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Cleantech industry dynamics and regional context

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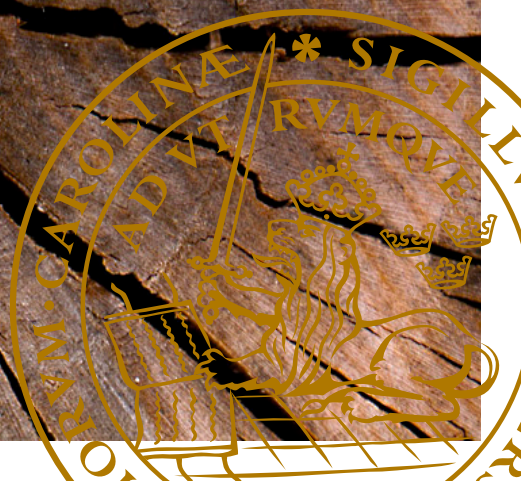
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The background of the entire slide is a close-up photograph of a tree trunk's cross-section, showing the natural grain and radial cracks of the wood in shades of brown and tan.

Innovation for tackling grand challenges

Cleantech industry dynamics and regional context

HANNA MARTIN | FACULTY OF SOCIAL SCIENCES | LUND UNIVERSITY



MEDDELANDEN FRÅN INSTITUTIONEN FÖR KULTURGEOGRAFI OCH EKONOMISK GEOGRAFI

AVHANDLINGAR XIII

Innovation for tackling grand challenges

Cleantech industry dynamics and regional context

Hanna Martin



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Abstract

Grand challenges such as climate change put focus away from innovations and innovation policy as engines of economic growth towards fulfilling societal goals and sighting sustainable development. The literature on the geography of innovation has provided valuable insight on innovation activities of firms and industries and how they are positively influenced by co-location. In particular, short geographical distances have been found to facilitate trust, knowledge exchange and interactive learning processes that favour innovation. Innovation activities that address grand challenges have however gained surprisingly little attention in the discipline. This PhD thesis addresses this shortcoming and studies how and why change processes of industries towards more environmentally friendly modes in regions occur – or not. In other words, it engages in the question how such industry dynamics are enabled and/or constrained by regional context conditions. Consequently, it also puts central focus on the role respectively possibilities and limitations of regional innovation policy to support desirable transformation processes.

The development of a bio-economy which draws on renewable resources from biomass possesses a key role in addressing grand challenges. Particularly, as biomass currently constitutes the only renewable resource for the production of liquid fuels and for materials such as plastics and chemicals. The dissertation engages in the possibilities and limitations of regions and their industries to realize shifts towards a bio-economy. Its theoretical objective is to contribute to a more coherent conceptual framework in the literature on economic geography regarding how to address grand challenges. The dissertation takes a regional innovation system perspective which considers economic and social interactions of actors from industry, academia and government as crucial for innovation to occur. This view is complemented by insights from the literature on socio-technical transitions which provides a co-evolutionary perspective on technologies and institutions. The findings suggest that in order to address grand challenges, regional innovation systems should be understood as being embedded into broader socio-technical systems. In other words, overall societal and economic developments impact activities of actors and actor groups in a regional innovation system. They can, on the one hand, reinforce ongoing (path-dependent) activities, while they, on the other hand, also can constitute triggers/origins for (radical) innovations. RIS can provide favourable settings for transformative, niche innovations to come about – for their further establishment however, the creation of so-called socio-technical alignments is crucial. These imply overall altered production and consumption patterns and co-evolving changes in technologies, infrastructures, regulatory frameworks and other societal dimensions, for example lifestyles. These

insights lead to a new perspective on regional innovation policy and its role to create such alignments, both within and across regional boundaries and spatial scales.

The research design is informed by a critical realist perspective, providing the ontological and epistemological basis for the conceptual advancement. The dissertation largely draws on qualitative research methods and studies industries in three different Swedish regions and their undertaking to increasingly, respectively more efficiently use biomass as raw material. In particular, the empirical focus is on the paper and pulp industry in the region around Örnköldsvik, the biogas industry in Scania and the chemicals industry in the Stenungsund-Gothenburg region.

This dissertation spans four articles that are published in or that are submitted to different, peer-reviewed journals. The articles are preceded by an introductory chapter which provides the overall theoretical background and framing, the research design and central findings of the dissertation.

Keywords: economic geography, regional innovation systems, regional innovation policy, regional path development, innovation system failures, socio-technical transitions, grand challenges, cleantech, transformative change, Sweden

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List of Publications

This dissertation includes four academic articles:

- I. Coenen, Lars, Jerker Moodysson and **Hanna Martin** (2015) Path Renewal in Old Industrial Regions: Possibilities and Limitations for Regional Innovation Policy. *Regional Studies* 49(5): 850-865.
- II. **Martin, Hanna** and Lars Coenen (2015) Institutional Context and Cluster Emergence: The Biogas Industry in Southern Sweden. *European Planning Studies* 23(10): 2009-2027.
- III. **Martin, Hanna** and Roman Martin (2016) Policy Capacities for New Regional Industrial Path Development – The case of New Media and Biogas in Southern Sweden. *Environment and Planning C*, Epub ahead of print 31 August 2016. DOI: 10.1177/0263774X16665845.
- IV. **Martin, Hanna**. Regional innovation systems and transformative change: The case of the chemicals industry in West Sweden (manuscript, submitted to a journal)

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List of acronyms

Cleantech	Clean technology
EEG	Evolutionary economic geography
EU	European Union
FORMAS	Swedish Research Council for Environment, Agricultural Science and Spatial Planning
MLP	Multi-level perspective
OECD	Organisation for Economic Co-operation and Development
RIP	Regional innovation policy
RIS	Regional innovation system
SIS	Sectorial innovation system
STT	Socio-technical transitions
STS	Socio-technical systems
TIS	Technological innovation system
VINNOVA	Swedish Governmental Agency for Innovation Systems

Preface

This dissertation/PhD thesis consists of four articles/papers that are published in or that are submitted to different, peer-reviewed journals. They are preceded by a general introduction (in Swedish termed 'kappa'; chapters 1-4) which provides the overall frame of the dissertation. In particular, the kappa introduces the overall aim, contribution and research questions addressed. Moreover, it provides a discussion of the theoretical framework and presents the research design of the thesis including the ontological, epistemological, methodological perspective, research methods applied and the research setting chosen. The kappa terminates with a concluding section which summarizes the central findings of the papers with regard to the main aims and research questions addressed in the thesis and the conclusions that can be drawn. The four articles and the kappa have been written in a period of three years between February 2012 and October 2016, interrupted by more than one year of parental leave. The articles are listed in the order they have been written.

1 Introduction

Since the United Nations Earth Summit in Rio de Janeiro in June 1992, the world community has committed itself to sight and target sustainable development. Challenges associated with achieving sustainable development have more recently been termed as so-called grand challenges, which include various themes such as climate change, health as well as water and food security. Grand challenges have in common that they constitute highly complex, persistent societal problems, and that they put new requirements on policy away from an engine of economic growth towards fulfilling societal goals. Consequently, grand challenges have increasingly become core on the agenda of policymaking (OECD, 2010; European Commission, 2013) and spark new questions regarding the role of the state in the economy (Mazzucato, 2013, 2015).

In light of grand challenges, concerns related to climate change, peak oil and pollution have in the recent past led to an increased awareness of the environmental impact of our economic activities. More and more, the need is communicated to transform our economy from one that runs on fossil towards one that draws on renewable resources. Becoming independent of non-renewable sources of energy and materials such as coal and oil makes it necessary to draw on a greater number of different renewables. Sustainable energy can be produced in many different ways, for example by wind, solar or waterpower. Biomass is however currently the only renewable resource for the production of liquid fuels and for materials such as plastics and chemicals (Sandén and Hedenus, 2012). The development towards a bio-based economy (or bio-economy) possesses therefore a key role in addressing grand challenges (Ollikainen, 2014; Bugge et al., 2016). The term bio-economy is usually associated with the use of biomass resources from both land and sea in order to cope with climate change and the (predicted) scarcity of fossil resources (OECD, 2009; European Commission, 2014). Although the transformation towards a bio-economy is an extensive global challenge, its actual realization depends on action and change (in the context of this thesis: innovation) at particular local places. Empirically, this dissertation engages in the possibilities and limitations of local places (in the context of this thesis: regions) to realize such shift towards a bio-economy. More particularly, it studies the transformation of regions and their industries towards increasingly bio-based modes.

The discipline of economic geography, and in particular the economic geography of innovation, has its central interest in researching the specific contexts in which innovations come about. Inspired by initial work on industrial districts (Marshall, 1920), economic geographers have since the early 20th century aimed at improving our

understanding why innovation activities are unevenly distributed across space. Especially regions have become an important geographical unit of study as they have been found to provide specific settings, resources and networks that favour innovation. For example, firms and industries have in their innovation activities shown to be positively influenced by co-location as short geographical distances facilitate personal, face-to-face contacts, the building of trust as well as networks and interactive learning processes among actors (Asheim and Gertler, 2005; Boschma, 2005). During the past decade, the economic geography of innovation has experienced an increasing interest in regional economic evolution. The question how innovations develop over time and relatedly, how and why regional industries emerge, grow, and decline have become central themes on the research agenda (Martin, 2010; Hassink, 2010; Boschma and Frenken, 2011a). Various types of industries have been studied and recently also policy approaches have been developed regarding how to support the build-up and renewal of industries (see e.g. Asheim et al., 2016a; Isaksen and Trippl, 2016a, 2016b; Moodysson et al., 2016; Morgan, 2016b).

When it comes to grand challenges, it seems however fair to state that this topic has traditionally not been core on the research agenda of economic geography and innovation studies (Aoyama et al., 2011; Martin, 2013; Coenen et al., 2015a). Addressing grand societal problems makes necessary broad system transformation that requires overall altered production and consumption patterns and which implies the need for co-evolving changes in technologies, infrastructures, regulatory frameworks and other societal dimensions, for example lifestyles (Geels, 2002; Borrás and Edler, 2014). Grand challenges in general and climate change in particular have been identified as a new normative and conceptual challenge by some scholars, admitting that established economic practices are crucial drivers of environmental change (Aoyama et al., 2011). Economic geography as it now stands has however surprisingly little to offer regarding how to conceptually address grand challenges, and consequently also with regard to providing policy approaches. Due to its inherent interest in how innovation activities come about in space and how they are shaped by economic and socio-cultural factors, the discipline should however be considered to possess potential to address these concerns.

Central interest of this dissertation is to study how and why change processes of industries in regions towards more environmentally friendly modes occur – or not. In the further course, these processes will shortly be termed as cleantech industry dynamics. On a conceptual level, the overall objective is to make a step towards a more coherent framework that allows addressing the possibilities and limitations of regions and regional industries to tackle grand challenges as well as to provide policy approaches how to support desirable processes. Thereby, it departs from the regional innovation

system (RIS) approach as main analytical framework (which will be more closely explained in the subsequent chapters). Empirically, the dissertation draws on qualitative case studies of industries in three different Swedish regions and studies their ambitions to increasingly, respectively more efficiently use biomass as raw material.

1.1 Thematic background

The question how and why regional industries emerge and grow respectively decline over time has only rather recently, during the past decade, entered the research agenda of economic geography. More precisely, the current interest in regional economic evolution and industrial transformation can be ascribed to the incorporation of ideas from evolutionary economics into the discipline. This research stream is usually termed as evolutionary economic geography (EEG) and is also described as the evolutionary turn (Boschma and Frenken, 2006; Boschma and Martin, 2010). EEG is in its core strongly influenced by the evolutionary theory of the firm (Nelson and Winter, 1982) and takes the micro-behavior of individuals and firms as unit of analysis. Firms are considered to compete on the basis on their routines (Teece et al., 1997) and consequently, EEG aims at understanding how routines are created by actors in their daily practices, how they are distributed across space, and how they evolve over time (Boschma and Frenken, 2006). In other words, EEG argues that knowledge accumulates at the firm level through the skills and learning processes of individuals working within them. As knowledge creation and innovation however do not occur in isolation within one single firm but rather take place in interactive learning processes, technological knowledge can be taken up by other firms and diffuse in the economy (Boschma and Martin, 2010; Boschma and Frenken, 2011b). Thereby, firms benefit from co-location through two different kinds of agglomeration economies: On the one hand, localisation economies emerge from the presence of firms from the same industry. These localisation economies provide access to knowledge that is core to the firm and which is shared easily and cost efficiently through co-location (MAR externalities) (Marshall, 1920; Arrow, 1962; Romer, 1986). On the other hand, urbanization economies emerge through the co-location of firms from different industries. Urbanization economies provide general access to knowledge and networks beyond the industry itself and are assumed to favour innovativeness (Jacobs externalities) (Jacobs, 1969). Particularly, EEG has brought to light that regions with a variety of technologically related sectors, usually referred to as related variety, possess higher growth rates than regions lacking such related variety (see e.g. Essletzbichler, 2007; Frenken et al., 2007; Boschma and Iammarino, 2009). As related variety affects the

extent of regional knowledge spillovers and thus the growth rates of regions, it is considered as a major source also for regional diversification over time: Due to specific routines accumulated at the firm-level, firms are expected to diversify over time into activities that are technologically related to their current competences (Boschma and Martin, 2010). This implies that industries are rather persistent in a region over time; but when they diversify, they slowly diversify into industries that are technologically related to their current industries. This evolutionary diversification of regional industries based on related variety is commonly referred to as regional branching (see e.g. Klepper, 2002; Boschma and Wenting, 2007; Boschma and Frenken, 2011b; Neffke et al., 2011).

According to EEG, pre-existing local economic and technological structures, knowledge and competences inherited from past patterns of development in the region form the environment in which new paths arise (Martin 2010), implying that new growth paths are “rooted in the historical economic structure of a region” (Neffke et al., 2011: 261). EEG has provided valuable insights regarding long-run economic trajectories of regions; or put differently, that history matters for regional economic evolution. This evolutionary approach is due to its overriding focus on firms as agents of change however not a meaningful approach as such to explain innovation activities addressing grand societal challenges.

Although grand challenges have not been core to the research agenda of economic geography, it would be wrong to assume that they have been completely ignored by the research community. Particularly, specificities of environmental innovation have received some concerted attention in the literature, mostly within the frame of the research stream of environmental economic geography (see e.g. Bridge, 2008; Hayter, 2008; Soyez and Schulz, 2008). Particular for environmental innovation is that it is different in the underlying drivers than conventional innovation: While conventional innovation is neutral regarding the actual content of change (Rennings, 2000), innovation targeting grand challenges is driven by normative issues and aims at solving an (urgent) societal problem. Environmental innovation in particular has its primary emphasis on energy and materials savings (van den Bergh et al., 2011). Therefore, it can be seen as innovation for doing things in an alternative, yet more environmentally friendly way compared to established solutions. This implies that the advancement of innovation lies in a reduction of environmental impact rather than the implementation of the innovation carries along direct benefit for its user (for example in form of quality improvement). Put differently, environmental innovation is challenged by an extensive (double) externality problem (Rennings, 2000): The development and diffusion of environmental innovation is desirable from a societal point of view as it implies a beneficial environmental impact – it however does not positively pay back in the private

costs of the polluter (i.e. firms). This results in low incentives for polluters both in the development and diffusion phase of innovation to invest in (costly) environmental innovation. Due to this problem of external (social) cost, environmental innovation in particular and grand challenges in general are associated with a strong policy notion, implying public policy efforts to regulate incentive structures (i.e. translating external costs into private costs).

Generally speaking, primary focus in contributions on environmental economic geography lies in addressing greening processes of industries. The argumentation follows in large parts ecological modernization and regulationist approaches (see e.g. Gibbs, 2000, 2006; Porter and van der Linde, 1995). These have the implementation of clean technologies at the heart of their agenda and assume that cleantech industries are (solely) shaped by stringent national and international regulations. Considering more broadly the field of regional studies, sustainability related questions have been addressed in contributions on industrial ecosystems (e.g. Chertow, 1998; Dunn and Steinemann, 1998) that also put technologies central in their analyses, yet by addressing the importance of proximity advantages and geographical co-location for achieving resource synergies and environmental effects (Truffer and Coenen, 2012). Moreover, contributions on sustainable regions (e.g. Haughton and Morgan, 2008) have addressed policy processes and governance experimentation for achieving sustainable regional consumption and production (Truffer and Coenen, 2012).

It goes beyond the scope of this dissertation to discuss the contributions of these research streams more in detail (for a detailed elaboration see Truffer and Coenen, 2012). Put in a nutshell and on the one hand, these contributions inaugurate attention to the topic of environmental innovation and provide to a certain extent insights regarding their spatial characteristics. On the other hand however, they lack an overall framework and have only a marginal conceptual interest in explaining regional economic evolution and transformation. These approaches are therefore only partly able to explain how, why and where technological change processes of industries towards more environmentally friendly modes occur – or not occur (Patchell and Hayter, 2013). The contributions have either a strong focus on technological determinism (i.e. assuming a linear understanding of technological dynamics that are regarded separately from social processes) while neglecting the importance of social processes and institutional change - or vice versa. Moreover, they have a dominant focus on regional production and consumption structures as well as policy experimentation while they lack a broader focus on the embedding into wider system transformation processes (Truffer and Coenen, 2012).

1.2 Aim, contribution and research questions

Although the grand societal challenge of climate change has been identified as a new normative and conceptual challenge for economic geography by some scholars (Aoyama et al., 2011; Martin, 2013, Coenen et al., 2015a), a co-evolutionary view with regard to how technologies, institutions and (ecological) sustainability concerns relate to one another does not yet exist (Angel, 2000; Truffer and Coenen, 2012). In this regard, economic geography has even been described as somewhat inertial when it comes to engaging in new conceptual challenges and policy debates (Dicken, 2004; Coenen et al., 2015a). As economic practices as crucial drivers of climate change are inherently spatial and multi-scalar in character, the discipline of economic geography should be considered to possess opportunities to address grand challenges in general, and environmental concerns in particular (Aoyama et al., 2011; Patchell and Hayter, 2013; Coenen et al., 2015a). In this PhD thesis I take the position that the regional innovation system (RIS) approach (Cooke, 1992; Cooke et al., 1997; Braczyk et al., 1998; Asheim and Gertler, 2005) constitutes a framework with potential to address the possibilities and limitations of regions and regional industries to tackle grand challenges; and moreover, to provide policy approaches for addressing them.

The RIS approach has during the past two decades become a popular framework to study innovation processes in regions. In particular, the potential of the systemic approach to innovation taken in RIS lies in a relatively broad perspective on the regional context: Next to firms, it allows considering the knowledge infrastructure (such as universities and research institutes), institutions and policies as important system components (Doloreux, 2002). Moreover, the RIS approach allows conceptualising differences in innovation activities based on the nature of system linkages among the components of the system - while it at the same time accounts for drawing attention also to relationships with extra-regional actors, networks and institutions (Asheim et al., 2011b). RIS are also understood as suitable device in the context of this dissertation as they are usually considered as overarching framework, spanning several industries (or clusters) in a region (Doloreux, 2002). This understanding is valuable as it allows putting focus not only on one, but on several industries in a RIS. The RIS approach consequently possesses strength in explaining differences in innovation performance across regions based on their endowment with firms (and industries), support organisations, institutions and linkages between these elements – both within and to outside the region. Moreover, the RIS approach has prominently been applied as device to design, implement and evaluate regional policy interventions (Uyarra, 2010; Asheim et al., 2011a; Uyarra and Flanagan, 2013; Coenen et al., 2016). As grand challenges have a strong policy notion, I also consider this understanding of RIS as favourable for

addressing grand societal problems. (A more detailed description of the RIS approach follows in chapter 2.2.)

In the following, I will draw on the above mentioned potential of RIS to address the barriers and limitations of regions and regional industries to tackle grand challenges. In particular, I will use these strengths to address three gaps that I have identified in the existing literature on regional economic evolution – and which I consider important to give attention to when dealing with innovation related to grand challenges.

The first gap concerns the role of institutions in the evolution of regional industries. Evolutionary approaches to economic geography take due to their dominant focus on firms as main agents of change the position that institutions possess a relatively small role for explaining where a new industry emerges and grows (Boschma and Frenken, 2006, 2009). Consequently, there is only little understanding on the role of institutions and policy during early formation and transformation processes of industries (MacKinnon et al., 2009; Gertler, 2010; Hassink and Klaering, 2011; Morgan, 2013; Rodríguez-Pose, 2013; Kogler, 2015). In evolutionary accounts, much explanatory power is ascribed to the role of ‘historical accidents’, ‘chance events’ or ‘random’ action for new technological pathways (David, 1985). From a RIS perspective, it seems fair to state that these evolutionary accounts possess a rather weak agenda with regard to addressing policies and institutions (Asheim et al., 2013; Coenen et al., 2016); although some EEG scholars are however more prone to take them into account (Martin and Sunley, 2006; Martin, 2010) or have explicitly expressed their concerns with regard to a neglect of institutions (MacKinnon et al., 2009). During the writing process of this dissertation, some authors have started to emphasize the importance to consider a broader range of actors, policy and institutions for regional economic evolution. These contributions include attempts to provide a sociological view on the creation of new pathways through knowledgeable agents (Karnøe and Garud, 2012; Simmie, 2012), or attempts to emphasize the importance of a broader range of actors by taking an evolutionary political-economic view (Dawley, 2014; Dawley et al., 2015). Furthermore, the literature has devoted some attention to different roles that the state can play during regional economic evolution (Morgan, 2013). However, surprisingly little attention is given to important policy preconditions for new regional economic path development. These include issues such as the capacities of regional actors to develop common interactions (over time), financial assets as well as the role of legal institutional factors (such as the level of regional political autonomy). As grand challenges in general and environmental innovation in particular have a strong policy notion, the role of region-specific institutions seems crucial for finding out about particular patterns of regional economic transformation. As it is a central understanding in the RIS literature that the institutional context is crucial for shaping differences in

innovation activities across space (Cooke et al., 1998; Cooke and Morgan, 1998; Asheim and Gertler, 2005), I consider the RIS approach as promising device to address this gap.

While the first gap addresses region-specific respectively region-internal institutions and policies, the second gap concerns the role of region-external institutions and policies for regional economic evolution. Due to the overriding focus on regional technological structures, technological knowledge and knowledge spillovers between co-located firms, evolutionary accounts largely neglect the impact of region-external influences to new development paths¹. Some recent, more institutionally inspired contributions have started to address the role of external-knowledge flows on regional economic path development (e.g. Binz et al., 2015; Trippel et al., 2015; Isaksen and Trippel, 2016b). Yet, there is little understanding on the role of region-external institutional and policy influences on regional economic evolution. Only a few contributions address how supra-regional policies influence the emergence and further development of industries in regions over time; or in other words, how supra-regional policy influences interact with particular regional contextual factors (Dawley, 2014; Dawley et al., 2015; Steen, 2016). Moreover, there is lacking understanding regarding whether and how regions can influence supra-regional institutional settings in ways favorable for their regional economic evolution. As grand challenges are multi-scalar in character in that they operate at various spatial scales (global-national-regional/local), policy approaches need to be coherent across these scales in order to be effective (Weber and Rohrer, 2012). Here, I particularly consider the conceptualization of RIS as nationally and internationally open and interlinked systems (Tödting and Trippel, 2005; Asheim et al., 2011b) as favourable to address this gap.

The third gap concerns the predominant supply-focused view on formation and transformation processes of regional industries that the current literature provides: In the discipline of economic geography, the core argument for the region as locus for innovation is that the competitiveness of individual firms as main innovators is built based on close interaction with their territorial environment. Particularly innovation activities that target the generation of new technologies and products are considered as central success factors for the competitiveness of firms and regional industries (Moulaert and Sekia, 2003). Individual firms thereby benefit from agglomeration economies that can be results of co-location of firms from the same or from different industries. Evolutionary accounts argue that related variety stemming from knowledge spillovers between firms with different but related activities is a major source for

¹ An exception constitute Martin and Sunley (2006) who mention transplantation of an industry or technology from elsewhere as a solution for escaping regional lock-in.

regional diversification over time (see e.g. Boschma and Wenting, 2007; Neffke et al., 2011). During the writing process of this PhD thesis, the potential of the RIS approach to contribute to our understanding on regional economic evolution has been recognized and taken up by scholars (e.g. Strambach and Klement, 2013; Tödting and Trippel, 2013; Trippel et al., 2015; Isaksen and Trippel, 2016a). Although opening up to a broader range of actors and institutions, the reasoning in these contributions focuses on knowledge creation and re-combination between firms and the knowledge infrastructure, as well as policy approaches to support these processes (Isaksen and Trippel, 2016a). This argumentation is yet much in line with the related variety argument in the initial evolutionary accounts. In fact, territorialized innovation models - including the RIS approach - constitute 'territorialized production systems' (Truffer, 2008) which face limitations to conceptualize broader societal change processes. Put differently, tackling grand challenges does not only require changes in technologies that lead to new products or production processes. Rather, it requires new socio-technical alignments that also pay attention to the adaptation and diffusion of innovations. In policy contributions outside the field of economic geography this requirement has been expressed in the stronger need for demand-side policies for addressing grand challenges (e.g. Mowery et al., 2010; Edler et al., 2012); yet acknowledging that these have to be accompanied by adaptations of various kinds of organisational and physical infrastructures.

The identification of the research gaps reveals that there is, on the one hand, a rather limited understanding regarding how and under what conditions regional industries emerge and evolve – and how institutions matter during such process. Partly, this is because research on RIS that aims to put forward a dynamic perspective on regional economies is rather recent. Traditionally, RIS have provided a rather static view on innovation, putting focus on existing relations and structures (Uyarra, 2010), which is particularly true for empirical work applying RIS. On the other hand, the research gaps indicate that the RIS approach alone is not fully capable to bridge the gap between regional economic evolution and grand challenges. RIS promise to offer important insights into innovation processes at the regional scale which seem crucial for addressing grand challenges. RIS however possess a weakness in that they not sufficiently allow to capture broader societal change processes. Hence, the RIS approach alone seems not capable to conceptualise and analyse transformation processes of regions and regional industries that are aligned towards tackling societal problems.

Luckily, several scientific disciplines are engaging in studying innovations; all approaching the topic from slightly different perspectives. Sometimes, insights from other research fields have to be used to advance the understanding on certain phenomena (Fagerberg, 2005; Fagerberg et al., 2012). I argue that this especially holds

for complex problems such as grand challenges. In order to address the identified research gaps, I take an interdisciplinary approach by drawing on the literature on socio-technical transitions (Kemp et al., 1998; Geels, 2002; Geels et al., 2008; Markard et al., 2012). Central to this research field is that it considers an evolutionary and highly interdependent relationship between technologies and their overall economic, societal and institutional context. It has particular strength to, on the one hand, explain the emergence and formation of new socio-technical configurations. On the other hand, it has strength in shedding light on the formation of production and consumption patterns in more general terms by considering their embedding into wider processes of system transformation. I argue that the consideration of socio-technical systems is particularly relevant for addressing grand challenges and their specificities, which by nature require a strong public policy involvement. The empirical focus on the bio-economy and biomass-based industries in this dissertation therefore possesses a comparatively strong theoretical notion. (The literature on socio-technical transitions will be explained more in detail in chapter 2.3.)

By taking such proposed interdisciplinary approach, I aim to contribute to a more coherent, multi-perspectival conceptual framework in the literature on regional economic evolution which allows addressing grand challenges in general and climate change in particular. While it is the strength of the RIS approach to consider different actors, institutions and policies as crucial for innovation, approaches from socio-technical transitions contribute with a co-evolutionary perspective on technologies and institutions and their embedding into broader socio-technical systems. In particular, the objective of this PhD thesis is to address the possibilities and limitations of regions and regional industries to tackle grand challenges as well as to provide policy approaches how to support desirable transformation processes. Central interest of this dissertation is therefore to study why and how change processes of industries towards more environmentally friendly modes in regions occur, respectively not occur. More particularly, the interest lies in researching how regional (institutional) context factors impact regional economic evolution towards addressing societal goals.

Empirically, I have studied cases of industries in three different Swedish regions and their undertaking to increasingly, respectively more efficiently use biomass as raw material. One empirical case deals with the paper and pulp industry in the region around Örnköldsvik in northern Sweden which attempts renewing itself by applying bio-refining technologies and broadening its output to other products than paper pulp. Another empirical case has its focus on the emergence of the biogas-industry in the region of Scania, southern Sweden, where biomass residuals from sewage, industry and households are used to run biogas buses in regional public transport. Yet another empirical case focuses on the chemicals industry in the Stenungsund-Gothenburg

region at the Swedish west coast. This industry is traditionally based on fossil resources but aims at reducing its fossil content in the future by drawing on biomass as a resource.

The term bio-economy is usually associated with the transformation of a fossil-based economy towards a resource efficient economy that draws on biomass raw materials both from land and sea (OECD, 2009; European Commission, 2014). In the academic literature however, there is lacking consensus with regard to what a bio-economy actually implies as multiple scientific fields approach this topic from different perspectives (Bugge et al., 2016). Important for the bio-economy understanding that I take in this PhD thesis is that the introduction, upgrading and conversion of biomass raw material implies new (optimally circular) supply and market linkages between industries. This is because of the increasing use of biomass in different sectors of the economy and society. As the development towards a bio-economy is considered to possess a key role in addressing grand challenges (Ollikainen, 2014; Bugge et al., 2016), the topic addressed in this dissertation is also relevant for other contexts beyond the Swedish setting. Sweden possesses a national strategy for the development of a bio-economy with the vision “to make the conversion to a bio-based economy within the first half of the twenty-first century” (VINNOVA, 2013). Thereby and in comparison to other countries, Sweden is assumed to possess rather good preconditions to transform into what can be understood as a bio-based economy (Formas, 2012): Particularly, this is due to Sweden’s traditional industry and infrastructure endowment as well as natural geographic conditions. Agriculture and forestry have for a long time been the basis for Sweden’s industrial sector, implying that the handling of biomass is traditionally rooted in a variety of Swedish industries. The Swedish setting can therefore be considered as a case to learn from, while barriers that the transformation in Sweden faces also are likely to apply to other national contexts. Furthermore, the Swedish context allows accounting for regions’ varying degrees of autonomy to decide on their economic development: While the majority of Swedish counties merely have the responsibility for transport and public health care, some enjoy extended devolution also for setting up their own regional development strategies (Sveriges Riksdag, 2010).

The overall research questions addressed in this thesis are as follows:

How are industry dynamics in the context of grand challenges enabled and/or constrained by regional context, particularly with regard to policy (theoretical RQ)? What are the (institutional) enablers and hindlers to new regional industrial path development in biomass-based industries in Sweden (empirical RQ)?

The research gaps addressed are:

- Region-internal institutions and policies during early formation, respectively transformation processes of industries
- Region-external institutions and policy influences to new regional industrial path development
- Socio-technical alignments for new regional industrial path development

1.3 Overview of the articles

In the following, the four papers included in this dissertation will briefly be introduced with regard to their theoretical and empirical foci as well as their contribution to the particular research gaps as identified in section 1.2.

The first paper, *Path Renewal in Old Industrial Regions: Possibilities and Limitations for Regional Innovation Policy* published in *Regional Studies* (Coenen et al., 2015b) deals with the potential and limitations of a national-level regional innovation policy programme to facilitate industrial renewal. The theoretical framework departs from the literature on old industrial regions, addressing typical problems innovation systems in these regions face. To account for a combined evolutionary-institutional approach, the paper moreover engages in the literature on socio-technical transitions. Empirically, the paper analyses the policy programme “Biorefinery of the Future” that is geared to promote renewal of the forest industry in the Örnsköldsvik-Umeå area in the north of Sweden through fostering science-based knowledge creation and exploitation. Being strongly dependent on this mature industry, the future development of this region is heavily tied to its fate. In recent years the industry is increasingly seeking new, alternative ways to extract greater value from biomass, while at the same time improving its energy-efficiency, carbon-emission impact and overall environmental performance. Instead of using the forest biomass exclusively for the production of paper and pulp, biorefinery technologies allow its conversion into additional or substitute products such as low carbon fuels, green chemicals, substances used in the construction industry, viscose for clothing, or ingredients for the food and pharmaceutical industry. At the same time, they aim for the efficient use of excess heat in the production process. The paper concludes that the policy programme is strong at fostering science-based knowledge creation and exploitation; in other words, it pays much attention to technology-related innovation and experimentation processes for regional industrial renewal. However, institutional adaptation has largely been overlooked, and

particularly the importance of creating socio-technical alignments. These largely remain beyond the scope of the regional innovation policy initiative.

The second paper, *Institutional Context and Cluster Emergence: The Biogas Industry in Southern Sweden* published in *European Planning studies* (Martin and Coenen, 2015) focuses on the role of institutions, and in particular regional innovation policy, for new industry emergence. The theoretical framework draws on a discussion of concepts such as path-dependence, related variety and regional branching. Moreover, it draws on the technological innovation system approach to highlight the role of institutions for regional industry formation. Empirically, it studies the evolution of the biogas industry in the region of Scania in Southern Sweden. Biogas activities started to emerge in the late 1990s and early 2000s. They were triggered by a policy programme that targeted local initiatives to reduce greenhouse gas emissions. Regional policies have induced further growth of this industry, especially through providing legitimacy for locally produced biogas by setting up of environmental goals. These have particularly stimulated the use of biogas as a fuel in the regional public transport system through biogas buses. The paper particularly sheds light on region-internal policy processes which have to be understood in the context of an economically and organizationally diversified, core region. The paper however also considers the influence of national (i.e. extra-regional) policy on the RIS and its actors and emphasizes the importance of long-term support, socio-technical alignments as well as the adaptation and diffusion of innovations for industry emergence and further development. The analysis reveals that the technological innovation system approach can be fruitfully employed in the analysis of the emergence of a regional industry.

The third paper, *Policy capacities for new regional industrial path development – The case of new media and biogas in southern Sweden* published in *Environment and Planning C* (Martin and Martin, 2016) argues for a stronger consideration of regional institutional aspects such as the political autonomy of regions and the capability of policy actors to shape regional development. To do so, it develops a framework based on RIS and the literature on new regionalism and capacity building. The empirical section analyses the emergence and further development of the biogas and new media industry in Scania. Thereby, the latter case provides valuable insights into regional industry evolution beyond the dynamics of bio-mass based industries. The paper shows that in both industries policy-led initiatives have played important roles in enabling new path development. In order to turn regional preconditions into new development paths and in order to harness supra-regional policy programmes, the paper concludes that RIS require strong policy capacities, consisting of formal and governance capacities: Formal capacities target legal and financial factors influencing new path development and include the political autonomy of a region to decide on matters with regard to regional

economic development. Governance capacities constitute the quality of historically grown local interactions and the scope to induce regional institutional change. In particular, the paper concludes that policy can play multiple roles in nurturing and maintaining new growth paths and that these are closely interlinked with particular policy capacities of regional innovation systems.

The fourth paper, *Regional innovation systems and transformative change: The case of the chemicals industry in West Sweden, submitted manuscript* (Martin, 2016) studies the possibilities and limitations of regional innovation policy to induce transformative change. Thus, it most explicitly addresses change that is putting new demands on the directionality of innovation by addressing societal challenges. By drawing on insights from socio-technical transitions, the paper develops a framework that makes explicit the possibilities and limitations of transformative regional policy action. In particular, it applies the notion of protective space which has previously been used to conceptualize and analyze how sustainable innovations emerge and grow respectively decline in the context of established innovation systems. Empirically, the paper studies the chemicals industry located in West Gothland, an economically and organizationally diversified region at the Swedish west coast, and its attempts to develop a more environmentally friendly profile. The industry constitutes Sweden's largest basic chemicals industry cluster and is a heavily polluting, fossil-resource intense industry with a long-term need to transform towards more sustainable, environmentally friendly modes. Despite proceeding technology development, ongoing cooperation between the public and private sector in the region and an ambition to become leading in the production of sustainable chemistry products by 2030, going from words to action seems in many respects difficult for the regional industry; making necessary actions that have been less addressed in the literature on systemic regional innovation policy. The paper contributes particularly to advancing the understanding on the importance of socio-technical alignments in regional innovation policies and, closely related, emphasizes the importance of extra-regional policy influences by pointing at policy-interaction with higher administrative levels.

2 Theoretical framework

2.1 A systemic perspective on innovation

Innovation is a term that is today fundamentally associated with keywords such as economic growth, wealth and prosperity. It is a crucial component of our economy and society without which modern life would be unthinkable. Innovation itself, however, is anything but a new phenomenon. It is rather something that has always existed. It is “as old as mankind itself” as it is “inherently human” (Fagerberg, 2005: 1) to think about improvement and to try new things out in practice. Without innovation, the majority of things in our daily lives would simply not exist (Fagerberg, 2005).

An innovation can be seen as the attempt to put a new idea into practice (Fagerberg, 2005). Yet, such idea should be of “economic significance” (Edquist, 1997: 1). A closely connected term is invention which describes the first occurrence of a new idea, yet without possessing a market link. Most commonly, innovations are differentiated into product and market innovations, targeting the introduction of a new product or the introduction of a new production process, respectively. Innovations are often also characterized by their nature, denoting whether an innovation is incremental or radical in scope compared to already existing goods, services or processes (Fagerberg, 2005). Notably, Schumpeter (1911) as the founding father of innovation studies had a much broader understanding of innovations - which he initially termed as ‘new combinations’. Schumpeter’s definition does not only focus on new products and production processes but also on the opening of new markets, the introduction of a new source of raw material, as well as organisational change (Schumpeter, 1934; McCraw, 2007). Such new combinations do not have to be new to the entire world in order to qualify as innovation; rather, they are seen as novelty put in place within a certain setting or context. Schumpeter’s understanding corresponds to the understanding of innovation that I take in this PhD thesis.

The interest in devoting scientific attention to innovations has only emerged more recently, during the second half of the past century (Fagerberg et al., 2012). In the 1950s and 1960s, innovation was largely considered to be a linear process with science (and science policy), as point of departure (Godin, 2006). During the 1970s and 1980s large focus was put on technology (and technology policy). Influenced by Kline’s and Rosenberg’s (1986) ‘Chain link model of innovation’ and their attempt to highlight the complexity of innovation processes, innovations became however increasingly

regarded as non-linear, interactive processes. Pioneering contributions made by Freeman (1987), Lundvall (1992) and Nelson (1993) on national innovation systems (NIS) reflected an increasing orientation of research towards a systemic understanding of innovation in which innovation is seen as the outcome of a complex, interactive learning process involving actors both from the public and private sector such as firms, industry associations, government agencies, research institutes, universities and other institutes for higher education (Edquist, 1997). Thereby, all actors in an innovation system can bring into being inventions; however the creation of innovation (i.e. the commercialisation of inventions) are carried out by firms or by firms collaborating with other actors (Fagerberg, 2005). Innovation processes can vary considerably in their lengths. Often, however, there is a long time lag between invention and the innovation (Fagerberg, 2005). In many cases, new ideas or improvements for products and processes exist, but they have hard times to be turned into practice. This is because barriers to their implementation may be existent as the appropriate conditions for commercialization may be lacking. More precisely, for a new idea to be implemented often a number of other, complementary innovations are needed and it is amongst others therefore why a systemic perspective on innovation has perceived high attention (Kline and Rosenberg, 1986; Fagerberg, 2005). From an innovation system perspective, public intervention is considered legitimate and desirable if the system does not function effectively. Consequently, innovation policy is understood as general tool to promote innovation and to address challenges of a specific innovation system. Here, the notion of system failures has been used to conceptualize challenges of innovation systems and to develop policy approaches to tackle potential problems (Smith, 2000; Klein Woolthuis et al., 2005; Bergek et al., 2008; Weber and Rohracher, 2012).

While initially providing frameworks for analyzing national level economic performance, the technological innovation systems (TIS) approach (Carlsson and Stankiewicz, 1991) and sectorial innovation systems (SIS) approach (Breschi and Malerba, 1997) emerged, which were stronger considering technology, respectively sector specific matters. Research by economic geographers in the early 1990s conducting in-depth studies on industrial regions in Europe particularly addressed the sub-national context as important for innovation activities and lead to the birth of the RIS approach (Cooke, 2008).

2.2 Regional innovation systems

This dissertation takes the RIS approach (Cooke, 1992; Cooke et al., 1997; Braczyk et al., 1998; Asheim and Gertler, 2005) as its main conceptual basis. The RIS approach

has innovation-based regional development as its main object of study and considers economic and social interactions of actors at the regional level as crucial for innovation to occur (Cooke, 1998; Asheim et al., 2011b). RIS are generally understood to consist of four different but interrelated elements which are considered crucial for shaping (regional-level) innovation: firms, knowledge infrastructure, institutions and policy (Doloreux, 2002). Moreover, this dissertation makes use of the conceptualisation of RIS in terms of system components, system linkages and system boundaries (Asheim et al., 2011b; Coenen et al., 2016).

2.2.1 Regional innovation systems as general analytical framework

Firms that are competing and/or collaborating with one another are inherently responsible for the exploitation of knowledge and for turning it into innovations. For this reason, firms are often also referred to as the knowledge application and exploitation subsystem of the RIS (Autio, 1998). One central argument is that the competitiveness of individual firms is built in close interaction with their territorial environment; or put differently, that firms benefit from the local-regional context that they are located in (Maskell and Malmberg, 1999). Next to taking roles as collaborators or competitors, firms can also be customers of one another in the innovation system (Autio, 1998).

The knowledge infrastructure constitutes the organizational infrastructure supporting innovation in the RIS and is also referred to as the knowledge generation and diffusion subsystem (Autio, 1998). The knowledge infrastructure consists of mainly public actors such as institutes of higher education (e.g. universities), research institutes or laboratories (Doloreux, 2002). Through carrying out research the knowledge infrastructure is important for knowledge input in the innovation system. Moreover, some knowledge infrastructure organizations such as universities also have the role of providing higher education and have thus also to be considered crucial for competence building through providing skills and training.

There is no standardized definition existing for the term institutions. Yet, a core and largely common argument of the RIS literature is that the institutional context is crucial for shaping differences in innovation activities across space, and that it is determined and shaped by the geographical context (Cooke et al., 1998; Cooke and Morgan, 1998; Asheim and Gertler, 2005). Broadly defined, institutions can be understood as social regulations or rules of the game (North, 1990) that are regulating, yet not completely determining, the interaction and behaviour of actors (Gertler, 2010). Institutions can be formalized in the form of laws and regulations, or they can constitute informal

(societal) rules such as cultural norms, values and habits (North, 1990; Noteboom, 2000; Morgan, 1997). Broadly speaking, institutions can therefore be understood as specific routines that are common to a group of actors and that shape their interactions; yet, institutions are also shaped by actors' interactions. In other words, institutions are decisive as they impact the extent and nature of how multiple actors such as firms, universities, research institutes, intermediary organisations as well as governmental agencies collectively contribute to regional innovation and growth.

As principal mechanism crucial for the success and efficiency of a RIS is the process of interactive learning (Doloreux, 2002). Learning is closely connected to innovation as it targets processes of knowledge generation and diffusion between actors in the system which is strongly influenced and shaped by institutions. In other words, knowledge is generally understood as the most important resource for innovation, while learning is considered as the most important process. Generally, knowledge occurs in two forms, codified and tacit, which are usually both part of innovation processes (Johnson et al., 2002). Codified knowledge is generally supposed to be easily transferable over geographical distances, while its tacit counterpart is assumed to be more sticky and bound to a specific spatial context (Gertler, 2003). The literature on regional innovation considers principally the tacit character of knowledge as crucial for innovativeness and competitiveness. In particular, short geographical distances are seen as essential, as the sharing and transfer of tacit knowledge depends on personal, face-to-face contacts and trust-building among actors (Morgan, 1997; Morgan, 2004). The RIS literature assumes that through interactive learning processes, knowledge becomes a collective asset in the RIS (Cooke et al., 1998). Institutions are particularly relevant in this regard as they are able to transfer but also to maintain knowledge in groups of actors and can thus be understood as untraded, 'relational assets' (Storper, 1997). Although geographical proximity is considered crucial for learning processes as it facilitates personal face-to-face contacts, it should not be seen as sufficient precondition: For learning to take place, also a balance of other proximity dimensions is important, such as cognitive proximity (the knowledge base of firms), organisational proximity (intra- and inter-firm network structures), social proximity (socially embedded relations between regional agents) and institutional proximity (stable institutional environment conditions at the macro-level for interactive learning) (Torre and Gilly, 2000; Boschma, 2005). Furthermore, not only the degree and extent of learning, but also the ability of actors to unlearn obsolete practices is important for regional competitiveness (Morgan, 1997).

Moreover, policy is an important element of RIS. The intention of RIS policies is generally to increase innovativeness by supporting learning and knowledge diffusion in the system (Doloreux, 2002). Such policies, in form of public policy intervention, can

on the one hand be set up by supra-regional authorities. On the other hand, policy is also seen as collective action which includes various public and private actors and stakeholders, and which commonly shape and result in public authorities' decisions (Morgan and Cooke, 1998). In other words, the understanding of policy that I take in this PhD thesis is that RIS actors are not simply passive targets of regional and supra-regional policy interventions, but rather that they are (directly or indirectly) influencing policy outcomes and by implication, shaping policies (Flanagan et al., 2011). I understand policies thus as being shaped by and resulting from institutional settings. Vice versa, and as policies have an impact on the behaviour of actors, they can also become institutions - and by implication, become institutionalized (Zukauskaitė, 2013). In a nutshell, the RIS literature does not advocate a full trust in pure market mechanisms, nor does it believe in the unlimited ability of the state (Morgan, 1997; Martin, 2012). Rather, it considers economic and social interactions of (regional) actors as important for shaping innovations and their outcomes.

The differentiation of RIS into their elements (firms, knowledge infrastructure, institutions and policy) constitutes a valuable approach to more closely describing and characterizing the single components of RIS. However, at the same time this approach involves a risk to lose sight of the inherent systemic character of the concept. In addition to system components, RIS can therefore also be conceptualised based on system linkages (that is the relationship between the single components) and system boundaries (Asheim et al., 2011b; Coenen et al., 2016): While the perspective on system linkages puts emphasis on the localised, RIS internal innovation network and interactive learning processes, system boundaries draw attention to the relationships with RIS-external actors, networks and institutions.

I acknowledge that a variety of other territorial innovation models has been introduced to address the spatial aspects of innovation (Moulaert and Sekia, 2003). These include concepts such as industrial districts (e.g. Marshall, 1920; Brusco, 1986), innovative milieus (e.g. Aydalot, 1986; Maillat et al., 1995), clusters (e.g. Porter, 1990, 1998) and learning regions (e.g. Asheim, 1996; Morgan, 1997). Several of them emphasize the importance of regional context, particularly social and cultural factors as well as tacit learning, for innovation. Yet, it goes beyond the scope of this dissertation to elaborate on the differences between these concepts². Partly, there exists disagreement among scholars regarding how and based on which criteria to delimit the concepts from one another. Agreeing with Doloreux (2002), I find that the territorial innovation models are not always easy to distinguish from one another. Also, I take the position that the RIS approach clearly shares common features with other concepts and that it can

² For an overview see Doloreux (2002) and Moulaert and Sekia (2003).

therefore be understood as a framework bridging and synthesizing the other concepts; or put differently, that it contains lessons and ideas from other territorial innovation models (Coenen, 2006). By way of example, I understand a RIS to (potentially) span several clusters in a region, and that it can be applied to a variety of different regional and industrial contexts, such as industrial districts. Furthermore, I consider RIS having clear synergies with the concept of learning regions in that they address institutions and organizations in a region that influence learning and innovation (Asheim et al., 2011a). That I have decided in favour of RIS as the main conceptual framework does however not mean that I consider RIS being superior to other territorial innovation models. Rather, I consider RIS as unifying framework of other territorial innovation models. Moreover, the choice of RIS is informed by the underlying research design (which will be introduced in chapter 3) and research questions addressed in this dissertation:

The RIS approach is applicable to a variety of regional contexts. Contributions to the RIS literature largely assume that different regions have different capacities to innovate (see e.g. Tödting and Trippl, 2005), thus take for granted that all regions possess an innovation system (see also Bunnell and Coe, 2001; Doloreux and Parto, 2005); yet there are also opposing positions (see. e.g. Cooke, 2001; Iammarino, 2005). Moreover, RIS are not conceptualized as self-sustaining units or isolated places; rather, they are understood to be embedded into broader (national and global) contexts. By way of example, important knowledge interactions may transcend the regional boundaries or they might be directly or indirectly influenced by higher level policies. Thus, the RIS approach should not be considered as a framework to exclusively study innovation at the regional scale – but rather as a framework also considering a region’s embedding into broader, national and international contexts. As grand challenges and their implications neither are limited to one spatial scale, nor can they be tackled at one spatial scale, this understanding of RIS is also important for the research objective of this thesis. Moreover, I consider the strong policy orientation of the RIS framework as instrumental for addressing grand challenges as they involve a policy notion.

Last but not least, it is important to mention that there are different understandings of the notion of region in the literature; consequently, many definitions exist (see e.g. Doloreux and Parto, 2005). In the context of this PhD thesis and particularly with regard to the strong policy notion of the RIS approach, I see regions as administrative units with a certain, yet varying, degree of autonomy to decide on issues related to their own regional economic development (Cooke et al., 1998; Cooke, 2001). At the same time, I understand a region also as a functional unit, for example a geographically concentrated labour market, in which several processes converge. Understanding regions as such ‘nexus of processes’ (Cooke and Morgan, 1998) that are embedded into

a broader geographical context is also crucial when considering regions as open, nationally and internationally connected systems.

2.2.2 Regional innovation systems as policy framework

In general, innovation system approaches are based on the understanding that public intervention is legitimate and desirable when the complex interactions taking place in the system do not function effectively (Laranja et al., 2008). Therefore, central on the agenda of innovation system approaches is the identification and support of processes and mechanism that stimulate innovativeness. Consequently, the literature on innovation systems has generally been strong at influencing policy agendas. The RIS approach in particular has increasingly developed into a popular policy framework to design, implement, justify and evaluate regional policy interventions in many countries (Uyarra, 2010; Asheim et al., 2011a; Uyarra and Flanagan, 2013; Coenen et al., 2016). It has been applied to shed light on place-based challenges to innovation, taking for granted that innovation activities face challenges that vary between regional contexts. An influential typology to address context-sensitive regional policy approaches has been proposed by Tödting and Trippel (2005) who identify challenges relating to different types of regions: peripheral regions that are characterized by organisational thinness, specialised old industrial regions suffering from technological lock-in; and metropolitan areas that can experience system fragmentation in terms of lacking networks and interactions. That is to say, regions are in their innovation activities challenged by different kinds of system failures, which require context-specific policy support. Work by economic geographers has strongly considered failures that are often referred to as so-called structural innovation system failures, based on a general innovation system typology proposed by Klein Woolthuis et al. (2005): First, infrastructural failures relate to lacking physical and knowledge infrastructures for innovation. Second, institutional failures relate to the absence or shortcomings of either formal institutions (such as laws, regulations, standards) or informal institutions (such as social norms and values, trust, risk taking). Network failures relate, on the one hand, to too intensive cooperation in tied networks (strong network failure) and, on the other hand, to too weak knowledge exchange and interaction among actors (weak network failure). Finally, capabilities failures relate to the lack of appropriate resources and competences (at the actor and firm level) in the innovation system (Klein Woolthuis, 2005; Weber and Rohrer, 2012). The regional level has been identified as appropriate scale to implement policies addressing these failures (Asheim et al., 2011a; Coenen et al., 2015a): Inherently, the failures point at central findings in the literature on the economic geography of innovation. They address that innovations have to be considered as economic and social

interactions that imply interactive learning processes among actors. Appropriate infrastructures, networks and institutions are crucial for supporting innovation; their formation and maintenance is facilitated by short geographical distances.

Due to their strong policy focus and policy implications regarding how to improve innovativeness, innovation system approaches in general and RIS in particular have (at least implicitly) a tradition in addressing economic transformation. Moreover, RIS scholars have traditionally also dealt with industrial change in structurally weak areas, such as old industrial regions (e.g. Grabher, 1993; Kaufmann and Tödtling, 2000; Trippel and Otto, 2009). However, research on RIS has until recently devoted little attention to a more systematic and conceptual understanding of regional economic evolution. Rather, the RIS approach has for a long time provided a fixed view through a focus on existing relations and structures (Tödtling and Trippel, 2013) implying a “tendency to focus on a static landscape of actors and institutions” (Uyarra, 2010: 129). In other words, RIS have hardly devoted attention to path dependencies in regional economic evolution on a more conceptual level. Policy approaches that more systematically address regional economic evolution have only rather recently, in response to the evolutionary turn entered the research agenda of RIS scholars. These approaches explicitly aim to broaden the focus away from firms by opening up to a broader range of actors, institutions and policy (Strambach, 2010; Tödtling and Trippel, 2013; Asheim et al., 2016b; Isaksen and Trippel, 2016a, 2016b). New regional industrial path development is generally described in terms of path renewal or new path creation (Isaksen, 2015; Isaksen and Trippel, 2016a)³. The first one is, closely aligned with EEG (Boschma and Frenken, 2011a), defined as “diversification of existing industries into new but related ones” (Isaksen and Trippel, 2014: 2). The latter one targets the rise of industries that are entirely new to the region and more explicitly addresses the lacking explanatory power of evolutionary approaches to explain the emergence of entirely new industries. While path renewal puts most emphasis on policy-supported intensification of knowledge creation and re-combination between firms, new path creation puts additional emphasis on more research-driven modes of regional economic development based on a strong organizational support structure of a RIS. In this view, RIS changes can also come about by network change and organizational change - that is change in a region’s knowledge generation and diffusion system. Subject to their organisational endowment and the degree of related variety,

³ As the interest of this dissertation lies in researching the enablers and limitations of the regional (institutional) context to bring about cleantech industry dynamics, it does not very explicitly engage in the differentiation between path renewal and new path creation. Rather, the overall notion of new (regional industrial) path development (Tödtling and Trippel, 2016a) is applied. More recent contributions use further types of new path development (see e.g. Grillitsch and Trippel (2016) for an overview).

different RIS are understood to require different policy interventions to stimulate new path development; implying that the role of policy is to identify, facilitate and strengthen combinatorial knowledge dynamics between firms and the knowledge infrastructure of the RIS (Strambach and Klement, 2013; Tödting and Trippl, 2013; Asheim et al., 2016b; Isaksen and Trippl, 2016a).

The RIS approach has recently also gained attention as framework for addressing innovation-based regional development under the label of smart specialization policies (Moodysson et al., 2016; Morgan, 2016a, 2016b). Smart specialization has become a prominent policy tool in the context of European Regional- and Cohesion policy (Foray, 2015). It describes the capacity of regions to discover new opportunity domains based on local resources and competences and has particularly been developed to support regions with less developed research and innovation systems (Trippl et al., 2016). Put differently, it encourages regions to identify development opportunities and by doing so, induce structural change. It targets the integration of existing local specializations with the development of other strongholds, thus the diversification into areas related to existing regional strengths. For this reason, some RIS scholars argue for 'smart diversification' as a more correct terminology for the approach (Asheim et al., 2016a). More precisely, smart specialisation targets the building of capabilities in specific fields in which a region has potential to develop a unique selling proposition and competitive advantage in the near future (Foray, 2015). Such path for (future) development is triggered by an entrepreneurial vision, also termed entrepreneurial discovery, which is informed by the knowledge on the respective opportunities, constraints and challenges (Foray, 2014). From a RIS perspective, entrepreneurial discovery has to be understood as interactions between actors from the RIS (Asheim et al., 2016a). Core are thereby strategic interactions between public and private sector actors, whereby central attention is given to firms and R&D to put innovations into practice: This is no wonder as, from a European policy point of view, core to the initial idea of smart specialization is to capitalize the regional knowledge-based development through attracting global firms' investment strategies and the location of their R&D departments to Europe (Foray et al., 2009).

These current RIS policy approaches aim at addressing challenges of structural transformation of regions whereby they put forward two notions on smart specialization: smart specialization as process and as policy (Morgan, 2015). It seems yet fair to state that policy approaches that target grand challenges have only received little attention (Aoyama et al., 2011; Martin, 2013; Coenen et al., 2015a). On the general innovation system level, Weber and Rohracher (2012) have put forward four innovation system failures that aim at addressing such shortcomings in the literature. They argue that in order to go beyond accounts of economic growth and innovation-

based competitiveness, the following failures should, next to the previously mentioned structural innovation system failures (Klein Woolthuis et al., 2005), be considered: Directionality failures target the lack of a shared vision regarding transformative change. They can operate in form of lacking collective coordination among agents in the innovation system, be due to insufficient regulations or standards or result from a lacking funding of required research and development projects as well as other infrastructures. Demand articulation failures target the lacking anticipation of respectively learning about user needs in the innovation system. Also stimulus from public demand is absent. Policy coordination failures point at a lacking coherence between different policies, both from a multi-level point of view bringing in line European, national, regional policies and from a vertical point of view coordinating sectoral respectively innovation, technology and research policies. Finally, reflexivity failures address insufficient abilities of the innovation system to anticipate change and deal with uncertainty and to involve actors in self-governance and learning towards transformative change (Weber and Rohracher, 2012).

Admittedly, pointing at shortcomings of innovation activities in general and transformative change in particular with the help of failures might lead to a somewhat mechanic (Coenen et al., 2015a) view and might run risk to lose focus on the inherent systemic character of grand challenges. However, the conceptualization of failures has advantages as it provides an accessible overview of shortcomings of innovation systems as well as policy advice regarding how to address them. The perspective on transformational system failures makes evident that the structural innovation system failures meet limitations to tackle grand challenges. Although RIS approaches extend the focus away from firms to a broader range of actors, policy and institutions to explain regional economic transformation, the existing contributions predominantly draw on urbanization and specialization economies and the role of firms in exploiting knowledge and turning it into innovations. Recent policy approaches such as smart specialization increasingly take up the notion of directionality and vision-led development, which are also denoted in Weber and Rohracher's (2012) categorization; however, they do hardly go beyond the consideration of innovation-based competitiveness. For addressing grand challenges in general and climate change in particular, a broader view on innovation is required (Frenken, 2016). It makes necessary also a stronger consideration of the adaptation and the use of innovations, implying a focus on broader societal change. I argue that the RIS approach, likewise other territorial innovation models, face limitations to conceptualize transformative change⁴.

⁴ Contributions of economic geographers addressing transformational system failures are still rare and are largely made by research on the geography of sustainability transitions, as will be explained in the next sub-chapter.

2.3 Socio-technical transitions

Due to this shortcoming of the RIS literature, I take an interdisciplinary approach in this dissertation. An interdisciplinary approach implies that ideas or concepts from more than one academic discipline are used and combined in order to achieve a specified research objective in the best possible way (Roy, 1979). Such step seems natural given the fact that grand challenges in general and climate change in particular are associated with several, interlinked challenges. In particular, the dissertation draws on insights from the literature on socio-technical transitions (STT) and aims at using them to complement RIS.

The research field on socio-technical system transitions has emerged during the last three decades out of increasing awareness among scholars that technology and societal conditions are closely intertwined; and more specifically, that technological development is both determined by and reflected in the social, cultural and economic context into which it is embedded (Geels, 2002; Geels et al., 2008; Truffer, 2008; Markard et al., 2012). The literature has its origin partly in evolutionary economics and draws on evolutionary terminology such as variation, selection and retention to explain processes of technological change (Nelson and Winter, 1982). Likewise, it is informed by approaches addressing the social construction of technological systems (Pinch and Bijker, 1984; Bijker et al., 1987).

A transition can initially be understood as a term to denote change, and more specifically change of something that already has been existing (van den Bergh et al., 2011). The term socio-technical refers to a interdependent relationship between technologies and their overall economic, societal, and institutional context. The research field on socio-technical transitions, consequently, is interested in explaining socio-technical change describing long-term processes of technological change in co-evolution with multiple other processes in the society and economy at large. Thereby, the literature has a focus on both the emergence and formation of new (sustainable) socio-technical configurations, and on conceptualizing and explaining how existing socio-technical structures hinder or support the formation of new production and consumption patterns. Within this discipline, two analytical frameworks have become most prominent in researching innovation dynamics in the context of socio-technical change: socio-technical systems with its multi-level perspective (MLP) (Rip and Kemp, 1998; Geels, 2002) and the TIS approach (Carlsson and Stankiewicz, 1991; further developed by amongst others Hekkert et al., 2007 and Bergek et al., 2008). Both frameworks have a central interest in studying technology and industry formation respectively transformation processes and argue that radically new technologies and

industries drawing on them require active protection and/or arrangements to get established besides existing mature technologies and industries. The literature is thus a suitable device to explain transformation processes that suggest a (relatively strong) public sector involvement. Many studies have dealt with the adaptation of infrastructures, and many of them aim at explaining transformation processes targeting environmental sustainability, for example low-carbon transitions in fields such as energy and transport (Smith et al., 2010; Unruh, 2000). Often, the contributions on socio-technical transitions are therefore also referred to as sustainability transitions literature (e.g. Smith et al., 2010; Markard et al., 2012).

Put in a nutshell, the TIS framework focuses on the functionality of the innovation system of one particular technology and the involved actors and institutions and takes up more specifically the mechanisms necessary for technologies to develop and diffuse. Thereby, its strength is to shed light on early formation processes of innovation systems. It is argued that certain functions have to exist around a new emerging technology in order for the technology to penetrate markets, substitute established technologies and by implication, to lead to new industry emergence. These functions have to be formed and carried out actively by actors and institutions in the innovation system. Equivalently, blocking mechanisms can be identified that hinder new technologies to diffuse (Johnson and Jacobsson, 2001). Likewise innovation system approaches in general, the TIS framework is thus strong at pointing at failures in the innovation process and at proposing policy action to target particular shortcomings. The MLP largely originates from a critique of innovation system accounts in having a too technology-specific view and optimizing innovation performance of the system as they neglect the social construction of technologies and technological systems and consequently the importance of societal change and social learning. Central to the MLP is the notion of socio-technical regimes that constitute technological artifacts, infrastructures, regulations and user practices that generate path dependencies on technological, economic and societal development (Geels, 2002). In other words, socio-technical regimes provide explanations why it is challenging to break up with the established way of doing things. Changes in the regime can either be triggered by growing pressure (e.g. about environmental concerns) from the overall societal context (so-called landscape forces) or by emerging novel socio-technical configurations – which are yet again triggered by landscape factors. Due to the stabilizing effect of regimes, new socio-technical configurations can only come about in protected spaces (so-called niches) that constitute spaces that are shielded against the selection pressures of regimes, and in which actors learn about and invest into new technologies and markets (Kemp et al., 1998; Hoogma et al., 2002). Socio-technical transitions research identifies a variety of mechanisms for transitions to come about, countering the niche-

driven bottom-up bias that some initial contributions implicate (e.g. Geels, 2002). By way of example, typologies are set up by the degree of coordination and type of resources used by regime actors to respond to perceived pressures (Berkhout et al., 2004). Others highlight more the timing of interactions as well as the nature of interactions between niches, regimes and landscapes to be crucial for the specific transition pathway (Geels and Schot, 2007). Papers number 1, 2 and 4 of this dissertation draw on these approaches (in combination with a systemic perspective on regional innovation) and also include a description of the particular frameworks (that is MLP, respectively TIS).

The two analytical frameworks (TIS and MLP) provide different perspectives on innovation processes and have developed quite different research schools within the discipline. In this dissertation I take the position that the different perspectives put forward in these frameworks show complementary strengths which can be used for the development of a more integrated conceptual framework (Markard and Truffer, 2008; Weber and Rohracher, 2012; Meelen and Farla, 2013); yet acknowledging that other scholars are more skeptical to such an integration (Stirling, 2011), which can be explained by concerns related to different ontological assumptions that TIS and MLP hold (Truffer and Coenen, 2012). In particular, I see potential to combine the frameworks as both intend to shed light on radical innovation processes and as they take a systemic perspective on innovation considering actors, networks and institutions. Thereby however, TIS take a more technology specific view and focus on the drivers and barriers of the diffusion of a particular product or technology. The MLP, in contrast, considers transformation processes in a broader context and at a more aggregated level by putting more emphasis on interactions with the system environment. That is to say, TIS can be considered as more inward oriented than the MLP and provide more insights regarding the actual role of institutions and actors as well as agency enjoyed by them in the innovation process (Smith et al., 2005; Markard and Truffer, 2008). In contrast, the MLP allows stronger considering external institutional influences that arise from the conceptualization of interactions between niches, regimes and landscapes. These differences indicate that the development of a common framework is challenged by, amongst others, questions regarding how to delineate systems (that is how to define system boundaries) or how to deploy appropriate definitions to various system elements (Markard and Truffer, 2008). Acknowledging that more fine-tuned conceptual advances in the research field are needed for the development of a coherent conceptual framework, I have following understanding of the relationships between TIS and MLP:

Innovation systems in general offer important insights valuable for addressing grand challenges and transformative change. However, as innovation systems put central

focus on the internal functioning of systems, they need to be complemented by elements from the MLP (Markard and Truffer, 2008; Weber and Rohracher, 2012). That is to say, to me it seems important to lean on insights from innovation systems while at the same time considering dynamics at the levels of niches, regimes and landscapes as well as their interactions. To begin with, niches shall be seen as important spaces, or application contexts, in which radically new innovations emerge and grow. They consist of a low level of structuration, implying that settings of actors, networks and institutions are initial and in flux. Technological innovation systems show a higher level of structuration and within them more particular roles of actors and institutions can be defined (Markard and Truffer, 2008). TIS can potentially span several niches and can take respectively undergo different stages of maturity: Very initial, immature TIS can be more niche-like while more mature TIS possess a considerably higher level of structuration, implying that they can develop regime-like characteristics (Bergek et al., 2008; Markard and Truffer, 2008). Moreover, TIS should be thought of as being surrounded by respectively embedded into regimes that represent the established way of doing things and which challenge the TIS. These regimes are usually defined around societal needs, such as housing, mobility or food (Weber and Rohracher, 2012) with which the TIS interacts. Finally, landscape factors impact both regimes and innovations (in TIS, respectively niches) and provide a conceptualization for external triggers of radical innovations. The environment of TIS shall thus be understood to constitute regimes, other TIS and influences from the landscape level (Markard and Truffer, 2008; Bergek et al., 2015). As TIS are strong at explaining innovation dynamics in particular fields, for a 'full' transformation to occur various innovation systems need to emerge, mature and become aligned with their respective broader socio-technical context.

2.4 Towards a more integrated framework

The research field on socio-technical system transitions possesses particular strengths, which have the potential to enhance the understanding of dynamics of transformative change in regional economic evolution (Truffer, 2008; Truffer and Coenen, 2012). The literature, however, refers only very implicitly to the spatial contexts in which transitions actually are generated (Truffer and Coenen, 2012). Yet, during the past few years, the geography of sustainability transitions has emerged as a new research field (Truffer, 2008; Smith et al., 2010; Truffer and Coenen, 2012; Hansen and Coenen, 2015). It aims at more explicitly addressing spatial dimensions of socio-technical transitions answering questions such as how transitions unfold across different

geographical contexts and why they occur in one place and not in another (Hansen and Coenen, 2015). It is work in this research stream that can be considered to have made some initial attempts to address transformational system failures in the literature on the geography of innovation (see Coenen et al., 2015a for an overview). Questions such as what are the typical characteristics of regions that promote the diffusion of environmental technologies and how related changes in their socio-institutional settings occur are however understudied in this emerging research field. It is thus fair to state that a comprehensive framework explicitly considering the spatial dimensions and dynamics of sustainability transitions does not exist yet (Truffer and Coenen, 2012)⁵.

I take the position that for the construction of such a framework, the RIS approach can learn from the literature on socio-technical transitions. In other words, I assume the two literatures to possess complementary strengths. However, they also possess commonalities which I consider as the basis for making use of their complementary strengths: Both follow a systemic approach to innovation and consider a multitude of public and private actors which take different roles in shaping innovation processes. Moreover, both put emphasis on the importance of learning and knowledge creation and acknowledge path-dependencies, lock-in and non-linearity of innovation processes. The latter are characterized by uncertainties regarding the innovation outcomes and institutions are assumed to have a central role in guiding actor behavior. Socio-technical transitions are inherently political in character and have, likewise RIS, found application as policy concepts (see e.g. Weber and Rohracher, 2012; Kivimaa and Kern, 2016). However, the translation of the complex socio-technical systems framework into policy advice implies challenges (Turnheim et al., 2015) and is therefore less developed than policy approaches derived from the innovation system literature. Although both literatures seem at first sight to be influenced by a mix of different theoretical propositions, they also possess common theoretical roots, particularly through influences by evolutionary economics (Edquist, 1997; Cooke, 2001, 2008; Markard and Truffer, 2008; Uyarra, 2010).

It is the strength of the economic geography of innovation in general, and RIS in particular, to provide explanations for how the interplay of economic and spatial contextual factors influences innovation processes. In contrast, the strength of socio-technical transitions is to address that technologies and societal conditions are closely intertwined (Geels, 2002; Geels et al., 2008), or put differently, that technical

⁵ This dissertation therefore also makes a contribution to the literature on socio-technical transitions; and more particularly, to the geography of sustainability transitions: It provides insights regarding how (and why) regional context factors impact socio-technical system transformation.

characteristics and institutions closely interact. Based on this understanding, I assume that the RIS literature can learn from the transitions literature. To start with, on a general level the innovation systems literature emphasizes the development as well as the diffusion of innovation as important activities that have to take place in an innovation system (Edquist, 2005). In the RIS literature, much emphasis is put on the development of technologies and products. The adaptation and diffusion of innovation has however received considerably less attention. Here, insights from the transitions literature have the potential to compensate for this shortcoming: Due to its focus on functions that, amongst others, emphasize the importance of market formation, the TIS framework allows paying stronger attention to the adaptation and diffusion of innovations. On a more aggregate level, the conceptualization of innovation processes as originating from dynamics between niches, regimes and landscapes in the MLP provide valuable insights regarding the origins of (and hinders to) change processes, which innovation systems do not capture. For instance, it can explain that the development and diffusion of (radical) innovations might be triggered by societal change. The TIS approach, in contrast, possesses strength in highlighting processes during the (early) build-up and further development of the innovation system. These conceptualisations in both TIS and MLP address the need for coherent socio-technical alignments in order for a transformation to occur, which are not addressed in RIS. Here, a particular strength of the MLP lies in paying attention also to industry-exogenous forces and the impact they might have on the evolution of technologies and institutions in both established and emerging industries. Although RIS are regarded as open, nationally and internationally connected systems, the consideration of industry-exogenous forces is so far not well developed due to the inward-oriented view of the innovation systems literature in general. Due to a central interest in explaining long-term processes of socio-technical change, socio-technical transitions implicate an inherently dynamic understanding of innovation processes. This can complement the still mostly static understanding of RIS: The fact that institutions (norms, values, laws and regulations) enable and/or constrain innovation is well known in the RIS literature (Morgan, 1997; Cooke and Morgan, 1998; Asheim and Gertler, 2005). That institutions however also matter for, and during processes of, regional economic evolution has until recently found comparatively little attention (Uyarra, 2010); particularly, as empirical studies have brought about a rather static view. As mentioned in the previous chapters, current work intending to further a dynamic view mainly focuses on knowledge combination and re-combination between the knowledge exploration and exploitation subsystems of RIS (e.g. Isaksen and Trippl, 2016a). Last but not least, socio-technical transitions, and in particular the MLP, manage to capture another directionality of innovation towards addressing societal problems; in contrast to RIS, which are applied to study innovation for the generation of economic growth.

Here, the niche-regime conceptualization in the transitions literature is valuable to address new path development based on radical innovation, while it at the same time allows to conceptualize path dependencies. RIS-based approaches to explain radical innovation focus on research as driving force, while this topic also has gained attention in work in entrepreneurial RIS (e.g. Cooke, 2007; Ylinenpää, 2009). These approaches are, however, weak with regard to explaining triggers for radical change that originate from overall societal developments. Table 1 on page 43 provides an overview of the commonalities and complementary strengths and of the RIS and STT literatures.

This and the previous sub-chapter have identified intersections between the transitions literature (i.e. TIS and MLP) and the literature on RIS. How should one now think of a more integrated, multi-perspectival, framework to capture possibilities and limitations of regions and their industries to address transformative change? To begin with, it seems straightforward to define the system boundaries: In this PhD thesis, regions are defined both as administrative and functional units; therefore I delimit the system boundaries to regional administrative borders. Within these borders, (functional) processes take place that support innovation and transformation. Following the conceptualization of the MLP, I argue that regional innovation systems should not only be thought of as being embedded into broader geographical contexts, but also into socio-technical systems. Such conceptualization allows to consider the broader societal context in which innovation (and transformation) processes evolve. Following this, RIS should not be considered independent of developments in surrounding regimes and landscapes. Rather, the socio-technical context influences RIS in that it can both trigger and hinder certain developments within the RIS. For instance, regime factors such as existing technologies, infrastructures, regulatory frameworks or established user practices provide explanations for path dependencies within the RIS that challenge the emergence of (radical) innovations. Regime characteristics that generate path dependencies are therefore not considered limited to the surrounding of a RIS; rather, they have to be considered as also being present within the RIS. Landscape factors such as climate change or pressure on natural resources, in contrast, can provide explanations for triggers of change in the innovation system. This perspective also suggests that a focus on innovations in terms of products and technologies is not sufficient, but rather that innovation should be aimed at creating respectively re-configuring socio-technical alignments that function. These should not be considered as being limited to the region, but also have to find alignment with the socio-technical context beyond RIS boundaries in order to function. I argue that this perspective also implies a novel view on the conditions under which agency takes place in RIS: RIS generally embrace many actors that may follow different (innovation) strategies and that may have varying intentions. Or in other words, various actors

respectively actor groups take agency in the innovation system. In the conceptualization that I suggest, agency taken by actors is likely to be influenced by various regime and landscape factors and might, by implication, impact different actors' intentions and strategies. As put forward in the literature on regional innovation in general and RIS in particular, short geographical distances facilitate personal, face-to-face contacts, the building of trust as well as networks and learning processes among actors (Asheim and Gertler, 2005; Boschma, 2005). This has to be considered as particularly true for innovation activities that are complex (Hansen, 2014; Morgan, 2004), such as those aiming to target grand challenges (Coenen et al., 2015a). For niche build-up to take place, the building of social networks, articulation and sharing of expectations as well as (second-order) learning processes are generally considered crucial (Hoogma et al., 2002; Raven, 2005; Schot and Geels, 2008). These processes are supposed to benefit from geographical proximity (Coenen et al., 2010).

I therefore assume RIS to provide supportive spaces for niche development; yet acknowledging that niches can also take global, multi-scalar character (see e.g. Binz and Truffer, 2012). If niches mature, they can develop higher levels of structuration of actors and institutions and develop a TIS (Markard and Truffer, 2008). The role of regional innovation policy (RIP) I consider to lie in aligning agency among actors and actor groups. In that way innovation respectively transformation processes can be supported. Ideally, and as TIS focus on innovation dynamics in specific technological fields, I argue that various other innovation systems both inside and outside the regional boundaries need to mature in order to create full alignments that function and that allow transitions to take place. This also implies that simultaneously, established innovation systems become destabilized (Kivimaa and Kern, 2016).

These elaborations indicate the complexities that transformative change involves and insinuate that the development of a detailed, integrated framework that captures all dimensions needed to address grand challenges is extremely challenging. In particular, the considerations point towards new interdependencies between RIS and socio-technical systems. At the same time, however, this attempt to integrate ideas from RIS, TIS and MLP provides a basis regarding how to think of a more multi-perspectival framework to address grand challenges from a systemic perspective on regional innovation. In particular, it makes evident the need for conceptualizing both radical change as well as path dependencies in regional economic evolution. Moreover, these considerations reveal that the three gaps addressed in this dissertation (region-specific institutions, region-external institutions and socio-technical alignments) are important to fill when aiming to tackle transformative change. Addressing these gaps, in turn, promises to offer valuable insights regarding the potential and limitations of regional innovation policy to tackle grand challenges.

Table 1: Commonalities and complementarities of RIS and STT

<u>RIS</u>	<u>STT (MLP+TIS)</u>
<u>Commonalities</u> <ul style="list-style-type: none"> - theoretical roots in evolutionary economics - systemic approach to innovation - multitude of public and private actors involved in innovation - acknowledge path dependence, lock-in, non-linearity and uncertainties - institutions guide actor behavior - application as policy concepts 	
<u>Strengths</u> <ul style="list-style-type: none"> - Studies spatial contexts in which innovations come about; geographical context important - (Regional) economic and social interactions of actors crucial; institutions matter (facilitate and/or constrain) - Focus on development of innovations (firm- and research driven processes) - Targets innovation for economic growth (localization and urbanization economies important); addresses structural innovation system failures 	<u>Strengths</u> <ul style="list-style-type: none"> - Close interdependency between technologies and institutions - Focus also on adaptation and diffusion of innovations - Consideration of socio-technical context/ societal conditions; considers therefore broader range of actors - Simultaneous conceptualization of path dependencies and radical innovation - Innovation for transformative change (directionality of innovation); address transformational system failures - Dynamic/evolutionary perspective
<u>Weaknesses</u> <ul style="list-style-type: none"> - Limited (rather supply-side) understanding on interdependency of technologies and institutions - Limited (rather initial) dynamic/evolutionary perspective - Lacking conceptualization of radical change 	<u>Weaknesses</u> <ul style="list-style-type: none"> - Only implicit consideration of spatial context - Consequently, limited explanatory power regarding how and what kind of regional context factors impact innovation activities

Source: own draft

3 Research design

Practicing research in general and writing a dissertation in particular requires a reflection on the underlying methods (i.e. the technique of data collection and transformation), methodology (i.e. the process of carrying out research), ontology (i.e. the conception of reality and theory of what exists in the world) and epistemology (i.e. the broader philosophy of knowledge). The objective of this chapter is to provide such a reflection, which adds up to the research design of the dissertation.

3.1 Critical realism as epistemological and ontological perspective

There exist two opposing philosophical positions regarding how a researcher finds out about the world: relativism and positivism (often also referred to as subjectivism and objectivism) (Sayer, 2000). They are rather oppositional in their underlying conception of reality (i.e. ontology) as according to positivism, research should aim at creating objective knowledge, while it is argued in relativism that all knowledge is socially constructed and thus subjective to the researcher (Sayer, 2000). The position that I take in this dissertation is placed in between these two extremes and is referred to as critical realist position (Bhaskar, 1975): Put in a nutshell, critical realism emerged out of some central disagreement with the perspective taken in positivism and postulates that there exists a reality (i.e. a world) independent of our consciousness and knowledge about it, but also that our knowledge about this reality is to some extent theory-laden and fallible (Sayer, 1992; Bhaskar, 1998; Yeung, 1997; Martin, 2012).

The position taken in critical realism implies that it is (notionally) possible to obtain objective knowledge, the possibilities for this are however rather limited because we all have own, subjective experiences of the world. This discrepancy in critical realism is usually referred to by distinguishing between the transitive and intransitive dimension (Bhaskar, 1975): The first is about the (subjective) experience of the world, expressed in scientific objects such as theories and concepts, while the latter is about the world (reality) independent of our experiences of it. The distinction between the transitive and intransitive dimension in critical realism is thus meant for illustrating that the world is independent of our theories of it and can also be referred to as the changing (transitive) and unchanging (intransitive) nature of knowledge (Pratt, 1995). The

critical realist position can be applied to both the physical and the human (i.e. social) world. As the latter is largely constructed by social agents, its entity is somewhat more entangled than the physical world and, following Bhaskar (1975), requires the distinction between three different domains: the real, the actual and the empirical. The real constitutes structures and mechanisms that define the 'real' world (i.e. reality) but are not observable, the actual is the level of events as observable (however not necessarily observed) phenomena, and the empirical constitutes experiences of these events (Sayer, 2000). Critical realism argues that knowledge is stratified around these three domains; however, they should be seen as separate, yet interdependent, layers of one another which "are ordered, not just jumbled up together" (Collier, 1994: 46). In critical realism, knowledge should thus be seen as "an accomplished *production* of knowledgeable actors in the social world. As such all knowledge must be considered to be not only fallible but also necessarily open to immanent, or ongoing, critique. In short, 'Truth' must be considered to be *conditional* and not as *absolute*." (Pratt, 1995: 66). Critical realism with its strong claim made at the ontological level regarding the independent existence of reality as well as the researcher's knowledge about it, can be regarded as an influential philosophy within human geography (Pratt, 1995; Yeung, 1997).

3.2 Methodology

Also the methodology (i.e. the process of carrying out research) is informed by the way a researcher sees reality and is in this PhD thesis based on a critical realism epistemology and ontology. In critical realism, abstract research constitutes the central methodology to approach the real (Sayer, 1992; Sayer, 2000). Abstraction thereby refers to the systematic understanding and examination of (social) objects, which is likely to be unstructured and superficial in the beginning but after several abstracted objects have been examined, they can be combined and formed into concepts (Sayer, 1992). Concepts should thus be understood as the outcome of a process of abstraction, which does not constitute a linear development but rather should be understood as a back and forth between the concrete and abstract, which Bhaskar (1975) refers to as retroduction. The process of retroduction terminates when further abstraction does not lead to any additional, significant explanation and improvement of the concept (Yeung, 1997) and as Pratt (1995) emphasizes, "it is only through such a dialogue between practice and conceptualization that critical realism can be applied" (Pratt, 1995: 62).

Next to abstraction, an important technique in critical realism is the so-called triangulation (Denzin, 1970; Downward and Mearman, 2007). It addresses the issue

of validity of experiences and interpretations and goes back to one central argument made in critical realism at the ontological level – namely that individuals (and researchers) are biased, their experiences subjective and their observations fallible. In order to counter such bias, research carried out should be based on different sources, which imply multiple data sources (data triangulation), collaboration with other researchers (investigator triangulation), interdisciplinary research (theoretical triangulation) and the use of supplementary research methods (methodological triangulation) (Denzin, 1970; Yeung, 1997).

Based on these explanations, important notions can be made on how theory is understood. The reasoning in positivism is that research should rely on what can be measured and observed; assuming that the world is operated by laws of cause and effect, and that science is to observe the relationship between these causes and effects. Thus, theory in positivism is regarded as ordering framework implying a posteriori theory formation through theoretical and empirical generalizations. In (critical) realism in contrast, theory is understood as means for a priori conceptualization by abstraction (Yeung, 1997). This is possible by the differentiation of the transitive and intransitive dimension, and more particularly, when researching the human (social) world through the definition of the real, the actual and the empirical. In other words, the objective of critical realism is to understand and explain reality, while at the same time implying that it will never reach the level of the real. Consequently, this implies that theory is considered to be temporary and that it can be revised – and also, that research is seen as being an ongoing process (Sayer, 2000). While positivism does not distinguish between ontology and epistemology, the differentiation between the real, the actual and the empirical in critical realism provides a rather rich ontology as it allows considering that the world can hardly be captured through (empirical) research - research, yet, has the objective to better understand the world (Sayer, 1992, 2000).

3.3 Methods and research setting

According to critical realism, methods (in social science) are means to identify the mechanisms that are producing social events (Flyvbjerg, 2006b). In this dissertation, thus also the choice of methods is informed by the critical realist position, implying that empirical research carried out should be abstract. An important distinction is generally made between intensive (qualitative) and extensive (quantitative) research methods (Berg and Lune, 2012): While the overall objective of extensive research is to identify common patterns of objects under study, intensive research in contrast is engaged with identifying causal processes in a case (or a limited number of cases).

Although both extensive and intensive research methods are compatible with the critical realist position, intensive research is considered particularly crucial for theory development (Sayer, 1992, 2000). As extensive and intensive methods have their particular advantages and disadvantages, it is reasonable to combine them.

This dissertation consists of case studies of different Swedish regions in which biomass-based industry formation, respectively transformation, takes place (the choice of the particular cases is explained further below). There is not a common, general definition of case study existing; yet a case study is usually understood as a detailed in-depth examination of a particular setting, which implies the systemic gathering of information (i.e. data) and its investigation with the aim to describe and explain specific phenomena (Berg and Lune, 2012). Through the lens of critical realism, case studies can be understood as means to put forward the understanding of the qualitative nature of social objects (Sayer, 2000) and therefore this dissertation has its main focus on the intensive approach (i.e. qualitative methods). In particular, the main aim of the individual case studies is to interpret interactions of actors, their experiences and knowledge as well as the why and how of their operation patterns; or put differently, to find out why actors act and interact in particular ways and what the underlying causes and mechanism are (Mason, 2002; Thorne, 2000).

With regard to research methods, the main source for the empirical data that I collected were semi-structured (or semi-standardized) in-depth interviews with key stakeholders of the studied regional industries. Semi-structured interviews are based on a theoretically informed and thematically organized interview guide that contains central, pre-formulated/pre-determined (open) questions and topics. Semi-structured interviews are also context sensitive as they allow adjusting the interview guide before each interview, based on the background of the particular interviewee. This method is somewhat flexible with regard to individual adjustment, while the formulation of central (key) questions at the same time ensures a certain level of comparability of the individual interviews (Mason, 2002; Patton, 2002; Atteslander, 2003). Semi-structured interviews are due to their typical open character an appropriate method if not only particular information, but also the talk about different topics in more general terms are central for the research objective (Schnell et al., 2005; Gläser and Laudel, 2006). During semi-structured interviews, the interviewer follows up on issues and topics that arise during the interview (Berg and Lune, 2012). As Pratt (1995) takes up, Sayer (1984) argues for such less standardized and more interactive interviews as particularly suitable for conducting abstract research taking a critical realist position as these constitute “a meaningful type of communication which maximizes the information flow by making use of communicative and social skills, by being willing to adapt preconceived questions and ideas in the course of the interview” (Sayer, 1984: 223).

From the critical realist philosophy follows that case studies have to be theoretically informed. Therefore, semi-structured interviews can be seen as a suitable method to carry out research following such position: The theoretically informed interview guide on the one hand and their open and flexible character on the other hand ensure the back and forth (i.e. retrodution) between the concrete and the abstract. This, in turn, is in line with the aim of this dissertation to not only make an empirical contribution, but also to put forward theory development. In other words, abstraction (i.e. conceptualization and theoretical reasoning) has been central in all articles included in this dissertation. Thereby, the interviewees (i.e. practical experts) provide tacit knowledge about the layer of the actual during the interviews, while the interviewer (i.e. researcher) attempts to systematically understand and examine this information in order to incorporate it into concepts and by doing so, come closer to the layer of the real (Flyvbjerg, 2001). Obviously, however, also some limitations of semi-structured in-depth interviews exist (Patton, 2002; Berg and Lune, 2012). These weaknesses refer to the nature of interviews in general and rely on the high context specificity of the interview situation: It is hardly possible to verify whether that what the interviewees state actually reflects the truth and their opinion. Moreover, the (elaborateness of) answers might depend on the general mood of the day of an interviewee and/or how the interviewer is perceived by the interviewee. Language in general has to be considered as having limitations and is also much influenced by how a particular interview situation is introduced and framed by the interviewer.

In order to account for these limitations of interviews and also to do justice to triangulation, the case studies included in this dissertation draw on a number of supplementary research methods (methodological triangulation): Studies of publicly available documents such as strategic plans, annual reports as well as content analysis of web-pages (Berg and Lune, 2012) constituted a supplementary method of my data gathering. Moreover, these were partly supplemented by extensive research in form of (descriptive) statistics which I used in some of the articles to embed the studied phenomena into the broader picture. The general research approach that I followed in all case studies is thus well in line with how one is supposed to conduct research from a critical realist position (Yeung, 1997): First of all, the critical realism position implies a careful and critical review of the existing literature and theory. Based on this review, I collected the empirical data, which included different data sources. The empirical data is in turn used for abstraction (i.e. a more systematic understanding of the social objects under study) which I applied to put forward the formation of concepts. Moreover, I accounted for the validity of interpretations through extensive discussions with co-authors, supervisors and colleagues as well as through presentation of the individual articles at conferences, seminars and PhD courses (investigator triangulation). Through

its explicit interdisciplinary theoretical approach, I also account for theoretical triangulation in this PhD thesis.

Acknowledging that the case study method, as all research methods, have their drawbacks and are exposed to critique (Flyvbjerg, 2006a), it is fair to state that from a critical realist position case studies provide clear scientific value. Opposed to positivism which assumes that the world is operated by laws of cause and effect and which aims at creating objective knowledge, generalization through the lens of critical realism has to be read in light to provide general tendencies or pieces of truth: the stratification of the real, the actual and the empirical implies that truth is conditional and can be revised. Yet, the quantity of observations as such is not decisive for new explanations, rather as Sayer (2000) puts it “What causes something to happen has nothing to do with the number of times we have observed it happening. Explanation depends instead on identifying causal mechanisms and how they work, and discovering if they have been activated and under what conditions” (Sayer, 2000: 14). Validity and truth are highly context dependent and here lies the strength of social science to discover interests and values through deliberation and reflexive analysis (Flyvbjerg, 2001, 2006b). The case studies that I conducted within the frame of this dissertation provide evidence from different regions with different characteristics. I have not only used these to derive conclusions from each particular case in the individual papers, but also to arrive at a more general level of generalization (without risking to overemphasize place-specificities). On this note, it is important to state that case studies can have varying units of analysis – that is the main entity of analysis in the study (Berg and Lune, 2012). As the interest of this PhD thesis lies in researching regional (institutional) context factors and how these impact regional economic evolution, the region constitutes in all articles the unit of analysis. More precisely, my dissertation is based on observations at the level of actors and institutions of industries in RIS which I have used to draw conclusions regarding regional characteristics.

Empirically, this dissertation focuses on three regions with biomass-based industry formation and renewal in Sweden. My sampling and case selection is motivated by the typology proposed by Tödting and Trippel (2005; see also Trippel et al. 2016) which has prominently been applied by RIS scholars to identify region-specific challenges to innovation and to suggest context-specific policy support. Moreover, the case sampling leans implicitly on RIS scholars’ considerations to differentiate between path renewal and new path creation (Isaksen, 2015; Isaksen and Trippel, 2016a); although I do otherwise not very explicitly engage in this differentiation.

The first empirical case (paper 1) is situated in a peripheral, old industrial region in the area around Örnsköldsvik in Northern Sweden. Particularly, it deals with the paper and pulp industry and its attempts to renew itself by applying bio-refining technologies

and broadening its output to other products than paper pulp. This case was the first empirical focus that I chose. It originated from the need to further enhance knowledge regarding the potential, barriers and limitations for regional innovation policy to facilitate industrial renewal in old industrial regions.

The second empirical case (papers 2 and 3) is situated in a core, organizationally thick and economically diversified region: Scania in Southern Sweden. This case I chose to shed light on new industry build-up by studying the regional biogas industry. In this empirical case, biomass residuals from sewage, industry and households are used to run biogas buses in regional public transport. I decided for this case as it constitutes a complement to the first case with regard to regional characteristics (core vs. old industrial region) as well as 'type' of industry transformation (new industry build-up vs. renewal of established industry structures). Due to the diverse mechanisms active in the region during the process of the emergence and further development of this biogas industry, I used this empirical case in two articles (i.e. case studies).

The third empirical case (paper 4) is likewise located in an economically diversified, organizationally thick core region: the region around Gothenburg on the Swedish west coast. It focuses on the chemicals industry which aims at reducing its fossil content by drawing on biomass as a resource. This case possesses similarities to the first case in that it deals with renewal/transformation of existing, large-scale basic industry structures; yet this time it is located in a core region.

The constellation of regional characteristics (core vs. old industrial region, industry characteristics (small-scale regional vs. large-scale basic materials industries) and type of transformation (new industry build-up vs. transformation of existing industry structures) in the empirical cases chosen allowed me maximizing insights regarding the role of regional context for cleantech industry dynamics. The empirical cases, including a description of the region-specific characteristics, are introduced more in detail in the individual articles. In addition to the cases of biomass-related industry dynamics, the dissertation includes in one article (paper 3) the empirical case of the new media industry in Scania. It was mainly conducted by my co-author. This case provides valuable evidence for the importance of institutions for industry emergence and further development in other fields than environmental innovation. Table 2 provides an overview of the case selection and sampling methods that I have applied in this PhD thesis.

Table 2: Sampling methods and case selection

Empirical case	Type of region	Type of new path development
Paper and pulp industry in the Örnköldsvik region, Northern Sweden (paper 1)	Peripheral, old industrial region	Path renewal of existing industry
Biogas industry in Scania, Southern Sweden (papers 2 and 3)	Core region	New industry build-up
Chemicals industry in the Gothenburg-Stenungsund region, West Sweden (paper 4)	Core region	Path renewal of existing industry

Source: own draft

This dissertation draws in total on insights from more than 70 semi-structured in-depth interviews, of which more than 30 were carried out by me (a few of them I conducted together with co-authors, but the large majority I conducted on my own). Paper 1 draws on a total of 20 interviews of which I was involved in six. The other interviews were conducted by my co-authors prior to 2012; yet, I had access to large parts of this empirical material gathered (that is recordings and/or written transcripts). Paper 2 draws on a total number of 17 interviews of which I conducted eleven by myself and six were conducted in the frame of a master student's research project. I had access to these latter interviews in form of interview transcripts. Paper 3 draws on the interviews used in paper 2. Some of these interviews I followed up by contacting some of the interviewees by email or phone; yet these follow-ups have not been counted as additional interviews. Additional 20 interviews were made for the new media case which was conducted by my co-author (I was involved in three of them). Paper 4 draws on a total number of 17 interviews of which I conducted eleven by myself; the six interviews carried out for paper 1 served as a reference for this paper as the cases of the chemicals and forest industry show some empirical links (for instance, they partly involve the same demonstration projects). In addition, I carried out three more interviews in the context of project work which have not been included in the interview counts of the single articles. These interviews did not involve actors of the studied regional industries, but actors from these industries in other regions (in particular, actors operating paper pulp and district heating plants) which also provided valuable input for the overall subject of this thesis. The interviews conducted shall not only be seen as method for data collection as such, but also for reflecting/elaborating on information gathered by secondary data (that is largely desktop research on webpages and strategy documents, as described above).

The large majority of interviews I conducted face-to-face, yet in a few cases I made follow-up interviews by phone: in these cases, however, there had mostly been a previous personal contact with the interviewee prior to the interview and more specific research questions were the reason for the follow-up (Berg and Lune 2012). The personal in-depth interviews lasted between 45 and 75 minutes. Thereby, the information gathered was decisive for how many interviews I conducted for each empirical case: the process of retroduction terminated when additional interviews did not lead me to crucial new insights with regard to the research questions under study. I recorded most of the interviews (in agreement with the interviewees) and used the records to write interview transcripts. During the few interviews that were not recorded (which were exceptions) I wrote down notes. Instead of subjecting the interview transcripts to a particular method of analysis, such as content analysis (Berg and Lune, 2012), I evaluated them by “rational abstractions” (Pratt, 1995: 69). Rational abstractions imply the search for a common line of agreement among the interviewees’ statements. This technique obviates that the inherently qualitative material is used for the production of quantitative data as according to critical realism, explanation depends on identifying causal mechanisms rather than on the number of times something has happened (Sayer, 2000). The interviewees were given the possibility to read the manuscript of the respective article. I applied this procedure both in order to inform the interviewees about the state of the research, but also to give them the possibility to approve (or mention disagreement with) direct quotes that I have used in the articles. As the interviews contained sensitive information capturing personal opinions regarding barriers (and drivers) of development, I assured the interviewees to stay anonymous in the studies. Therefore only the position and type of organization - and not the name - of the interviewees are indicated in context with direct quotes used in the articles.

The interview guidelines contained questions about the development of the regional industries during the past decades, the drivers and barriers of change/transformation respectively industry build-up, future development prospects as well as possible strategies and regional strength to address (potential) hinders⁶. The selection of interview partners was based on the specific regional innovation system in each of the empirical cases: crucial RIS actors and key persons I identified based on desktop research; public actors constituted cluster initiatives and regional governments, as well as representatives from universities/research institutes. Private actors constituted firms active in the field of chemicals, paper and pulp and biogas (and new media,

⁶ My interview guidelines as well as information about my interviewees are available upon request.

respectively). In each case study I aimed at capturing actors' perspectives both from the public and private sector.

3.4 RIS and socio-technical transitions in a critical realist perspective

From a critical realist perspective, RIS can be understood as constructs that help us to better understand the (social) world. Put differently, one should not consider RIS as real constructs, but rather as concepts that have the objective to put on paper how we think of the real. Likewise other concepts, RIS have come about through a process of abstraction - that is the systematic understanding and examination of social objects. In particular, RIS have the objective to conceptualize the (regional) conditions under which innovations emerge and develop. RIS have widely been applied by scholars to carry out abstract, concrete research in various regional contexts and have run through many processes of retrodution and abstraction throughout the past decades. Moreover, RIS have been helpful for industries, firms and governmental actors to identify opportunities and limitations for action in their specific region. RIS can be thought of as entities in which a variety of mechanisms such as networking, cooperation and competition occur and through which the single RIS components (i.e. public and private actors in the RIS) interact. Whether a particular event occurs or not depends on the specific institutional set-up of the innovation system (Coenen, 2006).

In this dissertation I have identified three gaps which explain why grand challenges cannot be adequately addressed with the RIS approach. Applying the critical realist terminology, this means that not all mechanisms that lead to the occurrence (or non-occurrence) of events can sufficiently be captured and explained. It implies that the process of retrodution and abstraction during the development of the RIS approach has not been constructive with regard to conceptualizing the conditions important for transformative change. From a critical realist perspective, research is considered as ongoing process, and concepts as temporary and revisable. Concepts have an open-ended character and should on no account be regarded as fixed frameworks or predictive theories (Flyvbjerg, 2006b). In this regard, the interdisciplinary approach (complementing RIS by STT) that I follow in this thesis allows for a high level of theoretical triangulation: it opens up for new possibilities of conceptualization and promotes putting the (subjective) understanding of the world into a concept. Theoretical triangulation allows extending empirical data collection towards novel, previously disregarded aspects (i.e. experiences of events). In that way, it expands the

‘dialogue between practice and conceptualization’ (Pratt, 1995), respectively between the concrete and the abstract; always aiming to progressively approach the level of the real. The approach to complement RIS by insights from STT allows to capture a larger variety of mechanisms that (potentially) cause, or hamper events to occur. On the conceptual level, this implies new insights regarding the components of RIS, their relationships (linkages) and the system boundaries.

In particular, the incorporation of considerations from the MLP promise complementary insights with regard to human beings being major agents of societal change. While the innovation systems literature is rather inward oriented (Weber and Rohracher, 2012), the MLP puts emphasis on the embedding of technologies into social practices. In particular, critical realism can be considered as valuable ontological foundation for conceptualizing radical change in the context of path-dependence and stability (Svensson and Nikoleris, 2016): The stratification of the real, the actual and the empirical allows considering that various (stratified) mechanisms interact with one another. Thereby, they can both reinforce and weaken the effects of one another and in this way impact the actualization of events.

4 Summary and conclusions

4.1 Summary

The papers included in this dissertation take slightly different perspectives on the overall research questions addressed. More precisely, they all deliver answers to the question how industry dynamics in the context of grand challenges are enabled and/or hindered by regional context. The papers take interdisciplinary approaches and provide empirical evidence from industries in Swedish regions that aim at increasingly, respectively more efficiently use biomass as a resource. Thereby however, the papers differ with regard to how explicitly grand challenges are addressed: While paper 4 puts grand challenges and transformative change central to its research objective, these notions are somewhat less pronounced in the remaining articles. Although not under the label of overall regional transformative change, the forest industry in paper 1 is facing similar pressures to transformation like the chemicals industry in paper 4: The firms are aware of their contribution to climate change and environmental pollution and have, on the one hand, an intrinsic interest to improve their (dirty) image; while they at the same time are in their activities influenced by mainstream industry logics. On the other hand, they realize that in the future, markets are likely to change and they aim at using these market prospects in order to renew themselves; particularly also in light of their, globally seen, peripheral location in the North of Europe. In the empirical case on biogas in Scania, the link to grand challenges is again more explicit as industry build-up directly relates to a regional strategy regarding a reduction of net emissions of greenhouse gases. All papers thus target the bio-economy as one important solution to tackle grand challenges (Ollikainen, 2014).

The case studies are based on the common understanding of RIS that institutional settings are highly context specific and that they have to be read in light of the particular region they are located in. In the following, this chapter discusses the papers more generally with regard to the overall gaps addressed.

The first gap (i.e. the role of region-specific institutions and policies), is most directly addressed in papers 2 (Martin and Coenen, 2015) and 3 (Martin and Martin, 2016). Martin and Coenen (2015) explicitly addresses the early formation process of the biogas-industry by shedding light on the interplay between technologies, industry dynamics and institutions. The region showed a latent potential for diversification of industries and subsequent processes of branching, which however only gained

momentum through the announcement of a national policy programme. This provided legitimacy for technological change and influenced actors' activities towards alignment with the policy programme. Subsequent political decisions taken by the regional government appointed biogas as a fuel with positive future prospect. In that way, regional authorities were tying up with the technological trajectory catalysed by the national policy programme and created further legitimacy for actors to engage in industry build-up. That is to say, legitimacy played a crucial role in focusing and aligning actors' activities in the RIS. Legitimacy has gained some attention in the literature on regional innovation in context of public procurement (e.g. Morgan, 2013); as the current literature is however weak at capturing the embedding of RIS into broader socio-technical systems, additional region-specific, institutional processes needed for a transformation to occur remain largely disregarded. Martin and Martin (2016) investigate more closely the particular regional policy preconditions for new industrial path development of biogas in Scania. Regional authorities could support industry build-up as the region had the formal preconditions in terms of regional autonomy (and partly financial assets) in place to take own decisions and provide legitimacy for industry-build up. Moreover, it highlights the importance of the capability of regional policy actors to shape regional development. Institutional thickness in form of historically grown local interactions that shapes an innovation and cooperation culture is crucial for recognizing regional preconditions; and moreover for aligning interests and expectations towards common development goals. At the same time, however, the capability and scope of regional policy actors to induce regional institutional change (i.e. to break up inefficient institutions, to learn and to shape new ones) has shown to be crucial. Also in paper 1 (Coenen et al., 2015b) and 4 (Martin, 2016) regional policy action in terms of a high quality of local interactions has shown to be important for addressing transformative change. Although somewhat less explicitly addressed, in the case of Örnsköldsvik in paper 1, RIS actors recognized their regional potential and preconditions, developed collective action and succeeded in attracting national-level funding for their initiative. In similar manner in paper 4, historically grown, local interactions based on common expectations and trust showed to be important for setting up visions and future development goals. These common region-internal actions show on the one hand close interdependencies to attracting supra-regional funding (in the shape of policy programmes) to the region (paper 1, 2 and 3). On the other hand and once attracted, these policy programmes in turn also (at least indirectly) shape collaborative innovation activities by strengthening interactive learning and the development of common strategies (paper 3), or likewise by commonly becoming aware of key challenges to further development (paper 1).

Yet, the analysed cases also show differences in how effective policies are with regard to achieving industry build-up, respectively transformation. The biogas case (Martin and Coenen, 2015; Martin and Martin, 2016) shows a comparatively unproblematic example in which regional actors, based on identified, advantageous regional and technological preconditions, reacted to a national policy programme; although the latter did not target industry emergence as such. Regional authorities had the formal capacity to decide on regional economic development, to set up strategies and to carry forward the path initiated by the national policy programme. Additionally, it is fair to state that the biogas industry in Scania is a rather regionally configured industry as its entire value chain from raw materials and production (organic waste residuals) to consumption (market) is located in the region. That is to say, RIS policy could build a TIS within the regional boundaries by institutionally supporting technological change through strengthening functions of the innovation system. Papers 1 and 4 in contrast deal with the renewal/transformation of existing industry structures rather than new industry build-up. They therefore stronger point out the barriers to new regional industrial development paths. Both cases show some enabling factors inside the region such as the existence of (lab-scale) technologies or interactions between actors from which, at least to a certain extent, develop common expectations and actions. Hinders seem largely to be of extra-regional institutional nature, situated at higher spatial scales. These hindes are largely related to policy, which makes this discussion arrive at the second research gap: the role of region-external institutions and policy influences.

The cases of the pulp and paper (paper 1) as well as chemicals industry (paper 4) have more pronounced linkages beyond the regional boundaries, for example in terms of purchase/access to raw materials and configuration of/dependence on national and international markets. They are therefore stronger dependent on long-term regulations from supra-regional levels: Supra-regional regulations would be required to support the formation of markets and import taxes on bio-raw material would have to be abolished. Supra-regional efforts would also be necessary with regard to funding for infrastructure investments that the industries cannot afford on their own because of sunk-investments in large-scale infrastructure. Furthermore, renewal of mature industries seems to be hindered by thinking in established industry logics. These partly concern the way agency is carried out by (incumbent) regional actors; however, they also become evident in established ways of thinking about industries in the society at large. These shortcomings result in lacking supportive, transformative incentives for these industries (i.e. chemicals and pulp and paper) from supra-regional policy levels and largely remain beyond the scope of regional actors to influence. Hence, coordination between regional innovation policy and adjacent domains and levels of policy-making is needed as some of the most pressing obstacles for renewal are not specific to the regions, but instead to

the industries at large. As shown in the case of biogas in paper 2 and 3, region-external institutions and policies can trigger and support transformation processes towards more environmentally friendly modes, if regional and national policy orientations are, or can become, aligned with one another.

On this note, the discussion arrives at the third research gap, the need to create novel socio-technical alignments to achieve transformative change. This gap is most explicitly addressed in paper 4, but it is an important aspect in all empirical cases and also addressed in paper 1 and 2: One crucial success factor in the case of biogas in Scania (paper 2) giving momentum to the industry is that regional policy could create policy-based long-term support for the (regionally configured) industry. The perspective on TIS functions puts focus on aspects such as the build-up of infrastructure, the set-up of development goals and supportive regulatory settings, as well as the creation of long-term demand for biogas in the region. In the case of the paper and pulp industry (paper 1), the analysis clearly reveals that the infusion of radical emergent technology is necessary for new regional path development; yet, the industry faces considerable barriers to renewal due to lacking institutional adaptation (as mentioned above). Likewise the pulp and paper industry, the chemicals industry faces barriers related to insufficient socio-technical alignments that hinder transformative change. The focus on the policy processes of shielding, nurturing and empowerment as taken in paper 4 shed closer light on the need to create socio-technical alignments both within and across the regional boundaries and policy levels: Whereas shielding puts emphasis on the need to create visions and achieve alignment of expectations, nurturing sheds light on region-internal processes related to the adaptation of production and demand patterns of industries, which need, amongst others, to be supported by adaptation of skills and training or regulatory settings. Empowerment strategies emphasize the need for socio-technical alignments across spatial scales and point out possibilities that regional actors have to impact supra-regional institutional context conditions. Due to its location in an organizationally thick, economically diversified core region, the chemicals industry possesses advantages for industrial renewal that the peripherally located pulp and paper industry in Örnsköldsvik (paper 1) does not possess. On the one hand, it enjoys greater overall economic impact which is likely to be favourable for exerting influence on supra-regional decision making. On the other hand, the regional economic diversity entails advantages in that it offers possibilities to expand a narrow (supply-side) focus on technology towards markets. Again, in the case of biogas in Scania (paper 2 and 3), the successful build-up of the industry can be ascribed to attempts to achieve new socio-technical alignments along the value chain, spanning production and diffusion as well as supporting processes such as infrastructure build-up. The perspective on socio-technical alignments implies that industrial and regional development become closely

intertwined. Moreover, it reveals that the three research gaps are interdependent and closely linked to one another as both region internal as well as external institutions and policies have to become aligned in order to achieve transformative change. Table 3 provides an overview of the content of the articles and the research gaps they address.

Table 3: Overview of articles and research gaps

	Paper 1	Paper 2	Paper 3	Paper 4
	Coenen et al., 2015b	Martin and Coenen, 2015	Martin and Martin, 2016	Martin, 2016
Empirical case	Paper and pulp industry in the Örnköldsvik-Umeå area	Biogas industry in Scania	Biogas industry and new Media industry in Scania	Chemicals industry in the Stenungsund-Gothenburg area
Region (type)	Peripheral, old industrial	Core	Core	Core
Industry dimension	Transformation of large-scale industry structures	Industry build-up	Industry build-up	Transformation of large-scale industry structures
Gap addressed (explicit)	National level RIP to influence renewal	RIP to induce industry emergence/build-up	Policy preconditions/capacities and policy roles of RIS	Transformative change and socio-technical alignments
Gap addressed (implicit)	RIS internal – RIS external institutions Socio-technical alignments	RIS internal – RIS external institutions Socio-technical alignments	Historically grown interactions in RIS Political autonomy, financial assets	RIS internal – RIS external institutions Historically grown interactions in RIS
Theoretical approach	RIS/old industrial regions; regimes/niches	EEG and TIS	RIS and regional governance	RIS and niches/regimes

Source: own draft

4.2 Conclusions

Central interest of this dissertation is to research how regional (institutional) context conditions impact industries in addressing grand societal challenges. More particularly, the PhD thesis studies how and why change processes of industries towards more environmentally friendly modes in regions occur – or not occur. It has engaged in the question how such industry dynamics are enabled and/or constrained by regional context. Consequently, it also puts central focus on the role, respectively possibilities and limitations, of regional innovation policy to support desirable processes. The theoretical objective is to make a step towards a more coherent, multi-perspectival conceptual framework in the literature on economic geography regarding how to address grand challenges. The RIS approach has been identified as framework with potential to make such contribution. It is complemented by insights from the literature on socio-technical transitions which provides a co-evolutionary perspective on technologies and institutions and their embedding into broader socio-technical systems. In particular, the dissertation identifies and addresses three research gaps that seem important to consider when explaining the evolution of regional industries: the role of region-internal/specific institutions, the role of region-external institutions and policy influences – as well as the need to create socio-technical alignments.

The interdisciplinary approach taken suggests viewing RIS as being embedded into broader socio-technical systems within which innovation respectively transformation processes evolve. In other words, overall societal and economic developments impact agency of actors and actor groups in a RIS. On the one hand, they reinforce (path-dependent) activities, while they, on the other hand, also constitute triggers/origins for (radical) innovations. Such conceptualization of RIS implies changes with regard to the understanding of system components, linkages and boundaries. More precisely, it means that additional (functional) processes take place within and across the boundaries of a RIS which have not found consideration in the literature so far. Moreover, it implicates that a broader range of actors and actor groups have to be considered which in various forms take agency in the innovation system. Particularly, it makes necessary a stronger consideration of the society at large. It implicates that a focus on innovations in terms of products and technologies as provided by the current RIS literature is not sufficient. Rather, innovations should be aimed at creating or re-configuring socio-technical alignments both within and across regional boundaries which, amongst others, make necessary a stronger focus also on the adaptation and diffusion of innovations. Socio-technical alignments target the transformation of production and consumption patterns and require the need for co-evolving changes in technologies, infrastructures, regulatory frameworks and other societal dimensions. The

critical realist position taken in this dissertation supported such re-conceptualization of RIS: It allowed seeing concepts as temporary and research as ongoing process. Critical realism allowed for a high level of theoretical triangulation; in this way it opened up new possibilities for conceptualization to put the (subjective) understanding of the world into a concept.

The findings of this PhD thesis are in line with the RIS literature in that regions have different potentials to bring about innovations (Tödtling and Trippl, 2005): The potential to bring about cleantech industry dynamics is context-sensitive and particular to each RIS with its specific economic, institutional and political settings. However, the findings also suggest that for tackling grand challenges, other aspects than previously addressed play a role. What are the possibilities and limitations of regional context to bring about cleantech industry dynamics? Cleantech industry build-up seems (notionally) possible within the regional context if all necessary system components are present or can be mobilized within the RIS; and if these components are connected through functioning linkages and relationships. In other words, if RIS can develop their own, small-scale socio-technical systems in which region-internal institutional settings are concerted in that they ideally shape socio-technical alignments. The build-up of a regionally configured industry (as in the case of biogas in Scania) is thus likely to have better prospects than cases of the transformation of established, large-scale industry structures that transcend regional boundaries (as in the cases of the paper and pulp industry in Örnsköldsvik and the chemical industry in Stenungsund-Göteborg). In the latter cases, not all system components and linkages can be mobilized sufficiently within the regional context. Important linkages in form of supra-regional institutions and policies exist which lie outside the direct scope of regional influence to turn them into functioning socio-technical alignments. This explains why economically diversified and organizationally thick core regions, generally considered to provide favourable preconditions for new regional industrial path development (Isaksen and Boschma 2015; Trippl, 2016a), can face severe hinders with regard to setting in motion or maintaining desirable cleantech industry dynamics. The perspective on socio-technical alignments also brings in a new perspective on relatedness through creating new, extended value chains. Transformative change should not be understood as transformation process of one single industry; rather, it is closely connected to regional transformation as a whole, implying that the borders between regional and industrial transformation become blurry. No matter what industries are present in a region, ideally all of them, sooner or later, need to undergo a transformation. Furthermore, evidence from this PhD thesis shows that organizational thickness is not automatically of advantage for tackling grand challenges: It is only favourable if organizational structures get adapted to the new requirements of transformative change. Not all

regions that possess organizational thickness and a variety of industries will be eager to experiment and transform. Here, the capacity of RIS to induce institutional change is crucial, putting new requirements of regional innovation policy for transformative change.

But what are the possibilities and limitations of regional innovation policy to address grand challenges? First of all, the extension of RIS based on TIS and MLP as framed above suggests that the current, overriding focus of the RIS literature to address structural innovation system failures (Klein Woolthuis et al., 2005; Asheim et al., 2011a) is not sufficient when attempting to address policy approaches for tackling grand challenges (Coenen et al., 2015b). In line with Weber and Rohracher's (2012) work on transformational innovation system failures, the findings suggest that additional policy action is needed to address grand challenges. However thereby, the possibilities and limitations of *regional* innovation policy have hardly gained attention.

Comprehensively, the extended perspective on system components, linkages and boundaries of RIS speaks for the need to correct failures both within and beyond RIS boundaries. Much aligned, the research gaps addressed in this dissertation emphasize the need for considering region internal as well as region external institutions and policy influences for transformative change. Moreover, they call for the need to create novel socio-technical alignments of technologies and institutional settings, capturing both RIS and their socio-technical environments. The question regarding the possibilities and limitations of regional innovation policy to address grand challenges goes thus back to finding out how and to what extent regional innovation policy can achieve the building of own socio-technical systems; and moreover, how and in what regard it can impact region-external socio-technical environments.

One important role of regional innovation policy is, in line with recent contributions on smart specialization, to support the building of regional visions in order to allow (transformative) innovation to emerge (Asheim et al., 2016a; Moodysson et al. 2016; Morgan 2016a, 2016b). This dissertation has identified 'policy capacities' of RIS as crucial in this regard (Martin and Martin, 2016): Historically grown policy action and the scope of regional policy actors to induce regional institutional change are important for aligning interests, developing shared expectations and sticking to common development goals. These policy capacities address what Weber and Rohracher (2012) aim to capture by directionality failures (i.e. the lack of a shared vision regarding transformative change). Likewise, policy capacities are likely to work against reflexivity failures in that they involve actors in self-governance and learning. Regional innovation policy should aim at creating more systematic linkages between components of a RIS and bring about organizational change in order to ideally build-up one (or several) TIS along an extended value chain. Policy processes that aim at achieving, or coming closer

to socio-technical alignments are in the TIS literature described as functions. These capture knowledge development and diffusion (generation, diffusion and combination of knowledge in the innovation system), the influence of the direction of search (incentives for organizations to enter the TIS), entrepreneurial experimentation (reducing uncertainty through probing and bringing a technology into practice), market formation (development of markets for emerging technologies), resource mobilization (mobilization of financial and human capital), and legitimation (exert influence on the public opinion with regard to a new technology) (Bergek et al., 2008). These functions extend the policy approaches for new path development common in the RIS literature, particularly as they put focus on the adaptation and diffusion of innovations through the development of markets, mobilization of (financial) resources and (long-term) legitimacy for industry formation (Martin and Coenen, 2015). These functions can however only be sufficiently mobilized within the regional context if the entire value chain from production to consumption can be mobilized within the regional context; and if regional policy also possesses the formal capacities to carry out the other necessary, supporting processes. Alternatively, but addressed in the context of this dissertation, regions could attempt to mobilize (TIS) functions also beyond regional boundaries, for instance with the help of resource- and powerful actors such as multi-nationals. Mostly however, the establishment of socio-technical alignments is needed that go beyond regional boundaries; or put differently, multi-level policy coordination failures have to be overcome (Weber and Rohracher, 2012). These point out that (bottom-up) regional innovation policy in most instances faces severe barriers to autonomously tackling grand challenges. Particularly demand articulation failures, hard infrastructural failures and hard institutional failures seem difficult to address solely by regional actors. Policy capacities within RIS are favourable for harvesting supra-regional policy programmes and aligning with them (Martin and Martin, 2016); however, the possibilities to impact the region-external socio-technical context in ways favorable to the RIS are limited (Coenen et al., 2015b; Martin, 2016). Regions have the possibility to communicate and make aware of the conditions necessary for change; decisions lie however largely outside of regional actors' room for maneuver.

The objective of this PhD thesis is to make a (first) step towards a RIS framework which is better capable to conceptualize innovation activities targeting grand challenges. It pays central attention to the importance of region internal and external institutions and policies as well as their overall socio-technical alignment. By doing so, it calls attention to the complexities associated with addressing grand challenges and the need for co-evolving innovations in different fields of the economy and society. On this note, the findings open up new questions and topics for future research. Comprehensibly, in order to arrive at a fully integrated conceptual framework, more investigation is

required than what can be captured in one dissertation. The critical realist perspective as taken in this PhD thesis suggests gathering more empirical evidence: more processes of retrodution are required to allow for further abstraction. In the following, I identify some directions for future research which in my view require further investigation; yet without raising claims regarding a complete future research agenda.

First of all, there is a need to systematically identify and include a broader variety of (RIS) actors and changing roles of actors and actor groups in the innovation process: Addressing societal challenges makes necessary changes in life styles and sparks questions regarding the role of end-users and civil society organizations in innovation processes. Considering such broader range of actors is likely to debunk further roles, barriers and limitations of regional innovation policy to tackle grand challenges. Thereby, also the role of large companies in the adaptation and diffusion of innovations requires closer investigation. At the same time, this is likely to further insights on the conditions under which agency takes place in (regional) innovation systems (Boschma et al., 2016). The findings also suggest a focus away from related variety towards connecting (from a supply-side) seemingly unrelated industries along (extended) value chains. Yet, there is a need for more knowledge regarding what favorable combinations of regional industries are to put forward transformative change; respectively what the roles and required competences of regional innovation policy and actors in RIS are to support transformative change.

The findings suggest that regions have to be considered playing a crucial role in tackling grand challenges. However, they also reveal that transformative change is not possible to achieve solely within the regional context; rather, it is dependent on socio-technical alignments across multiple policy levels and domains. There are national and international targets existing with regard to establishing a bio-based economy (OECD, 2009; European Commission, 2014), yet evidence from this dissertation shows that there is a limited overall knowledge existing how to implement and govern such extensive transformation. In other words, the future evolution of the supra-regional policy context is crucial for the possibilities of regions to realize transformative innovation. This raises crucial questions regarding the role of the state in making firms put into practice transformative change (Bergek and Norrmann, 2015; Mazzucato, 2015) and on a more general level, the question how to build-up new, while simultaneously destabilizing established innovation systems (Kivimaa and Kern, 2016).

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Article I

Path Renewal in Old Industrial Regions: Possibilities and Limitations for Regional Innovation Policy

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COENEN L., MOODYSSON J. and MARTIN H. Path renewal in old industrial regions: possibilities and limitations for regional innovation policy, *Regional Studies*. This paper analyses the potential, barriers and limitations for regional innovation policy to facilitate industrial renewal in old industrial regions. It draws on a case analysis of the policy programme 'Biorefinery of the Future' geared to promote renewal of the forest industry in Northern Sweden. It is shown that infusion of radical emergent technology is necessary for new regional path development, but not sufficient. To avoid a singular focus on technology-push, policy should pay more attention to complementary experimentation processes in relation to demand-side characteristics, firm strategies and business models as well as regulatory aspects. Moreover, coordination between regional innovation policy and adjacent domains and levels of policy-making is needed as some of the most pressing obstacles for renewal are not specific to the region but instead to the industry at large.

Old industrial regions Regional innovation policy Evolutionary economic geography Socio-technical transitions

COENEN L., MOODYSSON J. and MARTIN H. 旧工业区的路径革新：区域创新政策的可能性与限制，*区域研究*。本文分析区域创新政策促进旧工业区域的产业革新的潜力、障碍与限制。本文将分析一个促进瑞典北部林业革新、名为“未来的生物提炼”的政策计划。本文显示，新的区域路径发展，需要激进的新兴科技，但该科技本身却并不足够。为了避免单一聚焦于科技推力，政策必须更为关注与需求面特征、企业策略、商业模式及规范面向有关的补充性实验过程。此外，区域创新政策与政策制定的邻近范畴及层级之间，必须进行协调，因为追求革新的最为迫切的障碍之中，部分并不只专属于该区域，而是对整体产业皆然。

旧工业区 区域创新政策 演化经济地理学 社会—科技变迁

COENEN L., MOODYSSON J. et MARTIN H. La voie du renouveau dans les anciennes régions industrielles: les possibilités et les limites en matière de politique en faveur de l'innovation régionale, *Regional Studies*. Cet article analyse le potentiel, les obstacles et les limites quant à la politique en faveur de l'innovation régionale visant le renouveau industriel dans les anciennes régions industrielles. On puise dans une étude de cas, à savoir le programme politique appelé 'La bioraffinerie de l'avenir' qui est axé sur la promotion du renouveau de l'industrie forestière dans le nord de la Suède. On montre que l'apport de la nouvelle technologie radicale est une condition nécessaire mais pas suffisante pour le développement de nouvelles voies régionales. Pour éviter de donner la priorité à une poussée technologique, la politique devrait prêter plus d'attention aux processus d'expérimentation complémentaires par rapport aux caractéristiques de la demande, aux stratégies d'entreprises et aux modèles d'affaires ainsi qu'aux aspects réglementaires. Qui plus est, il faut la coordination entre la politique en faveur de l'innovation régionale et les domaines connexes et les niveaux de la mise au point de la politique parce que quelques-uns des principaux obstacles au renouveau ne sont pas spécifiques à la région mais plutôt à l'industrie en général.

Anciennes régions industrielles Politique régionale en faveur de l'innovation Géographie économique évolutionniste
Transitions socio-techniques

COENEN L., MOODYSSON J. und MARTIN H. Pfaderneruerung in alten Industrieregionen: Möglichkeiten und Grenzen der regionalen Innovationspolitik, *Regional Studies*. In diesem Beitrag werden das Potenzial, die Hindernisse und die Grenzen der regionalen Innovationspolitik für eine Innovationsanierung in alten Industrieregionen untersucht. Ausgangspunkt ist die Fallanalyse des Politikprogramms 'Bioraffinerie der Zukunft' zur Förderung einer Erneuerung der Waldindustrie in Nordschweden. Wie sich zeigt, ist eine Infusion mit radikalen neuen Technologien zur Entwicklung eines neuen regionalen Pfades zwar erforderlich, aber

nicht ausreichend. Um eine ausschließliche Betonung der Einführung von Technologie zu vermeiden, sollte die Politik stärker auf ergänzende experimentelle Prozesse im Zusammenhang mit den Merkmalen auf der Nachfrageseite, den Firmenstrategien und den Geschäftsmodellen sowie auf gesetzliche Aspekte achten. Darüber hinaus ist eine Koordination zwischen der regionalen Innovationspolitik und den angrenzenden politischen Bereichen und Stufen erforderlich, da einige der dringlichsten Hindernisse für eine Erneuerung nicht regionsspezifisch sind, sondern für die Branche als Ganzes gelten.

Alte Industrieregionen Regionale Innovationspolitik Evolutionäre Wirtschaftsgeografie Soziotechnische Übergänge

COENEN L., MOODYSSON J. y MARTIN H. Renovación de las rutas en antiguas regiones industriales: posibilidades y limitaciones de la política de innovación regional, *Regional Studies*. En este artículo analizamos el potencial, las barreras y las limitaciones de la política de innovación regional para facilitar la renovación industrial en antiguas regiones industriales. Nos basamos en un análisis de casos del programa político para la 'Biorrefinería del Futuro' cuyo objetivo es fomentar la renovación de la industria forestal del norte de Suecia. Mostramos que, aunque es necesaria una inyección de tecnología emergente radical para el desarrollo de nuevas rutas regionales, no es suficiente. Para evitar un enfoque único en la introducción de tecnología, las políticas deberían prestar más atención a los procesos de experimentación complementarios con relación a las características de la demanda, las estrategias de las empresas y los modelos comerciales así como los aspectos legislativos. Además, es necesaria una coordinación entre la política de innovación regional y los dominios y niveles adyacentes en la elaboración de políticas dado que algunos de los obstáculos más apremiantes para la renovación no son específicos de la región sino de la industria en general.

Antiguas regiones industriales Política de innovación regional Geografía económica evolutiva Transiciones sociotécnicas

JEL classifications: L, L7, L73, O, O1, O3, O18, O31, O38

INTRODUCTION

Since the early 1990s there has been an ongoing engagement in the field of regional studies with the particular problems, challenges and strategies for renewal of old industrial regions (BOSCHMA and LAMBOOY, 1999; COOKE, 1995; HASSINK, 1993; HASSINK and SHIN, 2005; HUDSON, 1989, 2005; KAUFMANN and TÖDTLING, 2000; MORGAN, 1997; TRIPPL and OTTO, 2009). This literature is primarily geared to identify and analyse the typical problems found in the innovation system of such regions focusing on issues related to path dependence and lock-in. Old industrial regions are typically considered to be those overspecialized in mature industries experiencing decline. A key challenge for regional development strategies concerns the question how such industries and regions may, or may not, be able to break out of locked-in paths of development by pursuing innovation, new technological pathways and industrial renewal.

More recently this debate has gained further momentum through the evolutionary turn in economic geography (BOSCHMA and FRENKEN, 2006; BOSCHMA and MARTIN, 2010; ESSLETZBICHLER and RIGBY, 2007; MARTIN and SUNLEY, 2007). At the core of the agenda in evolutionary economic geography two inter-related issues have been emphasized that are of interest and relevance for discussions on old industrial regions (COE, 2011). Firstly, a shift in the role of agglomeration economies has moved attention away from a predominant focus on specialization within regional clusters towards diversification of regional industrial structures through the notion of related variety (FRENKEN *et al.*, 2007). In particular processes of regional branching seem highly relevant to our understanding of how regions are able to diversify into new areas of industrial

development. Following the argument of regional branching, new industry formation draws on the recombination of different but related knowledge, skills and competences found in existing industries in the region (ASHEIM *et al.*, 2011). Secondly, evolutionary economic geography highlights the path-dependent nature of regional development. The distinguishing feature of path dependence is its emphasis on self-reinforcing mechanisms when explaining the dynamics of narrowing down the scope of alternative actions in and among organizations (SCHREYÖGG and SYDOW, 2011). Translated to regional development, this means that 'the combination of historical contingency and the emergence of self-reinforcing effects steer a regional economy along one "path" rather than another' (MARTIN, 2010, p. 3).

At the same time, various scholars have articulated a critique on evolutionary economic geography for an overriding focus on micro-level firm routines in its analyses of regional development at the expense of other actors and institutions (such as the state) (MACKINNON *et al.*, 2009; MORGAN, 2012). Especially, the role of policy has so far been relatively neglected in the literature (ASHEIM *et al.*, 2013; HASSINK and KLAERDING, 2011; RODRÍGUEZ-POSÉ, 2013). This omission is, to our mind, particularly problematic in the context of old industrial regions. As will be explained below, institutions and the role of the state in particular have been integral to much of the previous research. However, the existing knowledge base tends to be predominantly geared to identifying and explaining the specific problems that these kinds of regions face. While this has led to a solid understanding of the troublesome conditions for innovation in old industrial regions and, consequently, its challenges for renewal and revitalization, actual analyses of policy initiatives that seek to facilitate

such renewal are much less developed. Undoubtedly, this is a daunting task as 'the capacity of a region to transform the whole regional innovation system turns out to be the decisive factor for renewal processes' (TRIPPL and OTTO, 2009, p. 1231).

Taking stock with this gap, this paper conducts a case study of an existing regional support programme in an old industrial region in Sweden where mature industries dominate. This policy programme explicitly aims to develop a strong research and innovation environment around emergent biorefining technology in order to promote regional growth in the Örnköldsvik-Umeå area in the north of Sweden. The objective of the analysis is to further insights on the potentials, barriers and limitations for regional innovation policy to facilitate industrial renewal in locked-in regions.

More specifically, the paper provides a case study of an old industrial region where mature industries dominate and takes a closer look at the VINNVÅXT programme 'Biorefinery of the Future' (BioF). This initiative targets the forest industry that has been a traditionally important and large industry in this region in terms of employment opportunities. However, due to shrinking global demand for paper products and tightening global competition, scarcity and increased prices of forest raw materials, and increased requirements on more sustainable production methods, the local industry is facing challenges to remain competitive. Being strongly dependent on this mature industry, the future development of this region is heavily tied to its fate (as well as many other peripheral regions in Sweden). In recent years the industry is increasingly seeking new, alternative ways to extract and appropriate greater value from biomass, while at the same time improving its energy-efficiency, carbon-emission impact and overall environmental performance. A biorefinery can be seen as a platform technology that integrates biomass conversion processes and equipment to produce a portfolio of environmentally friendly fuels, power, heat and value-added chemicals from biomass (NATIONAL RENEWABLE ENERGY LABORATORY (NREL), 2014). Instead of using the forest biomass exclusively for the production of paper and pulp, biorefinery technologies allow its conversion into additional or substitute products such as low-carbon fuels (e.g. second generation bioethanol, dimethyl ether and biodiesel), green chemicals, substances used in the construction industry, viscose for clothing, or ingredients for the food and pharmaceutical industry, while making more efficient use of the heat in the production process. The notion of a biorefinery is comparable with that of an oil refinery, yet replacing fossil oil by renewable, low-carbon resources (i.e. biomass). As such, a biorefinery offers a possibility for forest industries to increase their efficiency and diversify into different markets. However, this requires cooperation with and establishing linkages to other industries. In doing so, biorefineries are considered to have the potential to contribute to renewing forest

industries (KARLTORP and SANDÉN, 2012; OTTOSSON and MAGNUSSON, 2013). At the same time, previous studies have shown that there has been a fair deal of resistance in the forest industry against what is considered to be a radical and disruptive technological pathway (LAESTADIUS, 2000; OTTOSSON, 2011). The research question guiding this analysis is as follows:

How can a regional innovation support programme, and its efforts to foster the adoption of science-based knowledge creation and exploitation, contribute to the renewal of mature industries? How is such a transition constrained and/or enabled by the regional context?

The remainder of this paper is organized as follows. The next section presents the theoretical framework of the study, drawing on literature on regional innovation policy, old industrial regions and transitions. The third section provides a short outline of the research design and methods applied in the study. This is followed in the fourth section by a presentation of the regional and industrial context of the policy initiative. The fifth section offers the empirical analysis of the regional innovation initiative. Drawing on the empirical analysis, the sixth section discusses the theoretical implications for regional innovation policy targeting old industrial regions, while the seventh section concludes by providing an outlook on how future research may address the challenges of old industrial regions by drawing on a wider framework based on the socio-technical transition literature.

THEORETICAL FRAMEWORK: REGIONAL INNOVATION POLICY, OLD INDUSTRIAL REGIONS AND TRANSITIONS

As this paper deals with renewal of mature industries in a regional context, the theoretical framework departs from the literature on old industrial regions. This literature is primarily geared to identify typical problems found in the innovation system of such regions focusing on issues related to path dependence and lock-in. While this literature provides a useful framework for identifying barriers to renewal in regional economies and how regions can strive to break out of lock-in (TRIPPL and OTTO, 2009), it is somewhat less developed with regard to explaining extra-regional influences to such regional lock-in and, as a consequence, what are the possibilities and limitations of regional innovation policy to address those barriers. To address this gap, a complementary evolutionary-institutional approach to understanding transformative change is suggested as well the role that regional policy plays in facilitating this.

Systemic innovation policy

In the burgeoning innovation systems literature, which emerged at the start of the 1990s, the regional

innovation systems (RIS) approach has been most explicitly concerned with spatial dimensions of innovation and place-based innovation policies (ASHEIM and GERTLER, 2005; ASHEIM and ISAKSEN, 2002; BRACZYK *et al.*, 1998; COOKE *et al.*, 2004). An RIS encompasses the private and public organizations in the region involved in innovation processes, their relationships and networks as well as the institutions guiding their behaviour (COOKE, 1998). In addition to localized networks and relationships, the RIS framework also takes into account relevant non-local linkages and institutions at higher scales. The approach holds the potential for improved 'on-the-ground' policy know-how about the specific place-based conditions for innovation (NAUWELAERS and WINTJES, 2002).

The approach has been widely used as a framework for the design, implementation and evaluation of regional innovation policy in a variety of countries and regions. Well-known examples are the European RIS/RITTS initiatives¹ as well as current programmes and strategies developed under the banner of smart specialization (LANDABASO *et al.*, 2001; BOSCHMA, 2014; CAMAGNI and CAPELLO, 2013). In terms of the theoretical rationale for the design of policy and choice of instruments, RIS draws on the more general innovation system perspective (LARANJA *et al.*, 2008; BORRAS and EDQUIST, 2013). This implies that public intervention is legitimate and needed if the complex interactions that take place among the different organizations in the RIS do not function effectively. On a general innovation system level, this has been conceptualized through the notion of system failures (SMITH, 2000; KLEIN WOOLTHUIS *et al.*, 2005; BERGEC *et al.*, 2008; WEBER and ROHRACHER, 2012). Examples of such system failures are the lack of appropriate competencies and resources for innovation at the firm level (capabilities failure), weakly developed institutions, both hard and soft, that insufficiently incentivize actors to engage with innovation processes (institutional failures), too closely tied networks leading to myopia (strong network failure), and/or too limited interaction and knowledge exchange between actors (weak network failure).

The general innovation system failure framework informing policy design has been resourcefully translated to the regional level through the seminal work of TÖDTLING and TRIPPL (2005) by looking carefully at specific regional endowments and its relationship to innovation barriers of weak or vulnerable regions (see also TRIPPL and OTTO, 2009; ASHEIM *et al.*, 2011; COENEN, 2007; ISAKSEN, 2001). To avoid a one-size-fits-all, best-practice models to regional innovation policy, they have introduced three main systems failures: organizational thinness, fragmentation and lock-in. Organizational thinness refers to lack of relevant local actors for innovation, fragmentation to lack of regional cooperation and mutual trust, while lock-in refers to regional industry being specialized in outdated

technologies (ISAKSEN, 2001). In reality, regions often face a mix of these deficiencies. However, TÖDTLING and TRIPPL (2005) argue that some innovation problems dominate in certain types of regions and, thus, require more attention than others.

Old industrial regions are typically considered as regions overspecialized in mature technologies and industries experiencing decline, thus facing lock-in. Innovation activities in these regions often follow mature technological trajectories mainly of an incremental character. Efforts to introduce radically new products into the market tend to be limited compared with process optimization and other efficiency-oriented activities. Even though, as TÖDTLING and TRIPPL (2005) observe, the region may have a highly developed and specialized knowledge-generation and diffusion system, this is usually oriented towards traditional industries and technology fields. Moreover, small firm innovation and entrepreneurial activity tends to be low given the dominance of larger firms, incumbent to the established and mature industrial and technological specialization (STEINER, 1985). Examples of old industrial regions are frequently found in regions specialized in heavy industries such as the Ruhr area in Germany (GRABHER, 1993), the North East of England (HUDSON, 1994; COENEN, 2007) or Wales (MORGAN, 2012). These regions are also well known for being sites with severe difficulties dealing with environmental waste and pollution (such as, for example, carbon emissions) (GONZÁLEZ-EGUINO *et al.*, 2012).

As TÖDTLING and TRIPPL (2005) acknowledge, regions may face a mix of RIS deficiencies (failures) as suggested in their typology. The present paper therefore also draws partly on a second type of 'problem description' related to RIS, namely that of peripheral regions and its dominant problem of organizational thinness. Similar to the old industrial regional typology, the emphasis is on incremental innovation and on process innovations. But now, the main explanation for a lower level of innovation activity is tied to low density as well as a 'thin' and less specialized structure of knowledge suppliers, technology transfer organizations and educational organizations.

In sum, the key problem of old industrial regions can nonetheless be characterized as primarily one of negative lock-in (HASSINK, 2010). Lock-in is closely connected to path dependence, a concept originating from the literature on evolutionary economics and technological change (DAVID, 1985). It is important to note that lock-in per se does not need to have a negative impact on a regional economy (HASSINK, 1997; ESSLETZBICHLER and WINTHER, 1999). Strong specialization in specific industries is a classic feature of clusters and regional competitive advantage (PORTER, 2000). Lock-in becomes however problematic when its path direction steers to (over)specialization in long-established technologies and industries with little scope

for further economic exploitation of knowledge while, often simultaneously, curtailing efforts by novel industries or technologies to emerge and develop. A closer look at lock-in is therefore required.

GRABHER (1993) highlights the multidimensionality of regional lock-in by distinguishing between three types of interrelated lock-in: functional, cognitive and political, and states that regional lock-in results from the interplay between these three types of lock-in. Functional lock-in refers to how overly strong and often hierarchical inter-firm networks in declining industries tend to block the development of alternative linkages and reorientations in the value chain. Cognitive lock-in refers to how a common world view or mindset among actors reinforces 'group-think' and precludes creativity and imagination needed for the development of new ideas. Political lock-in is related to the existence of dense relationships between public and private sectors that aim at preserving traditional industrial structures that hamper alternative directions for industrial development (GRABHER, 1993; UNDERTHUN *et al.*, 2014).

Adding analytical precision to address the question why it is that some regional economies become locked into development paths that lose dynamism, HASSINK (2010, p. 455) suggests a set of economic-structural and political-institutional impact factors. Economic-structural impact factors primarily leading to functional lock-in includes the following:

- A marked industrial mono-structure: the leading industry having an employment share of at least 30% of the total manufacturing employment in the region as a rough indicator for a mono-structure.
- A specific leading industry: capital-intensive, high entry and exit barriers, above-average company size, oligopolistic market structure and influential trade unions.

Political-institutional impact factors primarily related to cognitive and political lock-in include the following:

- An institutional constellation at the regional level, consisting of local, regional policymakers, captains of industry, regional trade unionists, representatives of industry associations, that is strongly focused on the leading industry and hence weakly on external relations.
- A national political system that enables regional actors to influence political questions concerning industrial policy.
- Supra-national institutions that strongly affect the conditions of industrial policy relevant to the leading industry.

In engaging with discussions on lock-in, recent studies from evolutionary economic geography have figured prominently, particularly with regard to strategies concerning how to unlock or rejuvenate old industrial regions. MARTIN and SUNLEY (2006) suggest a number of 'sources' for new path development

that regions may draw upon to escape lock-in. Given that our case, related to the adoption of biorefinery technology by an incumbent forest industry in the region, mainly draws on path renewal of already existing industry, as opposed to attraction or development of new industry, two strategies seem to be most pertinent. These escape sources are 'diversification into technologically related industries', which refers to the 'transition where an existing industry goes into decline but its core technologies are redeployed and extended to provide the basis of related new industries in the region' (MARTIN and SUNLEY, 2006, p. 420). Another relevant option is the 'upgrading of existing industries' referring to 'the revitalization and enhancement of a region's industrial base through the infusion of new technologies or introduction of new products and services' (p. 420). While examples of regions are provided for both escape routes, the authors also acknowledge that often they are not mutually exclusive but rather that different mechanisms may be at work simultaneously and in mutually reinforcing ways. Whether these escape routes may also counteract on each other is, however, left open for debate.

These mechanisms relate to a well-known advancement made in evolutionary economic geography around the importance of relatedness in knowledge and competences for innovation and renewal, often referred to as related variety (FRENKEN *et al.*, 2007). Especially in light of transformative change, combinatorial rather than cumulative knowledge dynamics are emphasized to foster radical, path-breaking innovations (STRAMBACH and KLEMENT, 2013). However, such combinatorial knowledge dynamics are characterized by high uncertainties in the pay-off and the time horizon of their outcome, and require high investment to ensure mutual understandings between the actors. Similarly, SIMMIE (2012) highlights the disruptive nature of regional new path development and stresses a process of 'mindful deviation' by innovators when introducing new and replacing old technologies (see also GARUD and KARNØE, 2001). While drawing our attention to the need for disruptive path-breaking innovation and technological change to transition old industrial regions into new pathways, it should also be stressed that this is a particularly cumbersome and challenging process precisely because of the path-dependent nature of technological change.

The path-dependent nature of technological change has been fruitfully explained and theorized in the literature on socio-technical transitions, with the help of the concept of 'socio-technical regimes' (GEELS, 2002; SIMMIE, 2012; TRUFFER and COENEN, 2012). Essentially, this concept extends the previous notion of technological regimes (DOSI and NELSON, 1994; BRESCHI *et al.*, 2000) to include 'the coherent complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory

requirements, institutions and infrastructures' (RIP and KEMP, 1998, p. 338). The 'structuration' of this complex is high, providing stable rules and coordinating effects on actors. Reflecting the 'established way of doing things', it primarily enables incremental, cumulative, path-following innovation yet constrains radical path-breaking innovation and helps to explain why combinatorial knowledge dynamics and mindful deviation are indeed difficult to achieve. The concept of socio-technical regimes has been particularly forceful to explain why current energy and transport systems remain locked-in to fossil fuel-based technologies (SMITH *et al.*, 2010; UNRUH, 2000)

The contrasting notion of 'niches' is used to conceptualize the genesis and development of path-breaking and deviant technologies (KEMP *et al.*, 1998; RAVEN, 2005). These niches are 'incubation spaces' for novel, yet immature, emergent technologies that challenge the established regime and, if successful in its maturation process, can replace the incumbent, old technologies. A niche is defined as an application context in which novel technology is temporarily shielded from the structuration forces found in a regime and acts as an important selection environment in which the process of new path creation may be started. As GEELS (2004, p. 912) puts it, '[t]hey provide locations for learning processes, e.g. about technological applications, user preferences, public policies, symbolic meanings. Niches are locations where it is possible to deviate from the rules of the existing regime'. At the same time, it should be stressed that the extent of structuration between the technology, knowledge, skills, user needs, regulatory requirements and institutions in such niches is very loose, at least compared with the structuration effects found in a regime context. In other words, it reflects the uncertainty and heterogeneity found in a situation of combinatorial knowledge dynamics.

Taken together, the literatures on old industrial regions and socio-technical transitions provide an evolutionary perspective, not only on the particular place-specific challenges related to lock-in of mature regional industries but also on the transition pathways to unlock these regions and industries through technological renewal. Here, the transition perspective adds a careful understanding of the room to manoeuvre for policy-making in relation to the introduction of new path-breaking technologies.

The above discussion concerning the challenges for old industrial regions to break-out of lock-in and transition into (re)new(ed) path development is used to frame and identify the challenges that the BioF initiative in Sweden is facing. However, the literature is less developed with regard to questions about whether and how regional innovation policy can in fact contribute to the unlocking and path renewal mechanisms that are needed in light of such a transition, in particular with regard to dealing with the complex interplay between regional and extra-regional impact factors. The analysis of this initiative will therefore contribute

to our understanding about the potentials, barriers and limitations for policy to facilitate industrial renewal in locked-in regions. After the empirical analysis, the paper will revisit the literature concerning old industrial regions and technological path dependence to discuss the role of regional innovation policy as niche experimentation for path renewal.

RESEARCH DESIGN AND METHODS

The analysis is based on a combination of qualitative research methods; document studies and personal in-depth interviews with key stakeholders being the two dominant data sources. Previous research on these and similar industries are used as reference cases, while primary data collection has been focused on publicly available documents such as websites, annual reports, strategy documents and publicly commissioned evaluations. A total number of 20 semi-structured interviews with representatives of the initiative and its target industries were conducted. The group of respondents includes representatives from the public sector (policy-makers) as well as universities and industry. Eight interviews were conducted in October 2008 when the initiative in its current form was recently launched. Six more interviews were conducted in January 2012. While the first interviews primarily aimed at collecting information on the industries, the initiative and the various challenges that served as a main rationale for the initiative, the second round of interviews focused more explicitly on activities, outcomes and remaining problems/deficiencies. In addition to those interviews, which explicitly dealt with the initiative and its target industries, another six interviews were made with actors doing research on or representing the industries, but with no specific stake in the initiative as such. These interviews, carried out in the period March–July 2009, are used primarily for reference and cross-check purposes. The interviews were conducted in Swedish, recorded and transcribed. Important quotes were translated into English by the authors.

REGIONAL AND INDUSTRIAL CONTEXT

Region

The area of Örnsköldsvik-Umeå is located on the Swedish east coast, more than 500 km north of the capital, Stockholm. In terms of administrative regions it covers the Swedish counties of Västerbotten and Västernorrland (NUTS-3). These are thinly populated regions with a population density of 4.7 and 11.0 inhabitants/km² respectively (2011).

The region suffers from typical problems of peripheral and old industrial regions with serious challenges to cope with renewal and economic growth. Since the mid-1990s the region has been lagging behind the national

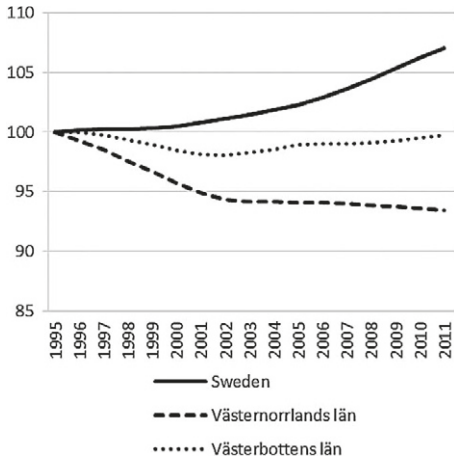


Fig. 1. Change in average yearly population
Source: Statistics Sweden

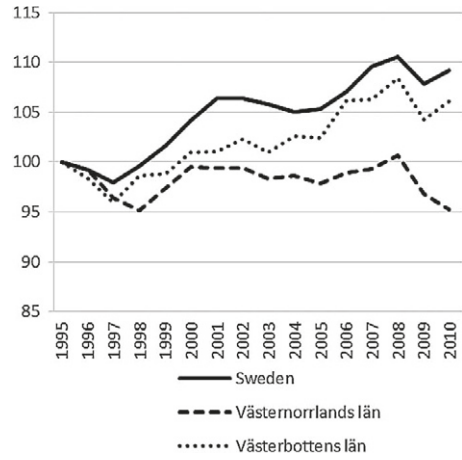


Fig. 3. Change in employment
Source: Statistics Sweden

average on most indicators reflecting economic development. While the Swedish population as a whole is constantly growing, as most European countries, the regional population in Västerbotten and Västernorrland is decreasing. A particular strong decrease is identified in Västernorrland, which displays the strongest depopulation trend of all Swedish regions (Fig. 1). Also regional employment is lagging behind the national average in both counties. This indicates not only gradual depopulation in the periphery but also increased challenges of maintaining regionally based economic growth (Fig. 2). Depopulation and decrease in regional employment is

also reflected in the relative change in regional gross value added, where the region is lagging behind the national average, however not as dramatically as could have been expected (Fig. 3). With regard to private research and development (R&D) expenditures particularly, Västernorrland displays negative development compared with the national average, while Västerbotten has managed relatively well despite a severe downturn in connection with the financial crisis in the early 2000s (Fig. 4).

A large part of the problem with regard to regional economic development can be found in the region's

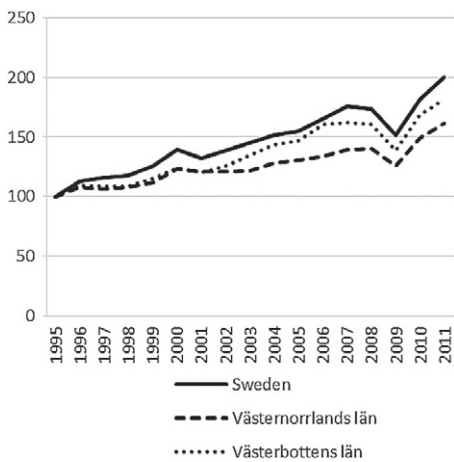


Fig. 2. Change in gross value added
Source: Statistics Sweden

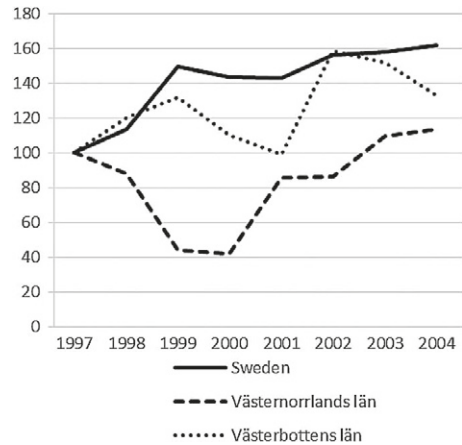


Fig. 4. Change in private sector research and development (R&D) expenditures
Source: Statistics Sweden

relative overspecialization in the declining forest industry. The forest industry represents 30% of the regional economy in Västernorrland and 20% in Västerbotten. This should be compared with the national average of 11%. Almost 30% of the working population is directly employed in the forest industry, which still generates almost 50% of the total regional production value (SKOGSINDUSTRIERNA, 2013). This strong dependence on one industry obviously makes the regional economy vulnerable, particularly when the industry in question is in decline. The total employment in the Swedish forest industry has been reduced by 50% since the 1990s (SKOGSINDUSTRIERNA, 2013).

Industry

As touched upon above, the forest industry has been very important for the northern part of Sweden, and the Ömsköldsvik-Umeå area in particular, since the late 19th century. Prior to the period covered in the descriptive statistics above, important transformation forces were set in motion. Between 1960 and 1990 the industry witnessed a period of structural change. In the 1960s a process of structural rationalization was initiated driven by the need to decrease costs and increase productivity as a result of increased international competition. As a result, production shifted increasingly away from small mills towards large-scale facilities, primarily located along the east coast. This rationalization was paralleled by an increased awareness of the polluting and energy-intensive character of paper and pulp production which, in turn, led to tougher environmental regulation for the industry. As a response to both challenges, the forest industry invested heavily in technology-driven process innovations which resulted in substantial improvements in environmental performance as well as productivity (BERGQUIST and SÖDERHOLM, 2011). During this process of structural change, the Swedish forest industry quickly caught up with North American forest industry and established itself as a dominant global player, capturing increasing shares of the global market (OJALA *et al.*, 2006). As a result of this rationalization process, the regional forest industry became dominated by a few large companies (MELANDER, 1997).

Since the late 1980s a new wave of structural change has started to influence the industry. Similar to the earlier period, environmental and energy concern feature prominently along the factors driving these developments (KARLTORP and SANDÉN, 2012). Concern for climate change and energy security has led to a number of policy measures that have substantially affected energy and feedstock prices for the industry. Exactly how this is going to impact the industry is still an open question. On the one hand, increased demand for bioenergy and biofuels to meet renewable energy objectives has resulted in higher prices for biomass feedstock. On the other hand, the introduction

of green electricity certificates in 2002 has created economic incentives for paper and pulp companies to produce and sell green electricity in their plants (ERICSSON *et al.*, 2014). An additional environment-related factor concerns the introduction of more stringent environmental regulation in the field of waste in Sweden. Increased taxation has created incentives to avoid waste production and, instead, created incentives to refine waste products into tradable products or intermediaries. Increased attention to energy and environmental issues is, however, not the sole source of pressure for change. Substitution of paper-based media by electronic media has led to an absolute decrease in demand for printing paper, traditionally one of the core products of the forest industry. Finally, increased production capacity in South America and Asia and deepening global trade liberalization has led to increased competition from firms with significantly lower production and feedstock costs.²

Increasingly, firms realize that they have to diversify their product portfolios to achieve higher value out of their feedstock. In doing so, the biorefinery concept offers new business opportunities but also represents a major challenge as it entails large investments in new process technology, knowledge and networks required to enter or establish new value chains (KARLTORP and SANDÉN, 2012). In this context, firms in the Ömsköldsvik-Umeå area have the advantage that they draw on a historical legacy. As a response to trade blockades during the Second World War and the resulting shortage of chemicals in Sweden, the paper and pulp industry in Ömsköldsvik-Umeå has made early attempts to broaden the range of products produced from forest raw materials. During these years, the production of bio-based chemicals and ethanol entered the scene and led to unique experiences for the industry with regard to product diversification based on forest feedstock. In the post-war years, however, chemicals production relocated back to the west coast of Sweden due to its closer connection to major international ports, which was of strategic importance for the petrochemical industry. The forest industry in Ömsköldsvik-Umeå returned to its traditional business in pulp and paper production. In the mid-1990s, scientific breakthroughs in life science made it possible to start research with dissolving cellulose by applying alternative technology (i.e. enzyme-based biotechnology processes). One of the paper mills in Ömsköldsvik was among the few pioneers worldwide entering into this field.

ANALYSIS

The BioF initiative

The successful application of the BioF initiative to secure support and funding through the VINNVÅXT programme³ built on existing activities and networks in the region based on a common biorefinery platform.

Following initial research and experiments during the mid-1990s, a technology park located on the site of the pulp and paper industry in Örnsköldsvik was established in 2003. Here, 12 small and medium-sized enterprises related to R&D in pulp and paper technologies, chemicals and energy production started collaborating with two large companies specialized in various applications of forest and chemistry-related production (Domsjö Fabriker AB and AkzoNobel). The primary focus was on energy efficiency, much in line with general trends in industry at this time (see above). The municipality, the county administration, a regional technology transfer agency (Innovationsbron) and a privately owned funding foundation (Kempestiftelsen) with its roots in the region's forest-based industry provided financial support. Over time, linkages to the nearby universities in Luleå and Umeå were established and increasingly formalized. This technology park evolved into a network of related firms and organizations distributed over a territory much wider than its initial core in Örnsköldsvik, encompassing the counties of Västerbotten and Västernorrland. A large grant from the Swedish Energy Agency was used to set up a pilot plant for cellulose-based ethanol production, which gradually developed into a platform for several products, primarily drawing on forest-based feedstock. A central firm in this pilot plant is a producer and developer of ethanol, SEKAB, today considered to be a world leading actor in the field of bioethanol. The pilot plant, the ethanol firm, a small firm specialized in pulp and paper-related R&D (MoRe Research), a large forestry company (Holmen), a sector-specific industry support initiative, and the regional universities can be seen as the nexus for the biorefinery initiative responsible for developing the VINNVÄXT proposal.

In 2008, the consortium with representatives from industry, academia and the regional public sector in Örnsköldsvik made a successful application for VINNVÄXT and received a ten-year grant for their initiative 'Biorefinery of the Future' (BioF). The aim of this initiative was to become a world-leading research and innovation environment for developing biorefineries based on forest raw material and energy crops by combining historical and current strengths in traditional forestry with new cutting-edge knowledge in science-based technologies. BioF aims to materialize industrial renewal of the local pulp and paper industry towards higher value-added activities as a collective regional strategic response to the aforementioned competitive and climate-related challenges. In this context, the BioF initiative acts as an operational incubation and experimentation space for technological learning processes targeting biorefinery technologies.

Taking a closer look at the supportive activities carried out within BioF reveals that an R&D council plays a central coordinating role. The R&D council is where most project ideas are evaluated to assess whether they can be financed through BioF. The

council consists of two representatives from member companies, two from Umeå University and two from Processum, the holding company for the biorefinery initiative.⁴ Its mission is to promote new products and process ideas in the biorefinery area. In funding decisions, the utility for the participating companies is a very important criterion as well as collaboration between industry, academic and public sector stakeholders. In 2012, approximately 100 projects were funded which resulted in ten new processes, 30 new products and prototypes, and just over 30 patent applications. Even though there is a focus on new product and process development, the lion's share of projects can be considered to be applied research with potential for member companies in areas such as green chemicals, products from residual streams, industrial biotechnology, smart processes/process efficiency and energy. More downstream innovation activities are coordinated under the header of 'pilot equipment' to scale up the most promising research, with a view to achieving a commercial scale in the near future. Of these, 11 pilot projects have been carried out in the initiative.

Even though these 'formal' support activities suggest that innovation support is primarily of a technological nature, which can be regarded as rather narrowly defined innovation activities, the interviews revealed that social learning processes have occurred in what could be seen as an indirect effect of the R&D activities and collaborations. The expectations and interests among different actors with regard to the products and processes developed in a biorefinery diverged considerably at the start of the initiative. This had partly to do with the heterogeneity among the firms involved, including paper and pulp companies, ethanol producers, chemical companies and energy utilities. Given their different industrial backgrounds, these firms operate in different markets and draw upon different competences and technologies. Through the BioF initiative, the firms are exploring and assessing the scope for collaborations across industries, which contributes to mutual learning and alignment of expectations within the initiative. For example, in the area of green chemicals, the forest industry is seeking out new applications and wants to learn more about the chemicals market, while the chemical industry is looking for ways how to replace today's fossil-based basic chemicals with a green supply. Another well-known example is the production of bioethanol based on forest material. In this context, the collaborations in the BioF initiative give rise to exploring the possibilities and difficulties in creating new value chains that cut across traditional industry boundaries.

In particular, the BioF initiative has contributed to a better joint understanding or common framing of some of the key challenges which actors in the BioF initiative are facing in their efforts to make products and processes related to biorefineries commercially feasible. As a result of the R&D activities carried out in BioF, a number of

technologies have become (technically) sufficiently mature for scaling up to full-scale application. However, this process has proven more difficult than initially expected across the industry, mainly due to non-technical institutional aspects. Challenges particularly concern the large-scale production of ethanol from forest biomass residuals (i.e. second-generation bioethanol) even though they, to a large extent, also apply for other biorefinery products.

One of the main challenges, related to lock-in, has to do with sunk investments in conventional technology and production facilities. Forest industries are very capital intensive, and massive resources have already been invested in facilities drawing on the existing technological paradigm geared to the production of pulp and paper. As stated by one of the interviewees: 'One has invested into a particular production and it is not easy to just change it over one night. The fact that the investments are so huge leads automatically to inertia in the system' (chief executive officer (CEO) of a local R&D company). These investments traditionally targeted the production of bulk products. This constitutes a challenge to the industry in terms of diversifying its outcomes and, by implication, adapting to (and entering) diversified, small-scale markets. To achieve profitability, a commercial, full-scale biorefinery is expected to require new investments of approximately SEK3 billion. Combined with the current lack of possibilities to employ premium pricing strategies for green chemicals and energy (i.e. an insufficiently developed market), this raises an urgent need for subsidies from the public sector.

An issue that is challenging is up-scaling, to go into full industrial scale, this we have realized over the last 2–3 years. There is very interesting research, but how the rules stand today, it is very difficult to get a commercial viability. [...] The State and the EU should take a more active role. It has become clear to me that it is a political issue.

(CEO, BioF)

This is, however, not exclusively a national, but rather a supranational issue related to a lack of attention on the largely peripherally located forest-related industries within the European Union (EU) policy agenda:

If you read the EU directive, it is not considered sustainable to cut down forest. There is so much to be done on the information side so that [politicians in Brussels] start to realize. [...] In the EU, it is agriculture that is important. Forest is only seen as spare time activity.

(Professor of Chemistry, Umeå University)

While subsidies exist in Sweden today, they lack a long-term horizon, which makes them uncertain and create critical financial liabilities for investors.

The problem with these systems and regulatory frameworks is that they are almost on one-year basis, and this is what limits us. [...] First they subsidize and then they

take it away. Ethanol was in for a while, then it was biogas and now it is electric cars. It is impossible to see what is coming as consumer or producer.

(CEO, ethanol producer)

Government policies are providing unclear and contradictory signals concerning the needs for carbon reductions and a shift to renewable energy and at what costs such needs should be supported. In addition to the direct effect in terms of economic realities for potential investors, these shifting policies also contribute to influencing consumer preferences and societal legitimacy of alternative technologies. It reveals the dependence of the regional actors on a national political system, particularly with regard to learning about demand-side aspects of new technologies. As a result of this lack of a clear future vision, investors hesitate, entrepreneurs are reluctant to take the necessary risks and consumers are ambivalent.

Another barrier to the fulfilment of the aims of BioF has thus to do with the public perception of a new technology. In the public opinion, forest-based biofuels (second generation) are often conflated with agro-based biofuels (first generation), which causes resistance with reference to the crops-for-food-or-fuel debate. In the current public debate, the producers of forest-based biofuels have severe problems explaining the differences in a way that is easy for consumers and investors to understand fully, which again points at the limitations of the regional actors with regard to influencing demand-side-related conditions. As stated by one of the interviewees:

There is good ethanol and there is bad ethanol. There exists a risk of competition with the food production in the world, and you should not make ethanol from that. [...] These facts are communicated and presented, but it does not have any impact in the press.

(CEO, ethanol producer)

On a more general level, being located in a peripheral part of Sweden seems to play an ambiguous role for the actors in the initiative. On the one hand, the location is seen as an important (positive) factor behind the creation and maintenance of social networks of firms and individuals involved in the initiative. The regional identity is considered to be strong. This means that knowledge exchange both within and across industry boundaries in the region is facilitated by a high degree of interpersonal trust. On the other hand, this also leads to less integration in national and international networks since the regional actors are strongly focused on intra-regional networking and consider themselves to be less connected to the outer world.

I feel that we have a pretty good situation network-wise and in terms of contacts. [...] The disadvantage of a small town is that it is some distance away, the advantage of a small town is that, with the right atmosphere, a lot

of people help each other. [...] But it is a disadvantage that we always have to travel.

(CEO, BioF)

This problem, however, seems to be diminishing, partly as a result of the BioF initiative. Recently, one of the dominant forestry companies, Domsjö Fabriker AB (part of the Holmen Group), has been acquired by an Indian multinational firm (Aditya Birla Group), which has led to an increasing focus on high-value-added products and materials (e.g. textiles) in the initiative. Likewise, the establishment of R&D collaborations between regional actors and universities in other parts of Sweden has increased through the BioF initiative, as well as an intensified collaboration with the petrochemical industry at the Swedish east coast.

DISCUSSION

The case presented in this paper demonstrates that regional innovation policy indeed contributes to 'on-the-ground' policy that addresses the specific challenges for innovation in the region. BioF explicitly seeks to transition existing but declining regional industry into new path development through a process of diversification that is fuelled by infusion with radical new technology (MARTIN and SUNLEY, 2006). The region clearly displays symptoms of functional lock-in (HASSINK, 2010) having a marked industrial mono-structure based on the paper and pulp industry that is characterized by industrial concentration in a number of established firms, high levels of capital intensity and high entry barriers. The initiative seeks to break this lock-in through systematic and concentrated R&D and innovation investments in a biorefinery platform. Through this focus on biorefining technologies, it has established new, but also built further on existing, relationships across related industries (and non-firm actors) in the region in a process of combinatorial innovation. To what extent these efforts will eventually result into processes of regional branching remains, however, to be seen. On the one hand, there is indeed evidence of diversification of incumbent firms into new markets as paper and pulp companies are becoming increasingly interested and active in producing biofuels and, albeit to a lesser extent, green chemicals and biotextiles. On the other hand, the involved firms also encounter severe obstacles to make a fully fledged entry into these markets. Here, the findings confirm the arguments raised by STRAMBACH and KLEMENT (2013) that combinatorial knowledge dynamics are conducive to path-breaking innovation but at the same time fraught with difficulties in light of the high uncertainties and time horizons concerning return on investment. Related to this, the case also points to rather modest levels of activity by new firm start-ups and entrepreneurs. If any entrepreneurial activity is to be observed, this

seems to come primarily from existing firms in the region rather than through new firm formation.

In sum, it can be argued that the initiative has been successful in planting and growing seeds for path renewal. At the same time, the regional actors are facing difficulties to develop and implement a large-scale biorefinery facility, which could be seen as an indicator of a more complete transition process. To understand this relative success as well as its limitations, it is important to acknowledge the regional context in which the initiative is placed. The place-bound historical legacy of the current industrial structure is one important factor. Even if the initiative is composed by a fairly large number of independent and relatively young knowledge-intensive small and medium-sized firms, most of which have their roots in the dominant forest industry in the region, providing a basis for technological relatedness. The same is true for a large share of the capital channelled through the private foundation. Between the late 19th century and the 1970s they were all part of the same organization, MoDo (today renamed as Holmen). This common history has been conducive to forging mutual understandings and expectations among the actors even though they over time have diverged into different fields of specialization (such as energy, chemicals, paper and pulp). Secondly, localized social networks built up over time (prior to and during the BioF initiative) provide important conditions enabling knowledge exchange and interactive learning (within and across industry boundaries), and have contributed to giving the actors a collective voice articulating key challenges with regard to biorefineries.

While there is a common and shared understanding among the regional actors in the initiative about critical challenges, it is doubtful that the actors themselves also will be able to address them effectively. The first challenge refers to mobilizing resources for full-scale operations that require large amounts of capital investments.⁵ This is not untypical for the forest industry. Here, actors obviously need to search for investment possibilities from outside the region. Attracting these kinds of investments remains still very problematic and would require a broader interest and legitimacy for biorefinery technologies within forest and related industries at a national and even international level. The actors seem to be very well-aware of this and are increasingly establishing connections beyond the region. However, its location in a peripheral part of Sweden entails structural disadvantages that a more centrally located region would probably not encounter to a similar degree. Also with regard to the second challenge, the initiative's location in a peripheral region is problematic. This refers to the importance of regulatory frameworks in market creation for typically 'green' products such as biofuels and bioplastics (see also DEWALD and TRUFFER, 2012). Most of the markets targeted by the actors in the BioF initiative are strongly affected by energy and environmental regulations through subsidies and

taxations. These regulations are mostly designed and implemented at, again, a national and/or international level. This means that many of the conditions determining the adoption of the new products developed within the initiative are well beyond the reach of influence to regional actors. While the actors collectively argue that compulsory quotas for biofuel or some form of long-term tax relief on green solutions are needed to facilitate the up-scaling of their facility, they lack the means to influence the decision-making process for such regulation. This is part of a political process that is embedded in wider debates and interests in terms of industrial, energy and climate policy. As such, it refers to a lack of coordination and/or integration across policy domains, which has a direct effect on the 'success' of this regional innovation initiative.

It can actually be argued that both these challenges, and the constraints of regional actors to address them effectively, are endemic to the fact that a regional transition from a locked-in mature industry towards related new industries (MARTIN and SUNLEY, 2006) is part and parcel of a wider industrial transition that transcends the regional level. The potential, barriers and limitations for a regional innovation initiative to address lock-in and facilitate industrial renewal should thus be seen in this light. This implies that the difficulties that the regional actors are experiencing to upscale biorefining technologies are not specific to the region, but rather specific to the industry. So far, the regional initiative has indeed been instrumental to technological learning, but ultimately the wider adoption of the technology, its products and processes is contingent on the extent to which the forest industry, and related industries, can deviate from their 'established ways of doing things'. That is, adopting biorefinery technology is not so much a process of technology adoption but would rather require in parallel a change in business models and institutional frameworks.

As such this points to two important limitations to regional innovation policy for industrial renewal, at least the way it is designed and implemented within the BioF initiative. First of all, innovation is still too narrowly defined as primarily relating to technological innovation. The challenge to upscale biorefineries can partly be explained by its tension with the prevalent business models of the paper and pulp industry. In its current form, companies primarily draw on economies of scale, bulk production of commodities and price-based competition. Producing a portfolio of bio-based products, including high-value-added products, as implied by a biorefinery would require economies of scope, a competitive strategy based on product differentiation and quality and ultimately production of niche products. These issues remain, however, beyond the scope of the regional innovation policy initiative alone. Secondly, industrial renewal is strongly contingent on institutional change, specifically in relation to the way markets for green products are to be regulated as well as more

normative institutions concerning demand for green products. Currently, the products and processes developed in a biorefinery can hardly compete with fossil alternatives and require support, either through 'greener' regulatory frameworks or because consumers are willing to pay a premium for the environmental externalities offered by these bioproducts. Again, the critical bottlenecks remain beyond the reach of regional innovation policy. Both limitations refer to wider 'regime' based barriers (GEELS, 2002; RIP and KEMP, 1998) that inhibit, or at least counteract, transformative and path-breaking change. How this now feeds into the theoretical development on lock-in old industrial regions will be discussed in the concluding section.

CONCLUSIONS

This study has shown that regional innovation policy has been important in facilitating the development of new biorefinery technology in the region and, thus, offers a diversification path for the forestry industry in the region. At the same time, supra-regional bottlenecks are constraining further advancement towards a more comprehensive industrial and regional transformation in the direction of a bio-based economy. Market-related regulatory barriers as well as industry-specific norms and established ways of doing things limit the development and adoption of radical, path-breaking innovation, thus hampering the ability of the regional economy to break out of its lock-in. It is argued that this is largely a result of inherent limitations of regional innovation policy in a context of locked-in old industrial regions.

It has been shown that infusion of new technology is indeed necessary for new path creation of old industrial regions, but hardly sufficient. The case of BioF illustrates that innovation support typically has focused most attention and resources on technology-related innovation while changing firm routines and institutional adaptation have been overlooked, or at least underemphasized. As an *indirect* result of collaborative innovation activities, however, these dimensions have become more explicitly framed as key challenges among the heterogeneous set of stakeholders in the initiative. This points to the importance of non-technical, social learning processes related to novel, emergent technologies as highlighted in the literature on socio-technical transitions (RAVEN, 2005). Drawing on this literature, and in particular its insights regarding niche dynamics in deviant, immature technological fields (such as biorefineries), this paper argues for a stronger acknowledgement of the *experimental* features of new technology-based path creation in policy-making. In doing so, inherent, fundamental uncertainties involved in path shaping are stressed not just in technological terms but, more importantly, in institutional terms.

Constructing new regional development pathways through regional innovation policy involves a

co-evolutionary process of technological, industrial and institutional change. Instead of primarily promoting innovation framed as technological change, as often seems the case especially when such technologies are still in an early stage of development and adoption, policy should focus more explicitly on other learning processes: learning about user characteristics and demand, regulatory aspects, mindsets related to firm strategy. Given the immature state of emergent new technology, this often takes shape through expectations that different stakeholders have about a technology and the new or improved products, processes and services it may give rise to. In such an emergent stage of path development, these expectations are often still rather diffuse and there may be considerable variation among the stakeholders, especially when the technological field cuts across different industries. Through iterative processes of learning-by-using and learning-by-interacting among actors, such expectations are articulated, tested, refuted and modified. On a collective level, this leads over time to alignment of expectations and, consequently, may increase knowledge about and legitimacy for the technology, its application context and institutional embedding.⁹ Building such legitimacy is crucial as a selection mechanism to maintain support and mobilize resources for innovation, especially in pre-market stages of development. Regions are seen as key sites to carry out such experimentation due to various proximity effects that compensate for the inherent uncertainties connected to new path creation (COENEN *et al.* 2010; HEALY and MORGAN, 2012). The case of BioF has shown that such experimentation processes have played an important role as an indirect outcome of more technology focused innovation interactions.

While being conducive to broad experimentation in new path creation, we argue that regional innovation policy should also be mindful of some of its inherent limitations related to the scale and reach of its activities. Our study shows that important bottlenecks to unlock an old industrial region prevailed beyond the local level and outside the direct sphere of innovation policy. Some of the greatest obstacles for renewal are not specific to the region but specific to the industry, which makes them largely out of reach for regional policy measures alone. The region, and its industries, is nested in a wider process of industrial transformation and institutional adaptation. Unless being integrated with measures to influence such industry specific institutions at a global (i.e. regime) level, such regional efforts will have a limited effect on path renewal, not only when seen in a global perspective, but also in the region.

In this context, it is argued that a promising topic for future research is to pay greater attention to the role of policy coordination between regional innovation policy and adjacent domains and levels of policy-making (NILSSON and MOODYSSON, 2014). Even though the region may act as a fruitful space for experimentation,

there is a risk that regional innovation policy will only deliver 'small victories' and remain peripheral unless policy coordination and learning beyond the level of regional innovation policy takes place. This study has shown that regional actors (including policy-makers) often are aware of the challenges to break out of the old industrial region 'mould' but are struggling to find ways and practices to effectively do so. This is obviously a long-term endeavour. The evolutionary turn in economic geography has at least opened up for greater attention for the path-dependent nature of regional development and helps avoiding the pitfalls of a quick policy fix in dealing with the problems of old industrial regions. The literature on socio-technical transitions allows for a compatible evolutionary framework to understand the wider context in which such processes of transformative change play out (TRUFFER and COENEN, 2012). More conceptual and empirical studies are, however, needed to arrive at a better integrated framework.

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NOTES

1. RITTS = Regional Innovation and Technology Transfer Strategies and Infrastructures.
2. For example, in 2009 softwood prices in Scandinavia were approximately US\$350/tonne compared with US\$90/tonne in South America (FORNELL, 2010).
3. The VINNVÅXT programme is organized as a competition for regions where winning regions receive funding up to SEK10 million per year for a period of ten years. A prerequisite for the programme is the active participation of actors from private, public and research sectors and from the political sphere. Currently, 12 regional initiatives receive funding.
4. Processum AB is 60% owned by the SP Technical Research Institute of Sweden and 40% owned by 21 member companies.
5. To illustrate, Processum (the holding company for the biorefinery plant) has secured €55 million for an

industrial-scale 200 MWth biofuel facility. However, it nonetheless cancelled the investment plans as an additional investment need for €275 million was considered too risky.

6. For a discussion about this process in connection with institutional entrepreneurship and commercialization of clean technology, see also AVDEITCHIKOVA and COENEN (2015).

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Article II

Institutional Context and Cluster Emergence: The Biogas Industry in Southern Sweden

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ABSTRACT *According to some scholars in evolutionary economic geography (EEG), the role of (territory-specific) institutions is relatively small for explaining where a new industry emerges and grows as firms develop routines in a path-dependent and idiosyncratic manner. This article evaluates this assertion by studying the evolution of the biogas industry in the region of Scania in Southern Sweden. The biogas is predominantly used as a fuel in the regional transport system and is considered as a crucial means to achieve environmental goals in the region. Recently, regional public policy has been actively promoting this biogas industry, aiming for cluster development. Drawing on literature from EEG and technological innovation systems, this article seeks to unpack the evolutionary process that has led to the emergence of this industry. In particular, it studies to what extent territory-specific institutions have been crucial in that respect. The analysis is case-based, drawing predominantly on in-depth interviews with key stakeholders and firms in the industry. By doing so, the paper seeks to make a contribution to our understanding of cluster development, considering the interplay between technology, industry dynamics and institutions.*

Introduction

Recently, with the “evolutionary turn” in economic geography (Boschma & Frenken, 2006; Boschma & Martin, 2007, 2010; Menzel & Fornahl, 2010; Martin & Sunley, 2011) there has been an increasing interest in the spatial emergence of economic phenomena, such as the origin of new industries. Having its roots in evolutionary economics, evolutionary economic geography (EEG) explains the uneven spatial distribution of economic activities and industrial structures based on the micro-level search and selection behaviour of firms understood as organizational routines. Emanating concepts such as related variety

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and regional branching have added considerably to the economic geography literature as they supplement the weakness of established systemic approaches to innovation by emphasizing the influence of historical preconditions and path-dependencies in regional economic development (Boschma & Frenken, 2006; Uyarra, 2010).

With the development of the research field, however, some scholars have criticized the strong emphasis placed on to firm-level routines at the expense of institutions and other actors, for example the state (MacKinnon *et al.*, 2009; Morgan, 2012). Due to this bias, EEG has until now only rendered limited explanatory power to factors such as policy interventions and institutions in actively favouring certain development paths (Asheim *et al.*, 2013), in spite of some notable exceptions (Martin & Sunley, 2006). According to pioneering proponents of EEG, the role of (territory-specific) institutions is considered relatively small to explain where new industry emerges and grows (Boschma & Frenken, 2009). At the same time, others have argued that there is a need in economic geography to better understand institutional evolution over time with regard to regional economic change (Gertler, 2010) as there is still a rather limited understanding of the role of public policy for the diversification of regions into new growth paths over time (Asheim *et al.*, 2011).

The objective of this paper is to make explicit and specify the role of institutions for industry formation and thereby, to contribute to our understanding of cluster emergence and development considering the interplay between technology, industry dynamics and institutions. To do so, the paper studies the evolution of the biogas industry in the region of Scania in Southern Sweden. Triggered by policy programmes targeting local initiatives to reduce greenhouse gas emissions as well as experiences and existing infrastructures related to the extraction and distribution of natural gas in the region, biogas activities started to emerge in the late 1990s and early 2000s. During the past decade and simultaneously with technological advances in the biogas area, regional policies have induced further momentum of this industry, for example through creating demand for locally produced biogas by setting up environmental goals that stimulate its use in the regional public transport system. The biogas industry constitutes today an emergent industry in the region and involves a network of both public and private actors along the value chain of biogas. Actors producing and using biogas constitute the probably most visible elements of the industry; examples are feedstock producers (such as farmers and food processors), utilities as well as energy and transportation companies. Moreover, various supporting activities such as those of manufacturers of biogas equipment are located in the region, and also local universities, research centres, support organizations and regional policy are involved in the biogas activities, explicitly aiming at strengthening cluster development. From an EEG perspective, the biogas industry in the region of Scania constitutes a relevant case to study the process of cluster emergence. In particular, this paper aims at investigating how territorial institutions, in combination with firm-level routines and technology development, can steer regional economic development and evolution along certain development paths. In doing so, institutions are primarily considered in the shape of policy interventions, including their impact on actors' behaviour. The following research questions are addressed:

How do specific territorial institutions matter for the emergence of the biogas industry in Scania?

How do policy interventions work actively in favour of new regional economic development paths?

The pronounced analytical focus on the role of public authorities and policies calls for taking a combined evolutionary-institutional perspective on cluster emergence and regional industrial development. Accordingly, the theoretical framework of the paper departs from a discussion on industry emergence in (evolutionary) economic geography introducing concepts such as path-dependence, related variety and regional branching. In order to account for an institutional perspective, the article draws on insights from innovation studies targeting the functions of technological innovation systems (TIS) regarding transformative technological change. The paper constitutes a theoretically informed case study, predominantly drawing on in-depth interviews with key stakeholders in the industry.

The paper is organized as follows. The next section presents the theoretical framework of the study, drawing on literature on spatial industry emergence as well as on TIS. The subsequent section introduces the empirical case study and analysis, also including an outline of the research design and methods applied in the study. The paper ends with a discussion and conclusion section.

Theoretical Framework

Spatial Industry Emergence and Evolution

Traditionally, the major part of the literature on economic geography and in particular, the subfield of geography of innovation, has been focusing on localized learning and agglomeration externalities for innovation processes. The functioning of clusters, understood as a geographical concentration of interconnected firms and various support organizations active in a particular field (Porter, 1998), as well as policies to support them has gained considerable attention within the discipline. The research done on clusters has, however, brought about a rather static view, hardly paying attention to a long-term perspective and consideration of the early roots of economic activities. Consequently, questions such as “how clusters actually become clusters” and “which factors and dynamics lead to their emergence” have hardly been addressed (Menzel & Fornahl, 2010).

The emphasis on the evolutionary nature of innovation processes in EEG responds consequently to an important critique raised against the “traditional” literature on the geography of innovation in that it provides snapshots of successful regions detached from their time–space context (MacKinnon *et al.*, 2002; Shin & Hassink, 2011). According to Uyarra (2010) the majority of regional innovation system studies can be characterized as “inventory-like descriptions of regional systems, with a tendency to focus on a static landscape of actors and institutions” (p. 129). Having its roots in evolutionary economics, the notion of path-dependence is central to EEG, denoting the importance of history and the dependence of past decisions for future events to occur. As a consequence, it is a widely shared understanding in the field of EEG that regional economic development is path-dependent. As Martin (2010) frames it, it is “the combination of historical contingency and the emergence of self-reinforcing effects” stemming from critical mass and spillovers that is considered key in steering the “technology, industry or regional economy along one ‘path’ rather than another” (Martin, 2010, p. 3).

Initial attempts in economic geography to understand industry emergence by paying attention to path-dependencies in regional economic development followed the “window of locational opportunity” (WLO) line of thought (Scott & Storper, 1987;

Storper & Walker, 1989). This literature argues that new industries experience a rather high degree of locational freedom as they put relatively novel demands on their locational conditions in terms of access to knowledge, labour skills and machines. As these requirements are still uncertain and not in place yet when a new industry starts to form, all regions have a similar potential to become the host of a new industry (Boschma, 1997). Once a critical number of firms carrying out a new type of industrial activity has established itself in the region, the WLO narrows down because the industry becomes tied to its location. In this manner, an industry becomes locked-in in a specific place (Storper & Walker, 1989). With regard to industry emergence, the WLO model assumes that new industries form and shape regional economic spaces (rather than the other way around) and ascribes much explanatory power to the role of chance and accidental events (Nygaard Tanner, 2012), thus resonating with the traditional model of technological path-dependence as laid out by David (1985) and its emphasis on “historical accidents”, “chance events” or “random” action for new technological pathways.

With the evolutionary turn, however, voices have recently been raised for a re-interpretation of path-dependencies, implying a stronger consideration of local (knowledge) resources in shaping regional industrial development paths over time (Martin & Sunley, 2006; Tripl & Otto, 2009; Simmie, 2012; Strambach & Klement, 2013). The literature on EEG gives evidence to path-dependent regional development, stating that firms are expected to diversify into activities that are technologically related to their existing competences. Consequently, regions are assumed to slowly diversify and branch out into technologically related fields, implying that industrial structures are rather persistent in a region (Boschma & Frenken, 2011a; Boschma & Martin, 2010). This industrial development and evolution is explained from an EEG perspective by knowledge spillovers between firms, assuming that for effective learning to take place a certain degree of cognitive proximity (or technological relatedness) between firms is needed so that firms can interpret, absorb and implement new knowledge (Cohen & Levinthal, 1990); however, also a certain degree of cognitive distance between actors is needed to stimulate novelty (Nooteboom, 2000). To address the question of optimal cognitive distance in a context of knowledge spillovers at the regional level the concept of “related variety” has been introduced (Frenken *et al.*, 2007), stating the positive impact of a variety of different yet technologically related regional industries on regional growth.

Due to its roots in evolutionary economics, the EEG framework has a pronounced perspective on, and interest in, firms and their routines. More precisely, the pioneering work on EEG (Boschma & Frenken, 2006) makes an explicit distinction between evolutionary and institutional approaches to economic geography, arguing that the role of (territory-specific) institutions is relatively small to explain where a new industry emerges due to the fact that firms develop routines in a path-dependent and idiosyncratic manner (Boschma & Frenken, 2009). This work does not neglect the impact that (territorial) institutions can have on the behaviour of firms, but institutions are treated as conditioning rather than determining the behaviour of firms and regional development as a whole (Boschma & Frenken, 2011b). Moreover, it is argued that institutions come into existence or become aligned to support a specific industrial activity once it has started to develop (Boschma & Frenken, 2009). As such, EEG follows the general line of arguments laid out in the WLO model in assuming that institutions are responsive to, rather than responsible for, new development paths.

The mentioned work on EEG has led to a general understanding in the discipline of economic geography that regional economic development is not random but that it relies on historical prerequisites in terms of firms' knowledge bases and routines as well as knowledge spillovers that lead to new industry emergence over time. However, the fact that the pioneering work in EEG puts much emphasis on path-dependencies in regional economic development has been taken up by scholars in the literature, arguing for an incorporation of institutions in approaches to explain path-dependence as well as a stronger consideration of change processes in evolutionary thinking (Martin, 2010) or emphasizing the importance of processes of collective agency in creating and steering certain development paths (Simmie, 2012). Others have mentioned their concern about a "theoretical relegation" of institutions and social agency (MacKinnon *et al.*, 2009), while some such as Essletzbichler (2009) and Grabher (2009) regard a stronger consideration and inclusion of institutions in EEG as highly relevant for the further development of the research field (Asheim *et al.*, 2013). As such, there is still a limited empirical and theoretical understanding of the role of institutions and public policy concerning the diversification of regions into new growth paths over time (Asheim *et al.*, 2011), as well as a lack of scientific work taking a more holistic perspective regarding the co-evolution of institutions and technology (Strambach, 2010).

Institutional Context and Industry Formation

In contrast to the literature on EEG, the literature on TIS and, more broadly, socio-technical transitions, allows taking a co-evolutionary perspective on technology and industry dynamics and their institutional embedding. A core tenet of this literature is that technology and institutional dimensions should not be analysed separately when trying to understand innovation. Rather, both aspects are understood in their co-determination over time. The analysis is therefore not restricted to "technologies" but rather addresses "socio-technical systems". The formation of socio-technical systems is conceived as a process of constructing "configurations that work" (Rip & Kemp, 1998) among technological artifacts and their organizational, institutional, infrastructural and use related aspects. During early formation phases largely all major components of a socio-technical configuration are still in flux: technologies need to improve in performance and cost characteristics, use patterns and user preferences have not yet been fully established and institutions to regulate the impacts of the technology are not yet fully spelled out (Dosi, 1982; Callon, 1998). On the other hand, established and mature socio-technical configurations may exhibit strong path-dependencies that go beyond lock-in effects based on increasing economies of scale (Arthur, 1994), but may be generated by the initial establishment of use patterns (David, 1985), standards, infrastructures or institutional structures (Granovetter & MacGuire, 1998).

Within the literature on socio-technical transitions, the TIS approach, introduced by Carlsson and Stankiewicz (1991) and further developed by among others Hekkert *et al.* (2007), Bergeek *et al.* (2008) and Markard and Truffer (2008), has gained considerable attention in developing a process view on early industry formation based on emergent technological fields. The framework takes a systemic perspective on innovation and considers different actors such as governmental and non-governmental organizations, research institutes and firms as well as different forms of institutions and their interplay as important elements for innovation to take place. Following Markard and Truffer (2008), a TIS can

be defined as “a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology and/or a new product” (Markard & Truffer, 2008, p. 611). As a framework for analysis, the TIS approach has a rather strong focus on mapping the functionality of the innovation system. In order to assess the performance of the innovation system, Johnson and Jacobsson (2001) and Bergek *et al.* (2008) have identified seven functions that have to exist around a new, emerging technology (i.e. they have to be carried out by actors and institutions) in order for a technology to diffuse and to lead to new industry emergence: (1) *knowledge development and diffusion* (generation, diffusion and combination of knowledge in the innovation system), (2) *influence of the direction of search* (incentives for organizations to enter the TIS), (3) *entrepreneurial experimentation* (reducing uncertainty through probing and bringing a technology into practice), (4) *market formation* (development of markets for emerging technologies), (5) *resource mobilization* (mobilization of financial and human capital), (6) *legitimation* (exert influence on the public opinion with regard to a new technology) and (7) *development of positive externalities* (achievement of clustering effects in the emerging industry) (Bergek *et al.*, 2008).

The strong focus on functions in the TIS framework has brought about important insights with regard to key activities in innovation systems as well as understanding processes of technological change and innovation (Hekkert *et al.*, 2007). This allows making statements concerning an active construction and the set-up of a supportive institutional context in emerging (clean-tech) industries. Furthermore, the TIS framework makes it possible to take a dynamic systems perspective on innovation regarding how specific functions have come in place. The TIS functions target various networks, actors and institutions of the system and makes it obvious that for new technologies to penetrate markets, multiple dimensions play important roles. The core strength of the framework on mapping the functionality of innovation systems as well as its underlying strength concerning policy implications to support new technologies is yet accompanied by its weakness in explaining regional differences in technology evolution and development (Coenen *et al.*, 2012).

Due to the strong focus of EEG on firms and their routines as main protagonists, the TIS framework will thus act as a complementary perspective to help specify the role of institutions on the early emergence process of the biogas industry in Scania.

Analysis

The biogas industry is considered to constitute an emergent industry in Scania, a region that traditionally has been characterized by its agriculture and food industries (producers of organic waste). Today, the region hosts a broad network of public and private actors on the supply as well as demand side of biogas. Figure 1 illustrates that the biogas activities in Scania cover the entire value chain, including feedstock production, collection and transport, pre-treatment and upgrading of biogas, distribution and retail as well as end-use (Ericsson *et al.*, 2013). Furthermore, it becomes apparent that the value chain actors represent existent sectors and industries (i.e. agriculture and food industry as well as the energy and waste sector) that become connected to one another through the value added created with biogas. In addition to these activities that are directly integrated into the value chain, supporting activities such as those of various producers of biogas equipment,

<u>VALUE CHAIN</u>	<u>VALUE CHAIN ACTORS</u>	<u>SUPPORTING ACTIVITIES</u>
Feedstock production ↓	Farmers Industrial food processors Households Municipal waste water treatment Service sector	Waste collection equipment
Collection and transport ↓	Farmers Municipal waste management Municipal waste water treatment	Storage of substrate
Pretreatment and upgrading ↓	Energy companies Farmers Municipal waste management Municipal waste water treatment	Biogas upgrading equipment Gas engines and gas turbines Plant engineering companies Pretreatment equipment
Distribution and retail ↓	Energy companies Oil companies Municipal waste management Municipal waste water treatment	
End-use	Private gas vehicle owners Public transport, municipal vehicle fleets	

Figure 1. Value chain actors of biogas and supporting activities in Scania.
Source: Own illustration based on Ericsson *et al.* (2013).

to a large part also having their roots in the direct value chain activities, are located in the region.

Based on Ericsson *et al.* (2013), a number of ca. 40 companies¹ can be identified in Scania that are either directly or indirectly part of the biogas value chain, not yet including actors in the service sector, farmers, private vehicle owners, universities, research centres, consultants and cluster initiatives. As shown in Table 1, Scania (Skåne) is today the county with the highest biogas production as well as count of biogas plants in Sweden, producing ca. 0.3 TWh of energy (in 2011) and amounting ca. 20% of the Swedish overall biogas production.

Scania is aiming for an increase of biogas production to 3 TWh in 2020, equal to 10% of the county’s total energy demand, and by doing so, to create 3300 new jobs in the region (Region Skåne, 2011). Furthermore, the region wants to develop into an internationally leading “Centre of Excellence” for biogas, that is a collective term used for establishing internationally leading research and collaborations within the biogas field.

The following sections will shed light on the formation process of the described industry. Due to the fact that biogas-related activities do not underlie any industry classification code, it is not possible to make statements on the development and (regional economic) impact of that industry in quantitative terms; that is in terms of employment or turnover. The analysis is therefore based on a combination of qualitative research methods, with personal semi-structured in-depth interviews constituting the main data source. The inter-

Table 1. Biogas plants and biogas production in the Swedish counties 2011

	Plants (count)	Production	
		County (GWh)	% of national total
Blekinge	3	1.4	0.1
Dalarna	12	24	1.6
Gotland	1	7.3	0.5
Gävleborg	6	11.7	0.8
Halland	11	72.7	4.9
Jämtland	3	9.2	0.6
Jönköping	11	39.6	2.7
Kalmar	10	28.4	1.9
Kronoberg	6	10.2	0.7
Norrbottn	8	32.5	2.2
Skåne	41	289.8	19.7
Stockholm	16	257.1	17.5
Södermannland	7	51.8	3.5
Uppsala	5	34.8	2.4
Värmland	10	14.5	1.0
Västerbotten	5	36	2.4
Västernorrland	13	109	7.4
Västmanland	8	43.5	3.0
Västra Götaland	35	215	14.6
Örebro	11	66.9	4.5
Östergötland	11	117.5	8.0

Source: Energimyndigheten (2012), own table.

views are based on a thematically structured guide containing pre-formulated central questions about the interview content. In this way, semi-structured interviews ensure a certain level of comparability between the single interviews, while at the same time allowing for individual adjustment to the experiences of the respective interviewee. As such, the semi-structured interviews have proved to be a suitable method for the explorative, however theoretically informed, design of the study. Additionally, the interview findings are complemented by document studies on publicly available data sources such as strategy documents and annual reports (Länsstyrelsen, 2011; Region Skåne, 2011; Energimyndigheten, 2012; Skånetrafiken, 2012). In total, the paper draws on a number of 17 interviews with key stakeholders of the biogas industry, involving public sector and industry, as well as a major university in the region. Eleven interviews were conducted between September 2012 and April 2013, explicitly addressing the research questions studied in the paper. An additional six interviews, conducted in May 2013 within the framework of a related research project, were used as reference and for cross-checking purposes. The interviews were in large part conducted in Swedish (a minority of them in English; depending on the interviewees' preferences), and transcribed and translated into English by the authors. Although the interviewees chosen for this study had different backgrounds (i.e. in the private or public sector or in research), they showed general agreement with regard to the mechanisms operative during the early phases of biogas industry development.

Emergence of the Biogas Industry: Unpacking the Evolutionary Process

Setting the scene: early activities in the region. Activities related to the production of biogas in the region of Scania had their first origin in the beginning of the 1980s and were a reaction to national regulations targeting the reduction of sludge emanating from water treatment at purification plants. Looking back, these early activities can be seen as one important element for the formation of the industry at later stages; at these times, however, these processes were also taking place in other parts of the country and moreover, they were not exclusively targeting the production of energy.

The production began at wastewater treatment plants, in order to find ways to treat the sludge and to reduce its volume. (. . .) You got energy that was used to heat the houses around, but at that time it was not the main purpose to produce energy—and it happened in many parts of Sweden. (Project coordinator, stakeholder association)

Also going back to the early 1980s, simultaneous activities of a large energy company in the region concerning the supply of Southern Sweden with natural gas and the construction of a natural gas grid along the region's west coast can be considered as crucial component for the later formation of the biogas industry. These activities can be seen as a strategy targeting secured energy supply in the southern part of the country as reaction to a national nuclear power referendum in 1980 to decide on the close-down of a nuclear power plant in the region. The experiences with natural gas as a new source of energy in Southern Sweden (also closely related to the oil crisis in the 1970s) as well as progress in technology development led to the political decision in the mid-1990s to run public city traffic (i.e. the city busses) in the region's capital Malmö on natural gas in order to reduce emissions, improve urban air quality and reduce traffic noise. In other parts of the region, mostly driven by environmental concerns, early attempts were made by some municipalities to collect organic waste from households and to use it as a renewable energy source. Simultaneously in the late 1990s, the previously mentioned energy company became involved in a municipal project targeting pilot experiments concerning the feed-in of biogas into the natural gas grid. Due to this demonstration project, the energy company became an international forerunner in upgrading technologies, targeting the upgrade of biogas to natural gas quality in order to distribute it through the existing grid and making biogas available in other parts of the region. The development of upgrading technologies can, in retrospect, be considered as a crucial element for industry build-up at later stages.

Particular for Scania was the natural gas grid as it is very limited in Sweden. That was a main reason to start the technology, to inject biogas into the natural gas grid. This development was unique in the world. (Project manager, energy company)

At that time (i.e. between 1998 and 2002), the regional capital set up local environmental goals to reduce greenhouse gas emissions and biogas was increasingly considered as a future ambition in public transport.

Industry emergence. The emergence of the biogas industry in Scania gained momentum in 2002, when the Environmental Protection Agency of Sweden (i.e. the national governmental agency responsible for proposing and implementing environmental policies)

announced a so-called Climate Investment Programme (KLIMP). KLIMP constituted a seven-year grant covering the period 2002–2008 and targeted local initiatives focusing on the reduction of greenhouse gas emissions and increasing energy efficiency in Sweden.

Previously, there was a support programme called ‘KLIMP’ and there one could apply for money to reduce the environmental damage. Biogas got a large share of this money because it was considered the best activity as it gives significant climate effects. But companies could not get this money, only municipalities could apply. (. . .) They saw that there was much that could be achieved with regard to biogas in Scania. (Project coordinator, stakeholder association)

Altogether, biogas projects in 17 of Sweden’s 21 administrative regions received a grant. However, the region of Scania stood out and received together almost half of the overall grant (of a total of 622 million Swedish krona). As such, the activities and built-up of infrastructures in the region of Scania prior to KLIMP during the 1980s and 1990s can be seen as a critical factor for success with regard to the KLIMP applications. KLIMP can be regarded as an institutional setting providing legitimacy for technological change targeting increased energy efficiency and a reduction of greenhouse gas emissions by exerting influence on the general and public opinion of new technologies. The programme can be considered as an instrument to communicate the message that technological change was desirable by relevant actors. By implication, as legitimacy influences expectations, KLIMP can likewise be seen as means of guiding the direction of search of actors and creating incentives to enter the TIS (Bergek *et al.*, 2008). Hence, KLIMP provided stability and was a crucial element for steering the development along a new development path (or a technological trajectory). However, at that time only comparatively little industrial activities targeting biogas were existent in Scania. Rather, the previously mentioned simultaneous (and largely independent) activities and prerequisites in the region such as suitable infrastructure and experiences with natural gas, a demonstration project targeting biogas upgrading technologies as well as early activities to collect organic waste from households can be seen as factors constituting an anchor for KLIMP to build on. The development in Scania was further strengthened in December 2002 when the County Administrative Board of Scania published an environmental action plan containing specific milestones concerning the reduction of greenhouse gases in the region. This action plan was worked out by a large number of municipalities, organizations and increasingly also companies in the region.

The network of actors involved in biogas activities in Scania gained increasing foothold in year 2005/2006 when a regional association for biogas stakeholders (Biogas Syd) was founded, driven by various public and private biogas actors in the region.

It was the biogas actors in the region who felt that they needed an organisation that collected all the questions and pushed them. The initial actors were waste management companies, energy companies, universities and some municipalities. (Project coordinator, stakeholder association)

The association can be seen as bottom-up initiative resulting from a growing need for operational and strategic interaction in the biogas area and it is founded and funded by its members as well as by regional authorities providing basic funding. Thereby, the increasing

need for interaction was resulting from the actors' rising awareness that biogas has a high potential in Scania. First, the region is characterized by a high amount of raw material (biomass) through the region's traditional stronghold in agriculture and food industries. Second, there was an increasing interest among actors such as energy companies and utilities to develop a more environmentally friendly profile. Furthermore, and also drawing on earlier experiences with natural gas, research regarding biogas technologies had made substantial progress in the region, leading among others to spin-offs from a technological university in the region. The establishment of the stakeholder association, being a support and network organization with the aim to increase the production and use of biogas in the region, can be seen as important for strengthening the regional networks in the regional biogas field. From an institutional perspective, the foundation of the network organization can be considered as supporting knowledge development and diffusion, a function regarded as central for a TIS and innovation processes in general (Bergek *et al.*, 2008). Network activities are considered crucial for knowledge exchange and interactive learning, and in the region of Scania these clearly profited from different, but related industrial activities existing in the region, such as agriculture and food industries. Likewise, the foundation of the network organization can be seen as means of resource mobilization (both financial and human capital).

From industry emergence to growth. A decisive moment for the biogas industry in Scania was in 2007 when the regional government's public transport committee set up a goal that all public transport in the region should be fossil free in 2020, with sub-goals targeting fossil free city traffic (city buses) in 2015, regional traffic in 2018 and remaining service trips in 2020. In reaction to the announcement of these goals, the company running the public transport in the region—being a publicly owned company and part of the regional authorities—thereupon took the decision to invest in biogas. Important for this decision was the fact that the energy needed for the public transport should be produced locally in order to obtain a direct environmental effect in the region. Biogas was regarded as the fuel with the highest regional potential; attributed also to the increasingly developing regional specialization in biogas.

There was a great potential seen in Scania and it has to do with the agriculture here. There are many residual products from agriculture, Sweden's best agricultural land is in Scania. This was a very important aspect, plus that in Scania there is a strong food industry and residual waste that can be used, (...) also including residual waste from households. (Head of strategic development, transportation company)

Furthermore, it was important for the transportation company, acting on behalf of the regional government, to decide only on one technology and not on several at the same time.

And it was also important to invest in one fuel. By focusing on biogas there was a clear signal given to the market that it is biogas that counts in Scania. (Head of strategic development, transportation company)

The latter can be seen as a clear example from the regional authorities to support entrepreneurial experimentation through reducing uncertainty and facilitating concrete actions

targeting a specific technology (Hekkert *et al.*, 2007). Moreover, the grant from the KLIMP programme, still in place when the regional climate goals were set up, was used for the acquisition of biogas buses and public filling stations. The regional public transport system thus played a crucial role in promoting the development of the biogas industry in Scania as it created a local market for the biogas produced in the region. The decision taken for the regional public transport system led to activities of private companies (such as energy companies) to extend investments regarding the (commercial) production of biogas.

The development of the industry was further supported in spring 2010 when the County Administrative Board of Scania set up a climate goal for the region, particularly to bring forward the regional production and consumption of biogas. The goal implies a total production of 3 TW biogas in the region in 2020, which equals 10% of the county's energy demand. As a reaction to that, in December 2010, a roadmap was worked out by the regional government together with municipalities, the County Administrative Board of Scania, universities and private companies in order to concretize specific actions to reach the above-specified goals and to form a basis for improved co-operation between actors in the industry. Although the action plan was worked out in collaboration with private companies and research organizations, the regional government played a major role in its development. As such, the roadmap is in line with the decision on fossil free public transport taken in 2007, and can be seen as further signal providing legitimacy concerning the future support of biogas-related activities in the region. The effect of the legitimacy and market creation on the industry becomes evident from the fact that over time increasingly also private actors have been entering the industry and that the industry is diversifying in terms of markets. Whereas in 2007 public transport was almost the only—and still is the dominant—commercial consumer of biogas, it has become increasingly accepted as a biofuel among private vehicle drivers in the region also.

Five to six years ago, Region Skåne [i.e. the regional government] was one of the major consumers of biogas, and it still is, but it has grown a lot of interest among private car drivers as well as among companies, i.e. company cars. (Head of strategic development, transportation company)

Future development. Although the biogas industry build-up has constituted a rather unproblematic process (apart from minor teething troubles with regard to the functioning of new technologies) that hardly encountered any resistance by actors, the industry may face challenges with regard to future growth. These are mainly a matter of missing explicit rules and transparency on the national level that run the risk of inhibiting the further development of biogas activities in Scania. Due to lacking long-term perspectives provided by national policy concerning regulations and incentives, actors become hesitant with regard to their investments—both on the production and demand side of biogas (Region Skåne, 2011). By way of example, recent plans of an energy company to construct a biogas plant in the region applying a new and more efficient technology were put hold on as the required investments are enormous and too uncertain in times of non-transparent regulations regarding tax benefits of biogas. As the decision of private households and companies to invest in biogas vehicles is much driven by financial incentives, the further future development of that market is unclear. The price of biofuels (and renewable resources in

general) has to be seen in relation to that of fossil resources, calling for a provision of long-term legitimacy also from higher political levels.

The price of [natural] gas is not increasing as much as it would be needed to be able to invest. (...) It is because [the price of biogas] cannot rise above the price of oil, petrol and diesel, but it rather has to be seen in relation to it. It may not be more expensive to run biogas—then you do not get any consumers. (Project coordinator, stakeholder association)

Discussion

As identified in the analysis, the emergence of the biogas industry in Scania was favourably conditioned by the co-location of different but related sectors encompassing largely the entire value chain for biogas production and consumption. However, the latent potential for diversification of incumbent industries and subsequent processes of branching offered through the production of biogas did only gain momentum through the announcement of the national KLIMP programme. By targeting local initiatives for energy efficiency and a reduction of greenhouse gasses, it provided much-needed legitimacy for technological change within waste and energy companies, while at the same time influencing actor's expectations and guiding their direction of search. The provision of legitimacy through KLIMP led subsequently to an arising need for increased knowledge development and diffusion, becoming apparent in the foundation of a network and support organization for biogas (Biogas Syd). This need can be seen as a path-dependent result of the preceding policy interventions, yet this time increasingly driven by private actors as a response to the legitimacy provided by the state towards (local) public authorities. Decisive for the further development of the emerging biogas industry in Scania were the subsequent political decisions taken by the regional government. By appointing biogas as a fuel with a positive future prospect, the regional authorities were tying up with the technological trajectory catalysed by KLIMP. In doing so, they became active in supporting regional market formation which can be seen as a crucial process for the commercialization of a new technology and product as it provides further legitimacy, entrepreneurial experimentation and guidance of the search for the actors.

This (stylized) account shows that the emergence of a biogas cluster in Scania was indeed partly conditioned by related variety between incumbent industries in the region as suggested by the literature on EEG. Its realization was, however, strongly influenced by policy decisions and subsequent collective action by industry actors as a response to these policy decisions. Drawing again on evolutionary thinking, it can be argued that these policy decisions were highly important in shaping a path-dependent process of inter-related technological and industrial change. The complementary TIS perspective helped specify how policy, as well as the responses by the actors, has been crucial for creating legitimacy among actors to invest and commit resources to a new technological development path. In addition, policy-led market creation for biogas further fuelled the legitimacy of this development path, encouraging firms to experiment, in a process of entrepreneurial discovery, with commercialization of biogas related infrastructure.

The fact that the TIS functions could be identified to have operated, as well as interacted with one another, during the early evolution of the biogas industry calls for a more detailed elaboration of the spatial levels at which the functions were supported. In order to allow for

a spatially differentiated analysis, Figure 2 demonstrates the evolution of the biogas industry in Scania, yet in a simplified manner.²

First and foremost, the figure illustrates that the majority of TIS functions is supported at the regional level (i.e. in Scania) whereas only the legitimacy and the mobilization of financial resources by the KLIMP programme are realized at the national level. As KLIMP initially targeted initiatives in all Swedish municipalities, it could have led to similar effects in all Swedish regions. However, the momentum in Scania was achieved due to the existence of specific local “prerequisites” prior to KLIMP was announced. These include the energy sector, particularly technological and infrastructural experiences regarding natural gas (existence of the grid, development of upgrading technologies) as well as traditionally strong food industries and agriculture providing resources, that is residuals, for biogas. The presence of these industries should thus be regarded as decisive for the success of the KLIMP applications stemming from municipalities in Scania. It has to be noted, however, that KLIMP did not target industry emergence; rather, industry emergence should be seen as an implication and consequence of KLIMP as it provided a common orientation to previously existent, but largely independent activities. KLIMP played thus an important role in aligning the activities of actors in the region, and by implication, creating linkages between established industries. In other words, KLIMP influenced actors’ direction of search and steered the development towards a new technological path through diversification of existing industries.

Based on these effects of KLIMP, several other processes (i.e. functions) such as a growing need for further knowledge development and exchange, resource mobilization, market creation, entrepreneurial experimentation and legitimacy became operative at the regional level. All these developments result either from decisions that were actively taken in the region and/or that profited substantially from the regional level. It has to be

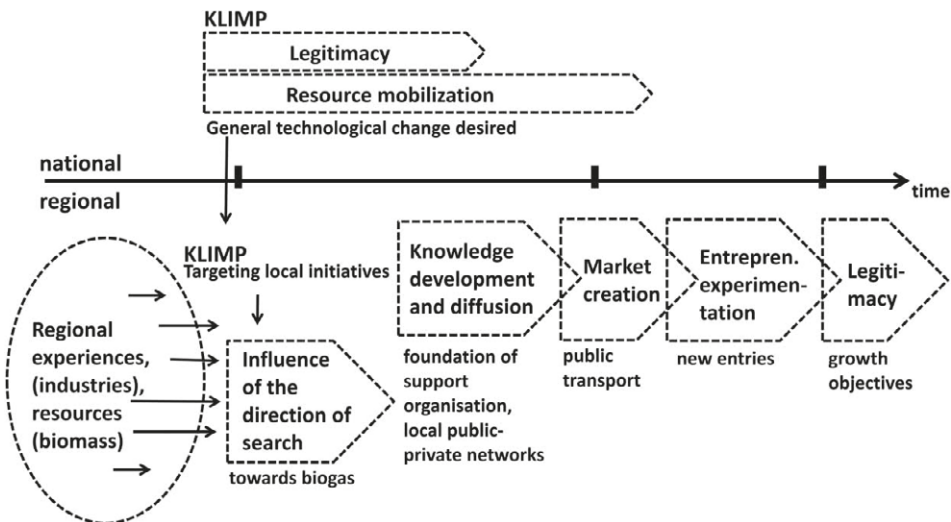


Figure 2. TIS functions—a spatial perspective on biogas development in Scania (simplified illustration).

Source: Own draft.

noted, however, that these processes do not follow any strict sequence as pictured in Figure 2; in some cases they overlap and are simultaneously active. Furthermore, not all these functions should be understood as being exclusively regional in nature as they may be linked to developments at the national or international level. By way of example, Scania is very likely embedded in knowledge networks exceeding the regional boundaries and moreover, developments targeting biogas are influenced by a general (international) endeavour to reduce the use of non-renewable resources.

In Scania, however, the regional level is considered crucial with regard to biogas industry formation. This is due to the specified regional “prerequisites” such as the presence of related industries. The process of industry diversification in the region was, however, initiated by a national policy programme (i.e. KLIMP), and would otherwise not have gained momentum; at least not at that time and not in the same manner. Subsequently, political decisions made in Scania itself led to further development of the biogas activities. This demonstrates that institutional dimensions should not be relegated in accounts of cluster evolution, especially in early stages of cluster emergence. Rather, it complements the firm- and competence focused perspective elaborated in EEG in helping explain under what conditions and how actors realize the latent potential for industry diversification.

Conclusions

The objective of this paper was to make a contribution to the understanding of cluster emergence and development from a co-evolutionary perspective involving technology, industry dynamics and institutions. To do so, the paper took a combined institutional-evolutionary perspective by, on the one hand, drawing on literature from EEG concerning path-dependence in regional economic development and the question where new industries form and why they form where they do. On the other hand, to account for the complementary institutional perspective, the paper made use of the literature on socio-technical transitions, particularly the TIS approach, concerning an active construction and the set-up of a supportive institutional context in emerging technologies and (clean-tech) industries. By studying the emergence of the biogas industry in the region of Scania in Southern Sweden, the aim of the study was to bring to light to what extent territory-specific institutions have mattered for its emergence—and in particular, to reveal how policy interventions can work actively in favour of new regional economic development paths.

Referring to the discussion on industry emergence in EEG, neither does the case support the WLO argument of industry emergence and location being a random phenomenon, nor can industry emergence be exclusively explained by firm-level routines. Rather, the analysis reveals that specific territorial institutions can (and do) matter for regional industry emergence. In Scania, a national policy programme (KLIMP) targeting technological change and energy efficiency was crucial for aligning existing competences and activities (in the broader sense) to one another which were different but not entirely unrelated with regard to biogas. In other words, infrastructures and technologies targeting natural gas proved to show synergies to biogas—and the existence of the closely related activities in agriculture and industrial food production proved to provide residuals. The potential of these synergies was, however, not made use of before KLIMP was announced. Here, the policy programme was decisive for steering the region towards a new development path.

This alignment of interests and expectations, caused by the policy programme, led subsequently to increased cooperation and a need for further knowledge development among both public and private actors in the region. Hence, it is a striking example of how policy programmes can (and do) shape behaviours of actors. A strategic perspective for the industry was thereupon built-up by active policy decisions on the innovation system in the region itself, i.e. by creating a market for the produced biogas and by setting up further strategic development goals. Thus, we argue that in the case of the biogas industry in Scania, institutions have initiated and strengthened a number of processes that were key to technological development, which, in turn, were driving the emergence of a cluster forward. These were either directly created by policy programmes, and respective decisions—or they developed as a response to these. The processes started to interact with one another and created path-dependencies and stability for technology and industry development at the regional level.

By way of concluding, we argue that the TIS framework has been helpful in making explicit and specifying the role of institutions, in the shape of public policy interventions, for the development and diffusion of new technology, which in turn gave rise to cluster emergence. These institutions explain to a considerable extent the path-dependent evolution of the cluster. While the general applicability of the patterns found in this study are limited—given the design of the study it has been impossible to control for local contingencies making broader generalization to other regions, industries and technologies troublesome³—we argue that the TIS framework can be fruitfully employed in the analysis of cluster emergence as it helps draw attention to crucial processes in the build-up of a (technology-based) industry. While “traditional” EEG approaches focus primarily on industrial and knowledge dynamics, we would argue that this is only part of the story. The case illustrates that suggested TIS functions such as legitimacy creation, market formation, and guiding the direction of search and entrepreneurial experimentation are indeed important processes that need to be taken into account, in addition to knowledge development and diffusion, to arrive at a more comprehensive understanding of the complexities involved in industry and cluster emergence, which includes a more prominent role of institutional factors.

This study has taken the TIS functions as a point of departure, which may to some extent limit the analysis at the expense of other processes and institutional factors that could be important in a context of cluster emergence (e.g. factors that condition the policy design of regional and national government, institutions underpinning the collaborative behaviour of firms (across sectors), factors that influence the propensity for public–private coordination). While it goes beyond the scope of this study, this article does invite future research in the context of cluster emergence and evolution not to relegate the role of institutions as this seems to be particularly important in early stages of cluster evolution. Here, we believe that insights on knowledge and industry dynamics from EEG would be highly compatible with adopting a systems approach to innovation and the central role played by institutions in this literature.

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Notes

1. Private companies and municipal actors in the region that were identified in Ericsson *et al.* (2013) are VASYD, NSV A, Kristianstad municipality (municipal waste water treatment); VASYD, Kristianstad renhållning, NSR, Sysav Biotec 2012, Kristianstad biogas (municipal waste management); Findus, Scan, Örtofta, Procordia, Örtofta Nordic Sugar (food industry/food processors); Lunds Energi, E.ON, Öresundskraft (energy companies); OKQ8, Preem, Shell (oil companies); Skånetrafiken, Veolia (public transport); WTM AB (waste collection equipment); Norups Gård, Purac, Purac Läckeby, Flinga Gårdsgas, Götene Gårdsgas (plant engineering companies); BioPreplant; MSI Teknik AB, Xylem, Spirac; Läckeby Products (pre-treatment equipment); Malmbergs Water, Terracastus Technologies, Cryo, Purac Puregas (biogas upgrading equipment); Compower (gas engines and gas turbines).
2. As the TIS framework has a weakness in explaining regional differences in technology development and evolution (Coenen *et al.*, 2012), the paper contributes by this means also to the literature on socio-technical transitions. In the majority of studies, TIS are set national boundaries that neglect local/regional specificities of TIS characteristics (for an exception, see, e.g. Binz & Truffer, 2012).
3. In particular we should acknowledge that many of the patterns found in this study may be specific for clean-tech industries and clusters.

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Article III

Policy capacities for new regional industrial path development – The case of new media and biogas in southern Sweden

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Abstract

Over the past few years, a growing body of work in economic geography and innovation studies has enhanced our understanding of forms and determinants of regional industrial path development. The importance of policy, however, has received limited attention and accordingly, the role of policy for the emergence and development of new regional industrial growth paths remains largely unexplored. This paper takes an institutional perspective and suggests that the regional innovation system approach can contribute to conceptualising and analysing the role of policy for new regional industrial path development. We argue that in order to turn regional preconditions into new growth paths, regional innovation systems require strong policy capacities, consisting of formal and governance capacities. In the empirical part, we analyse the emergence and further development of two new growth paths in the region of Scania in southern Sweden, namely biogas and new media. Based on personal interviews with policy makers, representatives from knowledge and supporting organisations and firms as well as a document analysis, we investigate how policy interventions have influenced the rise and evolution of these two industries. We show that in both cases, policy-led initiatives have played an important role in enabling new path development. We find that policy can play multiple roles in nurturing and maintaining new growth paths and that these are closely interlinked with particular policy capacities of regional innovation systems.

Keywords

New path development, regional policy, regional innovation system, capacity building

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Introduction

In economic geography, innovation studies and related disciplines, there is a growing interest in the question how new regional industrial growth paths¹ emerge. Evolutionary economic geography (EEG) has significantly enhanced our understanding of the path dependent nature of regional development and different forms and mechanisms of regional industrial change (Boschma and Frenken, 2006, 2011; Boschma and Martin, 2010; Martin, 2010). Recently, new contributions have sought to shed more light on the scope of policy-initiated and -supported new regional industrial path development. This includes attempts to connect evolutionary thinking with a geographical political economy perspective (Dawley, 2014; Dawley et al., 2015; Pike et al., 2016), with the technological innovation system (TIS) framework (Martin and Coenen, 2015) and with a more sociological view on the creation of new pathways (Karnøe and Garud, 2012; Simmie, 2012). Moreover, also protagonists of the regional innovation system (RIS) approach are increasingly engaging with the debate on new regional industrial path development (Asheim et al., 2016; Isaksen and Trippel, 2016; Morgan, 2013).

The current discussion, however, devotes surprisingly little attention to important policy preconditions for new path development, such as the capacity of regions to develop collective action. This paper seeks to address this shortcoming by complementing the RIS perspective with insights from the literature on regional governance in general (Jones, 2001; Morgan, 2004; Pike and Tomaney, 2001, 2004) and regional capacity building in particular (Cole, 2006a, 2006b). We aim at, on the one hand, going beyond firm centric accounts that dominate the EEG literature by considering a variety of actors, their interrelation and connections to higher spatial scales, and, on the other hand, at a stronger consideration of institutional aspects such as the political autonomy of regions and the capability of policy actors to shape regional development. We put forward the notion of 'policy capacities', which constitute the enabling and constraining factors for collective action at the regional level. By doing so, we suggest a conceptual framework to explain why and how (some) regions manage to exploit conditions, use existing resources and preconditions and in collective action turn them into new development paths. Furthermore, we establish a link between policy preconditions in the region and multiple roles that policy can play in shaping new regional industrial path development (Morgan, 2013).

The paper is structured as follows. The second section reviews the literature on new regional industrial path development with a particular focus on the role of policy. The third section develops a conceptual framework for analysing processes of new path development. The fourth section explores the emergence and further development of two successful new growth paths in southern Sweden, namely new media and biogas, and investigates how policy interventions and initiatives have influenced and accompanied their evolution. The fifth section concludes the main findings and provides suggestions for future research.

Literature review: New path development and the role of policy

Current approaches to new regional industrial path development are largely inspired by EEG (Boschma and Frenken, 2006; Boschma and Martin, 2010). EEG considers new path development as outcome of (mainly) endogenously triggered branching processes in existing industries by which firms over time slowly diversify into technologically related fields (e.g. Essletzbichler, 2007; Frenken et al., 2007; Neffke et al., 2011). In this literature, the role of policy is seen as assisting regional branching processes by stimulating cross-sectoral

knowledge flows through firm diversification, new firm formation, labour mobility and social networking (Boschma, 2013). Yet, the role of policy has gained relatively little attention in the EEG debate so far (Coenen et al., 2016; Hassink and Klaerding 2011; MacKinnon et al., 2009; Morgan, 2013; Rodríguez-Pose, 2013).

Recently, an emerging body of work has begun to address more specifically the role of policy in new path development. Simmie (2012) links evolutionary theories of path dependence with a sociological view on the creation of new pathways by knowledgeable agents. He concludes that new growth paths are often created in niches where pioneering actors set in motion change by deviating from established regime practices. National policy can play an important role through providing financial incentives such as subsidies and tax reliefs. Dawley (2014) and Dawley et al. (2015) emphasise the role of a wider set of actors that mediate the rise and development of new growth paths. They shed light on the importance of what they call 'evolutionary inspired (...) strategic and contextual regional policy intervention' (Dawley, 2014: 1). They show that regional policy actions are affected by the national political economy of market regulation and industrial policy, and demonstrate the need for an alignment of regional policy initiatives with national and supra-national policy frameworks.

Morgan (2013) draws attention to multiple roles of the state in shaping new path development, emphasising in particular 'its roles as producer, regulator, animateur and purchaser' (Morgan, 2013: 337). The first role refers to a direct involvement of the state into the production of goods and services, for instance in the case of state-owned companies. Such a direct market involvement can steer new developments, but also foster negative lock-ins, as it has been the case in many old-industrialised regions (Grabher, 1993; Morgan, 2013). The second role refers to setting and enforcing laws and regulations, for instance in the form of industrial standards, social and environmental regulations or intellectual property rights. By setting the regularly framework, the state can actively steer technological development and influence regional economic development (Coenen et al., 2015). The third role, the animateur, refers to bringing together public and private actors and facilitating knowledge exchange between them. This becomes visible in typical regional innovation policy tools such as clusters and science parks that aim at networking between firms, universities and governmental agencies (Martin et al., 2011). The fourth role, the purchaser, refers to a situation when the state procures goods and services from private sector suppliers. Through public procurement for innovation, the state can actively steer innovation and economic development (Edquist and Zabala-Iturriagoitia, 2012).

Recently, also protagonists of the RIS approach have sought to contribute to research on new path development (Isaksen, 2015; Tödting and Trippel, 2013). Isaksen and Trippel (2016) argue that regions have varying capacities to develop new growth paths, depending on their endowment with organisational thickness and degrees of specialisation of economic structures. Organisationally thick and diversified regions offer favourable conditions for new path development, as they can benefit from industrial variety and the possibility to combine diverse knowledge bases locally. This is less the case for organisationally thick and specialised as well as for organisationally thin RIS, which have less scope for local knowledge re-combinations. Subject on their organisational endowment and the degree of related variety, different RIS require different types of policy interventions to stimulate path renewal and new path creation (Asheim et al., 2016; Isaksen and Trippel, 2016).

The concepts mentioned above have in common that they focus on existing regional preconditions as enabling or constraining factors for new path development, calling for place-based and customised regional policy interventions. Furthermore, key contributions named argue for a stronger consideration of policy (Dawley, 2014;

Dawley et al., 2015; Simmie, 2012), emphasise multi-scalarity of policy processes and provide a clear indication of the importance of actions taken by multiple RIS actors (see also Fornahl et al., 2012; Martin and Coenen, 2015). Although pointing at different roles that the state can take (Morgan, 2013), we find that the literature remains rather descriptive about these roles, not paying attention to the actual capacities that are needed in order to actively shape new regional industrial path development. By taking a RIS perspective and drawing on insights from the regional governance and capacity-building literature, the next section elaborates more closely on this shortcoming and by doing so, develops an own conceptual framing.

Analytical framework: Policy capacities for new regional industrial path development

The RIS approach advocates a multi-actor perspective, with firms, universities, R&D centres, intermediary organisations as well as governmental agencies that collectively contribute to regional innovation and growth. From a RIS perspective, the broader organisational context, including private and public actors and their actions, as well as the institutional setting, including formal and informal rules and codes of conduct, need to be taken into account in order to understand new path development (Asheim and Gertler, 2005; Braczyk et al., 1998; Doloreux, 2002). Moreover, RIS are seen as open, nationally and internationally connected systems, which allows adopting a multi-scalar perspective, putting emphasis on the interrelationships between regional and supra-regional (policy) levels (Asheim et al., 2011b).

In the existing literature on policy and new path development, little has been said about the actual capacity of regional actors to align with and adopt to supra-regional policies (Dawley et al., 2015). EEG provides valuable theoretical insights on lock-in and path-dependencies in regional economic evolution, yet considers firms as main agents of change and pays relatively little attention to region-external influences (Boschma and Frenken, 2009; Coenen et al., 2016; Pike et al., 2016). Due to its focus on a broad range of actors, institutions and policies as well as multi-scalarity, we consider RIS as suitable framework to study the role of policy in new path development. However, RIS scholars have only recently started to engage in the debate on new path development, implying that a coherent conceptual framework does not yet exist. Particularly, we find that recent RIS accounts pay little attention to important policy preconditions, including the political autonomy of regions and the capacity of RIS actors to develop collective action (Asheim et al., 2011a, 2013; Isaksen and Trippel, 2016; Tödting and Trippel, 2013).

We put forward the argument that specific policy capacities should be considered crucial for new path development and that these are closely connected to specific roles of the state (Morgan, 2013). In the following, we aim at making these capacities more explicit. Thereby, we follow the broad understanding of policy common in the RIS literature, which considers policy as collective action of various public and private actors that commonly shape (and result in) public authorities' decisions (Morgan and Cooke, 1998). RIS actors are not seen as passive targets of policy interventions, but as directly or indirectly influencing policy decisions (Flanagan et al., 2011). Policies are designed and influenced by RIS actors who are embedded in an institutional environment, often described as the 'rules of the game' that govern the behaviour of actors (North, 1990; Rodríguez-Pose, 2013). Since policies also influence the behaviour of actors, they can be considered as part of the institutional environment. Thus, we see policies as part of the institutional environment of a RIS and as shaping and being shaped by the behaviour of RIS actors.

We use insights from the regional governance literature, which deals with the relationship between governance and economic development (e.g. Jones, 2001; Jones and MacLeod, 2004; Morgan, 2002, 2004) and focusses on the economics and politics of decentralisation and devolution (e.g. Morgan, 2006; Pike and Tomaney, 2001, 2004; Rodríguez-Pose and Gill, 2004, 2005). Similar to RIS, this literature understands regional actors not as passive targets of supra-regional policies and institutional settings. Rather, it sees regional institutions and relational assets (Storper, 1997) as crucial for the capacity of regional governments to steer economic development (Pike and Tomaney, 2009; Rodríguez-Pose and Gill, 2005).

Inspired by Cole (2006a, 2006b) who explains decentralisation as a process of local and regional capacity building, we argue that respective insights are valuable when addressing new regional industrial path development. Motivated amongst others by John (2001) and Pasquier (2002), Cole (2006a, 2006b) interprets capacity in two ways: On the one hand in terms of resources that regions have to possess to conform to national or supra-national directives or to implement policies; and on the other hand in terms of the 'internal qualities of localities and regions, their visions of the future and perception of their role' (Cole, 2006a: 39). Taken as a whole, capacity constitutes of several dimensions such as the emergence of more cohesive local government structures, strengthening of local political leadership, the development of more entrepreneurial forms of policy making, asymmetrical policy delivery, the growth of sub-national expertise and the emergence of new local and regional public arenas for collective action (Cole, 2006a: 32, 39). This literature provides insights on how policy-led change in regions can come about and considers both the importance of 'hard' aspects such as the autonomy of regional political decision making and 'soft' aspects such as regional identity and inter-regional collaboration between local policy and business actors for strengthening territorial visions. Moreover, it highlights that political arrangements must be understood in light of specific traditions, social dynamics and economic change; and most importantly, that capacity building should not be considered as a single event, but as process that takes place over time (Cole and Pasquier, 2015; Martin and Sunley, 1997).

These findings call attention to aspects that have been less discussed in the debate on new path development. In particular, we argue for a distinction between formal aspects and internal qualities of regions when addressing new path development and intend to integrate this differentiation in the RIS framework. We reason that the role that policy can play depends on the *policy capacity* of the RIS, and introduce two dimensions of policy capacities: formal and governance capacities.

With *formal capacities*, we understand the political autonomy of regions to decide on matters with regard to regional economic development (i.e. the degree of decentralisation), which sets the formal scope of action for regional authorities and determines the extent to which regional actors can formulate their own development strategies. In addition to political autonomy, we also consider a region's endowment with financial resources as important for new path development. Thus, we define formal capacities as the hard resources that regions have in order to implement policies and to steer economic development, and consider thereby both political autonomy and financial control. These formal capacities can be seen as formally tied to regions and relatively stable over time.

However, we contend that formal capacities alone are not a sufficient condition for new path development. Social features and dynamics, which are in the following termed *governance capacities*, should be considered important as well. In Cole's (2006a, 2006b) work the 'internal qualities' highlight the role of inclusive decision making between policy makers and other stakeholders in the region, the development of regional expertise and common expectations, the use of regional competences and the creation of common

future visions and platforms for collective action. We argue that such governance capacities are decisive for regions to make use of their formal capacities.

Attempting to tailor these internal qualities to RIS, we argue that one dimension of governance capacities refers to regional institutional thickness (Amin and Thrift, 1994). The literature on RIS implies that new path development does not only require organisational thickness, i.e. a critical mass of firms, universities and supporting organisations, but also institutional thickness, i.e. an innovation and cooperation culture between firms, policy makers and a wide set of stakeholders that interact for innovation and regional development (Cooke, 1992; Isaksen and Trippel, 2016). Intense and continuous interaction between these actors is an important prerequisite to recognise regional preconditions and to identify development opportunities that relate to existing competences and skills (Asheim et al., 2011a). Furthermore, it is crucial for developing shared norms and values, and for aligning interests and expectations towards a common development goal. It leads to trust and reciprocity (North, 1990; Sabel, 1993), which in turn improves interaction and collaboration in later stages of path development.

However, there is also a negative side to institutional thickness, as too intense collaboration can lead to political, functional and cognitive lock-in (Coenen et al., 2015; Grabher, 1993; Hassink, 2010) and hinder new path development. Therefore, we argue that governance capacities are also about institutional change (Mahoney and Thelen, 2010; Zukauskaitė, 2013). Institutional change can be seen as the spontaneous result of uncoordinated choices by multiple agents, or as purposefully designed and implemented by actors who interact in a collective process of lobbying, bargaining or voting (Kingston and Gonzalo, 2009). Incumbent actors often have an interest in preserving the status quo and hindering institutional change. Strong governance capacities therefore imply that policy makers have the necessary bargaining power to break up inefficient institutions and to shape new ones. Another hindrance to institutional change is bounded rationality of policy actors who are not fully aware of potential development opportunities (Ostrom, 2005). Overcoming bounded rationality requires policy actors to engage in continuous policy learning (May, 1992; Moodysson et al., 2015), and to build up the necessary absorptive capacity to recognise new developments and opportunities, to use old and develop new expertise and expectations, and to apply them for new path development. Institutional change is also closely related to organisational change, for instance through a modification of the organisational support structure of the RIS (Tödtling and Trippel, 2013).

Put briefly, policy capacities constitute the enabling and constraining factors for collective action at the regional level. Formal capacities define the general room for policy action; it matters greatly whether or not policy makers have the right to formulate their own regional development strategies and whether they have the financial assets to turn them into practice. However, regions can only make use of their formal capacities if they also possess strong governance capacities, referring to the quality of local interactions and the scope to induce regional institutional change.

Empirical analysis: The emergence of the new media and biogas industries in Scania

The following analysis is based on qualitative research methods, including personal interviews with key stakeholders and studies of policy reports and other strategic documents. Thirty-seven semi-structured interviews with firm representatives, industry experts, policy makers and university representatives were conducted between year 2012 and 2015 (17 for biogas and 20 for new media). The interviews were carried out

in Swedish or English and were transcribed; important quotes were, if necessary, translated to English.

The regional innovation system of Scania

Scania is the southernmost county of Sweden. Traditionally, its economy has been based on natural resources and agriculture. During the 19th century, the region developed an additional stronghold in the maritime sector, with a particular focus on shipbuilding in the capital city Malmö. After the maritime industry declined and eventually disappeared in the 1990s, considerable efforts have been undertaken to restructure the regional economy towards more high value-added sectors such as information and communication technology (ICT) and medical technology, and more recently, also clean technology and creative industries (Benneworth et al., 2009; Dahlström et al., 2010; Martin and Coenen, 2015). In terms of knowledge infrastructure, the region possesses a strong and diversified higher education sector, with amongst others Lund University (LU) and the young but rapidly growing Malmö University College (MU). Furthermore, the region is well endowed with a large number of intermediary RIS organisations (Martin et al., 2011). This makes it an organisationally thick and diversified RIS with favourable conditions for new path development (Boschma, 2015; Isaksen and Trippl, 2016).

With regard to political and administrative matters (i.e. the formal capacities), the county level in Sweden has the main responsibility to deliver on public health care and public transport. In addition to these core functions, however, Scania is one of few Swedish counties that enjoys extended devolution with the purpose 'to create sustainable regional growth and development' (Sveriges Riksdag, 2010).² This devolution can be considered significant as it gives regional policy actors the formal right to formulate their own regional development strategies (Dahlström et al., 2010; Region Skåne, 2013). However, as financial resources devoted to regional development are limited (of the total budget of 35.1 billion SEK in year 2016, 87.5% are devoted to public health care, 6.5% to public transport and only 0.5% to regional development) (Region Skåne, 2015a), the actual implementation of strategies remains strongly dependent on funding from higher administrative levels.

The role of policy in the emergence of the new media industry

New media is one of the most dynamic new growth paths in the region (Martin and Moodysson, 2011). With its epicentre in the western harbour area of Malmö, the industry comprises today several hundred innovative firms of mostly small and medium size, and a dedicated policy support structure. New media covers a wide range of activities at the intersection of ICT and creative media content, and includes market segments such as video games, digital design, app development, television, radio, film, advertising, marketing and others (Cooke, 2002; Grabher, 2002).

Early phase of new path development. An important stimulus for new path development has been the perceived need of the city of Malmö to overcome its negative lock-in into declining industries related to shipbuilding and heavy machinery. Attempts to overcome this local crisis include the conversion of the old harbour area into a modern business and housing district, which is today the location of most of the new media companies, as well as the foundation of MU in year 1998. With the establishment of a School of Arts and Communication (K3), MU focussed parts of its educational activities on media

and design, and thus, even though unconsciously, ensured at a very early stage the provision of skills needed for the new growth path. K3 also played a key role for building up governance capacities related to new media, by generating interest for design and creative industries among decision makers.

K3 was a driving force, but more as an exciting construction than as a concrete actor. We were fascinated by K3. (Representative of the County Council of Scania)

An important early step in new path development was a pilot cluster project named M-Town, initiated in 2002 by a group of entrepreneurial individuals who previously worked in the ICT industry, and supported by regional government bodies. M-Town was meant to bring together companies within the TIME industry (i.e. Telekom, Internet/IT, Media and Entertainment), and to create linkages between ICT and the media companies. The initiative illustrates that public and private policy actors very early made attempts to nurture new path development by playing the role of an amateur (Morgan, 2013), trying to facilitate knowledge flows across sectors to integrate different but related industries. M-Town had an important role as pilot project, building governance capacities and shaping common interest and expectations among RIS actors. Furthermore, it laid the ground for later policy initiatives around new media.

The mission was to form a cluster, out of believe that southern Sweden had a pretty good position in terms of games, filmmakers and mobile platforms. That was a good enough base to try to start a cluster. (Former CEO of M-Town)

Further strengthening of the organisational support structure took place in 2003, when Malmö Municipality established a business incubator for service companies (Malmö Incubator MINC), which soon hosted a number of new media ventures.

The next stage was the establishment of a cluster initiative named Media Meeting Place Malmö (MMM) in 2004. MMM reflects a continuation and widening of the previous initiative M-Town, and sheds light on the role of governance capacities in terms of close, continuous interactions between RIS actors. MMM was initiated by Malmö Municipality and the County Council of Scania, which successfully exploited funding opportunities from the national level. They jointly responded to a funding opportunity by a national research-funding agency in the framework of a nationwide strategy to foster creative clusters in Sweden. Potential cluster initiatives should be boundary spanning by linking government, academia and industry through a triple helix constellation, and by linking experience industries with related industries in the region (Heed et al., 2008). Policy makers in Scania could demonstrate a high potential for triple helix collaboration due to the early commitment of the regional government in supporting M-Town, a focus on media and design at MU, as well as a growing number of new media related companies in the region. They reacted on this opportunity and applied for finance, and the cluster initiative received funding for a five-year period. This underpins the influence of supra-regional policy influences on the development of new regional industrial growth paths (Dawley, 2014; Dawley et al., 2015; Simmie, 2012). Moreover, the successful application reflects strong governance capacities: RIS actors were seizing national funding opportunities and were able to tie them up to competences available in the region. This acquisition of funding compensated for a lack of financial means available for regional economic development in Scania.

Further path evolution. When the national funding for MMM ended in 2009, the cluster initiative had reached more than 70 member organisations. In order to keep the growth

momentum, a consortium of public and private actors got together to apply for European Union (EU) structural funds. With a growing number of regional firms collaborating around the theme of new media, the consortium could demonstrate that this has become a significant new growth path, and that regional policy makers have been dedicated to maintain the development. The engagement of private sector actors as well as the long-term commitment by public authorities convinced the EU level authorities to provide 1.24 million euro financing, which, co-financed by the regional consortium, permitted the initiative to continue for another three years. The role of the cluster initiative was again to provide a platform for regional networking, collaboration and knowledge exchange and, by implication, to act as animateur (Morgan, 2013). In this way, more and more RIS actors became engaged in the new growth path. Again, the success in attracting funds from the EU level can be attributed to strong governance capacities in terms of interaction among RIS actors and their ability to develop common expectations as well as in terms of aligning regional development strategies to incentives provided at higher spatial scales.

Simultaneously, the organisational support structure became more advanced. MU built up a research centre for digital media (MEDEA), financed partly with EU structural funds with the aim to further strengthening research and education in collaborative media and to enhance knowledge exchange with local firms. This points at the need for institutional and organisational change and the importance of absorptive capacity and bargaining power of regional policy actors to stimulate and support new path development.

The initiative came from the policy side: 'Let us focus on what could be the future in Malmö and in Scania?' (...) It was a very clever initiative by civil servants, who had the ability to look a bit in the future and take this initiative. It did not come from the business side, but it was easy for them to come on board. (Former CEO of MEC)

By 2011, the new growth path gained additional momentum. The regional government and Malmö Municipality further strengthened the organisational support structure by establishing a large business park for new media companies, named Media Evolution City (MEC), which opened in 2012 and hosts today around 100 companies.

The cluster initiative, renamed to Media Evolution (ME), has grown steadily in terms of member organisations. Initially financed by public funds, it became gradually more self-supporting and increasingly reliant on membership fees. Over time, private sector engagement in the cluster initiative increased both in financial and in managerial matters, and the influence by local and regional policy makers decreased. Today, the cluster initiative has reached 360 member organisations, which reflects both the success of the initiative and the dynamic development of this new growth path. Over the years, Scania established itself as reference point for new media companies in Sweden, and more and more businesses locate their offices close to the new business district.

Starting from zero, Malmö has become the hottest place for mobile communication in Sweden (...). That is why we moved to Malmö, because we wanted to be close to what is happening. (CEO of a new media firm)

The role of policy in the emergence of the biogas industry

The biogas industry constitutes another dynamic new growth path in Scania (Martin and Coenen, 2015). Scania possesses the largest number of biogas plants as well as the highest production of biogas (20% of the country's overall production) among all Swedish counties

(Energimyndigheten, 2015). The industry covers the entire value chain and includes feedstock producers such as farmers and industrial food processors, utilities and energy companies (i.e. actors dealing with the transport, treatment, distribution and retail of biogas). Transportation companies running the local public transport on biogas buses are today the main consumers of the regionally produced biogas. Altogether, about 40 companies can be identified as part of the value chain (Ericsson et al., 2013), the majority of which are large and medium-sized energy, water, waste management and transportation companies (of which many are publicly or public–privately owned) that have become active in the biogas business. Diversification processes of existing firms have thus formed the main mechanism of new path development.

Early phase of new path development. Scania provided favourable physical and industrial preconditions for new path development around biogas. Due to a regional stronghold in agriculture and food industries, local actors had accumulated competences in biogas related activities such as the exploitation of residuals stemming from food processing and agriculture. Some municipalities had an early interest in expanding the biogas production at water treatment plants into producing biogas from food waste. Moreover, Scania is comparatively densely populated, resulting in additional organic waste both in terms of household garbage and sewage water. Finally, a natural gas grid along the west coast of Scania provides an important distribution infrastructure for biogas.

Crucial for turning these regional preconditions into a new growth path was the so-called Climate Investment Programme (KLIMP), launched in the early 2000s by the Swedish Environmental Protection Agency. KLIMP was a national policy programme targeting increased energy efficiency and a reduction of greenhouse gas emissions in Sweden. It invited local authorities to apply for funding (seven years) for technical projects in form of public–private partnerships, to achieve environmental benefits within their municipalities. Biogas turned out to match the aims of the programme very well and biogas projects all over Sweden received funding. Municipalities in Scania were standing out with their (at this time yet largely independent) applications and received in total almost half of the overall KLIMP funding. This points at the influence of supra-regional policies on the development of new regional industrial growth paths (Dawley, 2014; Dawley et al., 2015; Simmie, 2012). Scania’s success in attracting national funding does not only reflect good physical preconditions, but has also to be ascribed to the local actors’ governance capacities to react to the call, that is to exploit their existing intra-regional relationships to turn old expertise into something new and to develop a common interest for new development areas.

The experience that I have from biogas at that time, in the beginning of the 90s, was that it was done locally due to some very few persons’ personal involvement and enthusiasm (...). And then came this KLIMP. And that was where a lot of biogas projects got supported by the KLIMP money, then there was also an economic support to do these things. (Professor in biotechnology, LTH)

During that time, research organisations in the region increasingly started to deal with biogas, adapting parts of their activities to the emerging growth path. In 2000, the Faculty of Engineering (LTH) at LU in collaboration with local farmers started a pilot plant on biogas production from crop residuals. This research facility was established based on national funds as well as co-funding from the host municipality and aimed at bringing scientists ‘out to the farm’. It can be seen as important for building up governance

capacities in terms of new personal networks, mutual trust and common knowledge among RIS actors.

A number of PhD students in biotechnology have worked on that plant, sitting now in strategic positions within the regional biogas community. It [the plant] has generated knowledge and new connections. (Professor in biotechnology, LTH)

The next step in new path development was the establishment of the regional network association Biogas Syd, founded in 2005/2006 by a bottom-up initiative of public and private biogas actors who felt the need for a better coordination of their activities. While the association was initially financed through membership fees, the regional government soon got involved and provided basic funding. Biogas Syd played the role as animateur (Morgan, 2013) by bringing together public and private actors and facilitating knowledge exchange. It also reflects strong governance capacities of RIS actors to engage in continuous interaction and align interests and expectations.

It was the biogas actors in the region who felt that they needed an organisation that collected all the questions and pushed them. The initial actors were waste management companies, energy companies, universities and some municipalities. (Project coordinator, stakeholder association)

Further path evolution

The next key instant in new path development took place in 2007, when the regional government announced a new development goal for public transportation in Scania, namely that all public transport should be fossil free in 2020. Among several possible technologies, the regional public transport organisation (Skånetrafiken) decided to invest in biogas as key technology. Important for this choice was the fact that the required energy should be produced locally to achieve a direct environmental effect in the region. Also in light of the increasing technological expertise in Scania, biogas was regarded to have the highest potential. This political decision was crucial as it created a local market for regionally produced biogas. As the formal capacity related to public transport is tied to the region and as significant financial resources are assigned to it, the regional government could act both as a regulator and as purchaser (Morgan, 2013) and create legitimacy for new path development in biogas.

That Skånetrafiken has gone out and said that they want to have it fossil-free - that has affected the market in Scania in a very positive way. (Project coordinator, stakeholder association)

In 2010, the County Administrative Board set up a climate goal for the region, particularly addressing biogas. The proclaimed aim was to cover at least 10% of the region's total energy demand with biogas by 2020 (Region Skåne, 2013). A roadmap was worked out by Biogas Syd and the regional government, in collaboration with a reference group consisting of universities, research institutes and companies in the region. Again, it was crucial that the region had the formal capacity to decide on issues regarding regional economic development. Moreover, strong governance capacities were important to organise collective processes and to develop a shared roadmap for future development.

The entire roadmap... that it is political and concrete – that gives it a weight. (...). It is good that policy here at the regional level is unanimous in this, all along the line. Here in Scania the politicians say that they are prepared to work on this long-term. (Project coordinator, stakeholder association)

New path development has been a rather smooth process and encountered hardly any resistance. Diverse RIS actors, including universities, research centres, firms, support organisations and policy makers, have been promoting biogas in a joint effort (Region Skåne, 2015b). However, the growth path still faces challenges regarding future growth. National policy influences appear more recently to be constraining for further development. After KLIMP terminated, a lack of long-term incentives at the national level make regional actors become hesitant to undertake major investments (Region Skåne, 2015b).

A lot of people are interested, a lot of people make plans, but they are slow to implement it. The big companies here [...] have made big plans for very big biogas plants, but they are slowing down, they are waiting and they are not investing. (Professor in biotechnology, LTH)

Recently, the regional government has commissioned researchers to investigate possibilities of setting up regional subsidies to overcome constraints set by the national level.

Discussion

The different roles that policy has played can partly be ascribed to industry specific differences in the needs and demands for policy support (Martin et al., 2011). However, as our framework brings to light, they can also be seen as consequence of varying policy capacities of RIS, spanning both formal and governance capacities. With regard to formal capacities, it is reasonable to argue that the degree of political autonomy has a major effect on the extent to which policy actors can influence new path development, and which actions they can take. Moreover, we highlighted financial resources as crucial aspect of formal capacities. Even though the county of Scania has the political autonomy to decide on regional development, funding is generally limited, and particularly in the case of new media. Consequently, policy actors put emphasis on support for networking (taking the role as animateur), which requires relatively little financial commitment. In the case of biogas, the financial ceiling has been higher, since public transport is one of the core responsibilities of Swedish counties. Accordingly, policy had more scope for action: it could act as animateur, but also as regulator and purchaser. These latter roles imply a greater possibility to provide long-run legitimacy, which is in line with insights regarding the role of policy in shaping innovation in specific technological fields (Hekkert et al., 2007; Martin and Coenen, 2015). In addition, governance capacities have been crucial in both cases. They appear to be important throughout the entire path development process and have co-evolved with the two paths. Policy actors were capable of changing the existing organisational and institutional RIS setting. In this regard, our analysis reveals the need for precedent institutional change, enabled through strong governance capacities that have been build up over time.

We also observe close interrelationships between formal and governance capacities, in that the latter are decisive for making use of the former: While formal capacities set the scope of action for regional authorities, strong interaction between policy makers and other RIS stakeholders are crucial for the formation of common expectations for identifying new growth areas and to implement effective policy actions. Closely related, the alignment of regional policy initiatives with policies at higher spatial scales proved to be a key factor. As financial resources were limited, opportunities for new path development were highly dependent on funding from higher spatial scales. The ability of regional actors to successfully apply for and make use of supra-regional funding also points at strong governance capacities. While such alignment also requires some degree of political

Table 1. Potential for new path development based on policy capacities of RIS.

		Governance capacities (define the scope to act as animateur)	
		Strong	Weak
Formal capacities (define the scope to act as producer, purchaser and regulator)	Strong	<p>High potential</p> <ul style="list-style-type: none"> - Political autonomy exists; financial resources define which role policy can play - Collective action fosters common expectations, development of regional expertise, inducement of institutional and organisational change - High potential to make use of formal capacities and connect to supra-regional policies 	<p>Limited potential</p> <ul style="list-style-type: none"> - Political autonomy and possibly also financial resources are available - Lacking collective action hinders institutional and organisational change - Limited potential to make use of formal capacities and to connect to/align with supra-regional policies
	Weak	<p>Limited potential</p> <ul style="list-style-type: none"> - Lacking political autonomy and financial resources; path development in control of higher administrative levels - Collective action exists, but institutional and organisational change impeded due to lacking formal frame; expected not to lead to continuous and long-term policy actions (i.e. lack of financial means to induce organisational change, risk that collective action 'dries up' in the long run) 	<p>Low potential</p> <ul style="list-style-type: none"> - Lacking political autonomy and financial resources; path development in control of higher administrative levels - Lacking collective action hinders institutional and organisational change

Source: own draft.

autonomy, both cases (particularly new media) indicate that strong governance capacities can potentially compensate for lacking financial resources.

Assuming policy capacities to be strong in some regions also implies that they can be weak in other regions, pointing more at constraining factors for collective action at the regional level. Table 1 illustrates possible constellations of policy capacities. Moreover, it points out the previously identified relationships between different policy roles and capacities (Morgan, 2013). We consider the role of the animateur as being closely linked to governance capacities, as it refers to interactions between RIS actors and does not require major financial resources. The roles of the producer, purchaser and regulator require stronger formal capacities.

Conclusions

The paper ties up to the current debate on how new regional industrial growth paths emerge and develop over time, and stresses the role that policy can play in this process. We reviewed existing work on the role of policy for new path development and developed an analytical

framework drawing on RIS and regional capacity building. We applied the framework to analyse the emergence of two new growth paths in southern Sweden. The question how policy makers and other RIS stakeholders interplay to identify opportunities (both internal and external to the region) and harness them for new path development has been central to our analysis.

The RIS perspective, complemented by insights from the literature on regional governance and capacity building, allows us highlighting the institutional and policy dimension of new regional industrial path development, which has hardly been addressed in the literature so far. The notion of policy capacities provides a new framework to analyse the role of policy. Our findings are in line with recent work that stresses the importance of a multi-level as well as multi-actor perspective on new path development (Dawley, 2014; Dawley et al., 2015; Martin and Coenen, 2015; Essletzbichler, 2012; Simmie, 2012). Furthermore, they support one of the core arguments of EEG, namely that new path development does not occur randomly and unconnected from existing regional preconditions, but is contingent upon pre-existing competences and industrial arrangements in a region (Boschma and Frenken, 2006, 2011; Martin, 2010; Neffke et al., 2011). Moreover, we find a close relationship between Morgan's (2013) roles of the state and policy capacities.

We discussed the potential of different constellations of policy capacities in RIS to bring about new path development, which is line with previous contributions pointing out that RIS require different, place specific policy interventions (Asheim et al., 2016; Isaksen and Trippel, 2016). However, our paper also challenges some of the arguments made in the literature on RIS and new path development. Though thick and diversified RIS are usually argued to offer favourable conditions for new path development, industrial and organisational diversity is neither a necessary nor a sufficient condition for such processes. Without strong policy capacities, regional actors will not be able to implement new development strategies and induce regional organisational and institutional change, which will impede new path development. Thus, even thick and diversified RIS can become trapped into path extension (and potentially path exhaustion) if they lack essential policy capacities to transform the regional knowledge and support infrastructure. Likewise, organisationally thick and specialised RIS as well as organisationally thin RIS, which have little scope for local knowledge recombination based on related variety, are not doomed to fail in new path development. If endowed with strong formal and governance capacities, even regions with little related variety can be successful in developing new growth paths, as they are able to effectively implement policy actions to overcome RIS deficiencies, for instance by implementing change in the knowledge and support infrastructure, by breaking up inefficient institutions, and by creating a shared vision among local stakeholders.

Our findings open up new questions for research on the role of policy in new regional industrial path development. The empirical analysis dealt with new path development in a thick and diversified RIS with strong policy capacities. What remains unexplored are new path development processes in RIS with weak formal and/or governance capacities. This leads to the question to what extent policies on higher spatial scales can compensate for a lack of regional policy capacities, or more interestingly, how regional policy capacities can be actively built up and maintained, calling for a deeper understanding of policy processes (Borrás and Edquist, 2015). Moreover, there is room for a closer investigation of the role of policy capacities in different phases of path evolution. Our findings point to the need to create common expectations between actors in the initial phase of path development, followed by more formalised policy actions such as building up an organisational support structure. This would suggest the importance of policy for institutional change in early phases of path development, whereas institutional continuity becomes increasingly

important once a path has gained growth momentum. Even though significant contributions have recently been made on the role of institutions for regional economic evolution (see for instance Boschma and Capone, 2015; Zukauskaitė and Moodysson, 2016), there is still scope for better understanding how regional industrial paths and institutions co-evolve and influence one another.

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Notes

1. The literature frequently distinguishes between path renewal and new path creation as two forms of new path development. The first describes the diversification of established industries into new but related ones, while the latter describes the rise of industries that are entirely new to the region. As we consider the two as hard to delimit empirically and the distinction as not core to our analysis, we apply the overall notion of new (regional industrial) path development (e.g. Isaksen and Trippl, 2016).
2. For more information about devolution in Sweden, see Organisation for Economic Co-operation and Development (OECD) (2010) and Region Skåne (2013).

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Article IV

Regional innovation systems and transformative change: The case of the chemicals industry in West Sweden

Hanna Martin

ABSTRACT

In economic geography and innovation studies, there has during the past decade been an increasing interest in the question how new regional industrial development paths emerge. The literature has so far however hardly paid attention to transformative change which is needed to cope with grand societal challenges such as climate change. This paper opens up for a broader view on technological change in regional economic evolution and address the scope that regional innovation policy has to impact transformative change of their industries. To do so, the paper takes an interdisciplinary perspective in which the regional innovation system framework with its focus on innovation-based regional development is complemented by insights from the literature on socio-technical transitions and its conceptualization of socio-technical regimes and niches. The empirical section studies the chemicals industry in the Gothenburg-Stenungsund region at the Swedish west coast which constitutes Sweden's largest basic chemicals industry cluster. Despite proceeding technology development, ongoing cooperation between the public and private sector in the region and an ambition to become internationally leading in the production of sustainable chemistry products by 2030, going from words to action seems challenging for the regional industry. The perspective taken suggests a broader view on new path development, including policy approaches that have been less addressed so far. In particular, the approaches attempt to create new socio-technical alignments of production and consumption which require co-evolving with changes in technologies, infrastructures, regulatory frameworks and other societal dimensions; both within and beyond the regional context.

Keywords: regional innovation systems, regional innovation policy, transformative change, grand challenges, socio-technical transitions

1 INTRODUCTION

In economic geography and related disciplines, there has during the past decade been an increasing interest in the question how new regional industrial development paths emerge. Contributions have shed light on different forms and mechanisms of path dependent regional economic evolution (Boschma and Frenken, 2011; Martin, 2010) and increasingly also emphasize the role of institutions and policy as drivers for regional industrial change (Dawley, 2014; Dawley et al., 2015; Martin and Coenen, 2015; Martin and Martin, 2016; Simmie, 2012; Steen, 2016). The current literature however mainly considers innovation for the generation of economic growth, implying a rather narrow view on firm- and research-driven processes. What has been less addressed is transformative change (Coenen et al., 2015a) that is change putting new demands on the directionality of innovation: Central to the term is that it addresses (grand) societal challenges which involve a more critical reflection about normative issues such as the nature of growth, well-being and human values (Healy and Morgan, 2012; Weber and Rohracher, 2012). By way of example, societal challenges include environmental concerns such as growing scrap heaps, climate change and pressure on natural resources.

This paper argues for a stronger consideration of transformative change in the literature on regional economic evolution (Frenken, 2016). In particular, it attempts to make the regional innovation system (RIS) approach a more compatible framework to address societal challenges. During the past few years, the RIS approach has increasingly been applied to conceptualize and explain new regional industrial path development, particularly attempting to address the role of policy in regional economic evolution (Tödting and Trippel, 2013; Asheim et al., 2016b; Isaksen and Trippel, 2016a, 2016b; Martin and Martin, 2016;). Existing policy approaches target the support of knowledge creation and re-combination between firms and the knowledge infrastructure of the RIS (Strambach and Klement, 2013; Asheim et al., 2016b; Isaksen and Trippel, 2016a). These firm- and research driven processes will in the further course of the paper be shortly termed as the ‘supply side’ and/or ‘production side’ of innovation. In order to address transformative change, such supply-oriented perspective seems however not sufficient. Tackling societal challenges makes necessary challenge-driven innovation to which is core that technical solutions co-evolve with new behavioural patterns both at societal and individual levels (Edler et al., 2012; Healy and Morgan, 2012; OECD, 2016). Put differently, societal challenges require a broader (more ‘holistic’) focus on creating appropriate alignments or ‘configurations that work’ to solve, respectively extenuate, a persistent societal problem¹. These require overall altered production and consumption patterns which need to co-evolve with changes in technologies, infrastructures, regulatory frameworks and other societal dimensions, for example lifestyles (Geels, 2002; Borrás and Edler, 2014). Amongst others, transformative change

¹ Yet acknowledging that these types of problems generally face a high level of uncertainty in terms of how they can be addressed (Coenen et al., 2015a; Bugge et al., 2016).

thus requires stronger paying attention also to the adaptation and diffusion of innovations which is often expressed in the stronger need for demand-side policies for addressing grand challenges (Mowery et al., 2010; Edler et al., 2012).

Due to its focus on a broad range of innovation actors and its popular application as policy framework (Coenen et al., 2016), the RIS approach is considered as suitable basic framework to study and conceptualize regional transformative change. In particular, the objective of this paper is to highlight policy approaches that RIS actors can apply to impact transformative change of their industries towards more environmentally friendly modes. Here again, RIS are seen as suitable device as they can be understood as overarching framework spanning several industries (or clusters) in a region (Doloreux, 2002). In order to shed further light on dynamics of (and policy action in) RIS during transformative change, the paper takes an interdisciplinary perspective on the literature on socio-technical transitions and its conceptualization of socio-technical regimes and niches (Geels, 2002; Schot and Geels, 2008). In particular, the paper draws on the notion of 'protective space' which has been used to conceptualize and analyze how sustainable innovations emerge and grow, respectively decline, in the context of established innovation systems (Schot and Geels, 2008; Raven et al. 2015a). Despite some recent notable contributions (Coenen et al., 2015b), socio-technical transitions in general, and the notion of 'protective space' in particular, lack an explicit spatial perspective (Coenen et al., 2012; Hansen and Coenen, 2015). The specific theoretical contribution of this paper is to combine the notion of 'protective space' (Smith and Raven, 2012) with the RIS framework which is concerned with the spatial dimension of innovation and innovation policies.

Emirically, the paper studies the case of the chemicals industry in the Gothenburg-Stenungsund region at the Swedish west coast. The industry constitutes Sweden's largest basic chemicals industry cluster and is a heavily polluting, fossil-resource intense industry with a long-term need to transform towards more sustainable, environmentally friendly modes. The region can be classified as a core region, possessing an organizationally thick and diversified RIS which is assumed to offer advantageous preconditions for new path development (Boschma, 2015; Isaksen and Trippel, 2016). Moreover, the region is considered to possess a high potential for an increased production and utilization of bio-based, sustainable chemical and material products as well as renewable energy: This is due the existing research orientation of firms, institutes and academia targeting bio-economy related issues, ongoing cooperation with the forest industry further up in the north of Sweden, as well as the existence of a district heating infrastructure with potential for increases in regional energy efficiency (Suurs et al., 2013). Despite proceeding technology development, ongoing cooperation between the public and private sector in the region and an ambition to become leading in the production of sustainable chemistry products by 2030, going from words to action seems in many respects difficult for the regional industry; making necessary actions that have been less addressed in the literature on systemic regional innovation policy.

The paper addresses the following research questions: *How can a core RIS impact transformation of a heavily polluting industry? What are the possibilities and limitations of RIS policy to bring about transformative change?*

The remainder of this paper is organized as follows: Section 2 develops a conceptual framework for analysing regional policy processes for transformative change. Section 3 introduces the empirical case and explores the barriers and limitations of RIS policy. Sections 4 and 5 discuss and conclude the main findings and provide suggestions for future research.

2 THEORETICAL FRAMEWORK

New path development in RIS

During the past two decades, the literature on RIS has brought forward our understanding on innovation-based regional development. It argues in favour for the endowment of regions with knowledge infrastructure (such as universities and research institutes) and firms as crucial for regional-level innovation to occur; commonly referred to as the knowledge exploration and knowledge exploitation sub-system, respectively (Autio, 1998). At the same time, RIS acknowledge the inherent influence of institutions and policies in (directly or indirectly) regulating the interaction and behaviour of actors (Asheim and Gertler, 2005; Doloreux, 2002; Gertler, 2010). The literature has emphasized varying regional preconditions for innovation, provides typologies targeting regions differentiated innovation potential, and argues for the adaptation of region-specific, place-based policies to promote innovation (Asheim and Isaksen, 2002; Doloreux, 2002; Nauwelaers and Wintjes, 2002; Tödting and Trippel, 2005).

Although the RIS literature has traditionally engaged in industrial dynamics, for example in the context of old industrial regions (Trippel and Otto, 2009), RIS scholars have only recently in response to the evolutionary turn (Boschma and Frenken, 2006; Boschma and Martin, 2010) started to more conceptually address how new regional industrial development paths come about, respectively change over time. It is argued that different types of regions have different capacities to develop new paths, mainly depending on their endowment with organisational thickness and degrees of specialisation of economic structures (Isaksen and Trippel, 2016a). Organizationally thick and diversified core regions are assumed to offer most favourable conditions for new path development as they can benefit from diversity of local industries, technologies and organizations which offer possibilities for combining different competences locally – and by implication, enable permanent economic re-configuration (Martin and Sunley, 2006). Following these contributions, RIS can be considered as variety selection environments for innovation in that they provide and define preconditions for change. Other contributions emphasize that RIS changes can

also come about and be supported by changes in networks as well as organizational change - that is changes in a region's knowledge generation and diffusion subsystem (Tödting and Trippel, 2013). This perspective puts more emphasis on the scope of change; or put differently, the extent to which RIS constitute a variety creation environment for innovation. Martin and Martin (2016) identify the importance of formal capacities (political autonomy and financial assets) in combination with historically grown interactions in RIS as crucial for putting forward regional industrial path development.

The central tenet in the introduced RIS contributions yet largely follows the argumentation of strengthening knowledge creation and re-combination within and between the knowledge exploration and exploitation subsystems of RIS; and by implication, promoting the supply- or production side of innovation. More precisely, in core regions these may happen either through firm-driven processes or by more research-driven modes based on a strong organisational support structure (Isaksen and Trippel, 2016a). Subject on their organisational endowment and the degree of related variety, different RIS are understood to require different policy interventions to stimulate new path development; yet again implying the role of policy to identify, facilitate and strengthen combinatorial knowledge dynamics between firms and the knowledge infrastructure of the RIS (Strambach and Klement, 2013; Asheim et al., 2016b; Isaksen and Trippel, 2016a).

Due to such focus on “increasing returns effects” and “network externalities” (Martin, 2010: 23) at the supply-side of innovation as mechanisms for explaining regional economic evolution, the need to create entirely new socio-technical alignments of production and consumption has remained largely unexplored. For transformative change, these are however important to consider as technologies with “sustainability promise” (Geels and Schot, 2008: 538) constitute an alternative to established technologies which are not (immediately) competitive on the market; not only with regard to production processes and products, but also with regard to issues such as user practices and regulatory frameworks. Put differently, for transformative change to take place, innovation system change will not only depend on the adaptation and novelty creation capacity of firms, but equally on the public sector and societal capacities (Healy and Morgan, 2012). Amongst others, stronger attention has to be paid also to aspects concerning the adaptation and diffusion of innovations (Mowery et al., 2010; Edler et al., 2012;). The technology-centred view in innovation systems can therefore be considered as being rather “myopic with regard to the explanation of technological transitions” (Markard and Truffer, 2008: 610).

A stronger perspective on socio-technical alignments is likely to imply policy processes that go beyond the support of combinatorial knowledge dynamics as addressed in the literature so far. Here, the literature on socio-technical transitions provides a valuable framework to conceptualise the role of socio-technical alignments and highlight

important policy processes during transformative change. This literature lacks in large parts an explicit spatial perspective but possesses potential to bring forward our understanding on regional industrial evolution (Coenen et al. 2015a, 2015b; Hansen and Coenen, 2015; Truffer and Coenen, 2012).

Socio-technical transitions and properties of protective space

Socio-technical transitions provide an explanation (and theorisation) of technological change within the context of an established, historically grown and privileged regime (Geels, 2002; Geels et al., 2008) and have been prominently used to explain low-carbon transitions in fields such as transport and energy (Smith et al., 2010; Unruh, 2000). From their general notion, 'socio-technical regimes' draw on the evolutionary economic terminology of technological regimes (Dosi and Nelson, 1994; Nelson and Winter, 1982), but extend them by capturing multiple (i.e. socio-technical) dimensions which generate processes of path-dependence. In particular, regimes constitute the "coherent complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructures" (Kemp et al., 1998: 338). Transforming production and consumption systems thus is connected to substantial challenges as social and technical practices are embedded within wider, mutually reinforcing processes. Put differently, socio-technical regimes constitute the selection environment for innovation and provide explanations why socio-technical regimes primarily render possible incremental innovation that is mostly cumulative in nature to already existing development paths (Coenen et al., 2015b).

More radical path-breaking (transformative) innovation is therefore conceptualized to emerge in 'niches' that constitute spaces that are protecting against the mainstream selection pressures operative in regimes (Kemp et al., 1998; Raven 2005). Niches are understood as "locations for learning processes, e.g. about technological applications, user preferences, public policies, symbolic meanings" (Geels, 2004: 912). In contrast to regimes which show a rather high level of structuration between the different regime dimensions, the extent of structuration in niches is considerably lower and in flux, reflecting a higher level of uncertainty. Niches can thus be seen as protective spaces that make it possible to deviate from the pressures operative in regimes and provide learning opportunities not only with regard to new technologies, but also with regard to the transformation potential of the other regime dimensions. From the conceptual notion, a successful maturation process of a niche can result in its upgrading and by implication, the transformation of regime structures. Smith and Raven (2012) consider niches (i.e. protective spaces) to have three properties in wider transition processes: *shielding*, *nurturing* and *empowerment*.

Shielding targets “processes that hold at bay certain selection pressures from mainstream selection environments” (Smith and Raven, 2012: 1027), i.e. it addresses the construction of ‘protective space’. Protective spaces can be passive in the sense that pre-existing, favourable places already exist that need to be exploited; or they can be created in an active way by strategic, purposeful action through specific interventions by advocates of path-breaking innovations. Shielding can originate both from public and private actors, for example from specific (technology) policies or incubator units. Raven et al. (2015b) find that advocates of niches first use pre-existing, passive spaces before strategically creating active spaces. *Nurturing* can be summarized as “processes that support the development of the path-breaking innovation” (Smith and Raven, 2012: 1027). It is the most researched property of protective space in transition studies and has been prominently elaborated on by drawing on the literature on strategic niche management (SNM) (Raven, 2005; Schot and Geels, 2008). SNM describes that niche development is based on three (niche-internal) processes: the articulation of expectations, the building of social networks, and second-order learning processes. Successful niche development is based on robust expectations that is if they are shared by many actors, are specific and of high quality. Social networks contribute if their membership is broad (i.e. if they provide plural perspectives) and deep (i.e. if substantial resource commitments are done by members). Also learning processes have to be broad and generate second-order learning about alternative, socio-cultural values, and implications for diffusion (Hoogma et al., 2002). *Empowerment* targets the interaction with the niche external, regime environment and can take two forms: empowerment through fit and conform as “processes that make niche innovations competitive within unchanged selection environments” and empowerment through stretch and transform, “processes that re-structure mainstream selection environments favourable to the niche” (Smith and Raven, 2012: 1030). Processes of stretching and transforming will however not be entirely internal to the niche but will “rely upon other processes of change within the regime and in the broader society and economy” (Smith and Raven, 2012: 1030). It is therefore why not all niche developments are likely to actually lead to full transformations and Smith et al. (2015b) find that in practice often a mixture of fit and conform and stretch and transform strategies are applied. Shielding, nurturing and empowerment have however to be seen as processes evolving over time rather than they can be assigned to specific events. Furthermore, these three properties should not be seen as a linear process (Smith and Raven, 2012). The focus on shielding, nurturing and empowerment also shows that transformation advocates need to be involved in both niche construction and regime reconstruction. In contrast to promoting innovation stimulating economic growth, policy interventions in the field of socio-technical transitions thus focus on stimulating societal transitions, that is they target a broader benefit for the society at large (Alkemade et al., 2009, 2011; Kivimaa and Kern, 2016).

Shielding, nurturing and empowerment as RIS policy

The aforementioned considerations targeting shielding, nurturing and empowerment will in the further course of the paper be applied to indicate the scope (that is the possibilities and limitations) of policy in a (core) RIS to impact transformative change. The paper thereby follows a broad understanding of policy used in the RIS literature (Cooke and Morgan, 1998) which considers policy as collective action of both public and private actors that are not simply considered as passive targets of (regional and supra-regional) policy intervention but are rather understood to be directly or indirectly able to shape policies and their outcomes (Flanagan et al., 2011; Uyarra and Flanagan, 2013).

Shielding addresses the scope of RIS to constitute and/or construct active or passive protective space against mainstream selection environments. In the literature on systemic regional innovation policy, processes of ‘shielding’ have recently gained attention in smart specialisation policies, aiming at strengthening regions’ respective competitive advantage to foster their international competitiveness. Put differently, smart specialisation targets the building of capabilities in specific fields in which a region has potential to develop a unique selling proposition in the near future (Foray, 2015). Such path for (future) development is triggered by an entrepreneurial vision, also termed entrepreneurial discovery, which is informed by the knowledge on the respective opportunities, constraints and challenges (Foray, 2014). More precisely, entrepreneurial discovery can thereby be understood as interactions between actors from the RIS (Asheim et al., 2016a). As vision-led development requires the setting of priorities, it is likely to be facilitated by a high quality of (historically grown) local interactions, crucial for achieving collective action and for making use of the existing (formal) scope for impacting regional development (Martin and Martin, 2016). In the context of transformative change, entrepreneurial discovery is likely to be based on expectations regarding overall changing (future) societal norms – that is a general increase of environmental awareness in the society. Such regional visions aim at achieving shielding of the RIS against the (national and international) mainstream selection environment. Shielding in the understanding of smart specialization is however of temporary nature as the process of entrepreneurial discovery is assumed to lead to market-competitive industries.

Nurturing of innovation has in the literature on systemic regional innovation traditionally received attention. Particularly, learning processes are considered to benefit from geographical proximity as short geographical distances are generally assumed to favor the building of trust and social interactions between actors (Boschma, 2005; Coenen et al., 2010). Social networks are, at least up to a certain extent, considered to stimulate innovativeness and are particularly important in selection environments consisting of high uncertainty and a low level of formalized institutions (Grillitsch and Rekers, 2016). Closely related, regions that are strong at changing

institutional context conditions are considered to provide promising settings for creating and maintaining favourable innovation (respectively path development) environments (Martin and Martin, 2016). As however particularly related diversity of local industries, technologies and organisations is considered as favourable for new regional industrial path development, current policy approaches aim at stimulating learning processes through targeting the (re-)combination of different regional local knowledge bases; yet, depending on the specific characteristics of a RIS (Asheim et al., 2016b; Isaksen and Trippel, 2016a). The literature on socio-technical transitions, in contrast, strongly highlights the importance of alignments between aspects such as technologies, infrastructures and societal practices. In contributions on regional economic evolution, the need for such alignments has widely been disregarded (for an exception see Binz et al., 2016). Also the adaptation and diffusion part of innovations is understudied; here, contributions focus on the role of public demand (Martin and Coenen, 2015; Morgan, 2013) or narrow the adaptation of innovations down to consumers as being knowledge providers in the innovation process (Grabher et al., 2008).

Empowerment addresses the interaction with the RIS external institutional and policy environment. Particularly, it targets attempts to influence sub-regional policy processes through so-called stretch and transform strategies. RIS are generally understood as open, nationally and internationally connected systems. In particular, they are acknowledged being embedded in supra-regional institutional settings and knowledge networks (Asheim and Isaksen, 2002), and also influenced by demand patterns at various spatial scales (Malmberg and Power, 2005). Processes that target the interaction of a RIS with its supra-regional institutional environment to impact the conditions for regional innovation and change have, however, gained relatively little attention in the discipline. Grillitsch and Rekers (2016) somewhat touch upon this issue by conceptualizing selection theory in the context of (regional) industrial dynamics, whereby they find that selection processes become increasingly formalized over time. As in the context of transformative change RIS have to be understood as entities which are embedded into a broader societal context, important preconditions to establish new socio-technical alignments are likely to lie outside the direct scope of RIS policy to influence. Empowerment strategies in the context of this paper shall therefore be understood as policy action that targets the facilitation of new alignments, for example through exerting influence on the setup of supra-regional regulatory frameworks.

In the following, the processes of shielding, nurturing and empowerment will be applied to empirically analyze the transformation of the chemicals industry in the Stenungsund-Gothenburg region at the Swedish west coast. In particular, they will be considered as RIS policy processes that are embedded into broader (political-institutional) contexts. RIS are thereby understood both as variety selection environment in that they provide certain preconditions for change; and as variety creation environment in order to understand the extent and scope for change,

particularly in formative phases of industry (respectively regional) transformation. The regional context (i.e. the RIS) should thus be understood as frame for transformative change processes; yet acknowledging that transformative innovation can also show (global) multi-scalar characteristics (e.g. Binz and Truffer, 2012). As various actors, respectively actor groups take agency within an innovation system, regime-characteristics, in turn, might also be present inside the RIS.

3 ANALYSIS

The empirical analysis is based on a combination of qualitative research methods with in-depth interviews as main data source. In total, a number of 11 semi-structured interviews with key stakeholders including regional firm representatives, industry experts, policy makers and university representatives were conducted between December 2013 and April 2016. In addition, the analysis draws on six interviews conducted in January 2012 in the context of a related research project which have been used as reference and for cross-checking purposes. The interviews were largely carried out in Swedish and were transcribed; important quotes were translated to English by the author. Moreover, the analysis is based on extensive document studies including the studies of websites, policy reports and other strategic documents.

Regional and industrial context

The area of Stenungsund-Gothenburg is located on the Swedish west coast and is part of West Gothland (Västgötaland), Sweden's second largest county: West Gothland hosts almost 20% of the Swedish population and the inhabitant count has continuously been increasing throughout the last decades (VGR, 2015b). The regional capital Gothenburg is Sweden's second largest city. Historically, the region has been a strategic hub for both Swedish exports and international imports to Sweden and Scandinavia as it hosts Sweden's largest trade harbour providing access both to the North Sea and the Atlantic. Next to shipping and trade, manufacturing (particularly automotive and textiles) were additional regional strongholds in West Gothland. Today, the automotive and transport industry, trade and logistics, chemicals, information and communication technologies, industrial electronics, life science and cultural and creative industries constitute economic strongholds of the region (BRG, 2016; Lindholm Dahlstrand, 1997; VGR, 2016). West Gothland possesses a strong and diversified higher education sector, with two of Sweden's largest universities (Chalmers University of Technology and Gothenburg University) which are amongst others, well recognized regarding knowledge creation related to sustainable development (Suurs et al. 2013). The region is also well endowed with a large number of research institutes (such as the Technical Research Institute of Sweden (SP), the Swedish Environmental Research Institute (IVL) and the Swedish Institute for Food and Biotechnology (SIK)) and intermediary

organisations. Furthermore, it shows a rich cooperation between universities and companies and is characterized by many university spin-offs (Lindholm Dahlstrand, 1997). Moreover, the county of West Gothland enjoys devolution to create sustainable regional growth and development (Sveriges Riksdag, 2010; VGR, 2015a), implying that the region has important capacities in terms of political autonomy in place which are considered important for new path development (Martin and Martin, 2016).

The regional chemicals industry

Regional background/ preconditions

The chemicals industry started to emerge in the coastal town of Stenungsund, located north of Gothenburg, in the mid-1950s. Initially important was a decision from a public energy company to build a steam power plant in Stenungsund due to advantageous transport connections both over land and sea. The project aroused echoes throughout the country as it concerned a sensationally big investment. Due to a secured power supply, direct access to a harbour as well as the availability of suitable land for building, chemical industry companies soon showed interest in locating in Stenungsund. In the mid-1960s, Scandinavia's first cracker plant was put into operation at the site, giving it a crucial position in the Swedish (and Scandinavian) petrochemical industry. Since then, the chemical industry in the region gradually developed and expanded (Berglund, 2010; Stenungsunds Kommun, 2016).

Today, five large chemical companies (AGA, AkzoNobel, Borealis, Ineos and Perstorp) are located at the site in Stenungsund. The companies have a focus both on the production of fuels and materials and can be described as process industries handling large quantities of raw materials. Furthermore, the firms have a high share of exports and are establishments of global, multinational corporations. Traditionally, the companies in Stenungsund have been collaborating around different infrastructure tasks as they are connected to one another through mass and energy flows that they exchange through commonly owned infrastructure. Large shares of the companies' output are thus used as energy or raw material in another firm (Berglund, 2010; Suurs et al., 2013).

Initiating regional transformation

In year 2009, the regional government (Västra Götalandsregionen, VGR) took the decision that the region's economy shall until 2030 be independent of fossil resources. It can be seen as ambitious reaction to a vision taken by the Swedish parliament that by 2050, Sweden's energy supply shall be resource efficient, sustainable and free of net emissions of greenhouse gases. The strategy was signed by more than 60 municipalities, organizations and firms in the region and was based on a common belief in a high

regional transformation potential due to the presence of “important industry representatives, a strong research environment, forward-looking public actors and many good ideas” (VGR, 2009: 6). Regional public actors and the chemical firms increasingly saw the importance of the chemicals industry to play in this transformation. *“10 years ago the regional authorities started to consider in their thinking that they [the chemical industry companies] had a key role to play in this transition towards a higher degree of renewables in our society. (...) And departing from that vision also the chemical companies realized that they had a very important role to play in this. (...) They realized that there was a marketing value for their industry.”* (Representative, business development)

Globally seen, the chemicals industry is steadily growing. Also the European chemicals industry has been increasing its production and sales on the global market in absolute numbers; however, its global market share has been decreasing drastically during the past ten years. In 2011, the five companies in Stenungsund initiated the vision “Sustainable Chemistry 2030” (Hållbar Kemi 2030) stating that in 2030, Stenungsund shall be the hub for the production of renewable chemical and material products as well as leading regarding the increase in resource and energy efficiency through recycling, process integration and improved use of excess heat (Kemiföretagen i Stenungsund, 2014). *“You do not feel the pressure from your customers but you can see maybe far away that the market is changing and if you don’t change, maybe you are not going to stay competitive.”* (Researcher, technical research institute)

From then on, both the regional and the companies’ vision have been closely aligned with one another, based on an awareness of close interdependency: the chemical industry is a large polluter, while it at the same time is an important employer in the region. *“We have to start with the chemical industry in order to show effect in the other industrial sectors. And if they can go for it and it becomes a big market and demand it will create jobs, of course.”* (representative, business development) *“And then I also think that the society and economy in the long term are heading towards an increased independence of fossil fuels. This is essential and we demonstrate loyalty to all who anticipate that there will be a transformation. And when we get such transformation, then it is important that there are products ready that are technically sound and competitive.”* (representative county council)

The setup of such (aligned) strategy can be understood as attempt of active shielding of the regional industry against the mainstream selection environment active at the national and international levels. It is based on an entrepreneurial vision aiming at strengthening (future) competitive advantage of the region. This, in turn, is based on a belief in changing overall societal norms towards increased environmental awareness, reduced pollution and well-being, (potentially) leading to changing societal demand patterns and markets for products. Vision-led development and priority setting are thereby facilitated by strong, historically grown interactions among regional actors (Martin and Martin, 2016): *“What is driving the chemicals industry in west Sweden is the*

belief that there is a possibility to stick out, that we have a niche.” (representative cluster initiative) *“There is a cooperation that I think is unique and which we have in our area here in western Sweden. There is a close proximity to each other. (...) Between firms, the public sector and academia. (...) I believe there is a spirit of cooperation and a common mind-set here. (...) ... It has evolved for many, many, many years, I would say. I do not think it is enough with 100 years.”* (representative, business development)

Moreover, the existence of organizational and industrial diversity as well as physical infrastructure (such as a district heating grid with the potential to both reduce the high energy costs of the industry and increase its energy efficiency) are considered as important preconditions for regional transformation. They can be understood as crucial for initial mobilization of passive spaces, and by implication a ‘regional’ selection environment, based on which protected spaces are created more actively and strategically (Smith and Raven, 2015b).

Barriers to transformation

Several (small) steps have been taken to reach the vision of a fossil-independent regional economy in 2030. However, today only 10-15% of the raw material inflow to the industry is bio-based and the region in general and the chemicals industry in particular, is facing several, largely inter-related, regime-based barriers to transformation (Kemp et al., 1998). There exist major hindrances with regard to markets and established user practices as the firms do not see a market for green products. Currently, it is therefore economically not justifiable for the companies to make the large investments that would be required. In particular, the low oil price is perceived as counterproductive and the absence of appropriate national and international policy incentives is described as hampering transformation. While there exist some incentives targeting bio-based fuels (e.g. tax exemptions for vehicles) which also have led to several investments, bio-based materials are hardly supported by current regulations. Another issue concerns the utilization of the chemical companies’ excess heat as the current regulatory framework does not allow classifying district heating as environmentally friendly. To broadly distribute excess heat, different local grids will have to be connected to a region-spanning grid. As district heating is a municipal task, there exist however severe issues with regard to risk taking for which new forms of organization and new business models have to be found (Mossberg et al., 2015). Moreover, the chemicals industry completely lacks national funding schemes (Mossberg, 2013). Although some technologies are in place that are crucial for achieving transformation, there is no clear view on which alternative is the best; further development is required. Many small-scale demonstration projects are carried out; however also there is a need to find new business models that allow reasonable solutions for risk taking as heavy investment in (unproven) demonstration plants is required (Suurs et al., 2013). Another crucial hinderer relates to a lack of competences (labour with appropriate skills) on the job market which is closely

connected to the negative image that the chemicals industry possesses (Mossberg, 2013; Mossberg et al., 2015).

Regional action targeting transformation

Despite these major barriers to transformation, the region is taking action to work towards restructuring of the chemicals industry. The cluster initiative has during the past years been re-named from “Chemical Industry Cluster” (Kemiindustriklustret) into “The west Swedish chemicals cluster” (Västsvenska Kemiklustret), and most recently into “the West Swedish Chemicals- and Materialscluster” (det Västsvenska Kemi- och Materialklustret) in order to capture a broader notion of the regional chemicals industry and the actors involved: The new name became a symbol for new connections that had been build up over time and also indicated the wider geographical focus increasingly spanning the regional capital Gothenburg. While first recycling and energy companies joined the initiative, the cluster has today more than 20 members, spanning a variety of companies, research institutes, universities and public actors (Suurs et al., 2013). The initiative was for a long time hosted by a public business development agency, Business Region Göteborg (BRG), while it in connection with the broadened focus on material changed host organization to a science park located at Chalmers, the technical university. The initiative is thus still in flux, demonstrating that new path development co-evolves with changes in (social) networks and RIS elements (Smith and Raven, 2012; Tödtling and Trippel, 2013). The broadened focus on material is primarily to stronger emphasize the continuous activities of the cluster initiative to incorporate customers in their activities (as will be described below). The actors realize that achieving commercially viable outcomes makes an extensive cooperation necessary, not solely among academia and companies, but also with customers in other industries (Suurs et al., 2013). More particularly, active attempts are made to bring together industries by creating an extended value chain of actors based on industries that need to be involved in order to make a transformation work – rather than involving industries based on a (related) industry code. *“So I thought that we have Södra [a foundation of forest owners], we have those who produce plastic components, we have the Volvo companies that can use that particular type of material in their vehicles and then we have fuels. Then I would like to connect it with cultural and creative industries as well. What happens to the design and layout - I want to involve more industries. We want to connect those rather ‘unexpected’, ‘unpredicted’ industries with one another. On this we put much focus in our activities. By doing this, one thus goes a bit out of the personal comfort zone.”* (representative, business incubator) *“I still believe that this with the ‘Närodlat Plast’ [a demonstration project on locally produced plastics] is very good. Because there IKEA is in, and so is ICA [a Swedish grocery chain] ... very large companies. They say that they want this; they should be prepared to pay a little extra for it. Not out of*

kindness I suppose, but primarily because they think that it will improve their image." (representative cluster initiative)

Put differently, nurturing processes happen through broadening membership by also allowing learning processes with (potential) consumers of products (Smith and Raven, 2012): Expectations about changing societal values, and closely related future regional competitive advantage, are shared throughout the value chain. Closely related and implied by the value chain perspective, the cluster initiative is actively intervening in improving the provision of skills to the industry. As the chemicals industry is facing challenges to attract engineers that rather work in the automotive industry, the cluster initiative is actively teaching the industry to make new demands – or in other words, not to see the supply of skills as given, but rather to actively shape it. *"... that they [the chemical companies] begin to transform, to think a bit differently when they recruit. And then also the universities and other educational bodies have to keep up and make sure that people get the right training. In the chemical industry cluster, for example, we have achieved that the companies are part of the instruction councils and form the focus of the courses and educational programs according to their needs."* (representative, business incubator)

The region is also actively shielding itself through regulatory-push, especially by favouring market creation. *"The political visions here are stronger than the national ones. (...) because there is a will to be present and to help push it so that it goes faster all the time."* (representative, business incubator) Closely related, actors realize that also increased communication is required with political actors to create awareness of the conditions necessary for a transformation (Suurs et al., 2013). In particular, regional actors have identified lacking knowledge among supra-regional (mostly national-level) decision makers regarding what technologies exist, and which requirements can be put on firms. Therefore, the cluster initiative is actively working with empowerment strategies by educating national-level decision makers in formulating regulations (VGR, 2009). *"Often the demands made are too low with regard to environmental, energy and climate issues. This is because of poor competence regarding what exists on the market. We try to hold various workshops and seminars to train those who sign procurement documents."* (representative, business incubator) As West Gothland constitutes an economically diversified core region with considerable national economic impact, such empowerment strategy is influential. Empowerment is, yet, not only practiced within Sweden but also abroad and particularly in combination with market development through identifying potential (public) foreign customers for technologies, such as district heating solutions. Moreover, the cluster has engaged an event firm (Göteborg Company) to attract large congresses and events to the region in order to spread knowledge about solutions to (potential) customers nationally and abroad. Also the five chemical companies' vision on Sustainable Chemistry 2030, often described as timely unfeasible and lacking common action (Mossberg et al., 2015; Suurs et al., 2013), is clearly perceived as success regarding empowerment of regional strategies and the influence of supra-regional selection pressures in ways favourable to the region. *"[The*

companies] are viewing it as a communication project (...) to getting access to arenas where you can have the attention and the ear of the politicians.” (Researcher, technical research institute) *“The logic is that ‘we are not seeing that we can make any investment today as we need the conditions to change, by using communication as a mean’.”* (Researcher, technical research institute) Due to close alignment, the industrial and the regional vision provide mutual legitimacy to one another, implying that the empowerment realized by the companies’ vision also brings about benefits for the regional strategy as a whole.

Over time and with proceeding efforts to create a more industry-spanning and value-chain extended cluster, the transformation of the chemicals industry has been assigned an increasingly important role also in the regional economic strategy (VGR, 2009, 2013). There are however also conflicts with regard to the transformation endeavour which have been less addressed in the analysis. Some dispute among the regional actors exist, by way of example, regarding the question for what biomass should be used (fuels vs. materials) or whether there should be a stronger focus on bio-based products or recycling. Furthermore, the companies’ vision can be understood as informal organization built around engaged individuals, implying that not all companies are equally engaged and that the region is lacking a commonly accepted vision (Mossberg et al., 2015; Suurs et al., 2013). Among the firms there is competition for both capital and other resources and there is a need to increasingly formalize the vision and collaborations (Mossberg et al., 2015) in order to achieve deeper commitments of actors (Smith and Raven, 2012). Moreover, there is further scope for regional policy to act. By way of example, one important task would be to develop the ‘cooperation’ and communication with the society at large (Suurs et al., 2013); or put differently, stronger involve private end-users in the transformation endeavour by creating increased environmental awareness. Increased cooperation with research taking a social science perspective on transformative change should be considered as a potential option to spur this development. Moreover, public procurement for plastic products is, according to some interviewees, seen as a possibility which however is not sufficiently developed yet.

4 DISCUSSION

The RIS approach complemented by socio-technical transitions allowed specifying policy processes that target both RIS internal policy action as well as interaction with the RIS external, institutional environment. In particular, the processes of shielding, nurturing and empowerment (Smith and Raven, 2012) were used to point up the role of socio-technical alignments for transformative change.

In the presented case, shielding is based on expectations regarding altered societal norms, demand patterns and future markets for products which are assumed to lead to a first mover advantage of the region and the prospective expectation of ‘green’ regional growth. It becomes apparent in the formulation of an industry-spanning regional vision

targeting transformation as well as in the set-up of ambitious environmental regulations (regulatory push). The identified nurturing processes focus on the involvement of customers in learning processes about alternative socio-cultural values throughout extended value chains. Thereby, industries (or clusters) in the RIS are identified not by (related) industry codes, but rather based on what competences are needed to make a transformation work. Moreover, nurturing processes addressed changes in the supply of, respectively demand for, skills as well as educational programmes. This implies that firms need to communicate demands with regard to (future) competences they consider crucial. The identified empowerment strategies aim at impacting decision making processes that lie outside the direct sphere of regional innovation policy. Empowerment is practiced through training supra-regional decision makers in what requirements can be set in the design of appropriate regulatory frameworks, particularly to support market formation. All these processes reveal that niche build-up and protection have to be seen as multidimensional constructs; they can take various forms and can be initiated by different RIS actors. Often processes are also applied in close interrelationship, respectively interlock with one another. By way of example, shielding through a vision can imply empowerment as it potentially causes attention among supra-national policy makers. Moreover, empowerment by teaching public decision makers can be practiced closely aligned with nurturing processes that attempted to find new (public) customers for technological (district heating) solutions.

At the same time, shielding, nurturing and empowerment shed new light on how to view RIS as variety creation and variety selection environments for innovation. Regional transformative change has to be considered in the context of mainstream selection pressures which can be moderated within the regional context so that alternative socio-technical constellations can form. The analysis reveals that policy processes can be various. One aspect of overarching importance for all processes appeared to be the variety creation capacity of the RIS in terms of (constantly) changing institutional context conditions. Strong historically grown interactions and a rather experiment-open mind-set among policy actors in the RIS facilitated initial vision-led development and priority setting. Also during the further course of transformation, such governance capacities (Martin and Martin, 2016) have been crucial for holding on to visions and for aligning activities with one another. Put differently, local interactions characterized by trust and the ability to induce institutional change facilitates the formation of 'alignments that work', necessary for transformative change.

The presented case has however also to be understood in light of the broader regional context into which it is embedded. Its location in an organizationally thick, economically diversified core region entails advantages for transformation that more peripherally located regions presumably do not possess (Coenen et al., 2015b). The analysed case is clearly benefitting from a rich variety selection environment in terms of diversity of regional industries. This has shown to be crucial for the initial mobilization of passive spaces based on which protected spaces are created more actively

and strategically: Core regions can more easily cope with the need to focus on the adaptation and diffusion of innovations, an aspect crucial for transformative change, as they benefit from possibilities to expand a narrow (supply-side) focus on technology towards markets. In the case under study, potential is seen in actively connecting the chemicals industry with industries such as automotive or creative industries. Moreover, also regional organizational thickness can be supportive for transformative change, however only if institutional change will also encompass organizational adaptation; prevailing organizational settings may not necessarily be supportive for a (future) transformation. Due to their economic impact, core regions are also likely to be able to exert more influence on decision makers through their empowerment strategies than peripheral regions. Moreover, the presented case provides evidence for the importance of a certain extent of regional legal autonomy to decide on economic development (Martin and Martin, 2016), and by implication, to initiate transformative change.

5 CONCLUSIONS

This paper has shed light on transformative change of RIS. It concentrated on the possibilities and limitations of regional innovation policy to address innovation geared towards societal challenges such as environmental concerns. The paper developed a theoretical framework complementing RIS by insights from socio-technical transitions in which transformative change is explained and theorized in the context of socio-technical regimes and niches.

The theoretical approach suggested viewing RIS as variety creation and variety selection environments for innovation. Through setting up transformation strategies and visions, regions can create protected spaces in which selection pressures can (to some extent) be 'turned off', respectively moderated, and in which new, alternative socio-technical configurations can form. These require overall altered production and consumption patterns which need to co-evolve with changes in technologies, infrastructures, regulatory frameworks and other societal dimensions. For this, regional policy can engage in actions such as strengthening learning processes about new socio-cultural values, the sharing of expectations regarding (future) markets and the building of social networks along extended value chains. Moreover, regional actors can attempt to impact the mainstream selection environment in ways favourable to the RIS. Such policy processes aim at altering the supra-regional institutional environment. This perspective also shows that even core regions face clear limitations to actively address transformative change: They have the possibilities to inform and influence; the final decision yet lies outside the scope of regional actors. These concern for instance aspects like markets, the creation of new business models, the provision of risk capital, or the build-up of infrastructure. These face clear limitations of implementation within the regional frame for action as they call for an increased need for the coordination of policies across different domains and scales. In the current setting, bio-based products can hardly

compete with the established fossil alternatives, implying a need for policy-learning also at supra-regional levels. Prevalently, many of the regional actors' activities target the adaptation and diffusion of innovations, one aspect crucial for transformative change (Mowery et al., 2010; Edler et al., 2012). This applies to the extension of value chains, the marketing of products as well as attempts to achieve regulatory settings that facilitate the creation of markets.

While the current literature focusses on agglomeration economies at the supply-side of innovation for explaining regional economic evolution, this paper suggests that transformative change requires a broader view. In particular, transformative change is strongly related to overall industry (and societal) transformation: It should not be understood as transformation process of one single industry; rather, it is closely connected to regional transformation as a whole. The chemicals industry as (heavily polluting) basic materials industry has a crucial role to play in this. Put differently, sustainable development in the region has to work in tandem with sustainable development of the entire region (Haughton and Morgan, 2008; Truffer and Coenen, 2012). It implies that borders between regional and industrial transformation become blurry and makes transformative change (optimally) a collective, evolutionary process involving multiple actors and multiple industries (or clusters) in the RIS.

The strong interdependence of industrial and regional transformation induces a new perspective on systemic regional innovation and innovation policies. In the current literature, the variety selection environment of a RIS is associated with the degree of organizational thickness and related economic diversity. Variety creation is strongly linked to organizational change and changes in networks. As transformative change ultimately implies the transformation of overall industry structures in a RIS, the selection environment becomes different: The focus shifts away from related variety towards increasingly connecting different industries along the value chain, implying new linkages between so far seemingly unrelated industries. Organizational thickness is only favourable if organizational structures get adapted to the new requirements of transformative change. Not all regions offering organizational thickness and a variety of industries will be eager to experiment and transform. Here, the capacity of RIS to induce institutional change is crucial. This calls for a stronger consideration of the ability to change institutional context conditions when addressing the variety creation environment of a RIS.

As actions to target transformative change can be various and be initiated by different RIS actors, the formulation of concrete policy advice seems challenging. Definitely, policy approaches have to go beyond the support of knowledge combination and re-combination at the supply-side of innovation. The set-up of a common development vision to which various actors can connect to should be considered as a reasonable (initial) step. The alignment of various industry-spanning activities is likely to be achieved and maintained with an experiment-open, trust-based innovation climate.

Therefore, policy approaches should aim at actively creating linkages also between (from a supply-side point of view) seemingly unrelated industries. Moreover, regional innovation policy should actively engage in policy-learning at supra-regional levels.

On this note, the findings open up a variety of questions for research targeting regional transformative change. This paper studied one empirical case; presumably however, the potential to initiate, impact and maintain transformation is likely to vary across regional contexts. The paper has shown that transformative change puts new requirements on new regional path development and provided evidence for a re-definition of variety selection and variety creation mechanisms as well as a re-definition of actors' roles in the innovation process. While this paper gives indication for a stronger consideration of value chains, the question what favourable regional 'combinations' of industries for transformative change are requires further investigation. Moreover, the findings suggest a closer view on mechanisms behind institutional and organizational change during regional evolution. Finally, this paper attempted to broaden the RIS approach to capture grand challenges. Many nurturing and empowerment processes that have been identified focus on the adaptation and diffusion of innovations, making these an (implicit) point of departure for other transformative action to build on. Amongst others, the role of large firms in contributing to transformation through generating demand for more environmentally friendly products has however not been captured sufficiently. Moreover, socio-technical alignments require the consideration of more aspects such as new business models, infrastructures and broad societal change which this paper has only slightly touched upon.

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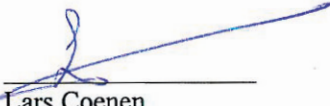
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To whom it may concern

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