise of the agriculture-based economy in the region began in the late 19^{th} century. Historically, the region was very poor. Most of it lay off the established trading routes, was poorly developed and sparsely populated. Thus, the region was unable to participate in the economic success of the prosperous nearby urban centres. The development gained momentum after World War II during the general upswing of the German economy in the so-called Wirtschaftswunder years (Windhorst 1975). In these years the region was connected to the national motorway network. Thus, it could participate in the general economic prosperity of that time. The regional economy strongly relied on pig production, but quickly diversified within the following decades into a broad set of agriculture-related economic activities including poultry and specialised crop farming (salad, strawberries) as well as food processing and agricultural engineering (Windhorst 1975). According to Windhorst (1975) the region could benefit from the general entrepreneurial spirit of the local population which resulted from the historical collective experience of dealing with unfavourable conditions in a formerly peripheral region. Today, parts of the region, especially the Oldenburger Münsterland area around the towns of Vechta and Cloppenburg, are well known for their intense livestock farming of pigs and chicken (Windhorst 1975; Tamásy 2013). Official statistics state that many districts of north-western Germany have the highest density of livestock in Germany (StÄBL 2007, see also figure 3.3 in chapter 3). For example, the small district of Vechta, while covering only 0.23% of the German land mass (StÄBL 2014b) and being home to only 0.17% of the German population (StÄBL 2014a), held 13.99% of all chicken in Germany in 2007 (StÄBL 2007). Even though younger figures are not available, the situation did not change much within the last nine years. Actually, industrial livestock farming tends to be even more concentrated today and stables become even larger.

Both, firms from the farm vehicle and the stable technology cluster became significant players on the national and international market in their respective fields. Similar to the powerful agriculture sector, the roots of these industries in the region partly date back to the late 19^{th} century when small village smithies supplied local farmers with basic farm tools. After World War II some of these traditional smithies as well as some newly founded companies of the agricultural engineering sectors started to develop as growing and successful companies. Today notable, partly worldwide active and successful companies from both agricultural engineering sectors are rooted and still located in the region and in both cases fully grown clusters have developed. Depending on the analytical perspective, they can be described as subclusters of the larger agribusiness cluster in the region as they co-evolved with the agriculture and food production industries. However, more recently, the market orientation of the agricultural engineering firms shifted more and more to a global scope. Therefore, they can also be perceived as clusters on their own. Today most of the firms from both clusters more or less concentrate along the motorway A1. Thus, Windhorst (2004) described the region as the Silicon Valley of agricultural engineering. The farm trailer cluster includes firms like Grimme, Amazone, Krone and Claas that hold significant shares of the global market for their respective segment. Furthermore, several other farm trailer producers as well as a row of supportive suppliers from fields such as tire making, specialised electronics and others are located in the region. Likewise, specialised R&D institutes like the COALA research centre (Competence Of Applied Agricultural Engineering) at the University of Applied Sciences in Osnabrück have been established. In the case of the other case study on stable technology, the cluster is widely dominated by the world market leader in pig and chicken-related stable design Big Dutchman. However, also other stable designers like WEDA, Schulz and PAL-Bullermann exist as well as specialised suppliers building stable machinery, specific concrete piles, plastic segments and the like.

Both clusters remained economically very successful over decades. However, new and ongoing global, European and national economic and political developments increasingly forced and triggered the companies to adjust and change their strategies more recently. Thus, as briefly stated before, in both cases significant processes of cluster renewal have occurred in the early 21st century. An increasing demand for scale economies in agriculture created a strong need for more productive and modern farm machinery. Furthermore, the increasing and ongoing introduction of modern ICT in almost every segment of modern life also affected the agricultural sector and opened new opportunities for sophisticated farm solutions. Today both industries use modern computer technology. Especially the global farm vehicle industry recently developed its own ICT solutions and standards including the very important ISOBUS standard for computer communication between tractors and trailers. In recent years, several actors from the investigated farm trailer cluster, including producing companies and the COALA research centre, established themselves as core innovators in this global development context of modern farm vehicle ICT solutions.

To a certain degree, the development in the stable technology cluster was quite different. Even though modern ICT became more important in this industry as well and modern stables are today run by sophisticated computer technology, the most recent process of cluster renewal depended on another factor. A different kind of opportunity emerged when in 2000 the national Renewable Energy Act (Erneurbare Energien Gesetz;

REA[1]) pushed and created the national market for renewable energies like biogas technology. Thus, some regional stable designers started to diversify into the field of biogas technology. They were able to do so due to the strong technological relatedness of stable and biogas technologies as will be described in more detail at several points in this thesis. As a result, structures of a biogas-based industry established in the region.

Thus, both the farm trailer and the stable technology cluster experienced strong structural and technological changes in the early 21st century. Old technological solutions, innovation structures and strategies have been replaced or complemented by new ones. Thus, both clusters experienced processes of cognitive, technological and structural change. Or in other words, they faced a process of cluster renewal. However, even though both clusters show some remarkable similarities in terms of historic origin, social and regional embeddedness and industrial context, they are widely based on separated value chains and technological and organisational principles. Also, their specific developments during the process of cluster renewal differ significantly. Therefore, they represent two cases that help to develop a better understanding of cluster renewal processes. In the case of the farm trailer cluster, cluster renewal was widely a process of cluster-internal collective action of cluster agents. During this process the cluster gained a significant degree of collective technological leadership in the global development of farm vehicle ICT solutions. In contrast, in the case of the stable technology cluster several agents diversified more or less simultaneously, but also widely independently from each other into the technologically related field of biogas technology. Even though some of these firms became more or less successful in the field of biogas, the cluster as a whole did not gain a similar significance on the biogas market[2].

Another factor that represents a significant difference between the two case studies is related to the process of renewal as such. In the case of the farm trailer cluster, the renewal process occurred within the traditional field of farm vehicle technology but involved new technological solutions on the component level. In contrast, biogas renewal of the stable technology cluster involved much of the existing technological knowledge from stable technology, which has been assembled in a different product. Actually, the two cases represent two different forms of innovation, which have been conceptualised by several authors in the past (e.g. Abernathy and Clark 1985; Henderson and Clark 1990; Tushman et al. 1997; Chandy and Tellis 1998; Popadiuk and Choo 2006). As an example, the difference between the two case studies is given upon the arguments of (Henderson and Clark 1990). They distinguish between knowledge on components of a final product (components knowledge) and the knowledge about the readily assembled product as such (architectural knowledge). In their terms, the farm trailer case represents modular innovation, where components knowledge is 'destroyed' (old components

[1]The German acronym is EEG. It is not used in this chapter due to the possible confusion with the acronym for Evolutionary Economic Geography (EEG). Please see also section 1.3.1.

[2]However, the global leadership on the traditional stable technology market remained unchallenged.

are replaced by new ICT-based components) while architectural knowledge (or knowledge on the design of the final product; here the farm trailer as such) is 'enhanced'. In such a case, the value chain on the supply side is widely restructured while the set of clients remains unchanged. The case of the biogas diversification of stable designers represents, in contrast, architectural innovation, where components knowledge is 'enhanced' (the existing basic technological principles of stable technology are reproduced) while architectural knowledge is 'destroyed' (the biogas plant as a new final product)[3]. In the case of the stable technology cluster, biogas diversification did not result in a process of cluster renewal that replaced the traditional stable technology, but was added to the portfolio of the firms as a second application field. In contrast, in the other case study old technological farm-vehicle solutions have been widely replaced by new ones. Thus, the restructuring of the farm trailer cluster was more or less encompassing, while in the case of stable technology the new application field was added to the traditional stable technology context that remained an important and successful market for the firms, even though they diversified into biogas technology.

The investigation of these different cases contributes to a better understanding of cluster renewal in differently structured clusters. It is thus strongly related to the arguments in chapter 4 which deals with the impact of different modes of innovation. However, the difference between the two case studies in terms of modular vs. architectural innovation is not further stressed in this thesis. It may be subject to future research. First attempts to include the issue in the thesis have been made in an earlier version of chapter 4. However, the subject has been dropped for the final version of the chapter as a result of comments at the internal iino seminar in Bremen 2015 as well as during the review process of the journal European Planning Studies.

The remainder of this introductory chapter is as follows. Section 1.2 discusses the so far briefly addressed theoretical background of the thesis in more detail. At its end, a research agenda is developed. Section 1.3 explains some general aspects of the conception and methodological background of the thesis. Section 1.4 summarises the content of chapters 2 to 4. Finally, section 1.5 gives a brief outlook to the remainder of the thesis.

1.2 Towards an enhanced concept of cluster renewal

1.2.1 Cluster renewal in the literature

The concept of the industrial cluster has become very popular within the last three decades among both, economic geography researchers as well as policy makers. It is based on the old concept of the industrial district (Marshall 1920) and became especially popular due to the seminal works of Michael Porter (1990; 1998). Early works on clusters mostly assumed that clustered firms outperform unclustered firms due to specific

[3] Actually, it is not really 'destroyed' as the firms still continued to produce stable technology.

favourable cluster-internal dynamics. However, some authors observed that clusters may also develop in an unfavourable way (e.g. Grabher 1993). Based on these observations, more recent efforts to develop the concept of the regional cluster have been made in terms of dynamic interpretations of cluster development within the new field of Evolutionary Economic Geography (EEG) (Boschma and Frenken 2006; Boschma and Frenken 2011b). Regarding the question of cluster renewal, one specific literature strand of EEG became very productive: the literature on cluster life cycles (CLC) (e.g. Swann 1998; Brenner 2004; Press 2006; Maskell and Malmberg 2007; Bergman 2008; Menzel and Fornahl 2010; Ter Wal and Boschma 2011). This literature has developed detailed assumptions regarding the question of cluster development in general and cluster renewal in particular[4] (esp. Maskell and Malmberg 2007; Menzel and Fornahl 2010; Ter Wal and Boschma 2011). Most central to CLC concepts is the perception of cluster development as a sequence of distinctive development phases (see for example figure 1.1). Furthermore, most authors agree that cluster renewal is perceived to be a result of two aspects: firstly, the building of external linkages to actors outside the cluster (who, however, can be already situated within the region) who hold new knowledge and routines; and secondly, very specific cluster-internal development dynamics of co-evolving actor capabilities, regional institutional settings and cluster-specific network structures. In the tradition of most cluster literature the relevance of cluster-internal factors is strongly emphasised. Cluster development is mainly understood as driven by the cluster and its agents themselves. External factors are often believed to be less relevant to explain cluster-internal dynamics that are distinguishable from the developments of the industry as a whole. External knowledge, which is perceived as a core ingredient for cluster renewal, is thus more of a passive factor that is 'out there' and is occasionally acquired by cluster agents and unfolds its effect on the cluster's development when it diffuses systemically within the cluster network.

However, Martin and Sunley (2011) formulate broad criticism on such an underdeveloped understanding of clusters and cluster development. Firstly, they suggest dropping the idea of a rigid life cycle for a more flexible adaptive cycle. Clusters, as well as other systems like national industries, are very complex and it is very unlikely that the development of all clusters can be described by a uniform model. Thus, they advocate for a more open concept of cluster development that allows for more complex and flexible arrangements of development phases (see figure 1.2). In their adaptive cycle model cluster renewal may occur at multiple moments of the cycle's development.

The idea of a more open adaptive cycle of cluster development by Martin and Sunley (2011) points to a shortcoming of the CLC literature. However, it has its own shortcomings too as it cannot explain why certain clusters develop in one way while others follow another pattern. To deal with this problem explanations for cluster development need to be connected to factors from the cluster and its industry themselves that can be linked to

[4] A detailed discussion of these assumptions is given in chapter 2.

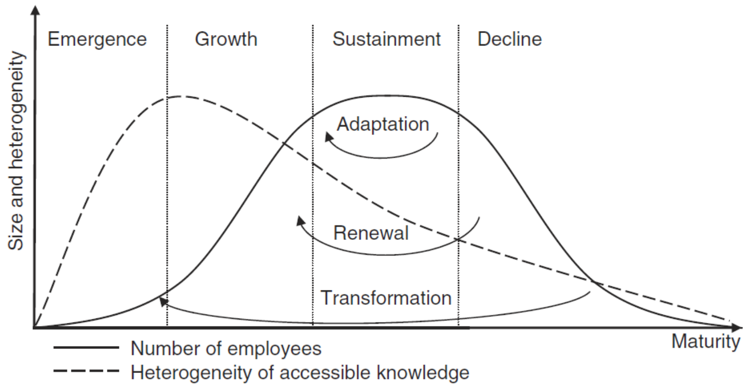

Figure 1.1: Quantitative and qualitative dimensions of the cluster life cycle. Source: Menzel and Fornahl (2010, p. 218).

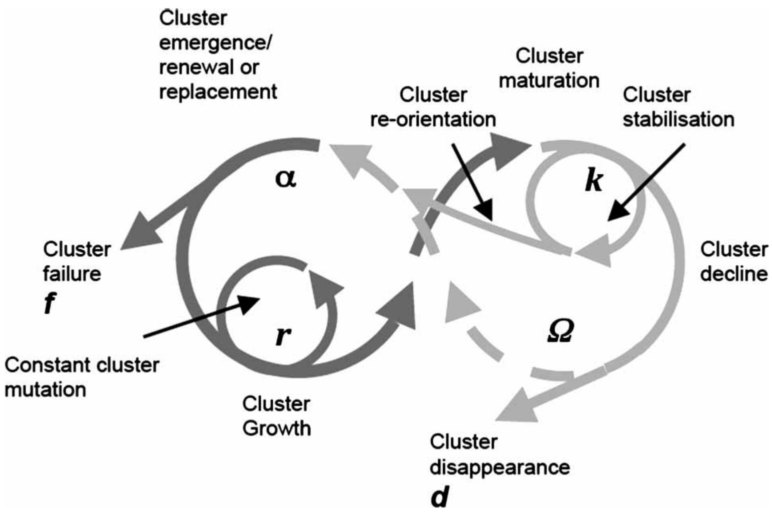

Figure 1.2: Modified cluster adaptive cycle model. Source: Martin and Sunley (2011, p. 1312).

a profound theoretical base. The economic geography literature offers some of these possible differences. For example, in recent years the literature on knowledge bases (Asheim and Coenen 2005; Cooke et al. 2007; Mattes 2012) and modes of innovation (Jensen et al. 2007; Isaksen and Karlsen 2012) emerged, which implies that industries differ in the way they innovate and the type of knowledge they use. As a result, they rely on different forms of collaboration with R&D partners from different contexts. Thus, the literature on knowledge bases distinguishes between (science-based) analytical, (engineering-based) synthetic and (creativity-based) symbolic knowledge bases that are characteristic for different kinds of industries and which determine the way firms innovate. In a similar way, the literature on modes of innovation distinguishes between a science-technology-innovation mode (STI), which is characteristic for science-based industries that often rely on an analytical knowledge base, and a doing-using-interacting mode (DUI) that is characteristic for mainly incrementally and application-oriented innovating firms with a synthetic or symbolic knowledge base. Finally, the combined and complex innovation mode (CCI) combines STI and DUI mode innovation in a complex way. Learning, knowledge diffusion and collaboration within cluster networks and with external partners are central conceptual pillars of both the knowledge bases and modes of innovation literatures on the one hand and the CLC concept on the other hand. Therefore, one can expect that the way firms in a cluster generally innovate and cooperate has a significant effect on the way a cluster develops and renews itself. Thus, it appears wise to bear these aspects in mind when thinking of a more pronounced idea of cluster renewal.

However, the CLC critique of Martin and Sunley (2011) stretches to a second argument. This argument is related to the interrelationship of the cluster with its external environment. The embeddedness of the cluster within its external environment has been formulated within the CLC literature. For example, based on earlier ideas from the cluster literature (e.g. Porter 1998) Menzel and Fornahl (2010) understand the cluster as a system of interrelated agents that share a common narrow geographical context and are active within a shared industrial or thematic context (see figure 1.3). Interconnections through collaborations with external agents are possible and perceived to be necessary for the creation of novelty within the cluster context. Nevertheless, the critical dynamics that are believed to be responsible for technological change within the cluster are perceived to rely mainly on cluster-internal factors. This is criticised by Martin and Sunley (2011). They argue that the complexity of cluster development does not only apply to cluster-internal factors but that the cluster is strongly embedded and interactively interrelated with its external environment.[5] Thus, and in contrast to the CLC, their own adaptive cycle model is more of an industry-driven interpretation scheme (Trippl et al. 2015). However, Martin and Sunley (2011) suggest that a cluster as a complex system is

[5]Similar and related ideas about the interrelation of the cluster with its external environment have also been formulated by other authors (e.g. Bathelt et al. 2004; Crevoisier and Jeannerat 2009; Coenen et al. 2012; Santner and Fornahl 2014; Trippl et al. 2015).

integrated in a hierarchy of systems that co-develop in a two-way interactive relationship (see figure 1.4). Along this relationship, upward and downward influence is possible and clusters are perceived to co-evolve with systems and subsystems in both directions of the hierarchy (e.g. the national industry or individual firms within the cluster). This interrelation is believed to be complex. For example, disruptions at larger systems mostly have significant effects for subsystems. Nevertheless, larger systems can also help subsystems to 'remember' and 'restore' old factors of prosperity (Martin and Sunley 2011, p. 1310) when narrow and encrusted structures of a locked-in subsystem becomes replaced by and connected to more open structures from the parental one. In turn, larger systems can also be disrupted and influenced by their subsystems if the resilience of the larger system is low enough. The regional cluster is, for example, a subsystem of its respective national or global industry. Furthermore, individual firms may be understood as subsystems of the cluster. Thus, the cluster can be expected to be a system that is in an interrelationship with its parental system as well as its own subsystems. However, Martin and Sunley (2011) also state that these systems and subsystems retain a certain degree of system autonomy which explains why clusters show a very characteristic development that can be distinguished from more general development patterns.

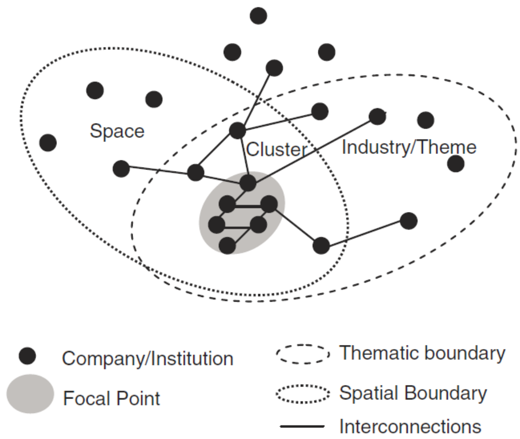

Figure 1.3: Elements of clusters. Source: Menzel and Fornahl (2010, p. 214).

1.2.2 Research agenda

Thus, according to the literature and the previous discussion, three main aspects arise that can be expected to determine cluster development and renewal. Firstly, as for example suggested in the CLC literature, clusters develop and renew themselves upon general cluster-internal factors and dynamics. These include systemic factors like the cluster's network structure, its internal institutional arrangement as well as the systemic

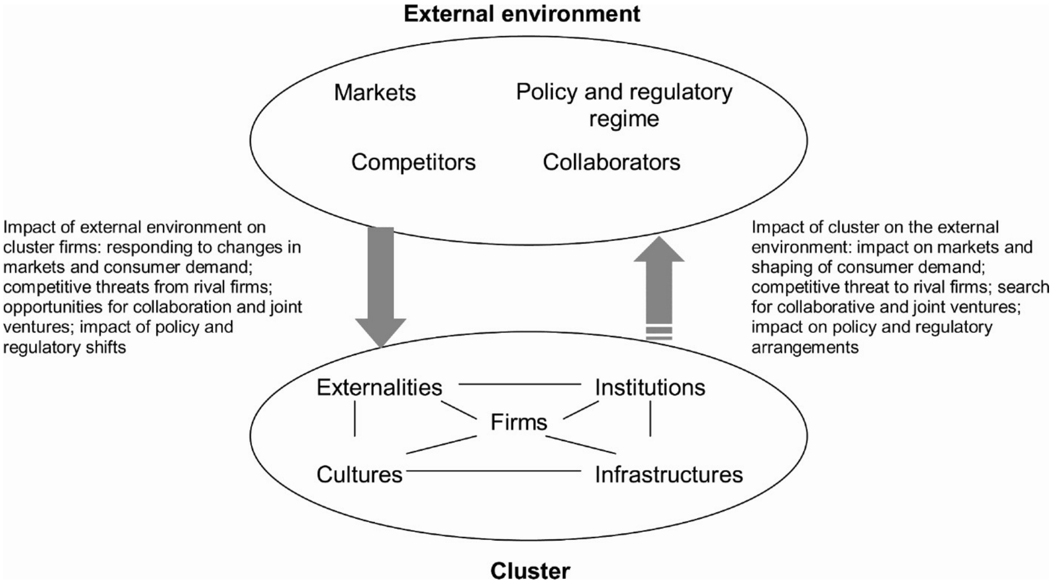

Figure 1.4: Two-way interactions between a cluster and its external environment. Source: Martin and Sunley (2011, p. 1311).

utilisation and diffusion of knowledge within the cluster as suggested by Menzel and Fornahl (2010). Furthermore, factors and dynamics that arise from the cluster's subunits (cluster agents like firms, R&D organisations and so forth) play a role. As formulated by Ter Wal and Boschma (2011), firms' capabilities like their absorptive capacity, the ability to reposition themselves within the cluster network and the ability to reproduce routines into new contexts are fundamental for the understanding of cluster renewal.

Secondly, as suggested by Martin and Sunley (2011), clusters are in a tight two-way interrelationship with their external environment. Thus, clusters and their external environment can be expected to affect and influence each other. The specific distinctness of inbound and outbound influences depends on the structures and significance of the cluster itself. For example, leading clusters like Silicon Valley have significant influence on the global development of their own industry, while the effect of small insignificant clusters can be expected to be low and their development more strongly driven by the external environment than the other way round. Thus, the interrelationship of a cluster with its external environment is strongly affected by the structure and significance within the wider industrial context of the cluster itself. Furthermore, the notion of the significance may induce that the boundaries of a cluster are open, changing and not strictly defined. To a certain degree this aspect has already been stressed in the CLC literature. For example, Menzel and Fornahl (2010) state that in a growing cluster its boundaries are shifting when new agents with novel knowledge become part of the cluster network.

Nevertheless, due to a certain degree of system autonomy clusters remain developing more or less specifically.

Finally, clusters and industries differ in terms of their structures, knowledge bases and dominant modes of innovation, which implies that some clusters may renew themselves in a different way than others. Different kinds of learning and collaboration depend on specific and varying effects that derive from cognitive, social, institutional, organisational and/or geographical proximity. As these dynamics are likely to change in the process of cluster renewal due to shifts in relevant knowledge and the significance of collaboration partners, cluster renewal may be a process of shifting knowledge bases and innovation modes in such cases. However, it remains widely unclear how these shifts look like. Thus, in conclusion from these observations the following research questions arise:

- How can cluster-internal processes and factors explain cluster renewal in the two case studies?
- How do the clusters interact with their external environment during processes of cluster renewal and how do internal and external factors correspond to each other in these processes?
- How are these processes determined by the specific characteristics of the clusters like the dominant knowledge base and mode of innovation and in which way is cluster renewal a process of changing knowledge bases and innovation modes?
- What implications can be drawn from the answers to the previous three questions in terms of a more pronounced understanding of cluster renewal?

These aspects are addressed from different perspectives in the three chapters of this cumulative thesis. An overview is depicted in table 1.1. The table shows, which of the broader thematic fields are stressed in each chapter. This is indicated by the boxes. Furthermore, each chapter highlights one of the three topics in a specific way. This is indicated by the word 'focus'.

Each chapter is based on a different set of theoretical strands. A detailed summary of each chapter is given in section 1.4. Chapter 2 functions as a starting point as it is widely based on the CLC literature (mainly Maskell and Malmberg 2007; Menzel and Fornahl 2010; Ter Wal and Boschma 2011) including its main criticism by Martin and Sunley (2011). It investigates how the CLC literature can explain the process of cluster renewal and where its strengths and shortcomings are. According to the main character of the CLC literature it mostly stresses cluster-internal factors and developments but also addresses the role of the external environment to a certain degree. Chapter 3 explores the role of the external environment in more detail. It is based on a strand of literature that is, so far, more or less unconnected to EEG: the literature on geographies of transitions (Coenen et al. 2012; Truffer and Coenen 2012; Raven et al. 2012; Binz et al. 2014;

Table 1.1: The addressed topics in this thesis. Own table.

	innovation mode dynamics	internal factors	external factors
chapter 2		focus	
chapter 3			focus
chapter 4	focus		

Murphy 2015), which in turn is based on the field of transition studies (e.g. Carlsson and Stankiewicz 1991; Rip and Kemp 1998; Geels 2002; Elzen et al. 2012). This theoretical strand understands industrial change as a process of socio-technical transition, which involves complex co-evolutionary alignment processes of technologies, agent networks and institutional arrangements from one context to another. In contrast to the other two chapters, this chapter is solely focussing on the case study on biogas diversification of the stable technology cluster. It is shown and discussed how a technology from a formerly separated context was applied to an already existing cluster context and which role cluster-internal territorial embedded factors as well as geographical and thematical external factors from various geographical scales and territories played. The chapter investigates how cluster-internal and cluster-external factors corresponded in this process. Finally, chapter 4 takes a closer look on the role of different ways of knowledge creation and innovation during the process of cluster renewal. It is widely based on the arguments from the modes of innovation literature (Jensen et al. 2007; Isaksen and Karlsen 2012) and adds some arguments from the proximity literature (Boschma 2005). It is thus, more or less focussing on cluster-internal dynamics, but from a different perspective than the CLC literature. It is shown that cluster renewal occurs differently depending on the mode of innovation that is applied. However, it is also shown that the mode of innovation may also change when new kinds of knowledge are introduced to the cluster context.

1.3 Conception, background and methodology

1.3.1 Conception and specifics of the thesis

This PhD thesis is conceptualised as a cumulative thesis. Thus, it is made of the three individual chapters 2 to 4 as well as this introductory chapter 1 and the concluding chapter 5, which provide the conceptual framework for the other chapters. Chapters 2 to 4 are by themselves structured and conceptualised as individual scientific works that can stand on their own. They all apply to the formal requirements of a standard article in a common scientific journal in the field of economic geography. As a reference the requirements of the journal 'European Planning Studies' have been applied to all three chapters. Therefore, all chapters do not exceed a word count of 9,000 words including all tables and references. Furthermore, each chapter has its own introduction, theory and methodology parts, as well as empirical and conclusions sections. Thus, to a certain degree, the overlapping and duplication of certain aspects cannot be avoided. For example, the methodology sections of all three chapters are strongly overlapping as they are all based on the same empirical data. Furthermore, some specific empirical observations are addressed in some or all of the three chapters. However, they are discussed differently due to the different theoretical background of each chapter. Finally, some figures are used in more than one paper. For example, a map of Germany, highlighting the investigated region, can be found in chapters 2 and 4 (figures 2.2 and 4.1). To keep the character of the chapters as individual pieces of literature, the figures remain repeated. Thus, chapters 2 to 4 appear in this thesis as they could appear in a scientific journal.[6] Nevertheless, two main exceptions apply. Firstly, the reference lists of all chapters are summarised in one merged reference list at the end of the thesis. As the reference list is not an integral part of the written text, a summary at the end of thesis avoids unnecessary repetitions and allows the reader a direct continuing from one chapter to the next one. The second exception applies to direct interview citations as can be found in chapter 2. For transparency reasons in the review process of the thesis these citations have been marked with identifiers that link the citations to the interview transcripts in the appendix. Due to data privacy issues of the interviewed firms, as well as due to the limited space in journal articles, these markers, as, for sure, the whole transcripts in the appendix, are not included in the version of the chapter that has been submitted to the journal. Furthermore, this information will not be included in the published version of the whole thesis.

Finally, another aspect needs to be addressed. In this thesis several acronyms are used, which are each explained in the respective chapters and are also listed in the list of abbreviations at the beginning of the thesis. In two cases acronyms are overlapping. The acronym EEG is generally used for 'Evolutionary Economic Geography' as well as

[6] All chapters have been submitted to scientific journals. Because of the ongoing review process textual differences may arise between the current and the finally published versions.

'Erneuerbare Energien Gesetz', two terms and concepts that play a significant role in the thesis. This also applies to the acronym CCI, which stands for 'Combined and Complex Innovation' as well as 'Competence Centre ISOBUS'. In some of the chapters both terms for one or both acronyms play a role, while in other chapters no such conflictive use appears. As each chapter stands alone as an individual piece of scientific literature, whenever possible, the common acronym EEG and/or CCI is used for either term. However, in those chapters, where conflictive and overlapping acronyms occur, alternative acronyms are used. In those cases, EEG remains the acronym for 'Evolutionary Economic Geography' and 'Erneuerbare Energien Gesetz' is shortened with REA, which stands for 'Renewable Energy Act'. In the other case, CCI remains the acronym for 'Combined and Complex Innovation' while 'Competence Centre ISOBUS' is shortened to CCISOBUS. Which acronym stands for which concept is explained in each chapter separately. Furthermore, the list of abbreviations reflects this information as well.

1.3.2 Methodology and project background

The analysis of the two case studies for all three chapters has been conducted within the context of a research project on cluster life cycles, funded by the European Science Foundation (ESF) under grant number 10-ECRP-07 and the Deutsche Forschungsgemeinschaft (DFG) under grant number HA 3179/6–1. Within the international project research team, questions for a common semi-structured interview manual have been developed. For this thesis several other questions have been added including some additional interview material. The manuals for the interviews as well as the additional material are included in the appendix. The analysis of the two case studies in all three chapters is mainly based on the results from the conducted interviews. In total, 33 semi-structured interviews have been conducted between 2012 and 2015. The transcripts of these interviews can be found in the appendix.[7] Of these interviews, nine have been conducted with stakeholders of innovating agents from the farm trailer sector (firms and COALA) and twelve with stakeholders from the stable technology sector (only firms). Four interviews have been conducted with stakeholders from the biogas context. The remaining eight interviews have been conducted with industry experts from contexts like academia, trade and crafts chambers, interest organisations and local business development agencies. The identification of relevant interview partners was mainly based on references in earlier interviews but also on secondary sources like trade fair participant lists, company data banks and the like. Some well-connected industry experts were very important door openers and some interview partners were directly acquired or identified at the Agritechnica trade show in Hanover 2012. All interviews have been conducted in German. Relevant passages that have been cited in the chapters have been trans-

[7]This is not included in the final published version of the thesis.

lated to English. The analysis of the interviews was conducted with the software tool MaxQDA 11.

Thus, this thesis is widely based on qualitative data and analysis. To a certain degree, this is a result from the research design of the cluster life cycle project. Nevertheless, it also contributes to the aim of the thesis itself as it has its very specific and from the project distinguishable research agenda. The thesis itself has an explorative character as it seeks to find new empirical evidence for the development of the theoretical discussion of cluster renewal. New insights can be better acquired from qualitative data as the information of such data is more open and less restricted by formal data structures as in the case of quantitative data. However, in some cases, as for example in chapter 3, some basic statistical data are used to complement the argument. Nevertheless, the character of the study remains widely qualitative. The use of quantitative data has also been limited by the fact that the two analysed sectors of agricultural engineering are both hardly identifiable in quantitative data as they do not fit well into the common categories of official statistics. For example, the stable technology sector is not identifiable as an own sector in official categories of industry classification systems like the international ISIC, the European NACE or the German WZ systems. Also, the potential use of patent or subsidy data is widely limited. Agents of both industries tend not to patent their innovations nor do they often apply for subsidies.

The use of qualitative interview data limits the potential scope of the study. Interview statements are strongly subjective and their reliability decreases significantly if the subject of the statement lies further back in the past or if it has not been personally experienced by the interviewee. Therefore, the study focusses on events that mainly occurred since the beginning of the 21st century. Furthermore, interviewees with a longer background in their firms were preferred. Except for one interviewee all interviewees were working for their company for at least five years or, if the company was younger, since the founding of the company. In many cases interviewees had decades-long experience.

1.3.3 Personal contributions of the author to the papers

General remarks

As stated before, the general idea for the research on cluster development patterns is based on an international research project on cluster life cycles. The interview manuals for the firms and the industry experts have been developed within this project in collaboration with the research partners. The manuals have been enhanced by the author of this thesis (Dominik Santner) through the addition of several questions that are of his own interest. The manual for the interviews from the biogas industry context that have been conducted in 2015 has been developed completely by the author. All manuals can be found in the appendix.

Almost all interviews have been solely conducted by the author. The first two interviews with the industry experts Prof. Dr. Christine Tamásy and Prof. Dr. Hans-Wilhelm Windhorst have been conducted together with PD Dr. Dirk Fornahl. In these two interviews Mr. Fornahl took the lead. All other interviews were solely conducted by Dominik Santner. PD Dr. Dirk Fornahl also helped to initiate these first two contacts. The contact to all other interview partners, including all of the firms has been done by the author. However, the two interview partners Prof. Dr. Hans-Wilhelm Windhorst and Dr. Henning Müller helped to identify some relevant interview partners.

Within the research project it was initially the idea to investigate the food sector of north-western Germany. The idea and the decision to concentrate on the agricultural engineering sectors were the author's. However, even though the research project and the thesis have been implemented in a common context, they are both widely independent projects. The conception of the thesis, including relevant aspects of the empirical research, have been realised by the author. Thus, the author set the rules of the thesis as an individual research project. Finally, the transcription of the interviews was done by three different persons: the author himself, the student assistant Alexander Barros and a person from a professional transcript service.

Introductory and concluding chapters (chapters 1 and 5)

These papers are solely written by the author Dominik Santner and based on his own ideas. They are loosely based on some ideas that have been formulated by the author in a different way in an earlier working paper (Santner and Fornahl 2014). The author wants to thank Isa Reinecke for proofreading.

Cluster-Internal and External Drivers of Cluster Renewal. Evidence from Two German Agricultural Engineering Case Studies (chapter 2)

This paper is solely written by the author Dominik Santner and based on his own ideas. This work was presented at the iino seminar in Bremen 2016 at the Faculty for Business Studies and Economics of the University of Bremen. The author wants to thank the participants of this seminar, mainly Prof. Dr. Christian Cordes and PD Dr. Dirk Fornahl, for helpful comments on an earlier version of this paper. Furthermore, he likes to thank Isa Reinecke for proofreading.

The Geographies of Socio-Technical Anchoring and the Case of Biogas in North-Western Germany (chapter 3)

This paper is solely written by the author Dominik Santner and based on his own ideas. It has been presented at the northern German doctorate colloquium in economic geography (Norddeutsches wirtschaftsgeographisches Doktorandenkolloquium) in Bremen 2016. The author wants to thank the participants of this seminar for helpful comments on an earlier version of this paper, especially Prof. Dr. Robert Hassink, Prof. Dr. Max-Peter

Menzel, PD Dr. Dirk Fornahl, Prof. Dr. Ivo Mossig, Rodrigo Troncoso and Cathrin Söllner. He also wants to thank two anonymous referees from the journal 'Research Policy' for further comments. Even though the paper has been rejected from the journal, their comments helped to improve the paper. Finally, the author wants to thank Isa Reinecke for proofreading.

Proximity and Modes of Innovation – Evidence from Two German Agricultural Engineering Clusters (chapter 4)

This paper is solely written by the author and based on his own ideas. It has been presented at the iino Seminar in 2015 at the Faculty for Business Studies and Economics of the University of Bremen. The author wants to thank the participants of this seminar for helpful comments on an earlier version of this paper, especially Prof. Dr. Christian Cordes and Isa Reinecke. He also wants to thank two anonymous referees from the journal 'European Planning Studies' for very helpful further comments. Finally, the author wants to thank Isa Reinecke for proofreading.

1.3.4 Current state of publication of the papers

Cluster-Internal and External Drivers of Cluster Renewal. Evidence from Two German Agricultural Engineering Case Studies (chapter 2)

This paper has been submitted to the journal 'European Planning Studies' on December 18th 2016. It is currently under review.

The Geographies of Socio-Technical Anchoring and the Case of Biogas in North-Western Germany (chapter 3)

An earlier version of the paper had been submitted to the journal 'Research Policy' on March 16th 2016. It has been rejected on May 28th 2016. It has been submitted after a strong revision to the journal 'Industry & Innovation' on December 15th 2016. It is currently under review.

Proximity and Modes of Innovation – Evidence from Two German Agricultural Engineering Clusters (chapter 4)

An earlier version of the paper had been submitted to the journal 'European Planning Studies' on December 15th 2015. A response with a request for major revision has been given on June 6th 2016. It has been resubmitted in a strongly revised version on December 18th 2016. It is currently under review.

1.4 Summary of chapters 2 to 4

1.4.1 Cluster-Internal and External Drivers of Cluster Renewal. Evidence from Two German Agricultural Engineering Case Studies (chapter 2)

This chapter takes a focus on the CLC literature and its main assumptions according to the nature and reasons of cluster development in general and cluster renewal in particular. Furthermore, it discusses the criticism that has been formulated recently. Therefore, the aim of the chapter is to find out how the CLC concept can explain the renewal processes of the two investigated clusters of agricultural engineering and which limitations arise from the concept. To a certain degree it follows a similar and overlapping theoretical conception like the introductory chapter 1, but focusses on the arguments from the CLC literature in more detail.

One of the core assumptions of the CLC literature (e.g. Maskell and Malmberg 2007; Menzel and Fornahl 2010; Ter Wal and Boschma 2011) is that clusters are path-dependent, self-organising and emergent entities. This implies that the development of a cluster can be explained widely by the cluster and its elements. Thus, a cluster's development can to a large degree be explained independently from more general development patterns like industry or product life cycles. Nevertheless, CLC concepts generally acknowledge that a cluster is embedded in an external environment that functions as a source of novel knowledge and routines. Especially Menzel and Fornahl (2010) differentiate between an external environment within the region but outside of the thematic context, one within the thematic context but outside of the region, and one outside of both (see figure 1.3). However, the role of the external environment for a clusters' development remains underdeveloped as CLC concepts concentrate on cluster-internal processes and factors. Especially two cluster-internal sets of factors are discussed. The first one includes a cluster firm's capabilities. These capabilities explain how an individual firm becomes able to be innovative on its own. Ter Wal and Boschma (2011) distinguish three core capabilities, which they call dynamic capabilities, as they cannot just help a firm to solve problems, but help to change the way it can solve problems: firstly, the absorptive capacity (Cohen and Levinthal 1990) of a firm that enables it to learn from a more or less broad set of knowledge sources; secondly, the ability of the firm to reposition itself within the own agent network to get strategical access to and control over knowledge; and thirdly, the ability of a firm to reproduce its routines to new (geographical) contexts. The second broad set of factors includes the systemic dimension of clusters. Menzel and Fornahl (2010) argue that relevant knowledge has to be utilised systemically within a cluster's network to unfold cluster-wide effects. Maskell and Malmberg (2007) point to the relevance of pinpointed institution building and adjustments among cluster agents. These effects widely unfold more likely within a cluster context than outside of it due to the tendency of economic agents to search for potential collaboration partners myopically within their closer geographical, social and industrial environment (Maskell and Malmberg 2007). By doing this, they can exploit advantages that potentially arise from different forms of proximity in terms of access to new forms of knowledge and routines (Boschma 2005).

However, even CLC approaches point to the necessity of external knowledge for cluster change, growth and renewal. The issue is often built on the global pipeline argument by Bathelt et al. (2004). Relevant external knowledge is occasionally acquired and absorbed by cluster agents. This may result in agents capability building and systemic utilisation processes. However, CLC approaches generally argue that external novelty is not an explanatory factor by itself but gains its influential character through the active acquisition and utilisation by cluster agents.

However, as explained earlier in this introductory chapter, the CLC has been criticised by Martin and Sunley (2011). They argue that the assumptions of the CLC literature are too deterministic and that clusters may show more diverse development patterns. Clusters are interrelated with their internal and external environment in complex ways. They are subsystems within a larger socio-economic environment. As such, they show, to a certain degree, system autonomy. However, they are strongly intertwined with their external environment. Martin and Sunley (2011) describe this as a two-way interrelationship. The cluster is influenced by its environment by large-scale regularities and seemingly erratic evolutionary trends. Furthermore, the cluster also takes an influence on its external environment. As cluster renewal is strongly dependent on external knowledge flows, this interactive relationship of the cluster with its environment can be expected to be very intense in a process of cluster renewal while still strongly determined by cluster-internal dynamics.

These theoretical assumptions are applied in the chapter to the two investigated case studies of the farm trailer and stable technology clusters of north-western Germany that renewed themselves in the early 21st century. In both cases strong cluster-internal drivers can be observed. In the case of the farm trailer cluster learning from new and emerging partners enabled traditional farm trailer producers to build their individual absorptive capacities. Furthermore, as many firms in the cluster engaged within a newly emerged collaboration network (the CCISOBUS-network), they became able to reposition themselves within their innovation and collaboration network. Based on the dynamics of the CCISOBUS network the newly developed and acquired knowledge could be utilised systemically within a growing and changing cluster.

In the biogas case of the diversifying stable technology cluster absorptive capacity building processes can also be observed as stable designers integrated knowledge from biogas firms through acquisitions and hiring. However, other capability building processes were less cluster-specific. The firms could reposition (or better newly position) themselves within their innovation network. However, this positioning did widely not happen within the own traditional cluster context of stable technology, but in the context of the national biogas technology innovation network. Nevertheless, this represented a process of capability building, as the firms could reproduce their routines within a new industrial context. This whole development was strongly driven by an external cluster-unspecific factor: the national Renewable Energy Act (REA). Thus, the biogas diversification process of the stable technology cluster was driven cluster-internally and externally.

However, even though the renewal process of the farm trailer cluster was strongly driven by cluster-internal dynamics, the interrelation with the external environment played a significant role as well. On the one hand external knowledge was acquired by the firms. Nevertheless, some of these formerly external sources became later internalised within the cluster structures. Agents like the research centre COALA and the technology producer Anedo were initially no integral part of the cluster but quickly became central elements of the cluster in the process of renewal. Thus, the cluster could enhance its thematic borders into the field of specialised ICT. Furthermore, the farm trailer cluster developed a strong outbound influence on its global environment. The CCISOBUS network became a very relevant innovation driver of the global farm vehicle technology. It holds a global innovation leadership.

In contrast, biogas technology was widely developed outside of the context of the stable technology cluster in a separate and established biogas technology industry. However, this pattern did not change much after stable designers from the cluster entered this technological field. In the end, the influence of the stable technology industry on the national biogas context remained minor. Moreover, biogas-related technology development remained mainly driven externally by factors like the established biogas industry and political intervention on the national level through the REA and its amendments.

Thus, the main conclusion of the chapter is that in both case studies cluster renewal was driven by cluster-internal factors that were in an interrelationship with factors from the external environment. However, it seems that the character of the interrelationship of a cluster with its external environment strongly depends on the relevance of the cluster in its environment. A leading cluster like the farm trailer cluster has a stronger effect on its external environment than a more insignificant cluster like the stable technology-based biogas cluster.

1.4.2 The Geographies of Socio-Technical Anchoring and the Case of Biogas in North-Western Germany (chapter 3)

This chapter takes up the perspective of socio-technical transitions. This strand of literature deals with the question on how the development and use of technology in terms of technological artefacts and/or socio-technical practice emerges and diffuses into mainstream application and how they stabilise as new established socio-technological states-of-the-art. The literature mainly builds upon two core concepts: the Technological Innovation System (TIS) (Carlsson and Stankiewicz 1991) and the Multi-Level Perspective (MLP) (Rip and Kemp 1998; Geels 2002).

Traditionally, transition studies investigate technological change widely aspatially.

Socio-technical systems are at best investigated from the perspective of closed analytical containers like nation states. However, as geographers are well aware, the role of place and scale is much more complex in reality. Thus, this lack of the recognition of the role of place, scale and geography has recently been criticised (Coenen et al. 2012; Truffer and Coenen 2012; Binz et al. 2014; Murphy 2015). Two main conceptual shortcomings are generally discussed: firstly, socio-technological systems are, to a certain degree, characterised by territorial institutional embeddedness; and secondly, social space is made-up by a patchwork of structures on multiple socially constructed geographical scales (the region, the nation state, etc.) that interact in a multi-scalar way.

This chapter is building upon this discussion by developing a geography-sensitive concept of the recent anchoring approach (Elzen et al. 2012). Anchoring is a concept that is based on the MLP literature. One of the core arguments of the concept is that the transition and establishment of a new socio-technological arrangement (like for example a new technology) can only be successful if it is fully anchored to the targeted socio-technical context (like for example the context of an established industry). This includes technological anchoring (the introduction of the technology to the context), network anchoring (the involvement of the agents of the context in use, innovation and production) as well as institutional anchoring (the creation of legitimacy for the new technology by linking it to values, strategies and belief systems, the creation of specific legislation and the establishment and integration into functioning market structures). In the tradition of transition studies, the anchoring concept is aspatial (Murphy 2015). However, a reasonable and comprehensive geography-sensitive concept of anchoring is still missing in the geographies of transition literature. Therefore, the chapter discusses what implications can be drawn from the aspects of territorial embeddedness and multi-scalarity for a sufficiently geography-sensitive concept of anchoring.

Territorial embeddedness can be directly linked to some contemporary core concepts of economic geography. Especially the contiguous concepts of proximity (Boschma 2005) and related variety (Frenken et al. 2007) offer some strong explanatory power for the issue of territorial embeddedness of socio-technical systems. The issue of proximity has recently been addressed in the transitions literature (e.g. Coenen et al. 2010; Raven et al. 2012; Murphy 2015). However, the conceptual profundity strongly varies. As some of these works offer some more pronounced expectations for the role of different forms of proximity (e.g. cognitive or social proximity) in socio-technical transitions (e.g. Coenen et al. 2010), others do only apply a naïve and flat concept of proximity (e.g. Raven et al. 2012; Murphy 2015) that lacks a pronounced distinction of the effects of different forms of proximity and the role of place. Therefore, a sound understanding of the interrelationship of proximity and territorial embeddeness in socio-technical transitions is still missing. Thus, the chapter is building on a more pronounced distinction of the role of cognitive, social, institutional, organisational and geographical proximity for the notion of territorial embeddeness in transition studies in general and the concept of anchoring in particular.

The recognition of the multi-scalarity issue has another implication for the understanding of socio-technical transitions and anchoring. As socio-technical transition and anchoring can be expected to occur simultaneously at multiple spatial scales and in multiple territorial contexts, they may align specifically to their conditions. As a result, anchoring may result in multiple and potentially overlapping processes of alignment and misalignments. For example, institutional anchoring on the national scale and alignment to national industrial structures may result in misalignments of this anchoring process with the specific conditions in a certain regional context. As a result, the establishment of the new technology to the investigated regional industrial context may fail due to these misalignments.

Thus, from the geographical perspective, socio-technical anchoring is a complex process that results from specific proximity-driven territorially embedded alignment processes and potential misalignments that arise from parallel and intertwined anchoring processes on and in various scales and territories. These theoretical assumptions are applied to the case study of biogas technology anchoring in the agribusiness, and especially the stable technology context of north-western Germany since the early 21st century. It can be observed that, due to specific territorially embedded structures specific proximity effects could arise between the regional stable technology industry and the biogas technology context. These included cognitive proximity between the two technologies, institutional proximity of both contexts due to their compatibility for entrepreneurial activities in the farm context as well as social and geographical proximities that promoted the process. As a result comprehensive alignment processes helped to anchor biogas technology in the investigated socio-technical context of north-western Germany. However, some significant institutional anchoring processes occurred solely on the national scale. As a result, the regulative framework that was created to support renewable energies in Germany (the REA) proved to be increasingly misaligned with the investigated socio-industrial structures in north-western Germany. These misalignments contributed to the downfall and loss of legitimacy of biogas technology in both the national and the regional context.

Concluding, the geographical dimension of socio-technical transitions and the anchoring of external technology to a cluster context is a complex process that is characterised by specific possibilities that arise from the territorial embedded proximity effects within a cluster context and multiple possibilities for alignment and misalignment across socially constructed spatial scales. Thus, the successful anchoring of a new technology in a cluster context depends on whether cluster agents as well as policy makers succeed in creating sufficient conditions within the cluster's regional and thematic context. Especially institutional anchoring remains critical as juridical and social legitimacy of a technology is often strongly influenced and driven by factors on the global and national scale. Thus, the creation of sufficient and broad institutional legitimacy on the regional and cluster level can potentially help to prevent the failure of anchoring due to misalignments with processes and structures on other spatial scales.

1.4.3 Proximity and Modes of Innovation – Evidence from Two German Agricultural Engineering Clusters (chapter 4)

The role of different forms of proximity (Boschma 2005) between economic agents for their collaborative innovation activities became one of the core EEG concepts in the recent years. The degree of the cognitive, social, institutional, organisational and geographical proximity and distance is thus widely understood as crucial to understand why and how certain firms innovate in the way they do. Because of the relational character of collaborative activities and innovation, proximity is also a helpful concept to understand technological changes in whole industries or regional clusters.

The effect of the different forms of proximity on the innovation activities strongly depends on the quality of the knowledge involved and the general way the firm innovates. Incremental innovation often depends on cognitive proximity of agents holding tacit knowledge. Geographical and social proximity may be helpful in this case as they promote the transmission of tacit knowledge. In contrast, more radical and sophisticated science-based innovation is often widely based on codified knowledge. Thus, it is more strongly dependent on cognitive proximity between agents understanding the 'code' of the codified knowledge (e.g. the scientific principles). Geographical and social proximity is less helpful here, but sometimes organisational proximity helps to gain control of otherwise easily transferable codified knowledge. However, also firms from sectors that are traditionally innovating more incrementally (including the two investigated farm trailer and stable technology industries) may start to innovate in a more sophisticated way. As a potential result, firms, clusters or even whole industries may shift in their technological background over time. Depending on the quality of that shift, this may result in more general and fundamental changes in the firms', cluster's or industry's knowledge base and the general way innovation is applied. In some cases, this process is accompanied by changes of the relevant effects that unfold due to proximity arrangements (the forms of proximity that are central for innovative collaboration) within a changed innovation network. Or in other words, firms that traditionally innovated incrementally and started to introduce more science-based processes and technologies need to learn to exploit other forms of proximity with their new collaboration partners. Thus, the aim of the paper is to investigate how these firms change their proximity arrangements in relation to their established and newly emerging collaboration partners to become able to innovate more sophisticatedly.

Besides the proximity approach, the paper builds upon the literature on modes of innovation (Jensen et al. 2007; Isaksen and Karlsen 2012). This literature generally assumes that industries follow certain modes of innovations (science-technology-innovation – STI; doing-using-interacting – DUI; or combined and complex innovation – CCI) that each are characterised by different innovation outcomes, strategies and structures. Engineering-based firms traditionally often can be characterised as DUI mode firms as they rely on tacit knowledge, innovate mainly incrementally and in collaboration with partners along the value chain (so-called DUI partners) like clients and suppliers. More sophisticated and radical innovation is perceived to be more characteristic for STI mode firms as they rely on science-based knowledge and innovate often in own R&D departments or in collaboration with STI partners (universities, researchers, ...) apart from the daily production routines. CCI mode innovation represents a hybrid form of STI and DUI mode innovation and demands very complex coordination abilities of the innovating agents to recombine the outcomes of the very different DUI and STI mode innovation activities.

So far, the issue of proximity has only partly been addressed in the modes of innovation literature. Especially a comprehensive framework is missing. To close this conceptual gap, the paper is discussing the interrelationship of proximities and modes of innovation in detail. However, some assumptions can be identified in the literature. STI mode innovation is thus mainly built upon cognitive proximity to STI partners (universities, etc.) and organisational proximity to close cognitive gaps to collaboration partners (Fitjar and Rodríguez-Pose 2013). It can be created by hiring skilled staff from the STI context like universities (Herstad et al. 2015). According to the literature, institutional, social and geographical proximity do only play a minor role.

DUI mode innovation also relies on cognitive proximity. However, this cognitive proximity needs to be built to DUI partners (clients, suppliers, other DUI mode firms). Because of the tacit character of the relevant knowledge and the often applied learning-by-doing style of learning, institutional proximity is often also very important. Social and geographical proximity can be very supportive in this process but are not necessarily needed. Herstad et al. (2015) conclude that the creation of organisational proximity through hiring or mergers and acquisitions is only helpful if it involves staff or firms from a related (but not the same) industry as this helps to strengthen the firm's knowledge base and processing routines. This enhances the likelihood for innovation.

Finally, the role of proximities for CCI mode innovation is widely not discussed in the literature. However, due to its hybrid and complex character one can expect it to rely on cognitive proximity to a broad range of partners from STI and DUI contexts, organisational proximity, widely involving STI partners to bridge cognitive gaps and a strong degree of institutional proximity to create a sufficient environment for the complex coordination activities between DUI and STI partners. Social and geographical proximity may also be helpful.

Thus, these theoretical assumptions provide two possible developments for traditional DUI mode firms if they seek to innovate more sophisticatedly beyond simple incremental innovation. Firstly, they may switch to a CCI innovation mode with its complex arrangements of proximities to a broad set of agents; or secondly, they may retain a DUI innovation mode if they are able to switch to a different DUI technology from a technologically related industrial context. These two possible ways can be observed for the two investigated case studies. A majority of the firms from the farm trailer cluster switched to a CCI mode when they increasingly introduced and developed ICT technology. This included a change of relevant forms of proximity between the firms and their old and new collaboration partners which widely fits to the assumptions from the theory section. In contrast, stable technology firms diversifying into biogas technology could retain a DUI mode because of the technological relatedness of biogas and stable technologies and the fact that both technologies are widely developed in a DUI mode. Cognitive proximity was created by the creation of organisational proximity through mergers and acquisitions.

Thus, two main theoretical conclusions can be drawn from these observations. Firstly, a switch of economic agents and groups of agents from incremental innovation to more sophisticated innovation may happen within a DUI or a more complex CCI mode, depending on whether the newly used knowledge and technology are similar (e.g. a related DUI technology) or dissimilar (e.g. a STI technology) to the traditional knowledge and technology. And secondly, firms may change their innovation mode over time through the adjustment of the cognitive, social, institutional, organisational and/or geographical proximity arrangements to their existing and new collaboration partners. This has some policy implications as policy makers often seek to influence technological change within localised industries and clusters in a favourable way. However, the chapter shows that the specific necessities for such a successful intervention depend on the applied mode of innovation and the relatedness of the newly introduced knowledge.

1.5 Outlook to the thesis

This introductory chapter offered both a conceptional framework as well as a brief summary of chapters 2 to 4. Furthermore, it gave all the necessary information for the assessment of a cumulative dissertation. The remainder of the thesis is as follows. This introductory chapter is followed by the chapters 2 to 4. These chapters form the core of this cumulative thesis and are each conceptualised as individual scientific works. Chapter 2 deals with the issue of how the CLC literature can explain cluster renewal and what shortcomings may arise. It identifies cluster-internal and external factors of cluster-renewal in the two case studies and discusses them in relation to the CLC literature. Chapter 3 concentrates on the stable technology case and biogas. It discusses how biogas technology has been introduced to the context of stable technology in north-western Germany and what implications can be drawn in terms of a geographically better understanding of socio-technical transitions. Its contribution for research on cluster renewal lies in its explanations for the interrelationship of the cluster with its external environment. Chapter 4 connects the issue of cluster renewal with questions on innovation modes and knowledge bases. It addresses the question on how different forms of cluster renewal may result from different industry and knowledge structures. Finally, chapter 5 offers a discussion of the thesis as it connects the three chapters 2 to 4 with the framework of the introductory chapter 1. Furthermore, it draws some conclusions.

2 Cluster-Internal and External Drivers of Cluster Renewal. Evidence from Two German Agricultural Engineering Case Studies

Author Dominik Santner

Abstract The question on how regional clusters renew themselves and start a new cycle of prosperity is of vital interest for the affected companies, politicians and regions. Recently, the idea of renewing clusters has been conceptualised within the literature on cluster life cycles (CLC). CLC approaches generally assume that cluster renewal is widely driven cluster-internally through agent capability building processes and the systemic utilisation of novelty. Critique from other authors highlights the neglected role of the external environment in the CLC literature and suggests an interactive relationship of the cluster with it. This article sheds light on renewal processes in two agricultural engineering clusters in north-western Germany. It is shown that in the case of a farm trailer cluster renewal can be widely explained cluster-internally, while in the case of a stable technology cluster that diversified into the field of biogas technology, internal factors played a less significant role and much of the development was driven externally by political decisions on the national level. A possible explanation lies in the differences in the stage of the novel technologies' development. Thus, the assumptions from the CLC literature do only draw a limited picture of cluster development and renewal and more punctuated and enhanced CLC concept should better incorporate the role of the cluster's external environment.

Keywords cluster renewal, cluster life cycle, agricultural engineering

JEL classification O14 O31 O33 R11

2.1 Introduction

Today the idea of regional industrial clusters has become one of the main tools for regional economic policy. Policy makers generally expect clustered firms of a common industrial-thematic context to grow more prosperously and innovate more dynamically due to positive spillover effects between co-located firms. However, several empirical examples reveal that clusters may experience a downfall due to unfavourable developments and cognitive lock-in (e.g. Grabher 1993). Thus, clustered firms as well as policy makers have a vital interest to build and maintain the economic prosperity of their clusters to prevent this decline. One promising option may be to renew the cluster by introducing novel knowledge, routines and technology.

In the last years, the issue of cluster renewal experienced an increasing degree of attention in academia. It has been a subject of discussion in various studies with different research foci and conclusions in the past (e.g. Cooke 1995; Tödtling and Trippl 2004; Tappi 2005; Sammarra and Belussi 2006; Staber and Sautter 2011; Fornahl et al. 2012; Tomlinson and Branston 2014). For example, Tödtling and Trippl (2004) argue that clusters may renew themselves if they can build upon a strong regional innovation system (RIS), newly established innovation networks and more indirect forms of policy intervention. Staber and Sautter (2011) highlight the role of a strong and flexible cluster identity and Fornahl et al. (2012) point to the relevance of opening windows of opportunity to initiate renewal processes. It has to be stressed that all of these studies point to single aspects of cluster renewal without offering an encompassing explanation. However, recently, the idea of cluster renewal has been integrated within the literature on cluster life cycles (CLC) (e.g. Swann 1998; Brenner 2004; Press 2006; Maskell and Malmberg 2007; Menzel and Fornahl 2010; Ter Wal and Boschma 2011)[1] within the research field of evolutionary economic geography (EEG). CLC concepts are based on arguments from the product life cycle (Vernon 1966; Utterback and Abernathy 1975) and industry life cycle (Klepper 1997) literature. They mostly assume that cluster development follows a sequence from an embryonic or emergent stage, via a growth stage to a stage of maturity and ends in the downturn of a stage of decline (see also figure 2.1).

This development along the life cycle is based on the general assumption that cluster development is a path-dependent, self-organising and emergent process (Boschma and Frenken 2011a; Tanner 2011; Fredin 2014). Or in other words, cluster development is believed to be driven by the cluster and its agents themselves. Therefore, the CLC can be strictly distinguished from the industry life cycle. CLC concepts point to a number of relevant cluster-internal driving factors including changing firm capabilities like the firm's absorptive capacity (Menzel and Fornahl 2010; Ter Wal and Boschma 2011), cluster-internal network formation processes (Menzel and Fornahl 2010; Ter Wal and Boschma 2011) as well as adjustments of the cluster's institutional settings (Maskell and Malmberg 2007). As cluster renewal as an integral part of cluster evolution is also believed to mainly rely on these cluster-internal factors in a systemic cluster-internal adaptation process, cluster renewal is a process of co-evolution of cluster agent's capabilities, cluster-internal network structures and cluster-specific institutional settings.

[1]An overview on early approaches is given by Bergman (2008).

However, clusters are not isolated from the rest of the world. Especially cluster renewal involves new knowledge, routines and technology that are introduced to the cluster and its agents. CLC concepts generally recognise this fact by stressing the global pipeline argument (Bathelt et al. 2004). Novel knowledge, routines and technology are tapped and absorbed by cluster agents through collaboration ties with cluster-external agents from different geographical and/or industrial-thematic contexts. However, the process of knowledge acquisition and adaptation is perceived to be solely cluster-internally driven by the cluster agents themselves.

This strong focus on cluster-internal drivers of development in the CLC literature has been criticised in the last years. One of the most recognised critiques has been formulated by Martin and Sunley (2011). They argue that the assumptions in the CLC literature are too deterministic and that cluster development is in reality much more complex and cannot sufficiently be described by a simple life cycle model. One core argument of them takes a strong focus on the role of the external environment of clusters. Martin and Sunley (2011) state that clusters are subsystems of larger systems (e.g. the national economy or the respective global industrial sector) and that systems and subsystems influence each other in a two-way interrelationship. Even though Martin and Sunley (2011) acknowledge that subsystems like clusters show a certain degree of system autonomy, it cannot be ignored that clusters may be very well influenced and driven in their development by factors of their external environment and that such a development can be still cluster-specific due to cluster and agent-specific capabilities and structures.

This article seeks to investigate this interrelationship of internal and external factors for cluster renewal processes. It is investigated through the analysis of two empirical case studies of agricultural engineering clusters in north-western Germany, namely the Osnabrück-centred farm trailer cluster and the Vechta-centred stable technology cluster. Both clusters share a very similar and overlapping regional, social and industrial context and both clusters experienced cluster renewal within the first years of the 21st century. However, renewal processes occurred very differently. In the case of the farm trailer cluster, cluster renewal was mainly driven cluster-internally through cluster-internal knowledge and network formation and capability building processes. In the second case study on stable technology, a significant renewal process was mainly driven by external policy intervention on the national scale that was not directly designed to target this specific industry or cluster.

The remainder of this article is as follows. The second section describes and discusses the concept of cluster renewal as it has been formulated in the CLC literature including its critique. It concludes with some research expectations. The third section investigates the two case studies of agricultural engineering clusters in north-western Germany. And finally, the fourth section offers a discussion of the results and draws some conclusions.

2.2 Cluster renewal and the cluster life cycle (CLC)

As stated before, the issue of cluster development, including the occasional event of cluster renewal has been recently conceptualised within the cluster life cycle (CLC) literature (e.g. Swann 1998; Brenner 2004; Press 2006; Maskell and Malmberg 2007; Bergman 2008; Menzel and Fornahl 2010; Ter Wal and Boschma 2011). As already mentioned, CLC approaches tend to explain cluster development and renewal as mainly cluster-internally driven, while also acknowledging the significance of external knowledge and routines that occasionally are adopted by cluster agent. This section seeks to take a closer look on what the CLC literature tells us about cluster renewal. Three more recent CLC approaches, namely the concepts of Menzel and Fornahl (2010), Ter Wal and Boschma (2011) and Maskell and Malmberg (2007) are observed regarding their assumptions on cluster development in general and cluster renewal in particular. Furthermore, this section discusses the critique on the CLC that has been formulated recently. Based on the assumptions formulated in the discussed literature two research expectations are formulated in the end of this section.

In the CLC approach of Menzel and Fornahl (2010) cluster development is a function of the interplay of the cluster's size (number of firms or employees) and the accessibility of heterogeneous knowledge to cluster agents (see figure 2.1). This development pattern is based on three presumed factors: the absorptive capacities and capabilities of individual firms, the systemic character of a cluster and the role of external knowledge. New external knowledge is introduced to the cluster through network ties to agents that are geographically and/or industrial-thematically external to the cluster. The adaptation of such knowledge by individual cluster agents has the potential to enhance the agent's absorptive capacity (Cohen and Levinthal 1990), which in turn enhances its future possibilities for interactive learning with heterogeneous partners. However, individual learning alone is not sufficient to drive the development of a whole cluster. Menzel and Fornahl (2010) state that to drive cluster development it is necessary to utilise knowledge in a systemic way within the cluster. Interactive learning among cluster agents helps to diffuse knowledge within the cluster. As a result, through knowledge diffusion and the incorporation of new agents into the cluster, the thematic and/or geographical boundaries of the cluster may be enhanced. Such an event may have the potential to take the cluster to a new growth phase. To distinguish different degrees of such a change, Menzel and Fornahl (2010) distinguish between three forms: incremental adaptation, renewal through the integration of a different technology beyond the cognitive scope of cluster agents or transformation into a totally different field of application.

In a very similar way like Menzel and Fornahl (2010), Ter Wal and Boschma (2011) describe the cluster life cycle to be mainly driven by the systemic character of the cluster (or its network dynamics) and the individual capabilities of cluster firms. However, in contrast to Menzel and Fornahl (2010) they conceptualise agent capabilities much more detailed. In addition to individual absorptive capacities they add two other forms of

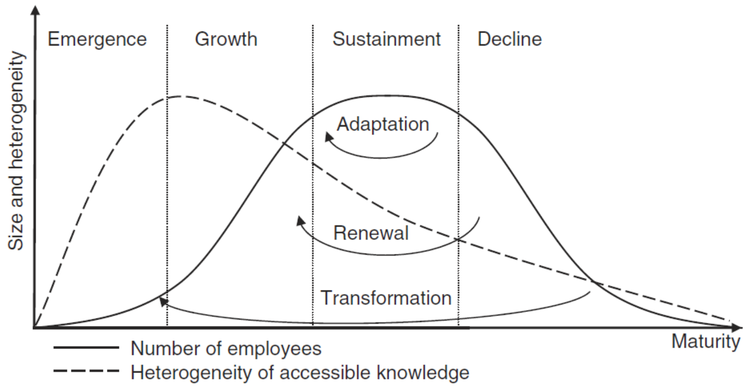

Figure 2.1: Quantitative and qualitative dimensions of the cluster life cycle. Source: Menzel and Fornahl (2010, p. 218).

capabilities: the ability of the firm to reposition itself within the cluster network and the ability to reproduce routines into new geographic contexts[2]. Ter Wal and Boschma (2011) state that these three forms of individual capabilities are dynamic capabilities as they not simply help the firm to solve problems but help to change the way a firm solves problems (Zahra et al. 2006). Through network effects these dynamic capabilities have the potential to drive the development of the whole cluster towards new systemic problem solving structures. Or in other words, changes in the dynamic capabilities of cluster firms may lead to cluster change. If agents strategically build and use their dynamic capabilities they potentially help to renew the cluster in a way that fits to their needs. Thus, according to Ter Wal and Boschma (2011), cluster development and renewal are mainly driven by those cluster agents that where most successful in building their absorptive capacities, strategically repositioning themselves within the cluster network to gain access to knowledge and resources and reproducing their routines to new promising contexts.

The role of individual firm routines and their cluster-internal systemic effects is also highlighted by Maskell and Malmberg (2007). However, in contrast to Menzel and Fornahl (2010) and Ter Wal and Boschma (2011) they take a stronger focus on cluster-specific institutional settings. According to Maskell and Malmberg (2007) routines of cluster agents co-evolve with the cluster's institutional setting. The value of individual routines is strongly enhanced if other relevant agents share the same or similar routines. Shared routines are the foundation for the creation of a common institutional setting, which in turn enables and eases mutual learning and collaboration. However, such a dynamic is perceived by Maskell and Malmberg (2007) to be much more likely within

[2]Even though Ter Wal and Boschma (2011) do only point to new geographic contexts, one could also think about the ability of agents to reproduce their routines into new thematic or social contexts.

a shared industrial and/or regional context as agents tend to search myopically for potential collaboration partners within spatial, cognitive or social proximity. According to Maskell and Malmberg (2007) cluster evolution is driven by these processes. Myopic search and pinpointed institutional adjustment are main cluster-internal factors driving the CLC. This also applies for the event of cluster renewal, which they call cluster rejuvenation. The rejuvenation of the cluster depends on whether some of the co-located firms remain able to acquire and utilise external ties to external agents with dissimilar routines and thus, start a new co-development with new and adjusted institutions. Thus, cluster rejuvenation is the cluster-internal utilisation process of external novel routines.

This brief overview shows that cluster development in general as well as cluster renewal in particular are perceived in the CLC literature to be mainly be driven cluster-internally. All three studies are based on the two main assumptions that cluster development depends on the two cluster-internal factors of cluster agent capabilities (or routines) and the systemic character of the cluster of interacting agents within the shared spatial and thematic context. However, this strong focus on cluster-internal factors in the CLC literature is not unchallenged. Martin and Sunley (2011) formulate broad criticism. They argue that the assumption in the CLC literature that cluster development that can be distinguished from the more general industry live cycle can only be explained by cluster-internal factors is too deterministic and gives little space for alternative forms of cluster development and renewal. According to them, clusters may develop very differently due to the clusters' specific characteristics and their environment. Due to individual specific circumstances and characteristics of single clusters they suggest a model of an adaptive cycle with multiple possible development patterns of phases of emergence, growth, conservation and decline that is interdependent with the cluster-internal interconnectedness of agents and resources. One of the main arguments of Martin and Sunley (2011) to explain this variety lies in their conceptualisation of the cluster within its external and internal environment. As Martin and Sunley (2011) state, CLC approaches tend to explain development from the analytical unit of the cluster. Thus, the clustering affects, for example, firms' capability building in a downward causation process. External novelty is actively utilised through the cluster network. However, Martin and Sunley (2011) argue that this interrelationship is much more complex and that cluster development has to be understood as a two-way interactive interrelationship of the cluster with its internal and external environment. Subsystems (like clusters) receive development impulses from their larger parental systems (like the national economy) that may help a cluster to 'remember' and restore its growth, leading to renewal processes (Martin and Sunley 2011, p. 1310). Clusters are affected by large-scale regularities and seemingly erratic evolutionary trends (Martin and Sunley 2011, p. 1309). Clusters are intertwined with the national and global economy and mostly also with clusters in other locations. Furthermore, they are affected by general societal trends and political decisions on various geographical scales. These interrelationships have a strong influence on the cluster-internal knowledge flows and spillovers. Often, these interaction ties to cluster-external partners are more intense than these to other firms within the cluster. Thus, it is unwise to believe that cluster development and renewal is mainly based on cluster-internal factors. Especially cluster renewal strongly depends on these external knowledge flows. Therefore, one can assume that cluster development and renewal can be driven by external factors. However, because the cluster itself retains its own specific system characteristics, and thus, a certain degree of system autonomy, cluster development can be still distinguished from the more general life cycle.

Thus, two possible general patterns of cluster renewal can be distinguished from this literature. The CLC literature strongly emphasises the role of cluster-internal factors, while Martin and Sunley (2011) advocates for a more open concept that combines varying patterns of cluster-internal and cluster-external factors, depending on the specific situation of the investigated cluster. In such a concept, the assumptions from the CLC literature represent only one (extreme) case. Thus, the two following research expectations can be formulated:

1. Cluster renewal is driven cluster-internally by two interacting factors: the building and using of individual agent capabilities and routines that enable agents to get access to novelty as well as the systemic and interactive utilisation of that novelty among cluster agents.

2. This development is interrelated with driving and influencing factors from the external environment of the cluster.

2.3 Case studies

2.3.1 General information and methodology

This section describes the two case studies of the farm trailer and stable technology clusters in north-western Germany, with the first roughly centred on the city of Osnabrück and the second roughly centred on the city of Vechta (see figure 2.2). The analysis is based on 33 semi-structured qualitative interviews which were conducted between 2012 and 2015 for an international research project on cluster life cycles. Interviewees can be classified as on the one hand as relevant agents (executives and managers) from cluster firms from the stable technology, farm trailer and biogas technology sectors of which all but one had been working for their company since at least five years prior to the interview or, in the case of younger firms, since the founding of the firm. The second group of interviewees is made up by industry experts from various contexts like the local chamber of handicrafts, academia, regional politics and administration and the like. The first group was mainly asked about the development of their own firm during the last ten to fifteen years prior to the interview with a strong focus on innovation and collaboration activities. The second group was mainly asked about general economic trends within the industry and the region within the same time frame, but also in earlier times when appropriate. All interviews were conducted in German. The cited interview sequences have been translated by the author.

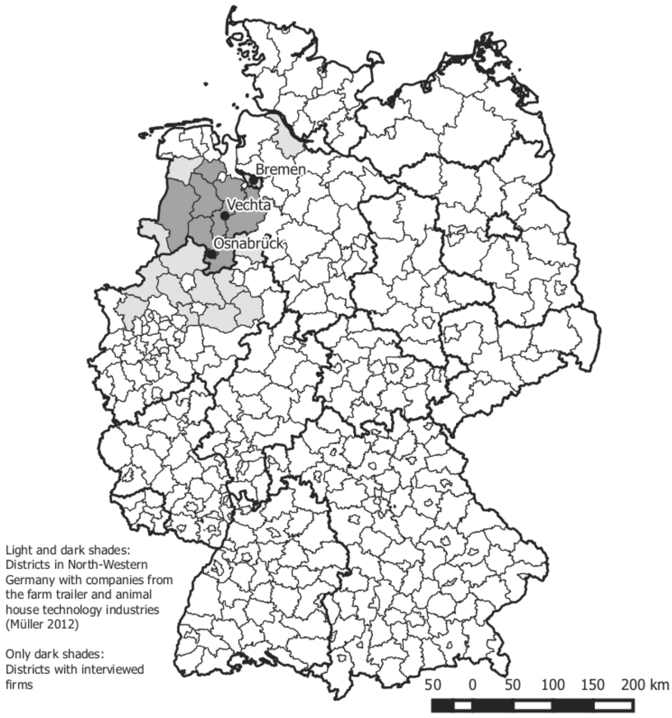

Figure 2.2: The investigated region within Germany. Source: Santner (2016a, p. 7).

The investigated clusters are located in an industrialised rural region with some urban centres (mainly Osnabrück, Oldenburg, Vechta and Cloppenburg). The region is situated half-way between the metropolitan areas of the Ruhr to the south and Hamburg and Bremen to the north. Since the post-war period, it is well connected to the national transport systems through the motorway A1. Since the beginning of the 20th century the region is also one of the most productive agricultural areas in Germany, including livestock (mainly chicken and pigs) and crop farming (potatoes, turnips, strawberries, salad and others). It is the region with the highest concentration of livestock in Germany (StÄBL 2007). Around this very productive agricultural sector a fully grown agribusiness industry has been developed, including notable companies from the food sector (with the most notable firm PHW/Wiesenhof and many other firms) and relevant food and agriculture-related research institutes (e.g. DIL). The two investigated clusters of this study from the agricultural engineering context represent supportive sectors that emerged in the region and that developed into own prosperous clusters by themselves. Having a partly common historical and regional background, both clusters share a similar, social and partly institutional context. However, they are also characterised by various dissimilarities in terms of industrial structure and innovation activities. These differences also become evident when having a closer look at cluster renewal processes.

2.3.2 The farm trailer cluster

The farm trailer cluster in north-western Germany consists of headquarters and dependencies of several larger, medium-sized and smaller companies, including firms like Amazone, Grimme, Krone, Lemken, Claas, Bergmann, Kotte, Tebbe and Grégoire-Besson. Some of them are world market leaders in their specific field. The cluster is more or less located around the city of Osnabrück and stretches from the area around Oldenburg in the north to the Münsterland and Ostwestfalen regions in the south. The north-west is one of the core regions of that industry in Germany (Krawczyk and Nowak 2009). Furthermore, specialised suppliers from sectors like tire making, farm vehicle electronics and others can be found in the region as well. The cluster is more or less specialised in farm trailers and self-propelled farm vehicles. Tractors are not produced in the region[3]. Many of the firms have a long history dating back up to the 19th century. Most of them are family owned until today.

Since the beginning of the 21st century the cluster faced a technological upgrading through the introduction of high-tech information and communication technology (ICT) in various application fields. The firms of the cluster were able to reposition themselves on the market and to enhance their technological scope, resulting in a process of cluster renewal. The introduction of modern ICT was a general trend in many industries of this time. One of the main challenges for the farm vehicle industry was that tractors and trailers are mostly produced by different firms. Thus, the communication between the control system in the tractor cabin and the machinery of the trailer depends on a functioning electronic interface between both. Therefore, after a longer period of failing standardisation efforts, the global ISOBUS standard was introduced in 2001. ISOBUS is a standard of an interface, including related software solutions, between devices in the trailer and the control systems in the tractor. Today, it is used by most notable producers of farm vehicles and related machinery. It is designed for the often adverse and dirty conditions in the agricultural context.

The introduction of ISOBUS generated a growth impulse for farm vehicle producers worldwide, including most of the firms in north-western Germany. Within only a couple of years, the region developed into one of the core innovative regions for ICT in farm vehicle applications in general and the refinement of ISOBUS technology in particular. This development depended on two cluster-internal factors: firstly, the founding of a

[3]However, Claas produces tractors in another location.

focussed and professional research centre for farm vehicle engineering at the University of Applied Sciences in Osnabrück, the so-called COALA centre (Competence Of Applied Agricultural Engineering); and secondly, the formation of an institutionalised collaboration network, the so-called CCI network (Competence Centre ISOBUS).

COALA was founded in 2007 as an interdisciplinary research centre at the University of Applied Sciences in Osnabrück. It combines several competences that are relevant for modern farm vehicle engineering; including research groups for engineering itself and other fields like crop research. COALA is today a very relevant collaboration partner for farm trailer companies in the region and beyond. Several interviewees from cluster firms mentioned that the personal engagement and the high competence of the researchers of COALA are a major input for high-end innovation for their firms (see also Santner 2016a). Some of the cluster firms became able to enhance their cognitive scope, and thus, their absorptive capacity through interactive learning within the innovation process with COALA. For example, one interviewee mentioned:

> "We got in contact with Professor [X] from COALA. He thought about our problem and finally said that we will find a solution. And this Friday we build the prototype of our sensor. We had now two, three years of groundwork and we found a sensor of which we think it will fit to our needs. Now we build a prototype of this sensor and hope that we can develop a product that we can sell in one year."

The firms of the farm trailer sector generated a demand for high-tech solutions for new applications that were beyond the scope of their own cognitive capacities. Furthermore, students from COALA often were engaged by the local firms after graduation. The cognitive abilities (or absorptive capacity) of both COALA and the firms were enhanced in this process. The firms provided the researchers with the necessary problems that needed to be solved and the researchers provided the respective problem solutions. For example, the same interviewee stated:

> "[...] 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 fertilise the ground when the hose is clogged. A farmer asked us if we can find a solution for this problem: 'How can I recognise the problem when I am sitting in the cabin.' And then we said: 'Let us see if we can find a technical solution.' We asked several research organisations 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."

The COALA research centre was founded in 2007. However, the core researchers have worked at the University of Applied Sciences of Osnabrück earlier due to the regional demand for specialised academic education. The motivation to found COALA came due to the strong concentration of the farm vehicle industry in the region and the resulting demand for high-tech solutions and specialised engineering personnel. However, it was not initialised on behalf of the industry but through the initiative of the researchers. The development was accompanied with the further specialisation of working groups into the field of farm vehicle engineering. For example, the laboratory for farm vehicle technology and mobile work machines spun off from another more general engineering working group after the topic of farm vehicles became increasingly important. Thus, the cognitive scope, and thus, the absorptive capacities of both, firms and researchers, was systematically enhanced in a co-evolutionary way[4].

The second cluster-internal factor that played a significant role in the process of cluster renewal was the formation of the Osnabrück-based CCI network in 2009. CCI is a network organisation of farm trailer producers, supporting firms as well as COALA that seeks to further develop the global ISOBUS standard and to establish its member firms as global technology leaders. The foundation of CCI occurred shortly after the establishment of the globally organised AEF network (Agricultural Electronics Foundation) that follows a very similar strategy (CCI 2015). CCI is a member of AEF. CCI was founded by the six companies of Amazone, Grimme, Krone, Lemken, Kuhn and Rauch. The first four companies of that list are located in north-western Germany, while Kuhn and Rauch are located in eastern and southern Germany. The office of CCI is located in Osnabrück in close proximity to COALA, another core member of CCI. Until April 2016 the network grew up to twenty members. Today the members of CCI hold a significant share of the global market on farm vehicles[5]. The founding members and COALA form the core of the network. Members that joined later are from the core region (e.g. Bergmann) as well as from outside the region including some companies in other European countries (e.g. Pöttinger from Austria). The network also includes companies that are not farm trailer producers by themselves, like the company Anedo, a producer of ISOBUS interfaces. It supplies farm trailer producers with ISOBUS technology and know-how.

So, this description of the case study shows that the renewal process of the farm trailer cluster towards a more sophisticated ICT-based technological paradigm was mainly cluster-internally driven. Furthermore, some of the assumptions of the CLC literature can be observed, including agent capacity building and network formation. The building and using of firm (or agent) capabilities was a main factor in the renewal process of the farm trailer cluster. The collaboration between farm trailer firms and other agents like COALA or Anedo started a process that enabled the collaborating agents to learn from each other and to enhance their own absorptive capacity. Furthermore, the creation of the CCI network gave participating firms the chance to reposition themselves within the

[4]Co-evolutionary as in the sense of for example Murmann (2003).

[5]Accoring to one interviewee more than 50% in spring 2013. However, the author is aware of the fact that this kind of information may be very subjective.

cluster's as well as the global innovation network. Some, if not all of the firms of the CCI network are today better positioned in their innovation network as they have been before because the CCI network provides better access to strategic technology partners like COALA or firms like Anedo. The strong involvement of the firms within the CCI network enabled them to utilise their knowledge systemically. The formation of COALA and CCI was, furthermore, an outcome of myopic search as the shared regional and social context of most of the participating firms increased their awareness for the potential of joint collaboration and the possibilities for frequent interactions with partners like COALA. However, in the end the cluster agents were not just able to renew the cluster but also enhanced its thematic and spatial borders by including new agents from other locations (e.g. Pöttinger) and other industries (e.g. Anedo) over time.

2.3.3 Biogas diversification in the stable technology cluster

The stable technology cluster, roughly centred on the city of Vechta, emerged with the region's upswing of a vertically integrated livestock farming industry (Windhorst 1975; Tamásy 2013), in the second half of the 20th century. It is specialised in pork- and poultry-related machinery, including feeding, water supply, stable climate, egg collection, manure disposal, caging and other technologies. It is made up by stable designers, like Big Dutchman, WEDA, Schulz, PAL-Bullermann and others, and supplying firms producing components (like cages, machinery and others), including companies like Lubing, Hellmann, Stallkamp, atka and so forth.

The time since the millennium turn was widely characterised by economic growth. Farmers today increasingly demand larger stables with increasingly effective stable technology. Technologically, two main developments can be distinguished in the stable technology cluster during the last two decades (see also for a more detailed description Santner 2016b): firstly, the general incremental refinement of existing technology, including the enhanced, but still incremental development of modern ICT[6]; and secondly, an event of cluster renewal through the diversification of some stable designers into the field of biogas technology. However, this renewal process differs in two significant points from what can be observed for the case of the farm trailer cluster: firstly, this renewal process into biogas technology was initiated and widely driven by cluster-external factors (mainly national jurisdiction); and secondly, the cluster-internal adaptation of biogas technology was characterised by a very weak systemic utilisation of the new knowledge within the cluster.

The firms in the stable technology cluster today strongly rely on more or less incremental innovation. Technological developments are mainly conducted on behalf of farmers who request changes or due to changing animal protection or environmental legislations.

[6]The use of ICT in the stable technology sector has a long tradition and dates back to the 1970's. Furthermore, it is strongly related to control technology in plants of other industries.

Stable designers often develop adjusted products and assign supplying companies to build them, as stated by the interviewee from a supplying company:

> "We produce client-oriented products, meaning, the client comes to us with an idea or a drawing or a blueprint and says: 'I need something like that. Can you make this for me?' Well, and then we make an offer."

Most of the innovation is within the cognitive scope of the companies and there is only little need for collaboration with research organisations. Thus, in the region no research organisation exists that is directly involved in technological developments in the stable technology context (like for example the COALA centre in the case of the farm trailer industry). However, there are some R&D facilities like the Bakum dependency of the Veterinary University of Hanover that test new products regarding their fit to animal purposes, juridical demands and other factors.

These findings also widely apply to the field of biogas technology in which some stable designers (mainly Big Dutchman, Schulz and WEDA/Stallkamp) diversified since the beginning of the millennium (see also Santner 2016a; Santner 2016b). Modern biogas technology was developed in Germany and other European countries since at least the 1980's and gained a certain degree of professionalisation till the end of the 1990's, including an established national innovation network around the so-called widely southern Germany-based Bundschuh practicals group and its successor the German Biogas Association. The diversification of the stable technology cluster into biogas technology was strongly externally induced and driven: the Renewable Energy Act (REA) of 2000 and its amendment of 2004, a law providing attractive feed-in tariffs for renewable energies including biogas, offered a chance for firms from the stable cluster to diversify into this field. Furthermore, the amendments of 2004, 2009, 2012 and 2014 were the main drivers for the technological development in the national biogas industry, including those of the cluster. Much of the technological development was oriented on the incentives from the feed-in tariff policy as the subsidisation categories of the law directly created the market for specific technological biogas solutions. For example, the 2004 amendment introduced an attractive bonus for the digestion of plant material, resulting in the technological shift of most producers towards energy maize digestion. Thus, biogas firms in Germany, including the diversifying stable designers, oriented the design of their plants after the creation of the REA on these incentives.

Before the REA, the firms from the stable technology cluster were not involved in biogas or electricity technology. However, after the initiation of the REA, firms like Schulz (Envitec) and Big Dutchman integrated formerly independent small biogas companies. In contrast, WEDA founded a new biogas firm (Weltec) in co-operation with the company Stallkamp, a firm that has been active as a supplier for stable designers before. The reason for these firms to engage into a totally new technology cannot only be explained by the simple fact that the REA was created, but also due to the fact that biogas and stable technology share some similarities. For example, biogas technology is technologically very similar to stable technology. It is technology related to manure treatment and disposal as well as technology for wet feeding, as stated by one interviewee:

> "[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."

Thus, some of the diversifying firms, like WEDA and Stallkamp were able to engage in the field of biogas mainly due to incremental learning and collaboration within established structures from the stable technology context. The similarities of both technologies are even more comprehensive (Müller 2012). Both application fields rely on a similar form of computer control technology and the construction of stables and biogas plants are both project-oriented tasks. Furthermore, the existence of a heavily intense agriculture with a high degree of manure production in the region constituted a big potential market for biogas technology in the region, as biogas plants of the early years often digested manure and other disposals. Local farmers played an important role for the establishment of biogas technology in the stable technology context as trustful and established relationships among farmers and firms helped to communicate demand and innovation impulses between them (Santner 2016b).

Besides these similarities, both technologies target different application fields within the common farm context and are subject to different legislations and institutional settings. Thus, they constitute two different technological application fields within the common socio-economic context of the farm. The technological similarities and the similar client context enabled stable technology firms to diversify into the field of biogas without significant changes in their cognitive abilities.

So, according to the assumptions from the CLC literature one can see that some cluster-internal factors played an important role for the renewal process of the stable technology cluster into the field of biogas technology. Most importantly, firm capability building has been a very important factor. The diversifying firms increased their absorptive capacity to become able to engage in the field of biogas technology through strategic organisational integration. The fact that firms like Schulz or Big Dutchman integrated small biogas firms enabled them to be prepared for their challenge. This organisational integration had also a network effect as it repositioned (or better newly positioned) the firms within the network of the biogas industry. Due to the fact that stable and biogas technology share technological similarities the firms were able to reproduce their routines within a different industrial context quite easily. However, the systemic utilisation of the new knowledge was mainly target on the context of the biogas industry and had little impact on the structures and dynamics of the pre-existing stable technology cluster context. Thus, the systemic utilisation of the novelty did not much occur in the pre-existing cluster context as such. It was limited to local farmers that helped to anchor biogas technology to the stable technology context (see also Santner 2016b). Biogas diversification occurred parallel to the still ongoing incremental innovation path of stable technology. The diversification process occurred widely externally driven. The REA and its amendments were the main driving factors and technological impulses came not from within the cluster but more induced by the REA and from within the industrial context of the national biogas technology industry. However, the pre-existing technological knowledge developed in the stable technology context built the path for this process. Thus, the renewal process occurred in a tight interrelationship between the cluster and its external environment. The technological and socio-economical fit of both technologies in combination with external policy forces enabled the cluster to renew in the way it did.

2.4 Discussion and conclusion

As has been shown in this paper, cluster renewal processes occurred very differently in the two case studies of the farm trailer and stable technology clusters. The processes observable for the farm trailer cluster very much follow the expectations that have been developed in the CLC literature with a strong explanatory power of cluster-internal agents' capability building and systemic utilisation processes. Thus, the case of the farm trailer cluster fits very much to research expectation 1. In contrast, the renewal process of the stable technology cluster into the field of biogas technology was driven by a mixture of cluster-internal and cluster-external elements. On the one hand, cluster internal capability building processes linked biogas technology to the stable technology cluster. On the other hand, this process was only thinkable due to the strong driving force of the cluster-external REA, which pushed the biogas industry nationwide, but also had a very specific effect in north-western Germany, as it resulted in the linking of biogas technology to the stable technology context (see also Santner 2016b). However, capacious systemic utilisation processes within the stable technology cluster did not occur. Thus, this case study fits much better to research expectation 2.

The explanation to this difference seems to be complex, but one main factor seems to lie in the development of the novel technology that is introduced to the cluster in the process of cluster renewal. In the case of the farm trailer cluster the novel ISOBUS technology was an infant technology. Technological development and global innovation networks were not yet formed and established. Therefore, the existing industrial and innovation structures of the farm trailer cluster in north-western Germany represented a fruitful ground for the establishment of such structures. Because there were no strong and dominant external structures yet established, but there existed a global demand for such structures, the agents of the cluster could build upon their internal capabilities and innovation networks to adjust them to the needs for the new technology. The fact that agents tended to search myopically for their collaboration partners within their existing cluster and regional context enhanced this dynamic towards a cluster-specific renewal into the globally developing ISOBUS technology. The cluster could establish itself in a global leading position within its industry by building mainly on cluster-internal factors. In recent years, the success of the cluster resulted in the cluster's growth and the enhancement of its geographical and thematic boarders.

In contrast to this, biogas technology was as such much more advanced when it was introduced to the investigated stable technology cluster. Modern biogas technology was developed since the 1980's and a central innovation network had developed outside of the context of the stable technology cluster before. When biogas technology was introduced to the stable technology cluster in the early years of the 21st century, this cluster renewal process was mainly cluster-externally driven through the REA and the pre-existing cluster-external innovation network structures. However, a certain degree of cluster-internal factors remained necessary to explain cluster renewal. The building and using of cluster-internal capabilities was fundamental for the linking of the technology to the cluster. However, the cluster-internal systemic utilisation of the novelty remained widely underdeveloped because cluster-external structures were already established.

These findings imply that cluster renewal is a complex process of which specific characteristics strongly depends on a variety of factors. Cluster-internal factors seem to be relevant to explain cluster renewal when the cluster-internal utilisation of the novelty has the potential to offer a significant advantage for innovation activities. Especially young technologies have not yet developed their own effective innovation networks and certain specialised and established clusters may offer a fruitful ground to develop such structures. However, if such structures have already established elsewhere and a cluster starts to diversify or renew into a more mature technological path, it seems to be more effective to rely on established structures of that technology outside of the cluster. However, cluster-internal networks and capabilities may offer an advantageous background to position the cluster within the established national or global industrial context. The development status of the novel technology and its own specific life cycle is an external factor to the specific cluster development. As supposed by Martin and Sunley (2011), the cluster's development and the development of the novel technology are interrelated with each other but remain to a certain degree independent. However, the degree varies. While in the case of ISOBUS the investigated farm trailer cluster established itself as a central part of the global innovation network with a strong influence of cluster-internal dynamics, the case of biogas shows that a renewing cluster may just take a peripheral position within the national or global context and that this peripheral role resulted in a much stronger external influence. Future research may take a closer look on this interrelationship of clusters, their technologies and the national and global industrial structures in which they are embedded. As clusters have become one of the main instruments for contemporary regional economic development policies, a stronger focus on and better understanding of these nuances may help to find better and pinpointed policy tools when it comes to the renewal of individual clusters.

This study, for sure, has also some limitations. Firstly, the observations come in both cases from engineering industries that rely on similar principles and forms of knowledge (a synthetic knowledge base, Asheim and Coenen 2005). Thus, it offers only limited explanatory power for differently structured industries from the creative or science-based sectors. Future research on cluster renewal in those industries may also offer a more comprehensive view. Another limitation of the study lies in the possibilities of a qualitative study. 'Hard' facts from a quantitative analysis may offer more much stronger findings. However, the advantage of a qualitative study lies in its ability to reveal new patterns of socio-economic developments. For example, qualitative data offers detailed insights into aspects like firm strategies, perceptions and beliefs that cannot be gained by the use of quantitative data. However, a future quantitative analysis of cluster renewal, for example of patent data, may offer better insights on the diffusion of novelty within and outside of a cluster and other things.

Acknowledgements This work was supported by the European Science Foundation (ESF) under the grant number 10–ECRP–07 and Deutsche Forschungsgemeinschaft (DFG) under the grant number HA 3179/6–1. The author thanks all interview partners for participating in the study. Furthermore, he thanks Alexander Barros for the transcription of interviews. This work was presented at the iino seminar in Bremen 2016. The author thanks the participants of this seminar for fruitful comments on an earlier version of this article.

3 The Geographies of Socio-Technical Anchoring and the Case of Biogas in North-Western Germany

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Abstract Recently, the literature on transition studies including the recent concept of anchoring has been criticised for not sufficiently recognising the role of place and scale. The emerging literature on the geography of transitions formulates two main concerns that should be addressed: the territorial embeddedness and the multi-scalar character of socio-technical systems that emerge in a socio-economically constructed relational space. This article seeks to contribute to this debate by stressing two aspects: the role of different forms of proximity that have only weakly been addressed in this debate; and the problem of alignment and misalignment of anchoring processes on multiple geographical scales. Based on these arguments an analytical framework on the geographies of anchoring is developed. It is applied to a case study of biogas technology that has been anchored to the regional context of agribusiness, but especially to the context of stable technology of north-western Germany. The results show that anchoring was mainly driven by proximity effects arising from the socio-technical and socio-spatial context of stable technology in the north-west. However, anchoring remained incomplete, resulting in misalignments between the institutional arrangements on the regional and the national scale.

Keywords anchoring, geography of transitions, proximity, multi-scalarity, biogas

JEL classification O13 O31 O33 R11

3.1 Introduction

The question on technological and industrial change is one of the main topics of economic development policy. It is tightly connected to the issue of future prosperity and well-being of society. Thus, it has been addressed in numerous scientific approaches in disciplines like evolutionary economics and economic geography. One of the most advanced and influential strand of literature of the last decades is the one on transition studies that understands technological change as a socio-technical progress, meaning that technology receives meaning and is embedded into its social environment. It mainly builds upon two core concepts: the technological innovation system (TIS) and the multi-level perspective (MLP). However, even though these concepts offer powerful explanations for the analysis of technological change, they have been increasingly criticised for neglecting important influential factors, including the role of space and geography for transition.

The TIS concept refers to a "network of agents interacting in a specific economic/ industrial area under a particular institutional infrastructure or set of infrastructures [...] involved in the generation, diffusion, and utilization of technology" (Carlsson and Stankiewicz 1991, p. 111). It is used to describe the role of specific TIS functions (knowledge creation, entrepreneurial experimentation, market formation, influence on the direction of search, resource mobilisation, creation of legitimacy) on the innovation activities of agents of the focal TIS. Traditionally, a TIS is often perceived to be associated to a specific territory (mostly a nation state) which is embedded into a global context with a ubiquitous 'global opportunity set'.

The related MLP concept, mainly introduced by Rip and Kemp (1998) and Geels (2002), describes socio-technical change to be set up through a patchwork of socio-technical niches, regimes and landscapes (Geels 2002). These three analytical levels can be understood as different degree of system stability (Geels 2011). Usually, they are each analysed upon three additional analytical dimensions (technological, network and institutional dimension). Regimes are socio-technical systems of agents, institutions and structures that use a certain technology in an established way and innovate mainly incrementally. Novel and radical technologies and practices are developed in socio-technical niches. These niches represent 'protected spaces', where novelty can be developed, tested and used separated from mainstream regime pressures (for example in R&D offices, demonstration projects or much specialised market niches). Finally, the socio-technical landscape represents general societal developments and events that cannot directly and actively be influenced by regime and/or niche actors (e.g. long-term trends like demographic change or rapid shocks like wars).

Adaptation and diffusion of technology, practice and institutional settings between niches, regimes and landscapes can be understood as socio-technical transition. Transitions may occur through the adaptation of socio-technical practice from niches by regime actors or through multi-regime interaction (e.g. Geels 2007; Raven 2007; Sutherland et al. 2015). Recently, the process of alignment of a novelty to mainstream structures, and thus, the very process of transition has been much more detailed conceptualised within the anchoring approach by Elzen et al. (2012). Anchoring refers to a process of system alignment between socio-technical contexts (e.g. niches and/or regimes) that occurs in the three analytical fields of the technology, the agent network and the institutional setting of both contexts. It is better understood as an iterative and conflicting process of system alignment rather than a simple bottom-up diffusion process. However, this process may happen to be conflictive due to misalignments between the two contexts.

Transition studies, including the TIS and MLP approaches as well as second order concepts like anchoring, has recently been criticised for its missing or naïve conceptualisation of space and geography (e.g. Coenen et al. 2012; Truffer and Coenen 2012; Binz et al. 2014; Murphy 2015). It is a well-known stylised fact within economic geography and regional studies that innovation activities are unevenly distributed in space and that economic agents tend to search for collaboration partners within their local, social and cognitive environment (e.g. Levinthal and March 1993; Maskell and Malmberg 2007). The suggestions for a more pronounced and sensitive recognition of space in transition studies is widely centred on two core aspects: (a) the territorial (institutional) embeddedness of socio-technical systems, and (b) the multi-scalar nature of social space. Space is perceived to be socially constructed and relational in nature. It results from individual and collective interests, goals and expectations. Therefore, it may (but does not necessarily do) refer to territorial boarders on various (also socially constructed) geographical scales.

This paper builds upon this critique and seeks to contribute to the debate on the geographies of transition. It is tackling the process of transition itself by discussing the recent anchoring approach in a geographical way. The discussion is oriented on the two issues of territorial embeddedness and multi-scalarity. It will be shown for the case of biogas anchoring into the socio-spatial context of stable technology in north-western Germany that territorial embeddedness is strongly driven by very specific proximity (Boschma 2005) effects. Furthermore, it is shown that this anchoring process occurred in a multi-scalar way, mainly on the regional and the national scale and that these multi-scalar dynamics caused problems due to misalignments of institutional structures.

The remainder of this article is organised as follows. Section 2 is discussing the theoretical background, including general aspects regarding territorial embeddedness and multi-scalarity, as well as the anchoring concept. In its end the analytical framework is developed. Section 3 describes and discusses the observations from the case study. Finally, section 4 is offering a deeper discussion and draws some conclusions.

3.2 Transition studies, anchoring, and geographical critique

The critique regarding the lack or naïve conceptualisation of space in transition studies mainly builds upon two core aspects: firstly, the fact that socio-technical systems are often territorial embedded and that these territorially embedded systems interact with each other in a multi-territorial way; and secondly, that this process is not only occurring multi-territorially, but also in a multi-scalar way. This section offers an overview on these two discussions. Furthermore a focus on the issue of proximity is taken to illustrate the need for an even deeper discussion of space and scale in transition studies. Finally, this critique is applied to the concept of anchoring, resulting in an analytical framework for the empirical analysis.

3.2.1 Territorial (institutional) embeddedness

Many authors point out that socio-technical developments are often happening within territorially bounded institutional contexts. Territories like nation states or regions often hold regulative (e.g. laws), but also more normative (e.g. nationally organised industry standards) institutional structures that link economic activities to the respective territory. Thus, many empirical transition studies focus on the analysis of socio-technical systems within national or other territorial contexts. Most classical transition studies fail to recognise the relational and spatial nature of institutional settings. Social processes like economic activities and whole socio-technical transitions do not simply happen within national containers (Coenen et al. 2012; Truffer and Coenen 2012). Building upon arguments from relational economic geography (Bathelt et al. 2004), Coenen et al. (2012) point out that economic activity is a relational process and the development of institutional settings is related to the network of the involved agents. These networks have two important characteristics: firstly, as agents often search for collaboration partners myopically within their vicinity, agent networks often tend to show characteristics of territorial embeddedness (Levinthal and March 1993; Maskell and Malmberg 2007); and secondly, as territorial embedded networks are no isolated systems, they are overlapping and intertwined with networks from other locations. Due to specific historical reasons, each location has a different endowment of resources and individual agents have different absorptive capacities for learning (Cohen and Levinthal 1990). As a result, certain places have a comparative institutional and economic advantage (Coenen et al. 2012) and certain places establish as economic centres or regional clusters (Porter 1998) of a certain industry. As institutional and economic settings are sticky, clusters change slowly and alignment processes of a cluster with a novel technological context take time and may be faced with several misalignments that hinder or slow down change.

However, in comparison to larger scale systems like the same industry's structure on the national scale, institutional structures on the regional scale may change often more easily due to less rigid and complex institutional constraints and an often more pragmatic behaviour of relevant agents from politics, the industry and the like (Späth and Rohracher 2012). Furthermore, trust and acceptance towards novelty and thus, legitimacy, is often larger because of the social proximity between regional agents. Legitimacy is an important factor for the stabilisation of existing and emerging socio-technical arrangements. It may arise in an event of transition, when its specific structures are compatible with the institutional arrangements of the mainstream regime level. The creation of legitimacy is often strongly tied to different forms of proximity (Boschma 2005) between the involved agents that form powerful advocacy groups, often in a regional context (Späth and Rohracher 2012).

3.2.2 The role of proximity for territorial embeddedness

The mechanisms behind territorial embeddedness of socio-economic systems (legitimacy building, knowledge creation ...) are strongly related to proximity effects. It seems that geographical proximity within a shared regional or territorial context matters. However, a well-known stylised fact from the contemporary economic geography literature is that proximity advantages are much more complex and depend on more factors than the spatial dimension. Boschma (2005) distinguishes between five forms of proximity (cognitive, social, institutional, organisational and geographical). Economic agents tend to search for collaboration and learning partners within their social, thematic and spatial vicinity due to myopia (Levinthal and March 1993). Thus, proximity effects drive innovation and economic change, even though it has been pointed out that a certain degree of cognitive distance (Nooteboom 2000; Broekel and Boschma 2012) remains needed to prevent cognitive lock-in and that interactive learning is most effective if the exchanged knowledge is not the same, but just 'related' (Frenken et al. 2007).

The issue of proximity has been raised in transition studies for several times. Coenen et al. (2010) argue that proximity advantages drive the development of socio-technical niches and their potential alignment to structures on the regime level. They perceive niche dynamics to be widely localised. According to them, niche performance depends on different forms of proximity that unfold in niche-internal processes like the shaping of heterogeneous agent networks, the articulation of expectations and broad and second order learning. They state that especially social and organisational proximity are important factors, as they are agency-based, and thus, help to create trust and legitimacy within a limited agent network of an emerging niche. Institutional proximity among niche actors and between niche and mainstream regime actors is perceived to unfold as a result of these processes (especially from the articulation of expectations). It creates an even broader legitimacy base that helps to align to mainstream regime structures. This whole process can be promoted through a joint geographical context.

Raven et al. (2012) apply the proximity notion to a broader discussion of the MLP in terms of a concept of 'relative' proximity. Thus, they analytically do not distinguish between different forms of proximity like cognitive proximity and so forth. They state that the general level of relative proximity advantages differs between niches, regimes and the landscape. According to Raven et al. (2012), niches can be expected to be characterised by a low level of relative proximity as their short development histories have not yet established strong cognitive, social, institutional and organisational ties. In contrast, due to their longer development histories, socio-technical regimes can be expected to be characterised by high levels of relative proximity within the incumbent socio-technical system, while socio-technical landscapes are likely to show high levels of proximity across incumbent socio-technical systems. Thus, their notion of a relative proximity has much in common with the conceptualisation of niches, regimes and landscapes as different degrees of system stability as suggested by (Geels 2011) rather than a real geographical understanding of proximity. The geographical dimension of proximity in terms of scale and territoriality remains at best underdeveloped. This geographically underdeveloped proximity notion has also been applied by Murphy (2015) to the anchoring concept as will be described in subsection 3.2.4.

3.2.3 Multi-scalarity

The second broad critique on the weak conceptualisation of space in transition studies refers to the lack of recognition of multi-scalarity. Coenen et al. (2012), as well as Truffer and Coenen (2012), advocate for a more nuanced geographical understanding of scale in transition studies. They point out that a relational conceptualisation of space implies that economic activity, and thus, socio-technical transitions occur in a patchwork of geographical scales. Similar to territories, scales are socially and actively constructed by agents and linked to their interests and goals.

The critique applies to both TIS and MLP. Especially the MLP has been focussed as the trinity of socio-technical landscapes, regimes and niches may misguide the reader to interpret these analytical levels as geographical scales. However, the MLP as such is an aspatial concept and the three levels represent different degrees of system stability (Geels 2011) that can all unfold at different geographical scales. Thus, for example, due to the small and embryonic character of socio-technical niches they are often locally and regionally concentrated (Coenen et al. 2010). However, niche development may also occur within global epistemic specialists communities.

Similarly, such a critique also applies for the TIS concept (Coenen et al. 2012; Binz et al. 2014). Geographical scale within TIS studies often refers to the TIS itself, which is empirically (but actually not theoretically) often identified with the national scale. It is embedded in a uniform global environment with a ubiquitous 'global opportunity set'. Binz et al. (2014) conclude that from a relational point of view the notion of such a global opportunity set has to be dropped in favour for a concept of differential access to unevenly distributed resources in the space of a global TIS.

Scale is linked to the often territorially embedded agent networks. The role of scale varies within socio-spatial settings. For example, laws may be defined on different administrative scales and regime agent networks may unfold regionally in routinised clusters or globally in epistemic specialist networks. Coenen et al. (2012) point out that very similar processes show very different manifestations at different scales (knowledge spillovers via daily face-to-face vs. occasional gatherings at conferences). Thus, agents are involved in multiple network constellations within a shared territorial context and beyond. Contexts on different scales are in a two-way interrelationship with each other but also retain each a certain degree of system autonomy (Martin and Sunley 2011). Thus, transitions are characterised by an ongoing process of alignment and misalignment between related contexts on multiple scales. Therefore, one can expect that transitions on different scales like a regional and a national context may hold a significant potential for conflict if the institutional and socio-economic structures in one territorial context misalign with the newly introduced socio-technical structures. Thus, successful socio-technical transition depends on the degree of how the socio-technical system can be aligned on and in all relevant scales and territories.

3.2.4 Anchoring

The anchoring concept (Elzen et al. 2012) is one of the most promising recent concepts to describe socio-technical transitions in detail[1]. However, similar to the TIS and MLP concepts, the anchoring approach suffers from a weak understanding of space and scale and is thus in risk of overseeing important explanatory factors when applied empirically. Thus, in this section it will be discussed, how a sufficiently geography-sensitive anchoring approach may look like.

Anchoring is based on the MLP and refers to the linking of novelty (technology or practice) with existing contexts. Anchoring can occur between regimes and niches, between different niches or more firmly within the initial niche (Elzen et al. 2012). Furthermore, the literature on multi-regime interaction indicates that anchoring may also play a role between regimes (Geels 2007; Raven 2007; Raven and Verbong 2007; Konrad et al. 2008; Lauridsen and Jørgensen 2010; Sutherland et al. 2015) or within a single regime (Konrad et al. 2008). Elzen et al. (2012) observe that anchoring very often takes place at the fields of overlapping between the two interacting contexts. Or in other words, anchoring and alignment are dynamics that mainly occur in those fields where technology, the set of agents and/or institutional settings are similar or the same. Thus, in economic geography terms anchoring is a process that is associated to proximity effects. However, this notion has not been conceptualised more deeply by Elzen et al. (2012).

Elzen et al. (2012) distinguish between three different analytical forms of anchoring that are oriented at the classical analytical dimensions from the MLP literature (technology, agent networks, institutions). It follows a relational understanding. *Technological anchoring* is associated with the adoption and linking of material technology or socio-technical practice into an existing context. *Network anchoring* refers to the linking of agents and agent networks to communities of different socio-technical practice. Finally, *institutional anchoring* points to the adoption and alignment of institutional settings and may refer to values, beliefs and identities (interpretative institutional anchoring), formal rules and laws (normative institutional anchoring) or market creation (economic institutional anchoring). Successful anchoring depends on all of these forms as the creation of legitimacy is dependent on technological usefulness, a sufficient degree of application within a focal set of actors as well as the social and institutional contextualisation of novelty.

[1]It should not be confused with the similar but nevertheless different anchor hypothesis of Feldman (2003).

First attempts to find a more geographically sensitive concept of anchoring have been introduced by Murphy (2015). Building upon the discussed concept of relational proximity of Raven et al. (2012), Murphy (2015) suggests a concept of anchoring that identifies legitimisation and trust-building as central mechanisms of system alignment. These mechanisms are perceived to depend on the relational proximity between the two aligning socio-technical contexts. However, in a similar way like Raven et al. (2012), Murphy (2015) does not address the issues of scale and territoriality adequately as relational proximity is more similar to the aspatial notion of system stability by (Geels 2011) than it really addresses the issues of territorial embeddedness and multi-scalarity.

The analytical framework for anchoring in my article seeks to overcome this shortcoming (see figure 3.1). It builds on the notion of both territorial embeddedness that is perceived to be sensitive to multiple potentially positive proximity effects (Boschma 2005) and multi-scalarity that entails the risk for potential misalignments when socio-technical transition occurs at different scales and in multiple territories. As a result, alignments and misalignments may result in complex processes towards changed territorial and multi-scalar arrangements of technological, network-related and institutional settings.

The notion of multi-scalarity is also relevant for the understanding of anchoring as successful anchoring strongly depends on the alignment and misalignment of the developments on various scales and in multiple territories. Anchoring can expected to happen simultaneously on various scales. For example, network anchoring may unfold at the same time in a general national context as well very specifically in regional contexts. Furthermore, network anchoring may unfold mainly in a certain region, while the underlying normative institutional anchoring is widely provided by national laws. It is not unlikely that anchoring may fail or be accompanied with serious misalignments if anchoring involves agents and structures from different scales and territories.

3.3 Anchoring processes of biogas technology in Germany

3.3.1 General information and methodology

In this section the developed analytical framework on the geographies of anchoring is applied to the case study of biogas technology which was adapted and anchored to the context of agribusiness, and especially stable technology, in north-western Germany. As will be shown, these anchoring processes were on the one hand strongly influenced by territorially or regionally bounded factors and proximity effects. On the other hand, the process was embedded in a wider multi-scalar and multi-territorial context and certain forms of anchoring were mainly linked to the national context. This caused in the end misalignments of anchoring processes between different scales.

Biogas is a technology that lies on the overlap of several technological regimes, including energy, waste management and agriculture. It is one of the most investigated technologies

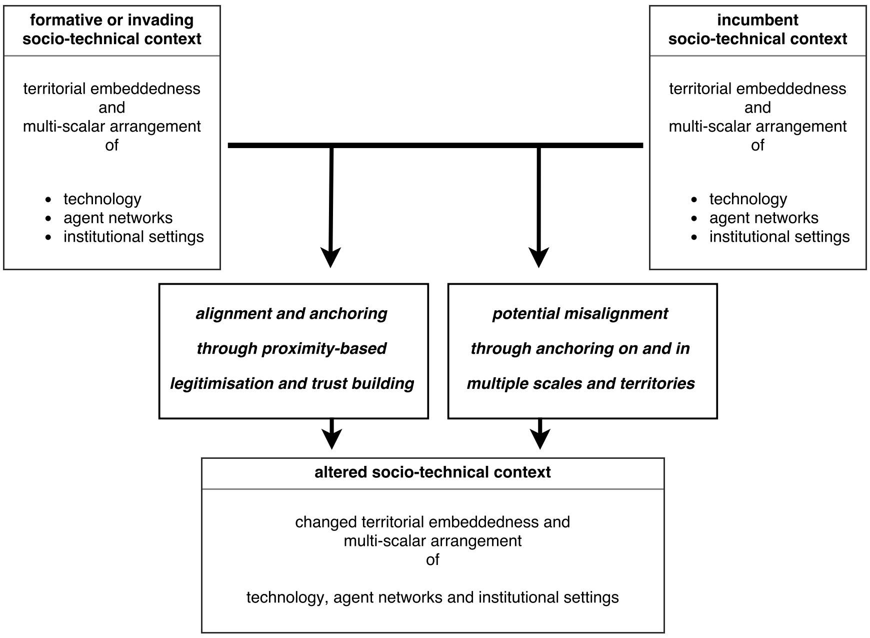


Figure 3.1: A geography sensitive concept of anchoring. Own figure.

in the transition studies literature. It is mainly investigated for its character of bridging technology between different regimes (energy, agriculture, waste management) and as a key technology in sustainability transitions. Most empirical transition studies on biogas have a national focus of analysis (e.g. Geels and Raven 2006; Raven and Gregersen 2007; Lantz et al. 2007; Verbong et al. 2008; Konrad et al. 2008; Markard et al. 2009; Poeschl et al. 2010; Raven and Geels 2010; Sutherland et al. 2015; Markard et al. 2016). Martin and Coenen (2015) took a regional perspective of TIS on Scania, Sweden, while Wirth et al. (2013) compare the role of regional institutional arrangements for the diffusion of biogas technology in different Austrian federal states. A geographical study with a regional focus but without theoretical links to transition studies is the study of Müller (2012) for the case of north-western Germany.

The investigated case study on biogas and agricultural engineering in north-western Germany (western Lower Saxony and northern North Rhine-Westphalia; see figure 3.3a) is based on a literature review as well as a qualitative study of 33 semi-structured interviews. The literature review is mainly based on the work of Sutherland et al. (2015) and Markard et al. (2016) who offer a good broad overview on biogas technology in Germany, but mainly stick to the treatment of geographical context as national containers. Therefore, the interviews take a more agent-based and regional perspective. The interviews were conducted with companies and industry experts that are involved in or well informed about the development of agricultural engineering (stable technology and farm trailer engineering) and biogas technology in north-western Germany. The main set of interviews was conducted in 2012 and 2013. In 2015 three additional telephone interviews were conducted with additional experts from the biogas context to answer some remaining open questions. Potential interviewees were mainly identified in explorative interviews, but also upon secondary data (trade fair participant lists and company data banks) and after the mentioning of firms in previously taken interviews. Interviewees from firms include managers, executives and heads of development offices of firms involved in stable, farm vehicle and/or biogas technology. All but one had worked for the company at least for five years or since the founding of the company. These interviewees were mainly asked about the economic development and innovation activities of their own company within the last fifteen years prior to the interview. The thematic focus was on innovation activities, reasons for innovation decisions, R&D and trade collaboration partners, recruiting and funding, but also contained some general questions on targeted markets, general growth and the like. In contrast, industry experts were mainly asked about general regional and sectoral development patterns. These interviewees came from a variety of contexts from inside and outside the region, including academia, industry and trade associations, interest groups, as well as administration.

3.3.2 Overview on biogas technology in Germany

Since the 1970's modern biogas technology development is mainly driven by western European countries, like the Netherlands, Germany, Switzerland, Denmark and Sweden. However, the developments in the different countries vary. While efforts in the Netherlands concentrated in the 1980s mainly on the development of large-scale plants for community use (Geels and Raven 2006; Verbong et al. 2008), the development in Germany focussed on smaller farm-scale plants. In Sweden, biogas is extensively used in public transport systems (Martin and Coenen 2015).

The development in Germany has recently been described by Sutherland et al. (2015) and Markard et al. (2016). To a large degree, the development of biogas in Germany is institutionally driven (*a fiat regime;* Sutherland et al. 2015). Sutherland et al. (2015) and Markard et al. (2016) both subdivide the development into each three periods (emergence, consolidation and boom, contestation) that are more or less oriented at the same turning points.

The biogas industry in Germany emerged in the 1970's and 1980's. Pioneering firms were often founded by young engineering graduates, mainly from the regional context of southern Germany. Innovation was at this time mainly incremental, but very experimental and innovative. Many of the young entrepreneurs frequently met in the so-called Bundschuh practicals group to discuss technological challenges and potential solutions. The Bundschuh group was the nucleus of the later formed German Biogas Association (GBA), which today represents the interest organisation of the biogas industry on the national scale. The emergence and development of the biogas industry in Germany was strongly supported by a general emerging, and later growing societal and political trend towards environmentalism in general and the need for environmental friendly energy supply in particular. It led to the establishment of several political instruments to support renewable energies, including the feed-in tariffs of 1991 and 1994 (Stromeinspeisungsgesetz). These programs and trends formed the ground for the rise of renewable energies, including biogas, by providing a sufficient degree of political, economic and societal legitimacy for the technologies (Markard et al. 2016).

Thus, biogas technology consolidated in the early years of the 21st century. The main event of this turning point was the establishment of the national Erneuerbare Energien Gesetz (EEG; renewable energy act) of 2000. It represented a strongly enhanced system of feed-in tariffs that helped renewable energies to break through and become competitive enough in comparison with carbon and nuclear-based energy. It gained further political support through the energy turn (Energiewende) policy of the national red-green government of 2002. For biogas technology the EEG amendment of 2004[2] was evenly important, as it included an attractive bonus for the digestion of energy crops. The EEG caused a strong increase of installed biogas capacity (see figure 3.2).

The EEG and its 2004 amendment did not only cause a strong increase of installed

[2]Other amendments followed in 2009, 2012 and 2014. One is planned for 2017.

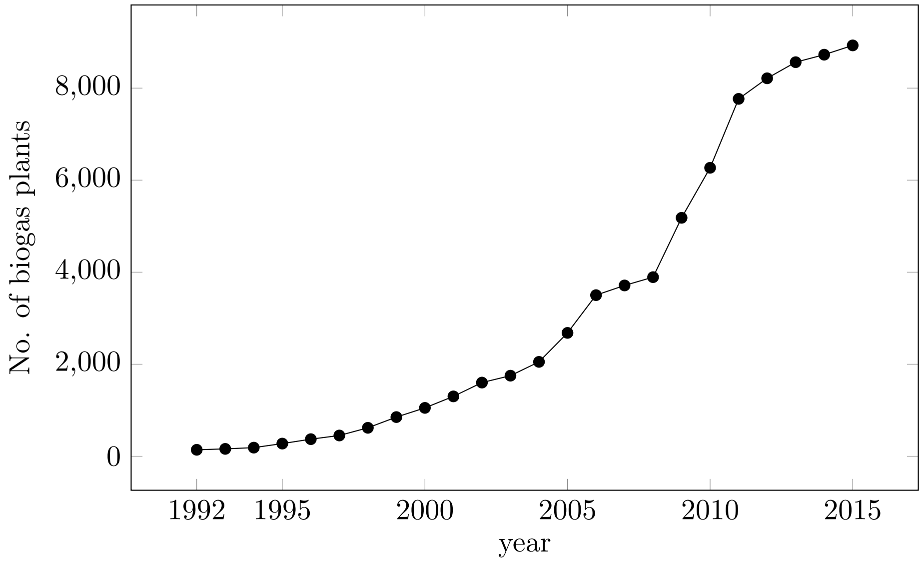


Figure 3.2: Number of installed biogas plants in Germany. Own figure based on GBA (2015).

biogas plants. They also strongly affected the technological development of biogas technology. Biogas technology increasingly and rapidly professionalised and developed a dominant design. This dominant design was mainly based on the incentives created by the EEG and after 2004 biogas technology in Germany was increasingly based on energy maize digestion and plant sizes oriented on the EEG subsidy categories. Before 2004 many new plants were based on the digestion of other organic materials like for example manure and many of these early biogas plants were built by livestock farmers, especially in those regions where industrial large-scale livestock farming was widely common.

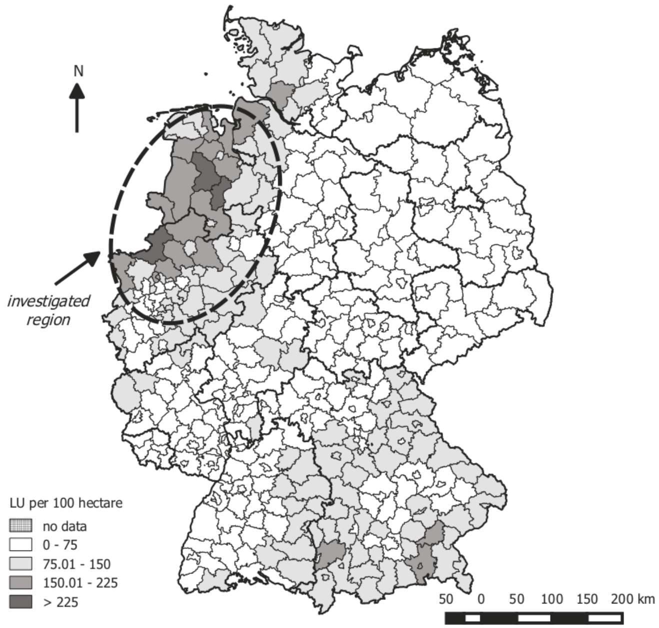
Biogas started to lose its legitimacy after 2007 due to increasing concerns about its environmental advantages (Markard et al. 2016). Large scale biogas plants increasingly were perceived to produce local odour nuisance and to be a potential risk for the local environment in the event of accidents. Furthermore, the strong increase of maize monocultures in biogas regions became strongly criticised. An increase in bad press significantly lowered the reputation and legitimacy of the technology in the local as well as the national population as well as within parts of the professional community (Markard et al. 2016). Thus, political decisions led to the cut of several bonuses and incentives in the EEG amendments of 2012 and 2014, resulting in the slow-down of the national biogas market (see figure 3.2).

3.3.3 The regional anchoring of biogas in north-western Germany

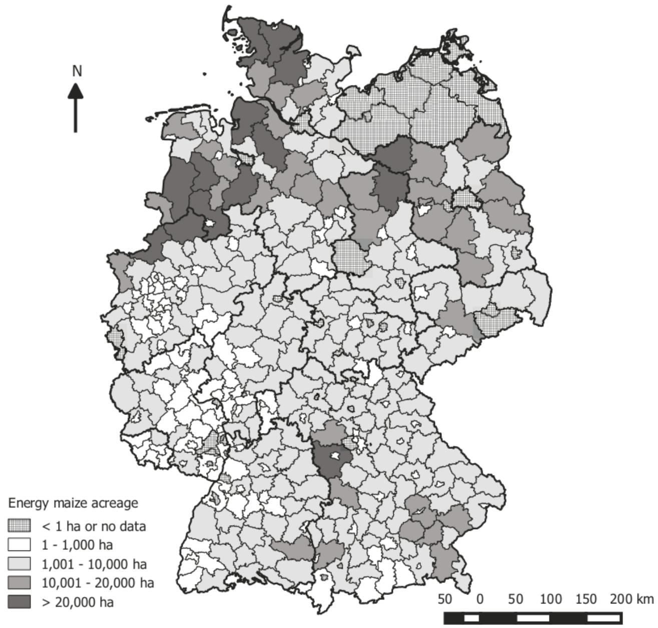
The EEG led to a shift of the geographical distribution of the biogas market from mainly centred on southern Germany before the year 2000 to some additional regional centres of biogas production in other parts of Germany (Markard et al. 2016). One of these regions was the north-west (western Lower Saxony and northern North Rhine-Westphalia; see figure 3.3). As stated, this mainly rural region is characterised by large-scale industrial livestock farming. Some districts of this region are among those in Germany with the highest concentration of livestock (figure 3.3a). Especially the districts of Vechta and Cloppenburg in Lower Saxony are well known for intensive livestock farming of pigs and chicken. As these animals produce a lot of manure, biogas digestion represented a welcoming possibility for those farmers to produce additional profit.

However, biogas technology was not just adopted by the farmers, but it anchored (mainly technologically and network-related) to the regional industrial context in a complex way. The industrial structure of the rural north-west is strongly based on its strong agricultural capacities. The region is home to a fully grown agribusiness industry, including food production but also related engineering activities. One of the main pillars of this regional industry is the stable technology industry, broadly centred on the town of Vechta. The stable technology industry includes both stable designers that assemble full stables as well as producers of components including feeding, climate and other machinery, concrete and plastic components and the like. The stable technology industry in the region is mainly based on pig and chicken related technology. Notable firms include Big Dutchman, WEDA, Schulz, Stallkamp, Lubing and others. Some of the firms like Big Dutchman are generally perceived to be world class in their field. Thus, the national, if not global, pig and chicken-based stable technology industry is strongly linked to the regional context of north-western Germany.

Throughout the 20th century complex industrial structures of the stable technology industry with clients, suppliers and some education and R&D facilities established in the region (Müller 2012, and interviews). Especially regional livestock farmers are an integral part of the innovation system. Farms in the north-west tend to be large in scale. Many farmers perceive themselves as entrepreneurs and investors and are thus open to new technologies and application fields. Thus, many farmers are strongly interested in farm-related technology development and thus, often are involved in the technological development of agricultural engineering firms like stable designers. Therefore, they formulate application problems and often act as test users for new products. This also happened for the case of biogas technology as will be shown in the next subsection. Some firms from this stable technology industry in the north-west, including Big Dutchman, WEDA/Stallkamp and Schulz, started to engage into the field of biogas technology after the establishment of the EEG.



(a) LU per 100ha arable land May 2007



(b) Energy maize acreage 2010

Figure 3.3: Livestock units (LU) and energy maize acreage distribution in Germany. Own maps based on (a) StÄBL (2007); and (b) DMK (2010).

3.3.4 Territorial embeddedness

The territorial embeddedness of the investigated context of stable technology in north-western Germany strongly determined the anchoring process of biogas technology. Especially in the first years after the initiation of the EEG anchoring occurred widely due to territorially specific proximity effects. In the advent of the EEG, the socio-technical stable technology context represented an established socio-technical arrangement, regionally concentrated in the north-west of Germany. Biogas technology could be aligned to this context due to specific proximity effects that could be exploited or have been actively created by the involved actors. However, not all forms of anchoring occurred within the regional context.

Some parts of the socio-technical anchoring of biogas in the north-west widely occurred upon territorial dynamics. These include technological and network anchoring as well as, to a certain degree, economic and interpretative institutional anchoring. However, institutional anchoring was widely arranged on the national scale (mainly through the EEG) as will be described in the next subsection.

Technological and network anchoring could build upon cognitive, institutional, social and organisational proximity, supported by geographical proximity within the shared regional context. As stable design and biogas plant manufacturing share many technological similarities and thus, are technologically related, *cognitive proximity* offered a fertile ground for technological anchoring. This was flanked by *institutional proximity* as stable design and biogas technology (at least in Germany) targeted strongly overlapping sets of customers (the farmers) with overlapping and compatible believe systems on good agricultural practice. In the case of north-western Germany, this had a strong regional dimension. Similar to what Wirth et al. (2013) observed in some Austrian regions, the mentality, entrepreneurial identity and belief system of both the farmers as well as the technology producers in north-western Germany played a significant role for the process of anchoring. As stated before, farmers in the north-west often identify as entrepreneurs. Their traditional involvement in the innovation processes of local engineering firms also helped in the process of biogas anchoring (network anchoring and economic institutional anchoring in terms of local market creation). Thus, biogas anchoring could profit from effects that emerged from *social proximity* from previous innovation relations of the stable technology context. The pre-existing social proximity provided a significant advantage of trust to create legitimacy. The common regional context and thus, *geographical proximity* supported this development. However, one has to note that the observed agent network widely already pre-existed in the advent of biogas anchoring and that geographical proximity was not that important to establish new network structures, but nevertheless helped to drive the processes. Besides social proximity, the active creation of *organisational proximity* played an important role. Firms like Big Dutchman and Schulz bridged the remaining cognitive gap between stable and biogas technology through the acquisition of formerly independent small biogas firms. Thus, organisational proximity functioned as an instrument for technological anchoring.

Thus, territorially bounded social proximity played a central role for the anchoring process of biogas in north-western Germany. The demand for biogas solutions was mainly formulated by local farmers that contacted the stable designers and asked whether they could supply them with biogas technology. As these firms had a good reputation due to years-long trustful relationships some farmers preferred to ask these firms for technology supply instead for buying technology from original biogas technology firms which had no such established trustful relations to the farmers. Stable technology firms, and especially stable designers, had been established to be the first address for some of the regional farmers when it comes to new technological solutions for their farms.

3.3.5 Multi-scalarity and multi-territoriality aspects

However, the anchoring process of biogas into the regional socio-technical context of north-western German agribusiness and stable design did not happen in an isolated regional container. Some of the anchoring and legitimisation occurred in other territorial contexts and on other spatial scales. Even others simultaneously showed a territorially bounded and multi-scalar dimension. This mainly applies to processes of institutional anchoring, but also to technological and network anchoring.

The rise of biogas mainly occurred through factors on the national scale, partly driven by differently territorialised arrangements. As stated before, biogas technology in Germany firstly emerged to a larger degree in southern Germany and notable industrial and institutional structures like the GBA are still located there. The anchoring of biogas in the north-west has to be understood upon this constellation. Biogas was not just anchored to the territorially embedded context of stable technology, but stable designers from the north-west also anchored to industrial structures on the national scale that are territorially embedded in a different regional context. By doing this, the anchoring process based on the creation and exploitation of cognitive and institutional proximity between biogas and stable technologies did not only affect the north-west, but for sure had also an impact on the national context as well as the regional context of biogas in southern Germany.

However, the main driving forces from the national scale like the EEG, but also general debates in politics and media, were only weakly connected to the specific territorial arrangements of the north-west. Thus, the anchoring of biogas into the north-western stable technology context strongly depended on these external factors. Agents from the north-west had only limited influence on these factors to address the institutional settings regarding their specific needs and structures and their interest conflicted with those from other socio-spatial contexts. This resulted in significant misalignments between the dominant institutional arrangements on the national scale and the specific structures on the regional scale. This became very obvious when biogas technology began to lose its legitimacy after 2007 (Markard et al. 2016). The lack of regional legitimacy and sufficient institutional anchoring beyond market factors resulted in the fact that the biogas industry of the north-west began to go down the spiral with the whole national biogas industry. Even though biogas had been successfully anchored technologically to the regionally concentrated context of stable technology in the north-west and a regional market has been created, the regional institutional anchoring process remained unfinished. Unlike in some Austrian regions (Wirth et al. 2013), no regionally specific support programs had been introduced.

The energy crop turn of biogas, induced by the EEG 2004 amendment, led to certain misalignments with the regional institutional and economic structure. These misalignments, in turn, had also an influence on the downturn of biogas on the national scale. As Markard et al. (2016) point out, much of the loss of legitimacy on the national scale resulted from concerns of the local population in regions with biogas plants regarding safety and negative local environmental effects of biogas plant operation as well as extensive energy maize cultivation. The north-west was (and still is) one of the main regions of biogas energy production and energy maize cultivation is very extensive (see figure 3.3b). There developed a strong opposition among the local population towards biogas plants and maize monoculture in several areas of the north-west like in the Vechta and Cloppenburg districts (interview). Even though these concerns are not limited to north-western Germany one can expect the region to be one of the centres of these counter movements.

Thus, there existed a significant lack of sufficient institutional anchoring on the regional scale that could have prevented the downturn. In contrast to, for example, some Austrian regions (Wirth et al. 2013), no regional political support structures have been developed in Lower Saxony or North Rhine-Westphalia that were targeted on the specific structures and needs of the local biogas economy. Agents from the north-west reacted to national programs that were not tailored for the specific needs of the region. This resulted in both, alignments and misalignments. The first version of the EEG in 2000 was highly compatible with the local agricultural structure of the north-west as no technological properties were favoured. The manure from the pre-existing extensive livestock farming represented a favourable digestion substrate which represented one of the initial ingredients for biogas anchoring in the north-west. Furthermore, biogas fitted well to the entrepreneurial identity of both, farmers and stable designers. Thus, alignments between the national EEG 2000 and the regional industrial structure initiated the regional anchoring process.

However, with the 2004 amendment energy crop digestion became more profitable and biogas technology decoupled from the regional agricultural structures. This resulted in a misalignment between different regional factors. While biogas became increasingly decoupled from the manure issue, the entrepreneurial spirit of farmers still fuelled the growth of the biogas market in north-western Germany. These misalignments resulted in negative environmental external effects, not only, but also prominently in north-western

Germany, leading to the loss of legitimacy of biogas on both the regional and the national scale.

3.4 Conclusion

The case study on biogas in north-western Germany reveals two main things regarding the nature of anchoring. Firstly, as agent networks are often territorially or regionally embedded, geographical proximity potentially catalyses and promotes the socio-technical anchoring process in a region or territory-specific way due to specific cognitive, social, institutional and/or organisational proximity effects. Unsurprisingly, cognitive proximity proved to be one of the main factors for anchoring. The socio-technological compatibility of biogas and stable technology offered the initial technological legitimacy for stable designers to engage in the development of stable technology. It made the feasibility of such an engagement obvious. To a large degree, stable designers could rely on their existing technological knowledge and routines. Cognitive proximity was even enhanced through the creation of organisational proximity through acquisitions. Social proximity played a key role for a broad set of anchoring processes including technological, network and economic institutional anchoring in the region. Due to the existing innovation and distribution channels that existed in the region from the stable technology context, trustful relations offered the legitimacy to introduce the technology to this network.

However, secondly, the creation of institutional proximity between the biogas and the stable technology context was very limited. It occurred in terms of alignment processes with the entrepreneurial identity of farmers and stable designers, but more general institutional settings determining these processes were defined nationally. Thus, the anchoring of biogas into the socio-spatial and socio-technical context of the north-west remained unfinished. Regional agents failed to create institutional legitimacy based on laws or support programs tailored on the needs of the regional economy. In the end, the misalignment of the national support program and the regional structure led to unfavourable developments resulting in the loss of legitimacy on both the regional as well as the national scale.

As Elzen et al. (2012) have already pointed out, for successful transitions all forms of anchoring need to take place to have a sufficient legitimacy for change. The geographical discussion offers some important additional implications. On the one hand, the notion of the complexity of proximity effects broadens the picture on the micro dynamics of anchoring beyond the simplistic notion of a relational proximity as suggested by Raven et al. (2012). Furthermore, the notion of proximity reveals that a shared and close regional context matters as it potentially enhances cognitive, institutional, social and/or organisational proximity effects and also represents a micro-cosmos that is to a certain degree decoupled from national pressures as explained by Späth and Rohracher (2012).

However, the region is not just another analytical container or another context to which a technology is anchored. Regionally or territorially embedded industries are in a close and complex interrelationship with other scales. On the one hand, they are part of, for example, national socio-technical systems. However, they also remain to a certain degree autonomous. This results in potential struggles in anchoring processes due to misalignments. Regional socio-technical contexts are not isolated but also not totally determined by the structures of the national scale.

This has some implications for policy makers. Policy makers should be aware of the fact that socio-technical change is complex and involves not only the application of a technology within a targeted group of industries and agents but also the adjustment of appropriate institutional structures. This notion as such is nothing new, but the case of biogas illustrates that the creation of legitimacy is sensible to scale and territorial context. National policy programs may be unable to provide legitimacy at the local scale if they are misaligned. The creation of legitimacy on the regional scale is most likely if regional actors are involved in the design of policy tools. These tools may target the guided and targeted exploitation of specific proximity effects in the targeted socio-spatial context.

For sure, this study has some limitations. As has been stated before, the role and effects of cognitive, social, institutional, organisational and geographical proximity strongly depends on a vast variety of factors. As, for example, the knowledge bases literature implies, innovation activities strongly differ between science-based, engineering-based and creative industries. This has a direct implication for the role of proximity effects (Mattes 2012) and further mechanisms of knowledge creation, resource mobilisation, legitimacy building and so on. Future research may thus broaden the picture by comparing the dynamics of anchoring and transitions in industries with different knowledge bases.

Furthermore, as Sutherland et al. (2015) point out, renewable energies are fiat regimes that strongly rely on the institutional settings provided by the state. A lot of other industries are much less dependent on political intervention and develop widely on their own (market regimes). The concept of anchoring strongly addresses the role of normative institutional anchoring. It is widely undescribed how anchoring in market regimes works and how proximity effects unfold in these cases. Another shortcoming of this paper is that the observation of proximity effects was widely limited to the regional scale. However, even though geographical proximity often supports and catalyses other proximity effects, the notion of the multi-scalar character of proximity effects may refine our understanding of socio-technical change and the anchoring of socio-technical contexts.

An even deeper intertwining of the debates from transition studies and economic geography could enhance our understanding of socio-technical changes in space. Economic geographers have developed their own concepts for socio-technological change in space. For example, the cluster life cycle literature (e.g. Maskell and Malmberg 2007; Menzel and Fornahl 2010; Ter Wal and Boschma 2011) is actually discussing and investigating pretty similar processes. However, in contrast to transition studies, processes like cluster development and cluster renewal are often observed from inside the cluster and due to cluster-specific factors. The broader view of transition studies, investigating multiple socio-technical contexts simultaneously may help to understand cluster development and change better.

Acknowledgements This work was supported by the European Science Foundation (ESF) under the grant number 10–ECRP–07 and Deutsche Forschungsgemeinschaft (DFG) under the grant number HA 3179/6–1. The author thanks all interview partners for participating in the study. Furthermore, he thanks Alexander Barros for the transcription of interviews. An earlier draft of this work was presented at the north German doctorate colloquium in economic geography (Norddeutsches wirtschaftsgeographisches Doktorandenkolloquium) in Bremen 2016. The author thanks the participants of this seminar for fruitful comments. Furthermore, he thanks two anonymous referees for comments on an earlier draft of this paper.

4 Proximity and Modes of Innovation – Evidence from Two German Agricultural Engineering Clusters

Author Dominik Santner

Abstract Cognitive, social, institutional, organisational and geographical proximities have been widely discussed by economic geographers regarding their impact on innovation activities and economic prosperity. One recent strand of literature that offers a broad conceptualisation of innovation activities in differently structured industries is the one on modes of innovation. However, even though some authors have discussed the role of some forms of proximity in certain modes of innovation, a comprehensive picture is missing. This paper seeks to offer such a framework. The role of proximities for science-technology-innovation (STI), doing-using-interacting (DUI) and combined and complex innovation (CCI) mode innovation is discussed. The framework is applied to two case studies of agricultural engineering clusters that developed sophisticated innovation within the early 21st century. While firms from the farm trailer cluster developed a full CCI mode with complex and intertwined influences of various proximity constellations, firms from the stable technology cluster could widely rely on DUI mode innovation with a strong role of organisational proximity for the incorporation of knowledge from a related industry.

Keywords modes of innovation, proximity, STI, DUI, CCI, agricultural engineering

JEL classification L64 O14 O31 O33

4.1 Introduction

The latest since the influential work on proximities by Nooteboom (2000) and Boschma (2005) the question on the role of cognitive, social, institutional, organisational and geographical proximities for innovation and economic prosperity became very prominent in many economic geography works and incorporated into the debate of many concepts like related variety (Frenken et al. 2007), knowledge bases (Mattes 2012), cluster life cycles (Menzel and Fornahl 2010; Ter Wal and Boschma 2011) and many more. Specific proximity constellations are perceived to potentially have a positive influence on economic development in specific contexts, while others may hamper prosperity. Thus, it is of vital interest for firms as well as policy makers to know how different forms of proximities influence innovation and economic growth. Especially, more sophisticated innovation that goes beyond incremental refinement is perceived to have the potential to start new cycles of prosperity (e.g. Menzel and Fornahl 2010). However, especially engineering-based firms with a synthetic knowledge base often lack the ability for more sophisticated innovation. Thus, it is worth to know how firms that traditionally strongly rely on incremental innovation become able to be more innovative and how these changes are associated with changes of the role of different forms of proximity.

One recent strand of literature that investigates different forms of innovation activities is on modes of innovation (Jensen et al. 2007; Isaksen and Karlsen 2012). It distinguishes between a science-technology-innovation (STI), doing-using-interacting (DUI) and combined and complex innovation (CCI) mode. Engineering-based firms often follow a DUI strategy, but they may increase their innovativeness when they manage to change to a CCI mode of innovation. However, even though the role of proximities in different modes of innovation have partly been discussed (e.g. Fitjar and Rodríguez-Pose 2013), an encompassing conceptualisation of this topic is missing. This paper seeks to shed light on this topic by offering a concept on the role of proximities in STI, DUI and CCI modes of innovation. It is especially targeting the question on how the roles of proximities change when engineering-based firms with a traditional DUI innovation mode seek to develop more sophisticated product innovation.

The investigation is based on two case studies from the agricultural engineering context of north-western Germany, including the farm trailer and the stable technology industries. The qualitative analysis is based on 33 semi-structured qualitative interviews. As many significant empirical studies from the modes of innovation literature are based on quantitative research (e.g. Jensen et al. 2007; Fitjar and Rodríguez-Pose 2013; Herstad et al. 2015; González-Pernía et al. 2015), a qualitative approach is offering a more pronounced in-depth picture on the role of proximities for sophisticated innovation in engineering-based industries. Changes in innovation modes differ between the two case studies. While many firms of the farm trailer cluster switched to a fully developed CCI mode of innovation, central actors of the stable technology cluster diversified into the related sector of biogas technology and thus, increased their innovativeness without significant changes of the innovation mode. In the first case the role of different forms of proximities became more complex, while in the second case changes in organisational proximity can be identified as the main drivers for change.

The remainder of this article 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. It is concluding with some research questions. Section 4 is offering an overview on 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.

4.2 On the relationship of innovation modes and proximity

4.2.1 Modes of innovation

Traditionally, the literature on innovation distinguishes between, firstly, firm internal, R&D and technology driven innovation (e.g. Maclaurin 1953; Audretsch and Feldman 1996; Cantwell and Iammarino 1998), and secondly, interactive, institution-driven innovation. The second group has been strongly embraced by economic geography concepts including national and regional innovation systems (Lundvall 1992; Cooke 2001; Asheim and Coenen 2006), industrial districts (Sforzi 1989; Markusen 1996), innovative milieux (Crevoisier and Maillat 1991; Maillat et al. 1997) and regional clusters (Porter 1998; Menzel and Fornahl 2010).

As Fitjar and Rodríguez-Pose (2013) point out, the interconnection of both ways of innovation has been developed in concepts like absorptive capacity (Cohen and Levinthal 1990) or open innovation (Chesbrough 2003). For example, building the absorptive capacity of a firm enhances the likelihood that a firm can learn from a different collaboration partner, especially if both agents are technologically related, but not the same (Frenken et al. 2007). Authors like Menzel and Fornahl (2010) or Ter Wal and Boschma (2011) point out that the quality of the absorptive capacities of firms in a cluster determines the development of the cluster as a whole. This role of absorptive capacity has also been incorporated in the concept of open innovation. According to this strand of literature, firms need to interact with external partners to get access to more relevant knowledge. However, they also have to build their absorptive capacity through internal learning and R&D to be able to learn from multiple external sources and to increase their own attractiveness for potential collaboration partners (Dahlander and Gann 2010; Brunswicker and Vanhaverbeke 2015).

The literature on modes of innovation builds on some of these arguments. Furthermore, it is based on the knowledge bases literature (Asheim and Coenen 2005; Cooke et al. 2007) as well as the literature on regional innovation systems (RIS) (Cooke et al. 1997; Cooke 2001). The modes of innovation literature generally distinguishes three ideal modes of innovation. Jensen et al. (2007) differentiate between the science-technology-innovation (STI) and the doing-using-interacting (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 knowledge base (e.g. pharmaceutics). However, synthetic knowledge also plays a role in form of applied research (Isaksen and Karlsen 2012). Knowledge is created in firm-owned R&D departments or acquired through interactive linkages to universities, R&D organisations and other scientific agents in a learning-by-searching mode. The often basic produced scientific knowledge mostly cannot be commercialised directly, while applied scientific knowledge is mostly market-oriented. As the knowledge creation process is widely independent from the daily production routines, there exists a relatively high potential that STI-mode firms create radical and sophisticated innovation. However, application-oriented learning-by-doing and thus, incremental innovation can be expected to play a significant role for STI mode firms as well as this kind of innovation is most common in most firms.

The DUI mode refers to firms that rely mostly on tacit knowledge and thus, a synthetic or symbolic 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 is associated to 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 and suppliers. This represents a learning-by-doing, using and interacting mode. Thus, radical innovation is much less likely in these industries. However, because of the market-orientation of innovation, new products can be more often easily commercialised 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).

These two modes are ideal types. In reality, firms rely more or less on a mixture of both. Furthermore, firms may change their innovation behaviour, leading to shifts in the applied innovation mode. Jensen et al. (2007) show in their empirical study on companies in Denmark that firms more or less evenly relying on both modes can expected to be on average more innovative than firms that widely rely only on one of both. Therefore, Isaksen and Karlsen (2012) formulated a third mode, the combined and complex innovation (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 and thus, CCI firms rely on a much broader absorptive capacity. Firms applying a CCI mode of innovation recombine resources and knowledge from their RIS in a much more complex way than DUI or STI firms. In accordance to much of the literature on RIS, regional clusters and the like, the regional context is perceived to alter knowledge flows in a specific way. CCI firms innovate in strong interaction with both subsystems of the RIS: the industry and the knowledge infrastructure, supported by policy intervention and the regional institutional setting. However, most firms also have knowledge ties to extra-regional agents. Isaksen and Karlsen (2012) argue that CCI firms need to strongly develop their core competences and technology platform to be able to do so. Scientific as well as application-related competences are needed to develop these absorptive competences. As a result, CCI firms use scientific knowledge to target application-oriented tasks. Therefore, CCI firms need to cooperate with both, STI agents like universities and R&D organisations as well as DUI agents like customers and suppliers in a complex way. This requires personnel that are familiar with both modes of innovation. Because of this complex innovation process Isaksen and Karlsen (2011) argue that, in contrast to STI and DUI mode firms, CCI mode firms are much more dependent on a broad RIS.

4.2.2 Modes of innovation and proximity

One central aspect of innovation that is stressed in the modes of innovation literature is that innovation, regardless of the mode, strongly depends on knowledge transfer and learning between interacting agents. This idea is not limited to the modes of innovation literature but has been stressed in many economic geography concepts like RIS (Cooke et al. 1997; Cooke 2001), regional clusters (Porter 1998; Menzel and Fornahl 2010) and others. These interactive learning processes are generally perceived to be sensitive to different proximity constellations among interacting partners (Boschma 2005). The role of these constellations in the STI, DUI and CCI modes of innovation are discussed in this section.

In the modes of innovation literature, interaction with external agents is perceived to be fundamental for advanced innovation. It follows a similar thinking as, for example, the open innovation (e.g. Chesbrough 2003; Enkel et al. 2009; Dahlander and Gann 2010) or relational economic geography (e.g. Bathelt et al. 2004) literatures. Interactive learning with other agents within and outside the company is important for all modes of innovation. Several authors find empirical evidence that collaboration with STI (universities and R&D organisations) as well as DUI partners (suppliers, clients, competitors, agents from other industries) more or less enhances the probability for certain kinds of innovation (e.g. Jensen et al. 2007; Fitjar and Rodríguez-Pose 2013; González-Pernía et al. 2015). Especially collaboration with STI partners seems to be related to more radical and sophisticated forms of innovation (Fitjar and Rodríguez-Pose 2013; González-Pernía et al. 2015). Very much in line with the expectations for a CCI innovation mode, González-Pernía et al. (2015) observe that the largest probability to be innovative can be observed for firms that collaborate with both STI and DUI partners. This effect can also be created through targeted hiring of skilled personnel, especially from STI contexts, as Herstad et al. (2015) point out.

As stated, these kinds of interactive learning are generally perceived by economic geographers to be sensitive to different kinds of proximity. Boschma (2005) distinguishes between five forms of proximities (cognitive, social, institutional, organisational, geographical). The role of proximities has been discussed in the context of knowledge bases (e.g. Mattes 2012) and, to a lesser degree, also in the context of modes of innovation (e.g. Fitjar and Rodríguez-Pose 2013). However, the modes of innovation literature lacks a pronounced discussion as well as a comprehensive conceptualisation. Thus, in the following paragraphs a more comprehensive picture on the role of proximities in different modes of innovation is drawn.

Fitjar and Rodríguez-Pose (2013) state that interactive learning of STI mode firms strongly depends on cognitive and organisational proximities. STI mode collaboration with scientist from firm internal R&D departments or external partners from universities and other R&D organisations demands a high degree of coordination. Cognitive proximity to R&D organisations enables those collaborations. Organisational 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 organisational incorporation of STI agents and personnel 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 the used and produced 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 and social proximity probably plays an insignificant role.

DUI mode innovation depends on different types of proximities. It is traditionally perceived by economic geographers to be more sensitive to geographical proximity. Geographical proximity can foster interaction but also raises the risk for cognitive lock-in due to too narrow collaboration networks. 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 for innovation in industries with a synthetic knowledge base.[1] 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 supports these interactions as the tacitness of learning, interaction and innovation often lacks a normative framework. Organisational proximity is perceived to play an insignificant role for DUI mode firms as mergers and acquisitions do not offer a better degree of control over tacit knowledge. For example, Herstad et al. (2015) find empirical evidence that recruitment from DUI

[1] In contrast to these theoretical expectations, 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.

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 organisational knowledge base and processing routines and may thus enhance the likelihood for 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 for 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. Isaksen and Karlsen (2011) state that a broad RIS is helpful for CCI mode innovation, but can be at least partly substituted by knowledge links to extra-regional partners. Organisational proximity may also be supportive but is less important than for STI mode firms. Depending on the specific innovation output, control over codified knowledge flows may be helpful but much of the often applied scientific knowledge can expected to be acquired through collaboration efforts with firm-external scientific partners, especially if the innovating firm traditionally had a stronger synthetic knowledge base. However, organisational 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.

Thus, several expectations regarding the role of different forms of proximities in STI, DUI and CCI modes of innovation can be drawn. They are summarised in table 4.1. These expectations are mainly based on the mentioned theoretical assumptions. However, as the different empirical studies from the modes of innovation literature show, empirical observations partly deviate from this (e.g. Fitjar and Rodríguez-Pose 2013). However, they can function as an analytical framework regarding the question on how engineering-based industries that traditionally rely on a synthetic knowledge base and that used to innovate in a DUI mode innovate in a way that is more sophisticated and that goes beyond simple incremental refinement of own existing products. 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.

This paper seeks to shed light on this issue. Thus, this study takes a focus on two qualitative case-studies of engineering-based clusters of north-western Germany that proved to be highly innovative within the early 21st century. Thus, one empirical and one theoretical research question emerge. Due to the qualitative character of the study, they are formulated more open and discussed in the context of the mentioned theoretical background:

- How did sophisticated innovation take place in the two observed case studies of agricultural engineering industries and what role do the different forms of proximity play for the innovation efforts in those two case studies?
- Are these observations in line with the discussed theoretical background and what implications can be drawn from these observations for theory development and future research?

Table 4.1: Modes of innovation and proximities. Own table.

	STI	DUI	CCI
proximities:			
cognitive	fundamental	fundamental	fundamental and complex
social	negligible	helpful	helpful
institutional	important	very important	very important
organisational	very important	mostly negligible	helpful
geographic	negligible	helpful	helpful

4.3 Case studies

4.3.1 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 PhD thesis. The interviews were conducted with stakeholders from twelve companies of the stable technology cluster, nine innovating agents from the farm trailer cluster (eight companies and the COALA research centre), two biogas companies without a direct connection to the two other clusters as references as well as ten industry experts with in-depth knowledge on the case studies which do not hold a position in one of the interviewed companies. Relevant interview partners were identified in first explorative interviews with some 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 organisations, 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 fifteen years prior to the interview with a strong focus on innovation efforts and collaboration activities[2]. Industry experts were mainly asked about the general development of the observed industries and clusters.

The two case studies include the farm trailer cluster broadly centred on Osnabrück and the stable technology cluster broadly centred on Vechta (see figure 4.1). Thus, 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 and 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 for 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 study investigates the two case studies separately. The reason for this decision lies in the fact that, even though both are part of a thematically very broadly defined agribusiness cluster, the value chains and innovation networks of both industries are widely independent from each other and show different characteristics. Even the connection to agriculture is of a different character as farm trailer technology is related to crop farming while stable technology is associated to animal husbandry. Thus, the two industries, while both related to agriculture can perceived to be widely separated sectors that have to be analysed separately.

The farm trailer and stable technology industries can be traditionally perceived as low-tech industries. For decades, the firms from both clusters traditionally used to follow a

[2]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 specialised 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 organisations 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 organisations; perception of the development of the own industry in general and within the own regional context.

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 21st century that are characterised by different modes of innovation and shifts in the relevance of different forms of proximity. Thus, both industries compared offer a good picture on innovation activities in engineering industries. Furthermore, the overlapping regional and thematic context offers a good comparability of the two case studies.

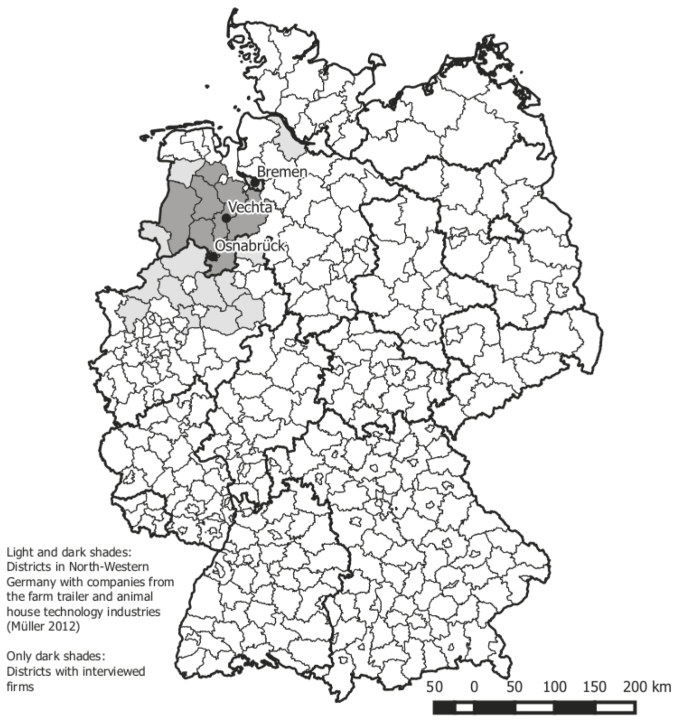


Figure 4.1: The investigated region within Germany. Own figure.

4.3.2 The farm trailer industry

Producers of the farm trailer industry can be found in several regions of Germany (Krawczyk and Nowak 2009). 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. Notable firms include Claas, Amazone, Grimme, Krone, Lemken and others. Furthermore, specialised suppliers from contexts like tire making, specialised computer control systems and others can be found in the region. The firms of the north-west are widely specialised in trailers and self-propelled vehicles, while tractors are not produced in the region[3].

Recently, the innovation activities of many cluster firms changed from a DUI to a more CCI mode character. Since the 1990's, the global farm vehicle sector was, as many industries of that time, characterised by the increased introduction of modern information and communication technology (ICT; e.g. on-board 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 cluster of north-western Germany managed to start a development with an explicit regional character. Two strongly interrelated processes are associated to this. Firstly, in 2007 the interdisciplinary research centre COALA (Competence Of AppLied Agricultural engineering) was founded at the University of Applied Sciences 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[4]), which is also located in Osnabrück. CCISOBUS is a collaboration network of farm vehicle producers, specialised 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 characterised by shifts in the importance of different forms of proximity for 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 4.2.2. Cognitive proximity to collaboration partners still plays a significant role for innovation. However, it now depends on a broader cognitive capacity as, in addition to the traditional DUI partners, much of the innovation is conducted in collaboration with the STI partner COALA. Even though some of the larger firms of the

[3]Claas produces tractors at other sites.

[4]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).

cluster have established their own R&D departments, much of ICT-related technology development is done in close collaboration with the researchers of COALA and specialised ICT-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 cluster, even though much of it is not conducted by the firms themselves but by researchers from COALA. Thus, both firms and researchers build their absorptive capacities in a co-evolutionary way.

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 standardised 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 commercialisation. CCISOBUS is offering the framework for the development of joint institutions based on CCI mode innovation.

Organisational proximity, or better, the role of organisational integration of formerly external individuals or organisations plays a supporting role in the case of CCI mode innovation of the farm trailer cluster. The University of Applied Sciences (including COALA) has established as an important source of human capital for farm trailer producers. 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 organisational context of COALA and which are sometimes directly or indirectly acquired by firms through hiring of key personnel.

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 cluster. 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 cluster was characterised by three main changes regarding the role of proximities for 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-organisational communication and collaboration but also relies on organisational proximity as firms increasingly hire specialised personnel from the context of academia. 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 for 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 cognitive distance. The CCISOBUS network pretty much develops into this direction. Thus, it may have the potential to remain innovative in the future. 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 cluster 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. 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 includes also certain specialised suppliers as well as the STI partner 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.

4.3.3 The stable technology industry

The development of the stable technology cluster 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. The technology includes today 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 1970's. 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 like 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, specialised suppliers from the plastics, metal and concrete sectors are located in the region.

As stated earlier, innovation in the stable technology cluster is mainly of a DUI mode character and incremental. However, in the early years of the 21^{st} 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 the supplier from the stable technology context Stallkamp. Biogas technology itself was developed in a separate sector since the 1980's. 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 farmer 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.

In contrast to the development of the farm trailer cluster, the diversification of the stable technology cluster was not characterised by a full shift to a CCI mode. Biogas technology is characterised by DUI mode innovation in a pretty similar way as stable technology. 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 that was at that time already developed mainly incrementally. 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 characterised by certain shifts regarding the role of different forms of proximity for the innovation process. These include mainly shifts in the role of cognitive and organisational 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 creation of more organisational proximity. Firms like Big Dutchman and Schulz acquired formerly small independent biogas firms to get access to this strategic knowledge. In the case of Weltec, the joint-venture of WEDA and Stallkamp, knowledge access was gained without acquisition. 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 cluster widely offered the necessary and supporting degree of geographical, social and institutional proximities for this diversification process.

Biogas represented a product innovation for stable designers that was fairly beyond their own cognitive scope. Even though the biogas plant as a product already existed before, the event of diversification represents an act of sophisticated innovation that goes beyond simple incremental innovation. This successful process was possible due to the fact that the absorbed knowledge was related. 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 for 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.

4.4 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 clusters of north-western Germany.

At the end of section 4.2.2 two relatively widely formulated research questions were developed. Both are dealing with the question on how sophisticated product innovation takes place in engineering-based industries and what role different proximity constellations play for these processes. Based on the literature on modes of innovation some very specific expectations for the role of different forms of proximities for interactive learning and innovation processes have been developed for STI, DUI and CCI mode innovation. The first research question was dealing with the two case studies:

- How did sophisticated innovation take place in the two observed case studies of agricultural engineering industries and what role do the different forms of proximity play for the innovation efforts in those two case studies?

The answer to this question has been comprehensively discussed in sections 4.3.2 and 4.3.3. The results regarding the role of proximities are summarised in table 4.2. In the case of the farm trailer cluster, several firms switched from a DUI to a CCI innovation mode, resulting in a complex pattern of significant roles of cognitive, organisational and institutional proximities as central driving forces. In contrast, diversifying firms from the stable technology cluster could continue to widely rely on a DUI mode. Their main strategy was the organisational integration of small businesses and staff from the technological related biogas context. These results offer some interesting findings regarding the theoretical framework, targeted in the second research question:

Table 4.2: Role of proximities for innovation in the case studies. Own table.

	traditional way to innovate (both industries)	farm trailer ICT upgrading	stable design biogas diversification
mode	DUI	CCI	DUI
relevant partners	clients/suppliers	COALA (STI), competitors, clients/suppliers	clients/suppliers, agents from related biogas sector
proximities:			
cognitive	fundamental	fundamental and complex	fundamental
social	helpful	helpful	helpful
institutional	important	fundamental (CCISOBUS as institutional frame)	important
organisational	negligible	very helpful	fundamental
geographical	helpful	helpful	helpful

- Are these observations in line with the discussed theoretical background and what implications can be drawn from these observations for theory development and future research?

The empirical observations from the two case studies are very much in line to what has been formulated as expectations in section 4.2.2 (see also table 4.1). CCI mode innovation is, as expected, dependent on a very broad and complex interoperation of different proximity constellations. The complex character of interaction with different partners from different contexts requires a complex and comprehensive utilisation of all possibilities to build the own knowledge base and absorptive capacity in a sufficient way. In a slightly more significant way as expected in theory, organisational proximity seems to play a central role for CCI mode innovation. Organisational integration through hiring and acquisition is an important strategy for several of the interviewed firms of the farm trailer cluster. However, in total, the empirical observations widely fit to the theoretical expectations.

The observed pattern of the DUI mode biogas diversification of the stable technology cluster is also in line to what has been formulated in section 4.2.2. Even though organisational proximity is generally perceived to play an insignificant role for DUI mode innovation, Herstad et al. (2015) have stated that recruitment from related, but different industries can strengthen a firm's organisational knowledge base and processing routines and may enhance the likelihood for innovation. This is exactly what used to happen when stable designers acquired formerly independent small biogas enterprises and hired skilled personnel.

So, what implications for theory development can be drawn from these findings? First of all, it has been shown that there existed a conceptual lack on the role of proximities in the modes of innovation literature. It has been shown that different forms of proximity matter in varying and context-specific ways. STI, DUI and CCI mode innovation is sensitive to and relies on different forms of proximities between interactively innovating agents. The recognition of the relevance of proximity in innovation activities is nothing new and has been discussed in manifold ways in innovation and economic geography literatures. However, it only received little attention so far in the context of modes of innovation. A stronger recognition of the proximity issue could thus help to link the modes of innovation literature more strongly into geographical concepts like regional cluster development or the like. However, there remain several open questions that may be targeted in future research. For example, even though this article started to comprehensively discuss proximity in the context of innovation modes, still little is known on 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 more 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'. This instance has also been recognised in the well-known related variety approach Frenken et al. (2007). So far, it remains unclear how this detailed, more or less U-shapes relationship of different forms of proximities is related to innovation in STI, DUI and CCI modes.

Besides the specific roles of proximities for innovation processes, the empirical observations also reveal some other aspects. Firstly, in both case studies one of the most central aspects for the changing innovation activities was the building of the firms' absorptive capacities to become able to adopt, use and develop the new knowledge. In both cases organisational integration through hiring or acquisition were central strategies of many of the interviewed firms. The role of internal capabilities for interactive innovation processes has been conceptualised in concepts like for example open innovation (Chesbrough 2003). Even though some authors already point to the interrelationship of open innovation and modes of innovation (e.g. Fitjar and Rodríguez-Pose 2013), a more comprehensive discussion of the role of proximities could also contribute to this strand of literature.

Finally, the case studies also show that modes of innovation are no strict states 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 cluster. This is associated with changing roles of proximities. Proximities by themselves are also concepts that recently have been reinterpreted in a more dynamic way (Balland et al. 2015). Future research may more precisely investigate the drivers and triggers of these dynamics of proximity roles in changing innovation modes.

This study for sure has some limitations. First of all, STI mode innovation has not been considered empirically in the study. Thus, a comprehensive picture is still missing and could be added in future research. Secondly, the study is based on qualitative interviews that do not offer a possibility for quantitative investigation. And finally, the case studies are limited to the context of agribusiness which contributes to their mutual comparability but narrows the interpretative value for generalisation.

Nevertheless, having a more pronounced and detailed understanding on innovation processes is of a high value for policy makers as well as for the firms themselves. Offering satisfying conditions that enable firms to make use of the knowledge of their collaboration partners based on the cognitive, social, institutional, organisational and geographical proximity can be a powerful policy tool when it is targeted on the specific innovation mode the firms apply or seek to apply.

Acknowledgements This work was supported by the European Science Foundation (ESF) under the grant number 10–ECRP–07 and Deutsche Forschungsgemeinschaft (DFG) under the grant number HA 3179/6–1. 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 article 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.

5 Discussion and Conclusion

Initially, it has been formulated and discussed that the question of cluster renewal is of vital interest for firms, policy makers as well as researchers as the technological, economical and institutional rejuvenation of localised and established industrial structures can help to prevent an economic downturn and to support new phases of prosperity of regional economies. In section 1.2 it has been described how the existing literature contributes to the understanding of cluster renewal. However, it has also been argued that existing approaches like the CLC may have some shortcomings regarding their explanatory power. Therefore, a research agenda has been formulated that encompasses three main fields of interest that need to be addressed for a deeper understanding of cluster renewal. Firstly, many approaches like the CLC assume that cluster-internal factors play a major role in processes of cluster renewal. Cluster agents like firms need to build their capabilities through learning. Relevant capabilities include the firms' absorptive capacity, the ability to reposition themselves within the cluster network to get strategic access to new knowledge and the ability to reproduce successful routines into new contexts (Ter Wal and Boschma 2011). Furthermore, cluster renewal depends on the systemic utilisation of new knowledge (Menzel and Fornahl 2010) to develop cluster-wide effects. Secondly, cluster-external factors may also play a significant role. While the CLC literature widely assumes that cluster-specific dynamics have to be explained by the factors of the cluster itself, other authors like Martin and Sunley (2011) expect a more interactive and two-way influential relationship of the cluster with its external environment. Thus, a better understanding of the interrelationship of the cluster with its external environment is a necessary step for a better understanding of cluster renewal. Finally, industries and clusters differ in terms of their properties. For example, clusters may differ in terms of knowledge bases, dominant modes of innovation and other factors. Thus, one can expect that these factors do play a role in the process of renewal as well.

5.1 Answers to the research questions

Building upon these general expectations, a set of research questions has been developed. These are now going to be answered and discussed upon the results and discussions from the three papers (chapters 2 to 4):

- How can cluster-internal processes and factors explain cluster renewal in the two case studies?

As described in the empirical sections of this thesis, three different events of cluster renewal can be observed for the two case studies within the observed timespan. These include incremental innovation in both clusters, the ICT-based upgrading of farm trailer technology and the diversification of stable designers into the field of biogas technology. Simple incremental innovation has not much been stressed in this thesis as it encompasses the general incremental type of technological change that is very typical for the everyday innovation activities of all kinds of industries. Whether these activities and their resulting minor socio-technical changes can be understood as a real renewal process or if they are part of a simple system stabilisation, enhancing existing structures, is not always easy to say. For example, in terms of the classification of the CLC by Menzel and Fornahl (2010), this type of development can be understood as part of the sustainment phase or as a process of adaptation that leads to a prolonging of the sustainment phase. In the two case studies these incremental changes are represented by minor or medium-degree changes of existing products and technologies like for example variations in chicken cage sizes and endowment. However, to represent the whole picture these incremental developments will now also briefly be addressed.

Much of these incremental innovations can be explained by existing cluster-internal structures. As stressed before, cluster-internal factors can be distinguished between agent-specific capabilities and cluster-wide systemic network factors. In the two case studies incremental innovation, like for example the development of a refined chicken cage mainly builds upon existing knowledge and capabilities of the innovating firm without much need for R&D collaboration. Ideas for incremental adjustments are often application-oriented and come on request of farmers or are induced by law. Such a pattern of incremental innovation activities and collaboration with partners along the value chain represents a DUI innovation mode. Incremental changes upon such a mode of innovation alone do hardly lead to cluster renewal as they strongly build upon existing knowledge and established collaboration patterns. However, they may unfold significant dynamics that may lead to more significant structural changes of a cluster as can be observed for the other two observed patterns of change in the case studies.

As explained in chapter 2, in the case of ICT-based farm trailer cluster renewal, cluster-internal factors including firms' capability building processes and systemic network dynamics played a significant role as well. However, the process was more complex. The involvement of a novel type of technology (ICT) resulted in complex capability building processes of the involved cluster firms. These include mainly the building of the firms' absorptive capacities and the ability of firms to reposition themselves within the cluster's innovation network. Firms enhanced their absorptive capacity by learning from formerly new technologically and cognitively different agents with knowledge on ICT (e.g. COALA or Anedo). Over time, these agents became central members of the cluster's altered innovation network. As described in chapter 4, this resulted in a change of the cluster's predominant mode of innovation from a DUI to a CCI mode as learning from partners like COALA involved science-based and codified knowledge. The learning process towards an ICT-based farm vehicle technology enabled some cluster agents to reposition themselves within their pre-existing innovation network. The systemic dynamics in the cluster network included the traditional DUI mode collaborations with (often local) farmers who formulated application problems as well as a newly emerging collaboration pattern that included suppliers and competitors as well as partners from academia like COALA within the CCISOBUS network. The cognitive distance between ICT and traditional farm vehicle engineering demanded an altered pattern of collaboration within the cluster. As described in chapter 4, this newly emerged and changed cluster network structure and collaboration pattern represents a CCI innovation mode. This whole process was highly systemic as the diverse partners of the cluster needed to cooperate strategically to become able to build their own knowledge base and absorptive capacity based on formerly unrelated knowledge. This was enabled by interaction possibilities that emerged from social, geographical and partly cognitive proximity within the shared regional and cluster context.

In the case of biogas diversification of stable designers, cluster-internal factors played a significant role as well, but in a quite different way. Agents' capability building processes were highly significant, too. Especially the building of the firms' absorptive capacities as well as the ability of firms to reproduce their routines into a new context strongly drove the process of cluster renewal. However, the quality of learning and absorptive capacity building was quite different compared to the previous case. Stable and biogas technologies share many technological similarities. Thus, one can classify both technologies as technologically related. Therefore, learning was built upon existing knowledge. The acquisition of unknown knowledge was partly conducted through acquisitions of small biogas enterprises or through hiring of skilled personnel. As pointed out in chapter 4 and according to Herstad et al. (2015), recruitment from related industries can have a positive influence on a firm's innovation activities. Because of the technological relatedness and similarities in terms of the targeted market (farmers as clients) stable designers could relatively easily reproduce their established innovation routines into the context of biogas technology production. Nevertheless, the systemic network effects in the case of biogas diversification were less complex than in the case of ICT-based farm trailer innovation. Stable designers could continue to rely on application-oriented innovation input that has been formulated by farmers. Thus, the degree of systemic utilisation of biogas technology within the pre-existing stable technology cluster context remained limited. The renewal of the cluster was therefore incomplete. As a result, the production of biogas technology was limited to a small number of stable designers while the majority of firms from the cluster did not start to engage in this field.

Thus, in all observed cases cluster renewal was significantly influenced and driven by internal factors. This is not very surprising. It is a trivial finding that changes of an object depend on the characteristics of the object itself. Thus, many strands of literature including the CLC literature strongly emphasise the role of cluster-internal factors. However, the aim of this thesis is to take a broader look. Therefore, the knowledge on these widely trivial findings is fundamental to develop a deeper understanding of cluster renewal. However, there seem to exist factors that cause a difference. While, for example, ICT-upgrading in the farm trailer cluster strongly depended on intense cluster-internal systemic network dynamics, the degree of systemic utilisation was much more limited in the biogas case. As has been shown throughout the thesis, these differences partly depend on factors that are specific to the industry and/or lie more or less external to the cluster context. These aspects will be discussed within the context of the next two research questions, starting with the first one:

- How do the clusters interact with their external environment during processes of cluster renewal and how do internal and external factors correspond to each other in these processes?

As has been highlighted in theory section 1.2, Martin and Sunley (2011) criticised the CLC literature for having too restricted assumptions on cluster development and neglecting the complex interrelationship of the cluster with its external environment. In this thesis, the interrelations of the observed clusters with their external environment have been investigated for the recent processes of cluster renewal in chapters 2 and 3. Two main observations can be extracted which will be described and discussed here in more detail. These include, firstly, the complex nature of the interrelationship of a cluster with its external environment which may result in a pattern of alignments and misalignments as described in chapter 3 for the case of biogas, and secondly, the problem of distinction between the cluster and its external environment based on the observations of ICT-based technological upgrading in the farm trailer cluster.

As described in chapter 3, biogas diversification of some stable designers was strongly externally driven and induced. The national subsidy program of the Renewable Energy Act (REA), which opened a window of opportunity for stable designers to engage in biogas technology, was created to support the use and technology development of renewable energies like wind, solar or biogas power. However, even though the development of biogas technology in general has been one of the core targets of this law, there was no direct intention to involve the stable technology industry. Biogas technology was developed in a separate industry since the 1980's in Germany. When the REA was introduced, biogas and stable technology were still two totally separated industries with totally different innovation networks. While the biogas industry mainly (but not exclusively) developed in southern Germany and formed an own innovation network originating from the so-called Bundschuh practicals group and its successor the industry interest group German Biogas Association (GBA), pig and chicken-based stable technology was mainly centred on the north-western German region around Vechta. The REA in 2000 and its biogas-supportive amendment of 2004 created a wider national market for biogas-based electricity production. Thus, it became profitable for stable designers to engage in this field.

However, according to Elzen et al. (2012) the full socio-technical anchoring of a technology in a (regional) context includes the application of the technology (technological anchoring), the involvement of the context's agents (network anchoring) and the creation of broad institutional legitimacy (institutional anchoring). As described in detail in chapter 3, the process of socio-technical anchoring of biogas technology in the regional and cluster context of stable technology and agriculture in north-western Germany remained incomplete as the legitimisation based on jurisdiction and political support remained based on the national level. Thus, institutional legitimisation remained widely incomplete of the cluster level. This resulted in a complex and uncontrolled pattern of alignments and misalignments between the socio-technical structures on the national and the regional level. As described in chapter 3, this was partly based on the territorial embeddedness of the cluster's socio-technical arrangements. These observations can be directly translated to the terms of Martin and Sunley (2011). In the process of cluster renewal the cluster stood in a two-way interrelationship with its external environment, but due to the system autonomy of the cluster context cluster-specific developments occurred that resulted in a pattern of alignments and misalignments with structures on the national level. This pattern of alignments and misalignments was changing over time. As described empirically, in the beginning of the process, stable designers from north-western Germany could profit from certain alignment processes between the more general development in biogas technology and the livestock and stable technology-based industry and agriculture in the north-west. These factors included strong technological complementaries and cognitive proximity between both technologies, a shared set of potential clients (farmers), the good reputation of stable designers among these farmers and a culture of technological experimentation and entrepreneurial spirit among both stable designers as well as local farmers. When biogas production became profitable to farmers after the initiation of the REA, the technology fitted very well to the socio-technical and economic arrangements of the north-west. This included both the stable technology innovation system as well as the regional market of entrepreneurial farmers. Nevertheless, as pointed out in chapter 3, certain misalignments arose between the development on the national and the regional scale of the north-west. The incentives created by the REA amendment of 2004 supported the increasing digestion of energy maize in biogas plants. On the one hand, this fitted well to the entrepreneurial character of farming in the region, but on the other hand it created misalignments in terms of environmental problems and conflicts with the traditional and established pattern of land use and crop growing. Furthermore, its potential positive impact through the digestion of animal manure, which is produced in the region in high amounts, increasingly vanished. This resulted in a loss of legitimacy in both the region as well as the national society. One has to state that this process of downturn was not limited to the north-west as it occurred in several regions all over Germany. However, the north-west became one of the core regions for these misalignments, as farms in the north-west tend to be large and strongly industrialised due to the dominant entrepreneurial identity of local farmers.

Thus, the conditions in the north-west had a significant impact on the downfall of the national biogas industry since the late 2000's. In conclusion, the interrelationship of the north-western stable technology and livestock-based agriculture cluster with its external environment was complex. First, the incentives through the REA can be understood as totally external. They aligned with existing structures in the cluster and enabled stable designers to diversify into a technologically and market-specifically related field. In the further development the industrial context of chicken and pig-based agriculture in north-western Germany gained some significance for the development of the biogas industry in Germany as it became one of the main markets for biogas technology. Due to an incomplete anchoring process of biogas technology in the cluster's context misalignments arose over time that contributed to a downfall of biogas legitimacy on both the national and the regional scale. Thus, using the terms of Martin and Sunley (2011) the interrelationship of the cluster was of a two-way character, even though the dominant direction of influence shifted over time.

The second broader observation regarding the nature of the interrelationship of a cluster and its external environment in a process of cluster renewal is linked to the problem of distinguishing between the cluster-internal and the external context. As described before, ICT-based upgrading in the farm trailer cluster was characterised by a complex cluster-internal restructuring of the cluster's innovation network and agent-specific capabilities. However, the renewal of the cluster was also initially induced by a (seemingly) external factor. When the global ISOBUS standard was introduced in 2001 and the global Agricultural Electronics Foundation (AEF) was founded shortly after, some of the core factors for the successful renewal of the farm trailer cluster of north-western Germany were given that enabled cluster firms to initiate the cluster-internal dynamics that have been described before. In this process of cluster renewal the cluster and its agents could build and maintain their dominant role within the global farm vehicle industry. Furthermore, farm trailer producers gained access to initially cognitively unrelated ICT knowledge. This knowledge was acquired through newly emerging collaborations with initially cognitively unrelated agents like COALA or Anedo. In the continuing process, the CCISOBUS network grew and included more and more firms over the years. Some of these firms cannot be associated with the regional context of north-western Germany. Thus, in line with some assumptions formulated in the CLC literature (e.g. Menzel and Fornahl 2010) the farm trailer cluster shifted its boundaries thematically and geographically. In the broader context, the cluster's agents and the CCISOBUS network became core innovators in the global farm vehicle ICT development. In summary, cluster renewal was at the beginning initiated by (seemingly) external factors that occurred on the global scale of the very same industry. In the further development the cluster-internal dynamics of firms' capability building processes, network formation and collaborative learning helped the cluster and some of its core agents to gain a central position in the global innovation network. Thus, the interrelationship of the cluster with its external industrial environment seems to have become much more of a bottom-up character over time.

However, as indicated by the word 'seemingly' in this description the interrelationship of the farm trailer cluster with its external environment is a bit more complex than it may appear in this superficial description. Firstly, the emergence of ISOBUS technology and the formation of the AEF network are only partly cluster-external factors as several firms of the cluster like Grimme, Amazone, Krone and Claas had been significant global players in their segments before. Thus, even though this information cannot be directly extracted from the interview material of the thesis, one can expect at least some of them to have had a significant impact on early global farm vehicle ICT development before 2001. Furthermore, agents like COALA or Anedo who introduced novel ICT knowledge to the firms of the investigated cluster have also been of a much stronger cluster-internal character from the beginning as they emerged within the context of the cluster. As described in chapter 2, even though COALA did not emerge on behalf of farm vehicle producers, the motivation of the researchers to found the centre was based on the increasingly emerging demand for ICT solutions among the locally concentrated farm trailer producers. Furthermore, the academic and vocational training of agricultural engineers at the University of Applied Sciences in Osnabrück, which existed many years before the founding of COALA, has to be understood in the context of the regional industrial structure. A similar notion can be made for the technology company Anedo. It emerged as a firm that concentrated on ISOBUS development from its very beginning. Even though it was not originally located in north-western Germany but relocated there from Baden-Württemberg shortly after its founding, its core clients have always been farm trailer producers in north-western Germany. Thus, even though Anedo can be understood from the perspective of farm trailer producers as an agent that entered the cluster at a later point in time and introduced novel ICT knowledge, it is a firm that was specialised on ISOBUS technology, which always strongly cooperated with farm trailer firms from the north-west.

According to these observations the case of the farm trailer cluster reveals that the distinction of a cluster-internal and a cluster-external environment is not a trivial task. Was a firm like Anedo initially cluster-external or did it emerge from the demand created in the cluster itself? Is the development of the global ISOBUS standard an external incentive for the renewal of the cluster or did it emerge upon significant efforts of some of the cluster's agents? Is a firm that is located in Bavaria, Italy or maybe even China and has or potentially will become a member of the CCISOBUS network part of the cluster or is it not? To what extent is the geographical dimension that is often stressed in conceptions of regional clusters relevant or not if a cluster cannot really be distinguished from its industrial and/or geographical external environment?

Initially, it has been discussed in the theory section of the introductory chapter 1 that Martin and Sunley (2011) expect clusters to be in a two-way interrelationship with their external environment with mutual influence between both. Furthermore, it has been argued that clusters retain a certain degree of system autonomy due to their specific internal coherence and structures. The empirical observations endorse these general assumptions. However, they also show that the interrelationship of a cluster with its external environment is a complex phenomenon that depends on a variety of factors. These unfold in a process of cluster renewal and socio-technical change. One of the main differences between the two case studies is that biogas diversification of the stable technology cluster somewhat struggled due to misalignments that arose from the tensions between the mutual two-way interrelation of the cluster and its external environment on the one hand and remaining system autonomy on the other. Such a tension cannot be observed for the case of renewal of the farm trailer cluster. Because the farm trailer cluster of north-western Germany has a very central position in the global innovation network of its own industry and because the boarders between the cluster and its global industrial environment seem to vanish to a certain degree, misalignments between global and the cluster's socio-technical arrangements are very unlikely. The agents of the network play a significant role for shaping the socio-technical pattern not only in the context of the cluster, but also increasingly on the global scale. Therefore, the farm trailer cluster of north-western Germany and the global farm vehicle innovation network become increasingly intertwined and interrelated.

However, scale is only one aspect that needs more attention for a better understanding of cluster renewal. In the theory section of this thesis it has been stressed that industry and cluster-specific innovation patterns and industry structures also need to be investigated more. Therefore, the third research question had been formulated:

- How are these processes determined by the specific characteristics of the clusters like the dominant knowledge base and mode of innovation and in which way is cluster renewal a process of changing knowledge bases and innovation modes?

In chapter 4 the two case studies are compared in terms of the knowledge bases and dominant modes of innovation. Innovation and thus, cluster renewal is based on knowledge. In the CLC literature the role of knowledge in the process of cluster development is highly emphasised. For example, Menzel and Fornahl (2010) point to the necessity of heterogeneous knowledge accessible to cluster agents for cluster growth and renewal. If cluster agents manage to receive access to and become able to utilise a broader set of knowledge within the cluster network, cluster growth or renewal are expected to occur. However, knowledge differs. As formulated in the knowledge bases (Asheim and Coenen 2005; Cooke et al. 2007; Mattes 2012) and modes of innovation literatures (Jensen et al. 2007; Isaksen and Karlsen 2012), different types of knowledge are related to different ways of innovation and collaboration. Thus, one can expect processes of cluster development, including cluster renewal, to be sensitive to the characteristics of the involved knowledge. The industries of the two case studies are both engineering industries that traditionally relied on a synthetic knowledge base and a DUI innovation mode. Nevertheless, as described throughout the thesis, the processes of cluster renewal in the two case studies used to happen in different ways. As has been pointed out in chapter 4, cluster renewal used to happen due to specific developments of the innovation modes of the two clusters. Due to the involvement of different types of knowledge different cluster-internal dynamics unfolded in both cases.

In the case of the ICT-based renewal of the farm trailer cluster the dominant innovation mode changed from a DUI to a CCI mode. This used to happen mainly due to the fact that the newly introduced ICT knowledge was to a certain degree science-based and widely unrelated to the previously existing engineering knowledge. Agents from academia like COALA supplied farm trailer firms with sophisticated knowledge beyond their original cognitive scope. However, the traditional DUI mode innovation style remained important as farmers still formulated the application problems for innovation. As a result a complex pattern of learning and interaction between diverse partners emerged. This development involved changes of cluster-internal dynamics. As has been described in chapter 4, these internal dynamics occurred upon the specific effects that arose from cognitive, social, institutional, organisational and geographical proximity between interacting agents. While changing to a CCI mode, cluster agents combined DUI and STI mode innovation patterns in a complex way. DUI mode innovation is perceived to rely mainly on cognitive proximity along the value chain (suppliers and clients) and institutional proximity in terms of shared understanding, trust and routines. In contrast, STI mode innovation relies mainly on cognitive proximity among science-based partners (universities, R&D departments and the like) and organisational proximity to ensure reliable and exclusive access to otherwise codified and easily accessible knowledge. In a CCI mode agents need to utilise these different forms of proximity effects to a broader and more diverse set of collaboration partners. This happened in the case of the farm trailer cluster. Firms participating in the process of ICT upgrading and the CCISOBUS network utilised a broad set of proximity effects within the cluster context. Thus, they developed their agent-specific and collaborative capabilities in a complex way as it has also been described for the first research question.

In the biogas case the pattern was quite different. Even though diversifying firms introduced a novel kind of knowledge to their existing routines they could widely continue to rely on a DUI innovation mode. In contrast to ICT in the farm trailer case, biogas technology was technologically related to stable technology and both technologies traditionally relied on DUI mode innovation. Nevertheless, the process of cluster renewal was characterised by some shifts of cluster-internal proximity effects. However, because of the strong cognitive, institutional and social overlapping of both technologies they were much less complex than in the farm trailer case. Thus, diversifying firms could rely on existing structures and bridge the remaining cognitive gap through the creation of organisational proximity through acquisitions and hiring. As described before, Herstad et al. (2015) already expected that the creation of organisational proximity through hiring and acquisition can help to increase the innovativeness of a firm if the novel knowledge is of a related character. Nevertheless, because the firms could widely rely on their existing DUI interaction patterns, cluster-internal network dynamics remained much less developed than in the case of farm trailers. Thus, the process of cluster renewal was quite less dynamic than in the case of the farm trailer cluster.

As has been described before as well as in chapter 2, the CLC literature highlights the role of cluster-internal dynamics including agent-specific capability building processes and cluster-internal systemic knowledge utilisation processes. However, as the two case studies reveal, the systemic utilisation of knowledge highly depends on the quality of the involved knowledge as it determines the way firms innovate and collaborate. CCI mode innovation as in the case of the farm trailer cluster seems to support cluster-internal collaboration with new and diverse partners as the complex innovation process beyond the cognitive scope of single firms cannot or can just to a limited degree be conducted by individual firms. Therefore, CCI mode innovation has a huge potential to induce dynamic collaboration patterns within clusters as well as with external agents. Thus, it is very likely that a successful switch of a large set of agents from a cluster network from DUI to CCI mode innovation leads to dynamic and successful cluster renewal processes. In contrast, cluster renewal based on DUI mode innovation seems to be of a much more limited scope as innovation remains to be based on an established innovation network between clients and suppliers. However, cluster renewal based on a continued DUI innovation mode can be successful as well if the agents remain able to acquire and utilise novel knowledge in the long run. In the empirical biogas case this did only happen to a limited degree. The introduction of novel knowledge was mainly based on a single event of acquisition and the firms quickly switched to incremental innovation. Therefore, and due to the unfavourable political decisions since 2011 (cut of biogas supports through REA amendments) the cluster could not really successfully diversify into biogas technology in the long run.

The answers to these three research questions reveal that cluster renewal is a complex process that strongly relies on the very cluster-specific internal, external and industry-specific arrangements. This leads to the final and encompassing research question:

- What implications can be drawn from the answers to the previous three questions in terms of a more pronounced understanding of cluster renewal?

The three chapters 2 to 4 of this thesis rely on a very broad set of theoretical strands that have not or only partly been discussed in combination in the past. However, this thesis has just limited possibilities to discuss all these approaches and combine the findings to a comprehensive picture of cluster renewal. The reason for this lies mainly in the cumulative character of the thesis and the character of each chapter as an individual piece of literature. Furthermore, the review processes at the scientific journals contribute to this fact as the comments partly lead to changes of a paper that contribute to the individual paper as such, but potentially change it in a way that it is, to a certain degree, less compatible to the other chapters of the thesis. Thus, a full and encompassing picture of cluster renewal or even the whole cluster development process, as conceptualised for example in the CLC literature cannot be given.

However, two core conclusions for the future development of concepts on cluster renewal and cluster development can be drawn. Firstly, as already suggested by Martin and Sunley (2011), the interrelations of a cluster with its external environment are much more complex as expected from many existing literature strands like the CLC literature. The observations on the biogas case in chapter 3, based on the transition studies literature, suggest that the expectations of Martin and Sunley (2011) in terms of a two-way interrelationship and a partly system autonomy of clusters can be observed. As described before, this pattern is characterised by processes of alignment and misalignment between the cluster and its external environment. This results from the fact that clusters are subsystems of the larger national and international economic context of their industry that retain a certain degree of system autonomy on their own. Cluster-internal factors like cluster-specific institution building can conflict with incentives and developments on a larger level if they are misaligned, or they may unfold positive developments if they can align with relevant external factors. The issue of alignments and misalignments between a cluster and its external environment has also an impact on the question of shifting borders of clusters. As for example Menzel and Fornahl (2010) have stated, clusters may enhance their borders through the integration of distant agents (shift of geographical borders) and/or of agent from a different technological context (shift technological borders).[1] A cluster can only successfully grow if its internal structures align with the relevant external contexts. As has been described in the thesis, the central firms of the farm trailer cluster were able to enhance the technological (Anedo, COALA, etc.) as well as geographical borders (firms in other parts of Germany and in other countries within the CCISOBUS network) of the cluster. Central firms of the farm trailer cluster of north-western Germany have been relevant agents within the global farm vehicle industry before. Thus, they shaped significantly the global technological development of ISOBUS technology. As a result, the cluster was perfectly aligned with the global environment. In contrast, the conditions between the stable technology cluster and the national biogas industry context misaligned due to widely separated development paths in the past. Future research may stress the issue of the interrelation of the cluster with its external environment in more detail to reveal the character of the cluster within its industrial and geographical environment. Important questions may be related to the dynamics of cluster-internal factors that arise from alignments or misalignments in the external environment. For example, how do firms correspond to misalignments with factors from the external environment and how can they successfully react to this in favour of a positive cluster development. Furthermore, a more detailed analysis of the external environment may be conducted in future research. The cluster literature (e.g. Menzel and Fornahl 2010) generally distinguishes between a spatial, a thematic and a totally external cluster environment (see also figure 1.3). A more distinctive analysis of the in-

[1]For sure, the opposite case of shrinking borders in a declining cluster is also possible.

terrelationship of a cluster with its different external environments could reveal an even better picture in the future.

Secondly, cluster development and cluster renewal are sensitive to the very specific innovation mode that is applied by the majority of the cluster's agents. The inclusion of this issue into general concepts of cluster development like the CLC is a little bit more complicated as it adds a new analytical dimension. Nevertheless, future research should be aware of this issue as it is very much related to the fact that empirically cluster development differs and that these differences are related to the specificities of each individual cluster. Martin and Sunley (2011) already suggested that cluster development may occur in very different ways and introduced their model of an adaptive cycle. Even though this adaptive cycle model does not specifically recognise differences in terms of knowledge bases or innovation modes, it shows that there exists awareness in the literature of the individual characteristics of each empirical case that leads to very specific cluster development patterns. Nevertheless, future research needs to specify in which case and under which conditions cluster development and renewal follows which pattern. This could help to develop a more precise understanding of cluster development that is less restrictive than the classic CLC and less arbitrary than the adaptive cycle model of Martin and Sunley (2011). Future research could thus investigate if certain ideal cluster development patterns can be distinguished that are based on the specific characteristics of a cluster like the dominant mode of innovation or other factors. The identification of such ideal cluster development patterns could help to understand why certain clusters develop in a different way than others. This could have direct benefits for future regional economic policy intervention. The empirical examples of this thesis show that cluster renewal is possible under different conditions. In the farm trailer case, cluster renewal was accompanied and driven by a shift from a DUI to a CCI innovation mode. As a result, the cluster renewed itself very successfully. The firms changed their innovation routines and collaboration patterns by keeping the market scope on farm vehicle technology. In the case of biogas and the stable technology cluster, innovation routines have been changed in a much less encompassing way. However, the firms reproduced their routines to a new technological context. Future research may deal with these differences by investigating how differences in innovation mode affect the whole cluster life cycle and how different ideal forms of cluster renewal may be identified. However, to answer this question evidence from a broader set of case studies from a variety of industries would be necessary.

5.2 Policy implications and limitations of the study

After answering the research questions, two aspects remain left that need to be discussed in these concluding remarks. These two aspects include the policy implications and the limitations of the conducted research. The regional industrial cluster has become a very popular tool in economic policy during the last decades. The support of clusters is widely perceived to contribute to the regional economic development. However, even though not all of these politically supported clusters are real clusters in the scientific sense and not all existing clusters (including the two case studies from this thesis) are supported through cluster policy, some main conclusions for future policy intervention can be drawn. First of all, cluster renewal is a very complex process that cannot be met with standard solutions. This notion is very much in line with the argument of Tödtling and Trippl (2005) who state that there is no ideal model for regional innovation policy. Knowledge of the very specific arrangements of each individual cluster is crucial to find the right form of support and intervention in each individual case. Because the potential way of a cluster's renewal cannot be predicted and needs to be developed by the cluster's firms and agents themselves, tight communication of policy makers with firms and key persons from the cluster context is necessary to find the right spots for pinpointed policy intervention. Furthermore, policy makers should be aware of the complex interrelationship between the cluster and its internal dynamics on the one hand and external factors and intervention on the other hand. If policy intervention is not sufficiently tailor-made for the conditions in the cluster, misalignments between policy intervention and the cluster's needs may arise that potentially harm the success of cluster development. This notion is not just of importance for regional policy makers that seek to support their local industries but also for policy makers that develop support programs on the national or European scale. National support programs may have a harmful influence on the development within certain regions because the regional or cluster-specific internal arrangements and structures need other support than those in other regions. If the support of a specific cluster is sought, pinpointed and targeted policy is always needed and policy makers should be aware of the necessity for policy coordination across administrative scales.

Nevertheless, for sure this thesis has some limitations. The empirical focus of the study has been on two case studies of agricultural engineering industries in a shared regional context. On the one hand, such a choice contributes to an argumentation as both clusters are, to a certain degree, well comparable. However, as has been stated in chapter 1, the comparability of the two case studies is limited. While, in terms of Henderson and Clark (1990) the renewal of the farm trailer cluster involves more of a modular innovation character, biogas represents more an architectural innovation for stable designers. Thus, farm trailer producers remained to stick on their traditional field of farm vehicle technology, while stable designers entered a different industrial field. Such a difference has some advantages and some disadvantages for a scientific study. It is an advantage as it represents two different processes that can be compared. It is a disadvantage as it also limits this comparability in a certain way. Future research may deal with these differences that arise from different forms of innovation in more detail.

Furthermore, in terms of finding general concluding remarks that contribute to theory development the scope of the study is limited. For a more encompassing picture of cluster renewal additional case studies from differently structured industries would be needed. For example, as described in chapter 4, both case studies traditionally relied on a synthetic knowledge base and applied a DUI innovation mode. Thus, the explanatory power of the chapter is limited to these kinds of industries. It cannot contribute to the question on how clusters renew themselves that already rely on an analytical or symbolic knowledge base or traditionally apply a STI or CCI innovation mode. Future research may tackle this issue in more detail to develop a broader picture. Another limitation is related to transition studies which have been the theoretical base of chapter 3. Even though not exclusively, transition studies, and especially the literature on sustainability transitions (e.g. Shove and Walker 2010; Geels 2011; Coenen et al. 2012; Truffer and Coenen 2012; Späth and Rohracher 2012; Markard et al. 2012), tend to stick to case studies that are related to technologies that are believed to lead to a more sustainable economy, and thus, rely on a certain degree of policy support. Examples include wind energy, waste management, biogas, electric mobility and the like. Sutherland et al. (2015) conceptualise these kinds of industries as fiat regimes which are the contrary to market regimes. Market regimes include those industries which widely develop on their own without the need for substantial industry or technology-specific policy support. Chapter 3 is limited to the analysis of the biogas case study. Thus, the results from chapter 3 are based on a fiat regime case study. Future research may analyse the geographies of transitions for cluster renewal also for a case study that is based on a market regime case study. As political intervention holds a very different role in market regime industries, the findings regarding misalignments between national policy intervention and cluster development may be much less significant in these cases. Actually, the farm trailer cluster represents such a case. However, the limited possibilities within a journal article created some restrictions in terms of available space. A future article on the cluster renewal processes of a market regime cluster from the perspective of transition studies may broaden the picture. Finally, a major aspect that several readers may have concerns about is related to the methodology. This thesis is widely based on qualitative analysis and interview data. Interview information tends to be sensitive to subjectivity, strategic answering and oblivion. Some scholars highlight the superiority of quantitative data and analysis regarding these problems. However, as stated earlier the possibilities for quantitative analysis of the two case studies were limited. Furthermore, qualitative analysis also offers some advantages as it can help to reveal new patterns and information that cannot or can only to a limited degree be obtained through the use of quantitative data and methods. Future research may thus built upon the arguments from this thesis in the context of a more quantitative approach.

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Appendix I – Overview on interviews

ID	Date	Interviewee	Organisation	Transcript
Explorative interviews				
Expl01	13.02.12	Prof. Dr. C. Tamásy	Uni Vechta/ISPA	only notes*
Expl02	08.03.12	Prof. Dr. H.-W. Windhorst	Uni Vechta/ISPA	yes
Expl03	27.03.12	E. Steenken	AbL/farmer	only notes
Expl04	04.04.12	U. Meyer	Landkreis Vechta	only notes
Expl05	18.04.12	K. Fahlbusch	ShowCo	yes/notes
Interviews with agents from stable technology cluster				
S01	27.03.13	M. Suding	Suding	yes
S02	09.04.13	M. v. d. Assen	Lubing	yes
S03	19.04.13	S. Wahnschaffe	ROWA	yes
S04	29.04.13	B. Mehrpohl	Big Dutchman	yes
S05	18.07.13	M. Tapken	Fienhage	yes
S06	26.07.13	H. Graf v. Reichenbach	Schulz	yes
S07	01.08.13	F.-J. Sextro	WEDA	yes
S08	06.08.13	B. Prüllage	Prüllage	yes
S09	06.08.13	T. Gehrdes	Otte	yes
S10	07.08.13	G. Sieve	atka	yes
S11	11.09.13	R. Wingenbach	Hedemann	yes
S12	11.10.13	S. Bullermann	PAL-Bullermann	yes

* there exists no audio file for this interview

Continuation from previous page

ID	Date	Interviewee	Organisation	Transcript
Interviews with innovative agents from farm trailer cluster				
T01	08.04.13	Prof. Dr. B. Johanning	HS OS/COALA	yes
T02	13.05.13	Dr. J. Middendorf-Bergmann	Bergmann	yes
T03	22.05.13	J. Horstmann	Krone	yes
T04	24.07.13	S. Kotte	Kotte	yes
T05	07.08.13	J. Dahmann	Grégoire-Besson	yes
T06	08.08.13	Dr. S. Hink	F·A·R·Msystem	yes
T07	08.08.13	D. Mentrup	iotec	yes
T08	14.08.13	D. Tebbe	Tebbe	yes
T09	14.08.13	A. Möller	Anedo	yes
Interviews with industry experts				
IE01	Feb 13	Prof. Dr. H.-W. Windhorst	Uni Vechta/WING	yes
IE02	15.04.13	Dr. H. Müller	HK Oldenburg	yes
IE03	05.06.13	M. Klumpe	WIGOS	yes
Interviews with agents from biogas sector				
B01	18.10.13	S. Wolkenhauer & I. Jagels	MT-Energie	yes
B02	16.06.15	J. Pellmeyer	Fachverband Biogas	no**
B03	22.06.15	E. Köberle	Köberle	yes
B04	10.07.15	H. Becker	PlanET	yes

** not transcripted due to the low degree of useful information

Appendix II – Interview manuals and material

Explorative interviews of 2012

Interview manual

Note Used for interviews Expl02–Expl05.

Fragen zur Region und zum Cluster

- Wie schätzen sie die allgemeine wirtschaftliche Entwicklung der Region (Oldenburger Münsterland, West-Niedersachsen, nördliches NRW) ein?
- Wie sieht es mit Gründungsaktivitäten und Spinn-Offs in der Region aus?
- Wie schätzen Sie die Entwicklung der letzten 10 bis 15 Jahre im Agribusiness/in den Teilbranchen ein (Wachstum, Schrumpfung, gesunde Stabilität, Stagnation, Umbruch, . . .)?
- Wie hat die Branche / haben die Teilbranchen auf die Wirtschaftskrise reagiert?
- Welche Bedeutung haben die Branchen des Agribusiness für die regionale Wirtschaft? (BIP, Beschäftigungseffekte)?
- Welche Entwicklungen sind in den letzten 10 bis 15 Jahren von Bedeutung gewesen (global, in der Region allgemein, in der Branche allgemein, im regionalen Cluster)?
- Welche besonderen Ereignisse haben die Entwicklung beeinflusst (auf allen Ebenen)?
- Sehen Sie Unterschiede in der Entwicklung der Branche/der Teilbranche in der Region zum nationalen Trend?
- Wie haben die Firmen des Clusters/der Branche darauf reagiert (Konzentration / Produktinnovation / Auslagerung / Konvergenz)?
- Wie schätzen sie die Entwicklung in den nächsten Jahren ein?

- Würden Sie im Falle des Agribusiness oder in Bezug auf die Teilbranchen in der Region von einem Cluster im wissenschaftlichen Sinn sprechen?
- Inwiefern sind die Branchen des Agribusiness /der Teilbranchen miteinander vernetzt (über Markt (vertikal /horizontal), FuE, Imagebildung)?
- Herrscht eher ein Klima der Konkurrenz oder der Kooperation?
- Welche Bedeutung für die regionale Wirtschaft haben andere Branchen (z.B. Kunststoff)?
- Wie abhängig ist die Region vom Wohlergehen der Firmen des Agribusiness?
- Welche Rolle spielen nichtindustrielle Akteure (Kammern, Unis, Forschungsinstitute, ISPA, DIL, COALA, ...)?
- Welche Rolle spielt der Handel?
- Welche Innovationen (Produkte/Prozesse) haben in der Branche/im Cluster in den letzten Jahren stattgefunden (Biogas, Privathofgeflügel, Biolandbau, Indoor Fish Farming, Direktvermarktung)? –> Agrartechnik und Veredelung
- Sehen Sie spezifische Gründe, warum sich das Cluster gerade in dieser Region herausgebildet hat (regionales Institutionensystem, ...)?

Was wir beobachtet haben: Ansprechen und nachfragen

- Imageproblem der Branche (z.B. ARD-Wiesenhofreportage, Lebensmittelskandale EHEC/Dioxin)
- Einbruch der Gewinne der Veredelungsindustrie 2007/2008 (zyklische Preisänderungen?)
- Verschärfung der Tierschutzgesetze (niedersächsischer Tierschutzplan)
- Konzentrationen (größere Tiermastbetriebe, extreme Konzentrationen in Oldenburger Münsterland)
- Im Jahr 2000 enorme Wachstumsraten im Agrarbereich im LK VEC. Was war da?
- Veränderung der Ernährungsgewohnheiten in Schwellenländern
- Weltmarkt für Agrartechnik jährlich stark gewachsen (BRIC, Biokraftstoffe, Rekultivierung, ...), 2008 sehr gutes Jahr (10% Beschäftigungswachstum deutschlandweit)

- Agrartechnik (LK OS) exportorientiert (aber weniger als im deutschen Durchschnitt), forschungsintensiv
- Agrartechnik im Großen und Ganzen in Weser-Ems-Region in den letzten Jahren sehr dynamisch
- Allgemeine Probleme des ländlichen Raums (Fachkräftemangel, geringes Lohnniveau, Landflucht)

Weitere Interviewpartner?

- Welche weiteren wichtigen und potenziellen Interviewpartner gibt es?

Gegebenenfalls

- Beschreiben Sie kurz ihre Organisation, ihr Aufgabenfeld und deren spezifische Entwicklungen der letzten Jahre.

Main set of interviews of 2013 – firms

Interview manual

Note Used for interviews S01–S12, T02–T09 and B01.

Der Zweck der Befragung ist die Analyse der Entwicklung (Entstehung, Schrumpfung, Transformation, etc.) der agrartechnischen Industrie im Oldenburger Münsterland und angrenzenden Gemeinden. Alle erhobenen Informationen werden selbstverständlich vertraulich behandelt und es wird für niemanden möglich sein, in späteren Veröffentlichungen sowie in weiteren Interviews Ihre Firma oder Sie persönlich zu identifizieren.

A Grundlegende Infos

- Name der Organisation.
- Adresse der Organisation.
- Name des Ansprechpartners.
- Funktion/Stellung des Ansprechpartners im Unternehmen.
- Anzahl der Jahre des Ansprechpartners in der Organisation.

B Allgemeine Firmencharakteristika

- Bitte stellen Sie kurz ihre Firma vor. (Falls ihre Firma Teil eines größeren Unternehmens ist, beantworten Sie bitte die folgenden Fragen nur in Bezug auf den Standort hier in der Region)

  - Ist dies der Hauptsitz des Unternehmens oder ist dies ein Zweigwerk? Gibt es weitere Standorte dieses Unternehmens? Welcher Art sind diese weiteren Standorte (Produktion, Vertrieb, FuE, . . .)? Sind diese auch in der Region?
  - Wann wurde ihre Firma gegründet? (Gesamte Firma sowie an diesem Standort im Oldenburger Münsterland, ist der Sitz innerhalb der Region verlegt worden?) Ggf. seit wann ist es Teil der Unternehmensgruppe?
  - Bitte beschreiben Sie ihre Hauptprodukte/Hauptdienstleistungen.
  - Wie viele Mitarbeiter arbeiten in ihrer Firma an diesem Standort? (Vollzeitäquivalent, heute, vor drei und vor zehn Jahren)
  - Wie hoch ist in etwa der Anteil von Mitarbeitern mit Universitäts- oder Fachhochschulabschluss?
  - Woher rekrutieren Sie Ihre Mitarbeiter, insbesondere die qualifizierten? (lokal/regional, national, international) Spielen bestimmte Ausbildungseinrichtungen oder Hochschulen eine besondere Rolle? Abwerbung von anderen Unternehmen?
  - Auf welchen geographischen Märkten hat ihre Firma in den letzten drei Jahren verkauft? (Lokal/Regional, National, Europa, Global) Wie sah die Situation vor zehn Jahren aus?
  - Ist Ihr Unternehmen in irgendeiner Weise involviert in irgendeinen Industrieverband/Clusterorganisation auf der regionalen Ebene? Wenn ja, in welche?

- Wie würden Sie die Geschichte ihrer Firma beschreiben? Welche Ereignisse in der Vergangenheit haben zu ihrem jetzigen Zustand geführt?
  - Phasen des Wachstums / Schrumpfens / technologischer, organisatorischer oder marktlicher Umorientierung
  - Einschneidende Ereignisse, wichtige Schlüsselpersonen (endogen oder exogene Faktoren)
  - Elementare technologische Veränderungen, neue Gesetze, veränderte Nachfrage, Globalisierung, neue Konkurrenz, Veränderungen in der regionalen Infrastruktur, Referenz- / Leuchtturmprojekte, etc.
  - Regionale Faktoren, die in der Entwicklung ihrer Firma eine Rolle gespielt haben (Fachkräfte, Hochschulen / FuE-Einrichtungen, regionale Nachfrage, andere Firmen in der Region (Kunden, Zulieferer, Konkurrenten, Kooperationspartner), Gesetze, regionale Investoren, Regionalpolitik, Netzwerke, weitere Faktoren). Wie hat sich die Bedeutung dieser Faktoren über die Zeit verändert?

  - Nationale / Internationale Faktoren, die in der Entwicklung ihrer Firma eine Rolle gespielt haben
  - Relative Bedeutung von regionalen vs. Nationalen / Internationalen Faktoren (welche Einzelfaktoren waren die bedeutendsten?)

C Innovationen und Fähigkeiten

- Hat Ihr Betrieb in den letzten ein / drei / zehn Jahren ein von Ihnen bereits vorher angebotenes Produkt / Prozess / Leistung verbessert oder weiterentwickelt? Welche?
- Hat Ihr Betrieb in den letzten ein/drei/zehn Jahren ein Produkt oder eine Leistung, das bereits vorher auf dem Markt vorhanden war, neu in ihr Angebot aufgenommen? Welche? Wann genau?
- Hat Ihr Betrieb in den letzten ein / drei / zehn Jahren ein völlig neues Produkt oder eine völlig neue Leistung, für das ein neuer Markt geschaffen werden muss, neu in ihr Angebot aufgenommen? Welche? Wann genau?
- Wo (Standort) werden diese Innovationen entwickelt?
- Beschreiben Sie bitte die Kernkompetenzen ihrer Firma und ihrer Mitarbeiter in Bezug auf die Entwicklung neuer Produkte / Prozesse / Dienstleistungen (z.B. Anteil akademischen Personals, bestimmte wissenschaftliche Wissensbasen, bestimmte handwerkliche Fähigkeiten, Kreativität/Design). Wie hat sich dies über die Zeit verändert?
- Auf welche Weise entwickeln Sie innovative Produkte / Leistungen? (gerichtete eigene FuE, ungerichtete zufällige Entwicklung (Learning by Doing) Kooperation mit anderen Akteuren (Unis, Firmen), Imitation von Konkurrenten).
- Wo (Standort) werden Innovationen entwickelt?

D Mit wem tauschen Sie Wissen aus, das für ihre Innovationsaktivitäten relevant ist (sowohl erhalten als auch weitergeben von Wissen)?

- Name bedeutender Partner
- Art des Partners
- Rolle von Bauern
- Lokation des Partners
- Aktivitäten und Kompetenzen des Partners
- Zeitraum der Kooperation
- Veränderung der Partner über die Zeit (Intensität, geographischer Rahmen)
- Wie ist der Kontakt zustande gekommen?

- Welche Faktoren haben bei dem Zustandekommen der Kooperation eine entscheidende Rolle gespielt? (räumliche Nähe / Ferne, technologische Nähe / Ferne, ...)
- Welche sind ihre wichtigsten Zulieferer von Produkten und Dienstleistungen? Wo sind diese angesiedelt? In der Region?
- Welche sind ihre wichtigsten Kunden / Kundengruppen für Ihre Produkte und Dienstleistungen in den letzten drei Jahren? Welche waren es vor zehn Jahren?

E Wie würden Sie Geschichte der agrartechnischen Industrie in der Region beschreiben und welche Ereignisse in der Vergangenheit haben zu der gegenwärtigen Situation geführt?

- Phasen des Wachstums / Schrumpfens / technologischer, organisatorischer oder marktlicher Umorientierung
- Einschneidende Ereignisse, wichtige Schlüsselpersonen (endogen oder exogene Faktoren)
- Elementare technologische Veränderungen, neue Gesetze, veränderte Nachfrage, Globalisierung, neue Konkurrenz, Veränderungen in der regionalen Infrastruktur, Referenz- / Leuchtturmprojekte, etc.
- Regionale Faktoren, die in der Entwicklung ihrer Firma eine Rolle gespielt haben (Fachkräfte, Hochschulen / FuE-Einrichtungen, regionale Nachfrage, andere Firmen in der Region (Kunden, Zulieferer, Konkurrenten, Kooperationspartner), Gesetze, regionale Investoren, Regionalpolitik, Netzwerke, weitere Faktoren). Wie hat sich die Bedeutung dieser Faktoren über die Zeit verändert?
- Nationale / Internationale Faktoren, die in der Entwicklung ihrer Firma eine Rolle gespielt haben
- Relative Bedeutung von regionalen vs. Nationalen/Internationalen Faktoren (welche Einzelfaktoren waren die bedeutendsten?)

F Finanzierung und Geschäftsmodell des unternehmerischen Projekts

- Wie finanzieren Sie ihre Innovations- und Investitionsprojekte? (traditionelle Bank Investments / Kredite, öffentliche Fördergelder, Investitionen im Rahmen eines multinationalen Unternehmens, die Veräußerung neuer Anleihen auf dem Aktienmarkt oder auch ohne) Wie hat sich dies über die Zeit verändert?
- Beschreiben Sie ihr Geschäftsmodell? Womit verdienen Sie ihr Geld? (Verkauf von Produkten, Verkauf von Lizenzen, Verkauf des Unternehmens an eine größere Firma, Sponsoring) Wie hat sich das über die Zeit Verändert?

- Wer investiert in ihre Projekte (Produkt, Technologie, Marktkonzept)? Wo sind die Investoren lokalisiert (Hauptsitz)?

G Einfluss von Politik und Regulierungen

- Welche Ihrer Aktivitäten werden (in Vergangenheit, Gegenwart und Zukunft) entscheidend durch öffentliche Intervenierung beeinträchtigt? (Networking, Förderung, Gesetze (Umwelt-, Arbeitsrecht, etc.), technische Genehmigung, Zulassungsregelungen, Normen, etc.)
- Welchen Effekt haben (in Vergangenheit, Gegenwart und Zukunft) diese öffentlichen Intervenierungen auf die Entwicklung und die ökonomische Verwertung in ihrer Firma und wie hat sich dies über die Zeit verändert?

H OPTIONAL!!! (nur, wenn zuvor nicht angesprochen)

- Welches waren die Hauptgründe für Ihre Firma sich in der Region Oldenburger Münsterland anzusiedeln?
  - Persönliche Gründe des Unternehmers und persönliche Beziehungen
  - Verfügbarkeit von Fachkräften
  - Kooperationspartner in der Region (Zulieferer, Kunden, etc.)
  - Universitäten und Forschungseinrichtungen in der Region
  - Unterstützende regionale Wirtschaftspolitik
  - Regionale Nachfrage
  - Soziale Normen und Werte in der Region (institutionelle Dimension)
  - Infrastruktur und andere regionale Vorzüge
- Welches sind die Gründe, warum Sie in der Region verbleiben?
  - Siehe oben

I Zukunftsaussichten und Erwartungen

- Welche Erwartungen für die Zukunft haben Sie bezüglich der Entwicklung Ihrer Firma und die wirtschaftliche Entwicklung der Industrie in der Region?
  - Phasen Wachstum/Stagnation/Schrumpfen/Transformation
  - Grundlegende Herausforderungen (endogene und exogene Faktoren) und ist Ihre Firma/die regionale Industrie gut für diese Herausforderungen gerüstet?
  - Welche notwendigen politischen Maßnahmen sind Ihrer Meinung nach notwendig, um kontinuierliches Wachstum zu garantieren?

Additional material for use in interviews

Bogen 1: FuE-Kooperationen

Seite:

Datum: ______________________________

Firma: ______________________________

Interviewpartner: ______________________________

Kooperationspartner	Ort	innovationsrelevante Kompetenzen des Partners	Wie ist die Koop zustande gekommen?	Zeitraum der Kooperation	Technologische Orientierung im Vergleich mit ihrem Unternehmen	Verhältnis zu ihrer Firma			
						Zulieferer	Kunde	Mitbewerber	Sonstiges
					☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	☐	☐	☐	☐ :
					☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	☐	☐	☐	☐ :
					☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	☐	☐	☐	☐ :
					☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	☐	☐	☐	☐ :
					☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	☐	☐	☐	☐ :
					☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	☐	☐	☐	☐ :
					☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	☐	☐	☐	☐ :

Bogen 2: Wirtschaftlich-Technologische Ausrichtung
Datum: ________________
Firma: ________________
Interviewpartner: ________________

Welcher technologisch-thematischen Ausrichtung gehören oder gehörten die Produkte/Leistungen an, die Ihr Unternehmen vermarktet?

Bitte kreuzen Sie alles an, was in der Gegenwart oder der Vergangenheit für ihr Unternehmen zutrifft und geben Sie den Zeitraum an:

Industrie / Handwerk

	Wirtschaftlich-Technische Ausrichtung	Zeitraum
	Herstellung von Produktionsgütern	
☐	Maschinen für den Einsatz auf dem Feld (Fahrzeuge)	
☐	Maschinen für den Einsatz auf dem Feld (sonstiges:)	
☐	Maschinen für den Einsatz in der Tierhaltung (Fütterung/Tränkung)	
☐	Maschinen für den Einsatz in der Tierhaltung (Fördertechnik)	
☐	Maschinen für den Einsatz in der Tierhaltung (Stallklima)	
☐	Maschinen für den Einsatz in der Tierhaltung (Hygiene)	
☐	Maschinen für den Einsatz in der Tierhaltung (sonstiges:)	
☐	Maschinen für den Einsatz in der Lebensmittelverarbeitung	
☐	Maschinen für den Einsatz in Biogasanlagen	
☐	Maschinen für den Einsatz in anderen Industrien	
☐	Stallmöblierung (ohne Maschinen)	
☐	Robotik/Sensorik	
☐	Software für den Einsatz in der Landwirtschaft	
☐	Dünger/Pflanzenschutzmittel	
☐	Tierfutter	
☐	Tiermedikamente	
☐	Fahrzeugbau (ohne Feldfahrzeuge, wie Traktoren, Erntemaschinen, ...)	

☐	Bau und Konzeptionierung von Biogasanlagen	
☐	Bau und Konzeptionierung von weiteren landwirtschaftlichen Anlagen	
☐	Sonstige:	
	Wirtschaftlich-Technische Ausrichtung	**Zeitraum**
	Weitere Industriefelder	
☐	Lebensmittel- und Getränkeindustrie	
☐	Konsumgüterindustrie	
☐	Holzindustrie	
☐	Papierindustrie	
☐	Metallindustrie	
☐	Kunststoffindustrie	
☐	Betonindustrie	
☐	Sonstige :	

Nicht industrielle/handwerkliche Branchen

	Wirtschaftlich-Technische Ausrichtung	**Zeitraum**
	Landwirtschaft und landwirtschaftsbezogene Dienstleistungen	
☐	Landwirtschaft (Pflanzenproduktion)	
☐	Landwirtschaft (Tierhaltung)	
☐	Betrieb von Biogasanlagen	
☐	Veterinärwesen (tierärztliche Leistung)	
☐	Großhandel mit landwirtschaftlichen Geräten	
☐	Vermietung von landwirtschaftlichen Geräten	
☐	Lohnunternehmertum	
☐	Sonstige:	

Bogen 3: Marktsegment / Produktionskette
Datum: ________________
Firma: ________________
Interviewpartner: ________________

Für welches dieser Marktsegmente/für welche Produktionskette produzieren oder produzierten Sie Güter?

Bitte kreuzen Sie alles an, was in der Gegenwart oder der Vergangenheit für ihr Unternehmen zutrifft und geben Sie den Zeitraum an:

	Marktsegment	Zeitraum
	Tiere	
☐	Schwein	
☐	Rind	
☐	Huhn (Mast)	
☐	Huhn (Ei)	
☐	Pute	
☐	Ente	
☐	Fisch	
☐	sonstige Tierarten:	

	Marktsegment	Zeitraum
	Pflanzen	
☐	Getreide (ohne Mais und Reis)	
☐	Mais	
☐	Ölfrüchte	
☐	Kartoffeln/Rüben	
☐	Kohl	
☐	Salat	
☐	Beerenfrüchte	
☐	sonstiges Obst/Gemüse (Feld)	
☐	sonstiges Obst/Gemüse (Bäume/Sträucher)	
☐	sonstiges Obst/Gemüse (Gewächshaus)	
☐	sonstige Pflanzenarten:	

Bogen 4: Mitbewerber

Seite:

Datum: ____________________________

Firma: ____________________________

Interviewpartner: ____________________________

Eigene Firma		**Konkreter Ort / Land**		**Bedeutung auf dem gemeinsamen Markt**
Eigene Firma				☐ am wichtigsten ☐ sehr wichtig ☐ wichtig ☐ mittel ☐ kaum wichtig ☐ unwichtig

Mitbewerber	**Regionale Einordnung**	**Konkreter Ort / Land**	**Technologische Orientierung im Vergleich mit ihrem Unternehmen**	**Bedeutung auf dem gemeinsamen Markt**
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	☐ am wichtigsten ☐ sehr wichtig ☐ wichtig ☐ mittel ☐ kaum wichtig ☐ unwichtig
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	☐ am wichtigsten ☐ sehr wichtig ☐ wichtig ☐ mittel ☐ kaum wichtig ☐ unwichtig

Mitbewerber	Regionale Einordnung	Konkreter Ort / Land	Technologische Orientierung im Vergleich mit ihrem Unternehmen	Bedeutung auf dem gemeinsamen Markt
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	☐ am wichtigsten ☐ sehr wichtig ☐ wichtig ☐ mittel ☐ kaum wichtig ☐ unwichtig
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	☐ am wichtigsten ☐ sehr wichtig ☐ wichtig ☐ mittel ☐ kaum wichtig ☐ unwichtig
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	☐ am wichtigsten ☐ sehr wichtig ☐ wichtig ☐ mittel ☐ kaum wichtig ☐ unwichtig
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	☐ am wichtigsten ☐ sehr wichtig ☐ wichtig ☐ mittel ☐ kaum wichtig ☐ unwichtig

Bogen 5: Zulieferer

Seite:

Datum: ______________________________

Firma: ______________________________

Interviewpartner: ______________________________

Zulieferer	Regionale Einordnung	Konkreter Ort / Land	Technologische Orientierung im Vergleich mit ihrem Unternehmen	Branche
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	

Bogen 6: Kunden

Seite:

Datum: ______________________________
Firma: ______________________________
Interviewpartner: ______________________________

Kunde	Regionale Einordnung	Konkreter Ort / Land	Technologische Orientierung im Vergleich mit ihrem Unternehmen	Branche
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	
	☐ in der Region ☐ restl. Deutschland ☐ restl. EU / EFTA ☐ restl. Welt		☐ fast gleich ☐ ähnlich, aber nicht gleich ☐ überwiegend unterschiedlich ☐ völlig unterschiedlich	

Main set of interviews of 2013 – industry experts

Interview manual

Note Used for interviews T01 and IE01–IE03.

Der Zweck der Befragung ist die Analyse der Entwicklung (Entstehung, Schrumpfung, Transformation, etc.) der agrartechnischen Industrie im Oldenburger Münsterland und angrenzenden Gemeinden. Alle erhobenen Informationen werden selbstverständlich vertraulich behandelt und es wird für niemanden möglich sein, in späteren Veröffentlichungen sowie in weiteren Interviews Ihre Firma oder Sie persönlich zu identifizieren.

A Grundlegende Infos

- Name der Organisation.
- Adresse der Organisation.
- Name des Ansprechpartners.
- Funktion/Stellung des Ansprechpartners im Unternehmen.
- Anzahl der Jahre des Ansprechpartners in der Organisation.

B Allgemeine Angaben zur eigenen Organisation

- Welchen Bezug hat Ihre Organisation zur agrartechnischen Branche (Maschinenbau mit Landwirtschaftsbezug und verwandte Bereiche) allgemein? (technische Entwicklung, Begleitforschung, Clusterorganisation, etc.)
- Welchen Bezug hat Ihre Organisation zur agrartechnischen Branche (Maschinenbau mit Landwirtschaftsbezug und verwandte Bereiche) in der Region Oldenburger Münsterland? (Clusterorganisation, Netzwerk, politischer Entscheidungsträger, Hochschule) Welche Rolle spielen Unternehmen der Agrartechnik der Region für Ihre Arbeitsroutinen und Aufträge?
- Welchen räumlichen Bezugsrahmen hat die Arbeit ihrer Organisation? Welche Bedeutung hat der regionale Bezugsrahmen?
- Wann wurde ihre Organisation gegründet? Seit wann besteht ein thematischer Zusammenhang ihrer Organisation mit der Agrartechnischen Branche (in der Region)?
- Bitte beschreiben Sie die Hauptaufgaben ihrer Organisation.
- (Ist Ihre Organisation in irgendeiner Weise involviert in irgendeinem Industrieverband/Clusterorganisation auf der regionalen Ebene? Wenn ja, in welche?)

C Wie würden Sie die Geschichte ihrer Organisation(-seinheit) beschreiben? Welche Ereignisse in der Vergangenheit haben zu ihrem jetzigen Zustand geführt?

- Aus welchem Grund ist Ihre Organisation entstanden?
- Phasen des Wachstums / Schrumpfens / technologischer, thematischer Umorientierung, Bedeutungszu- und abnahme
- Einschneidende Ereignisse, wichtige Schlüsselpersonen (endogen oder exogene Faktoren)
- Faktoren aus der Industrie: Elementare technologische Veränderungen, neue Gesetze, veränderte Nachfrage, Globalisierung, neue Konkurrenz, Veränderungen in der regionalen Infrastruktur, Referenz-/Leuchtturmprojekte, etc.
- Regionale Faktoren, die in der Entwicklung ihrer Organisation eine Rolle gespielt haben (Fachkräfte, Hochschulen/FuE-Einrichtungen, regionale Nachfrage, andere Firmen in der Region (Kunden, Zulieferer, Konkurrenten, Kooperationspartner), Gesetze, regionale Investoren, Regionalpolitik, Netzwerke, weitere Faktoren). Wie hat sich die Bedeutung dieser Faktoren über die Zeit verändert?
- Nationale/Internationale Faktoren, die in der Entwicklung ihrer Organisation eine Rolle gespielt haben
- Relative Bedeutung von regionalen vs. Nationalen/Internationalen Faktoren (welche Einzelfaktoren waren die bedeutendsten?)

D Wie würden Sie Geschichte der agrartechnischen Branche in der Region beschreiben? Welche Ereignisse in der Vergangenheit haben zu der gegenwärtigen Situation geführt?

- Phasen des Wachstums / Schrumpfens / technologischer, organisatorischer oder marktlicher Umorientierung
- Einschneidende Ereignisse, wichtige Schlüsselpersonen (endogen oder exogene Faktoren)
- Elementare technologische Veränderungen, neue Gesetze, veränderte Nachfrage, Globalisierung, neue Konkurrenz, Veränderungen in der regionalen Infrastruktur, Referenz-/Leuchtturmprojekte, etc.
- Regionale Faktoren, die in der Entwicklung ihrer Firma eine Rolle gespielt haben (Fachkräfte, Hochschulen / FuE-Einrichtungen, regionale Nachfrage, andere Firmen in der Region (Kunden, Zulieferer, Konkurrenten, Kooperationspartner), Gesetze, regionale Investoren, Regionalpolitik, Netzwerke, weitere Faktoren). Wie hat sich die Bedeutung dieser Faktoren über die Zeit verändert?
- Nationale / Internationale Faktoren, die in der Entwicklung ihrer Firma eine Rolle gespielt haben

- Relative Bedeutung von regionalen vs. Nationalen / Internationalen Faktoren (welche Einzelfaktoren waren die bedeutendsten?)
- Welches sind die Stärken und Schwächen der agrartechnischen Branche in der Region? Wie hat sich dies über die Zeit hinweg verändert (letzten 15 Jahre)?

E Innovationen und Fähigkeiten

- Ist Ihre Organisation in irgendeiner Form an der Generierung von Innovationen in der agrartechnischen Industrie oder anderen Industrien beteiligt?
- Wo werden diese Innovationen entwickelt?
- Ist Ihre Organisation an der Vermittlung von Kontakten zum Zwecke der Innovationsgenerierung in der Branche beteiligt?
- Beschreiben Sie bitte ihr/en/e neuste/s/en innovatives Produkt / Prozess / Dienstleistung, die Ihre Organisation (mit-)entwickelt hat, sowie Innovationen der Vergangenheit. Sind diese Innovationen ganz neu, neu für den eigenen Markt oder neu für die Organisation/beteiligte Firma?
- Beschreiben Sie bitte die Kernkompetenzen ihrer Organisation und ihrer Mitarbeiter in Bezug auf die Entwicklung neuer Produkte / Prozesse / Dienstleistungen (z.B. Anteil akademischen Personals, bestimmte wissenschaftliche Wissensbasen, bestimmte handwerkliche Fähigkeiten, Kreativität/Design). Wie hat sich dies über die Zeit verändert?
- Auf welche Weise entwickeln Sie innovative Produkte / Leistungen? (gerichtete eigene FuE, Ungerichtete zufällige Entwicklung (Learning by Doing) Kooperation mit anderen Akteuren (Unis, Firmen), Imitation von Konkurrenten).

F Mit wem tauschen Sie Wissen aus, das für ihre Innovationsaktivitäten relevant ist (sowohl erhalten als auch weitergeben von Wissen)?

- Name bedeutender Partner
- Art des Partners
- Rolle von Bauern
- Lokation des Partners
- Aktivitäten und Kompetenzen des Partners
- Zeitraum der Kooperation
- Veränderung der Partner über die Zeit (Intensität, geographischer Rahmen)
- Wie ist der Kontakt zustande gekommen?
- Welche Faktoren haben bei dem Zustandekommen der Kooperation eine entscheidende Rolle gespielt? (räumliche Nähe/Ferne, technologische Nähe/Ferne, ...)

G Finanzierung und Geschäftsmodell des unternehmerischen Projekts

- Wie finanzieren Sie ihre Innovations- und Investitionsprojekte? (traditionelle Bank Investments / Kredite, öffentliche Fördergelder, Investitionen im Rahmen eines multinationalen Unternehmens, die Veräußerung neuer Anleihen auf dem Aktienmarkt oder auch ohne) Wie hat sich dies über die Zeit verändert?
- Beschreiben Sie ihr Geschäftsmodell. Womit verdienen Sie ihr Geld? (Verkauf von Produkten, Verkauf von Lizenzen, Verkauf des Unternehmens an eine größere Firma, Sponsoring) Wie hat sich das über die Zeit Verändert?
- Wer investiert in ihre Projekte (Produkt, Technologie, Marktkonzept)? Wo sind die Investoren lokalisiert (Hauptsitz)?

H Einfluss von Politik und Regulierungen

- Welche Ihrer Aktivitäten werden (in Vergangenheit, Gegenwart und Zukunft) entscheidend durch öffentliche Intervenierung beeinträchtigt? (Networking, Förderung, Gesetze (Umwelt-, Arbeitsrecht, etc.), technische Genehmigung, Zulassungsregelungen, Normen, etc.)
- Welchen Effekt haben (in Vergangenheit, Gegenwart und Zukunft) diese öffentlichen Intervenierungen auf die Entwicklung und die ökonomische Verwertung in ihrer Firma und wie hat sich dies über die Zeit verändert?

I OPTIONAL!!! (nur, wenn zuvor nicht angesprochen)

- Welches waren die Hauptgründe für Ihre Organisation sich in der Region Oldenburger Münsterland anzusiedeln?
  - Persönliche Gründe des Unternehmers und persönliche Beziehungen
  - Verfügbarkeit von Fachkräften
  - Kooperationspartner in der Region (Zulieferer, Kunden, etc.)
  - Universitäten und Forschungseinrichtungen in der Region
  - Unterstützende regionale Wirtschaftspolitik
  - Bedarfe der Unternehmen
  - Politische Agenda
  - Regionale Nachfrage
  - Soziale Normen und Werte in der Region (institutionelle Dimension)
  - Infrastruktur und andere regionale Vorzüge
- Welches sind die Gründe, warum Sie in der Region verbleiben?
  - Siehe oben

J Zukunftsaussichten und Erwartungen

- Welche Erwartungen für die Zukunft haben Sie bezüglich der Entwicklung Ihrer Organisation und die wirtschaftliche Entwicklung der Industrie in der Region?
  - Wachstum / Stagnation / Schrumpfen / Transformation
  - Grundlegende Herausforderungen (endogene und exogene Faktoren) und ist Ihre Organisation / die regionale Industrie gut für diese Herausforderungen gerüstet?
  - Welche notwendigen politischen Maßnahmen sind Ihrer Meinung nach notwendig, um kontinuierliches Wachstum zu garantieren?

Additional interviews with biogas agents of 2015

Interview manual

Note Used for interviews B02–B04.

- Grundlegende Infos
  - Name der Organisation.
  - Adresse der Organisation.
  - Name des Ansprechpartners.
  - Funktion/Stellung des Ansprechpartners im Unternehmen.
  - Anzahl der Jahre des Ansprechpartners in der Organisation.
- Bitte beschreiben Sie kurz Ihre Firma/Organisation
  - Standort?
  - Wann gegründet?
  - Was ist die Aufgabe/das Geschäftsfeld Ihrer Organisation?
- Bitte beschreiben Sie die historische Entwicklung der Biogastechnologie, bitte haben Sie bei Ihren Erklärungen einen besonderen Fokus auf die Zeit vor dem EEG.
- Bitte immer angeben: wo (Region in Deutschland oder anderes Land), Welche Faktoren haben eine Rolle gespielt?
  - Wann und wo (Region oder Land)hat die Entwicklung eingesetzt?
  - Gab es eine Tüftlerphase (experimental stage)?
  - Wann sind die ersten Firmen gegründet worden?

- Wann sind entscheidende Erfindungen gemacht worden? Wer war das?
- Wann sind erste Produkte auf den Markt gebracht worden?
- Wann sind in der Technologie Standardisierungsprozesse eingetreten?
- Wie hat das Wachstum der Branche vor dem EEG ausgesehen?
- Gab es weitere wichtige Ereignisse in der Entwicklung?
- Gab es Entwicklungspfade, die wieder aufgegeben wurden und sich nicht durchsetzen konnten?
- Welchen professionellen Hintergrund hatten die Pioniere?
- Welche Rolle haben Universitäten und Forschungseinrichtungen gespielt?
- Welche Rolle haben politische Entscheidungen und gesamtgesellschaftliche Entwicklungen gespielt?
- Wann hat die Kommerzialisierung des Technologiefeldes eingesetzt? Haben die Akteure sich in dieser Phase professionelles Wissen jenseits der eigenen technologischen Fähigkeiten angeeignet?
- Welche Personen/Organisationen/Firmen waren entscheidend?
- Sind Technologie und Wissen aus anderen Branchen und Anwendungsfeldern in die Entwicklung der Biogastechnologie eingeflossen? Wann? Woher kam das Wissen (Ort, Branche, ...)?
- Sind Firmen aus anderen Branchen in das Feld eingestiegen? Wann? Welche Firmen und aus welcher Branche?

- Bitte beschreiben Sie die Entwicklung der Branche seit dem EEG
  - Welche Rolle hat das EEG und seine Novellen gespielt?
  - Gab es in dieser Phase andere Faktoren, die eine Rolle gespielt haben?
  - Wie hat sich die Branche entwickelt?
  - Insbesondere: Wie ist die derzeitige Lage seit der Novelle 2014?
  - Welche Unternehmen sind oder waren die bedeutendsten auf dem Markt? Aus Deutschland? Aus anderen Ländern?
  - Gab es technologische Pfade, Formen, Geschäftsmodelle, die sich nicht durchsetzen konnten? Warum? Wann?

Erklärung

Ich erkläre hiermit, dass diese Arbeit ohne unerlaubte Hilfsmittel angefertigt wurde und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt wurden.

Ich erkläre ferner, dass die den benutzten Werken wörtlich und inhaltlich entnommenen Stellen als solche kenntlich gemacht wurden.

Eine Überprüfung der Dissertation mit qualifizierter Software im Rahmen der Untersuchung von Plagiatsvorwürfen ist gestattet.

Bremen, den 13.09.2017

Dominik Santner