Micro-Dynamics and Institutional Change in Regional Transition Paths to Sustainability

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2	*Micro-dynamics in regional transition paths to sustainability – insights from the Augsburg region.*	Applied Geography 90 (2018): 296-307. **DOI:** https://doi.org/10.1016/j.apgeog.2017.04.012.	Simone Strambach	Main author (50 %)
3	*Developing Boundary-Spanning Capacity for Regional Sustainability Transitions – a Comparative Case Study of the Universities of Augsburg (Germany) and Linz (Austria).*	Sustainability 10 (2018): 1-26. **DOI:** https://doi.org/10.3390/su10040918.	Verena Radinger-Peer	Main author (70 %)
4	*The role of higher education institutions in regional transition paths towards sustainability. The case of Linz (Austria).*	Review of Regional Research 37 (2017): 161-187. **DOI:** https://doi.org/10.1007/s10037-017-0116-9.	Verena Radinger-Peer	Author with major contribution (30 %)
5	*The raise of publications on sustainability – a case study in Germany.*	Review of Regional Research 37 (2017): 189-225. **DOI:** https://doi.org/10.1007/s10037-017-0119-6.	Thomas Brenner	Author with major contribution (35 %)

Zusammenfassung

Angesichts ökologischer und sozialer Herausforderungen sind grundlegende gesellschaftliche Veränderungsprozesse hin zu nachhaltigeren Produktions- und Konsummustern erforderlich. Eine wichtige Grundlage für solche „Nachhaltigkeitstransitionen“ sind Veränderungen in institutionellen Strukturen (z.B. Gesetzen, Wertvorstellungen und Deutungsschemata), die nachhaltige soziale Praktiken fördern. Allerdings weiß man zurzeit noch wenig darüber, wie solche institutionellen Veränderungen angestoßen werden und wie sie sich entwickeln. So ist kaum bekannt, wie sich die Aktivitäten von Akteuren auf der Mikro-Ebene langfristig auf die Entwicklung institutioneller Strukturen auswirken und warum solche Prozesse zwischen einzelnen Regionen unterschiedlich ablaufen.

Die vorliegende Arbeit untersucht solche institutionellen Veränderungsprozesse in Richtung Nachhaltigkeit aus einer regionalen Perspektive, um zu verstehen, wie sich Nachhaltigkeitstransitionen regionsspezifisch entwickeln. Ausgehend von der Prämisse, dass sich regionale Nachhaltigkeitstransitionen von sektoralen Transitionen unterscheiden, die bislang im Fokus der Transitionsforschung standen, verfolgt die Arbeit drei Ziele:

(1) die Entwicklung eines konzeptionellen Ansatzes, der die Besonderheiten von institutionellem Wandel in regionalen Nachhaltigkeitstransitionen erfasst;

(2) die Entwicklung eines methodologischen Ansatzes, der es ermöglicht die komplexen institutionellen Dynamiken regionaler Nachhaltigkeitstransitionen zu analysieren;

(3) empirische Erkenntnisse über regionale Nachhaltigkeitstransitionen und die Akteure zu generieren, die diese Prozesse auf der Mikro-Ebene vorantreiben.

Der neu entwickelte konzeptionelle Ansatz der „Regionalen Transitionspfade zur Nachhaltigkeit“ (RTPS) verbindet Erkenntnisse aus der Transitionsforschung, der Neo-institutionellen Theorie und der Evolutionären Wirtschaftsgeographie (EEG). Anders als existierende Konzepte aus der Transitionsforschung (insbesondere die Multi-Level Perspektive; MLP) berücksichtigt der RTPS-Ansatz die Besonderheiten regionaler Nachhaltigkeitstransitionen, beispielsweise ihren graduellen und regimeübergreifenden Charakter, die räumliche Nähe von Akteuren, regionale Pfadabhängigkeiten und die Einbettung von Regionen in multi-skalare Governance-Strukturen. Der Ansatz fokussiert auf die Rolle neuer Organisationsformen als „Wegbereiter“ von Wandel *und* Stabilität in regionalen Transitionspfaden zur Nachhaltigkeit. Dadurch trägt er zu einem besseren Verständnis gradueller Veränderungen in regionalen institutionellen Strukturen und den ihnen zugrundeliegenden Mikro-Dynamiken bei.

Aufbauend auf dieser theoretischen Grundlage wird der methodische Ansatz der „Transitionstopologie“ entworfen. Dieses Instrument ermöglicht es, institutionelle und organisatorische Veränderungsprozesse in ihrem spezifischen Raum-Zeit-Kontext zu visualisieren und zu rekonstruieren. Die Topologie veranschaulicht somit, wie institutioneller Wandel mit organisatorischen Veränderungen innerhalb einer Region verbunden ist. Auf diese Weise lässt sich darstellen, wie Prozesse auf der Mikro-Ebene graduelle Veränderungen im regionalen Pfad auslösen, die über die Zeit zu einem fundamentaleren Wandel auf der Makro-Ebene führen können. Die Transitionstopologie ermöglicht es, Transitionspfade zur Nachhaltigkeit in verschiedenen Regionen systematisch zu analysieren und zu vergleichen.

Unter Anwendung dieser neu entwickelten konzeptionellen und methodischen Ansätze werden drei empirische Fallstudien durchgeführt: a) eine detaillierte Studie über die Mikro-Dynamiken von regionalen Nachhaltigkeitstransitionen in Augsburg (Deutschland), b) ein Vergleich der Einbindung von Universitäten in regionale Nachhaltigkeitstransitionen in Augsburg und Linz (Österreich) und c) eine Analyse der Rolle von Hochschulen in regionalen Nachhaltigkeitstransitionen in Oberösterreich. Ergänzt werden diese Studien durch eine auf einem mixed-methods-Design basierende Analyse der Motive von Forschern für die Wahl eines nachhaltigkeitsbezogenen Forschungsthemas.

Die Untersuchungen machen Prozesse und Dynamiken sichtbar, welche die Diversität von Transitionspfaden im Raum (z.B. deren unterschiedliches Tempo, ihre thematische Breite) erklären und bislang in der Transitionsforschung weitgehend verdeckt geblieben sind. Sie heben die Bedeutung von wertgetriebenen Individuen in regionalen Nachhaltigkeitstransitionen hervor, die oftmals gleichzeitig in verschiedenen thematischen Bereichen aktiv sind und dadurch Synergien herstellen. Vor allem wird die Relevanz unterschiedlicher Organisationsformen für institutionellen Wandel in regionalen Nachhaltigkeitstransitionen deutlich. Während temporäre Organisationsformen die Entwicklung nachhaltiger sozialer Praktiken unterstützen, sind langfristig angelegte Organisationen wichtig, um diese neu entwickelten Praktiken zu stabilisieren.

Die vorliegende Arbeit leistet originäre Beiträge zur geographischen Transitionsforschung sowohl auf konzeptioneller, als auch auf methodologischer und empirischer Ebene. Sie ermöglicht ein besseres Verständnis der institutionellen Dynamiken regionaler Nachhaltigkeitstransitionen und schafft somit eine wichtige Grundlage für die Förderung solcher Prozesse in der Praxis.

Abstract

Major ecological and social challenges require fundamental societal changes towards more sustainable production and consumption patterns. An important basis for such "sustainability transitions" are changes in institutional structures (e.g., laws, values and interpretive schemes) that promote sustainable social practices. Currently, little is known about how such institutional changes are triggered and how they evolve. In particular, it is poorly understood how the activities of actors on the micro-level affect the development of institutional structures in the long run and why such processes vary between regions.

This thesis analyzes institutional dynamics in sustainability transitions from a regional perspective in order to gain a better understanding of the place-specificity of these processes. Based on the premise that regional sustainability transitions differ from sectoral transition processes, which have hitherto been in the focus of transition research, the dissertation follows three aims:

(1) to develop a conceptual framework that captures the particularities of institutional change in regional sustainability transitions;

(2) to develop a methodological approach that enables to analyze the complex institutional dynamics underlying regional sustainability transitions;

(3) to generate empirical insights into regional sustainability transitions and the actors that drive them on the micro-level.

The newly developed conceptual framework of “Regional Transition Paths to Sustainability (RTPS)” builds on insights from Sustainability Transitions literature, Neo-institutional Theory and Evolutionary Economic Geography (EEG). Compared to existing approaches that serve to investigate sustainability transitions (in particular the multi-level perspective; MLP), the RTPS approach considers the particularities that shape sustainability transitions at the regional level, such as their gradual and regime-overarching nature, the spatial proximity of actors, regional path dependencies, and the embeddedness of regions in multi-scalar governance networks. The framework focuses on new organizational forms as enablers of both, change *and* stability, in regional transition paths to sustainability. In doing so, the framework is sensitive to gradual changes in regional institutional structures and their underlying micro-dynamics.

Based on this theoretical basis, the methodological approach of a “transition topology” is developed. The topology makes it possible to visualize and reconstruct institutional and organizational changes in their specific time-space context. The approach also makes apparent how institutional change is connected to organizational change at the regional level. In this way, it can be depicted how processes at the micro-level induce gradual changes in the regional path that lead to a more fundamental change at the macro-level over time. The topology allows for systematic comparisons between sustainability transitions in different regions.

The conceptual and methodological approaches are applied in three empirical studies: a) an in-depth study of the micro-dynamics of regional sustainability transition in Augsburg (Germany), b) a comparison of the involvement of universities in regional sustainability transitions in Augsburg and Linz (Austria), and c) an investigation into the role of higher education institutions (HEIs) in regional sustainability transitions in Upper Austria. These studies are complemented by an analysis (based on a mixed-methods research design) of the motives of researchers for choosing a sustainability-related research topic.

All the studies shed light on the processes and dynamics that lead to the diversity of transition pathways across space (e.g., regarding their different pace, their thematic breath), which remained largely “hidden” in previous research on sustainability transitions. They highlight the role of value-driven actors in regional sustainability transitions, who are often involved in several thematic fields at the same time and who are thus able to realize synergies. In particular, the relevance of new organizational forms for institutional change in regional sustainability transitions becomes apparent. While temporary organizational forms foster the development of sustainable social practices, more permanent organizations are important to stabilize these newly developed practices.

The thesis makes an original contribution to the Geography of Sustainability Transitions on a conceptual, methodological and empirical level. It enables a better understanding of institutional dynamics in regional sustainability transitions and therefore generates a basis for promoting such processes in practice.

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List of abbreviations and acronyms

AMU	Anwenderzentrum Material- und Umweltforschung User Center for Material and Environment Research
Bifa	Bayerisches Institut für Abfallforschung (heute: Bayerisches Institut für Angewandte Umweltforschung und -technik) Bavarian Institute for Research into Waste Disposal (today: Bavarian Institute for Applied Environmental Research and Engineering)
BINE	Bildung für Nachhaltige Entwicklung Education for sustainable development
BMU	Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit Federal Ministry for the Environment, Environmental Protection and Nuclear Security
BMWi	Bundesministerium für Wirtschaft Federal ministry of Economic Affairs
EEA	European Environmental Agency
EEG	Evolutionary Economic Geography
EMAS	Eco-Management and Audit Scheme
FFG	Forschungsförderungsgesellschaft Research Promotion Agency
FWF	Wissenschaftsfonds Research Fund
HEI	Higher Education Institution
HWK	Handwerkskammer Chamber of Crafts
IHK	Industrie- und Handelskammer Chamber of Industry and Commerce
IPCC	International Panel on Climate Change
JKU	Johannes Kepler University
KTU	Katholische Privat-Universität Catholic-Theological Private University
Kumas	Kompetenzzentrum Umwelt Augburg-Schwaben Environmental Competence Center Augsburg-Schwaben
LA 21	Lokale Agenda 21 Local Agenda 21
LAD	Least Absolute Deviation
LfU	Landesamt für Umwelt State Ministry for the Environment
ICLEI	Local Governments for Sustainability Initiative
MLP	Multi-Level Perspective
MRM	Institute for Materials Resource Management
OLS	Ordinary Least Squares
PATSTAT	Patent-Statistical Database
PH	Pädagogische Hochschule College of Education

RTPS	Regional Transition Path to Sustainability
SNM	Strategic Niche Management
STRN	Sustainability Transition Research Network
TM	Transition Management
UAL	University of Art and Design Linz
UoAS	University of Applied Sciences
UWI	Institut für Betriebliche und Regionale Umweltwirtschaft Institute for Environmental Management in Companies and Regions
VAR	Vector autoregression
WBGU	Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen Scientific Advisory Board of the Federal Government for Global Environmental Change
WCED	World Commission on Environment and Development
WoS	Share of world-wide publications
WZU	Wissenschaftszentrum Umwelt Research Center for the Environment

1 Introduction

1.1 Problem framing and research focus

The increased level of economic activities since the industrial revolution puts our ecosystems under massive pressure. Climate change (Rockström et al. 2009, IPCC 2014), biodiversity loss (Worm et al. 2006, Cardinale et al. 2012) and the looming phosphorus crisis (Abelson 1999, Cordell et al. 2009) are just a few examples of the negative side effects of industrialization. Scientists (e.g., Rosenzweig et al. 2008, Rockström et al. 2009) warn that many earth systems have crossed, or are about to cross, critical thresholds beyond which their resilience is compromised. They further argue that this irreversible damage to our ecological systems will have detrimental impacts on human development. With their "2030 Agenda for Sustainable Development" the United Nations (UN; UN 2016) recently affirmed their commitment to mitigate these ecological problems. At the same time, the UN pointed out that the latter are closely interrelated with socio-political challenges such as poverty, social exclusion and ongoing armed conflicts. Sustainable development would thus contribute to maintaining the resilience of our earth's ecosystems and at the same time enhance human well-being.

Scientists and politicians increasingly acknowledge that to achieve sustainable development, fundamental changes in many core systems of our society are needed (WBGU 2011, Markard et al. 2012, UN 2016, EEA 2018). They argue that deliberate efforts are necessary to change the way social functions (such as energy supply, mobility, food supply, recreation or education) are presently fulfilled (Smith et al. 2005, Markard et al. 2012, Loorbach et al. 2017). Such transformation processes, they claim, cannot solely rely on technological innovations, but also require institutional and economic changes as well as fundamental shifts in every-day practices and lifestyles (Geels 2004, Loorbach et al. 2017). These multidimensional long-term processes with a normative orientation towards sustainability are commonly referred to as 'sustainability transitions' (Smith et al. 2005).

However, these transitions turn out to be an ambitious endeavor, due to the complexity of systemic change processes. The different components of our social systems have developed in a process of mutual adaptation over very long periods of time (Geels 2004). Changes in one component are therefore dependent on changes in other components (Fünfschilling 2014). Sustainability transitions thus require cooperation between multiple actor groups (e.g., from the business, policy, civil society and scientific domains; Smith et al. 2005). The highly contested nature of sustainability complicates the matter even further. What, for example, a sustainable mobility, energy or education system should look like, is usually envisioned differently by different stakeholders depending on their respective interests and perspectives (Raven et al. 2016). Therefore, sustainability transitions are also of a highly political nature (Shove and Walker 2007, Meadowcroft 2011, Raven et al. 2016).

It has become apparent over recent years that cities and regions in particular are able and willing to deal with these challenges. An example is the "American Cities Initiative", a coalition of cities in the United States led by New York City's mayor Michael Bloomberg (Bloomberg.org Group 2019). The initiative was founded in the belief that actors at the local level can find more tailored solutions to context-specific sustainability problems than actors at the national or international level. By fostering local innovation as well as sharing and upscaling effective solutions and programs, the coalition meanwhile takes over a pioneering role in the field of climate protection and sustainable development in the United States of America (USA). The example suggests that cities and regions provide particularly suitable conditions for the development of sustainable innovations and thus can be important starting points for broader sustainability transitions.

It is therefore not surprising that the interest in cities and regions has significantly increased among transition researchers over the last years (Hansen and Coenen 2015, Köhler et al. 2019). Meanwhile, a broad range of empirical studies exist that focus on sustainability transitions at the urban and regional scale (Hansen and Coenen 2015, Wolfram and Frantzeskaki 2016). These studies indeed show that proximity advantages and already existing social relationships between local actors in cities and regions can provide favorable conditions for sustainability transitions (Späth and Rohracher 2010 & 2012, Mattes et al. 2015). It has recently also been suggested that cities and regions are the places where challenges and synergistic potentials are most likely to become visible (Hodson et al. 2017, Fünfschilling 2017). Moreover, it becomes apparent that local projects and initiatives are often important starting points for sustainability transitions of specific sectors at the national or global scale (Späth and Rohracher 2012, Rohracher and Späth 2014).

It has also been found, however, that sustainability transitions do not develop equally across space. On the contrary, sustainability transition processes turn out to differ substantially in terms of pace, scope and content, even within the same national context (Hansen and Coenen 2015, Köhler et al. 2019). A central question that is driving research on urban and regional sustainability transitions is therefore, why and how transition processes differ between places (Hansen and Coenen 2015, Köhler et al. 2019). Why do some cities and regions, as shown in the example above, become forerunners for sustainability transitions, while others are lagging behind? In this vein, studies have found regional institutional structures (comprising e.g., regulations, policies, values, interpretive schemes) to have a particularly strong influence on sustainability transitions (Hansen and Coenen 2015). While several studies have analyzed the effects of (existing) place-specific institutions on transitions, it is still underexplored how regional institutional structures transform towards sustainability. In particular, it remains a largely open question how different actors can impact such institutional changes within a regional system. The focus of this dissertation is therefore on the evolution of regional institutional structures that foster sustainability transitions across multiple sectoral domains, and the diverse actors that drive these processes on the micro-level. A better understanding of these processes, their interdependencies and their place-specific character, is key for conceptualizing policies to support sustainability transitions and to involve a broad range of actors in these processes.

1.2 Aims and scope of the dissertation project

This dissertation aims to make a contribution to the interdisciplinary field of sustainability transition research. The latter has developed into a main research perspective on sustainable development since the 2000s (Markard et al. 2012). Compared to previous scientific and political approaches that aim to achieve a sustainable development, transition scholars argue that paradigmatic shifts are needed in the ways societal functions are presently fulfilled (Wittmayer et al. 2016). Therefore, transition research is broader and more interdisciplinary than former research on sustainability that was usually focused on either technological or social aspects of transitions or on specific actor groups (e.g., engineers, policymakers, users; Köhler et al. 2019). Meanwhile, transition research includes a variety of different conceptual approaches to analyze how fundamental systemic change processes in our societal systems come about (Loorbach et al. 2017).[1]

[1] These comprise analytical approaches, as e.g., the multilevel perspective (Geels 2002 & 2004, Geels and Schot 2007, Smith et al. 2010) or technological innovation systems (Johnson and Jacobsson 2000, Hekkert et al. 2007, Bergek et al. 2008), as well as more experimental governance approaches, as e.g., transition management (Rotmans et al. 2001, Kern and Smith 2008, Loorbach 2010) or strategic niche management (Kemp et al. 1998, Smith 2007).

Several thematic sub-threads developed that deal with particular aspects of transitions or approach them from a specific theoretical perspective (Köhler et al. 2019). Among those is the so-called "geography of sustainability transitions" (Hansen and Coenen 2015). This sub-thread is concerned with differences of transition dynamics between places and the particularities of transition processes at distinct spatial scales. Empirical studies that focus on the geography of sustainability transitions clearly show that changes in regional institutional structures are a key mechanism driving sustainability transitions. However, as already pointed out in the introduction, it is largely an open question how such institutional changes towards sustainability evolve and, in particular, what role actors play in these processes.

This dissertation argues that these institutional changes cannot adequately be captured with current approaches from the sustainability transition research field, in particular the frequently used multi-level perspective (MLP). The reason is that regional sustainability transitions, which comprise multiple interrelated sectoral systems, are different from those sectoral transitions at the national level that have usually been analyzed with the MLP. The MLP conceptualizes transformative change as a disruptive process and also draws attention to particular socio-technical systems (Geels 2004, Loorbach et al. 2017). Empirical studies from the geography of sustainability transition field however, made apparent that regional sustainability transitions are, among others, characterized by more gradual change processes, proximity between actors and the embeddedness in multi-scalar governance frameworks (e.g., Rohracher and Späth 2014, Mattes et al. 2015). Therefore, an explicitly regional approach is necessary to address and understand regional sustainability transitions.

The **first aim** of the dissertation is therefore to develop a conceptual framework that models the regional particularities of institutional change as a basis for regional transitions to sustainability. Therefore, this dissertation combines a geographic approach with an institutional perspective on sustainability transitions. It refers on the one hand to recent approaches from Neo-institutional Theory (Meyer and Rowan 1977, Zucker 1977, Scott 1987) that especially focus on the interplay between actors and institutions, and more gradual forms of institutional change. On the other hand, it draws on insights from Evolutionary Economic Geography (EEG; Boschma and Frenken 2006, Boschma and Martin 2010) that shed light on the spatial shaping of these institutional change processes (see Figure 1).

Figure 1: Research context of the dissertation.

Methodologically, the analysis of institutional change processes in regional sustainability transitions is a great challenge. Institutional change is often diffuse and cannot easily be captured. Therefore, indicators must be developed that make these processes visible. At the same time, dynamics on the micro-level also have to be considered. To investigate the long-term impact of micro-level activities on

the regional institutional system, the methodological approach must enable these different levels of analysis to connect. The approach should furthermore facilitate systematic comparisons of cases in order to generate more generic insights (Frantzeskaki et al. 2017a, Köhler et al. 2019). A narrative case study approach that solely relies on a thick description of the empirical phenomenon (which is currently the most frequently used approach in the sustainability transitions research field; Geels 2011), seems inappropriate for this endeavor. Such approaches make it difficult to compare processes in different regions without merely highlighting spatial particularities. The complexity of regional sustainability transitions makes it at the same time difficult to analyze these processes with quantitative approaches (Geels 2011, Köhler et al. 2019). As Geels (2011: 36) pointed out, transition researchers might need to find an *"…epistemological middle way between on the one hand the search for laws and statistical correlations between variables (as in mainstream social science), and on the other hand an emphasis on complexity, contingency, fluidity, untidiness and ambiguity (as in constructivist micro-studies)."*

The **second aim** of the dissertation is therefore to provide a methodological approach that enables the systematic mapping and analyzing of the complex institutional dynamics underlying regional sustainability transitions, and that provides a basis for comparative case study research. The conceptual and methodological approaches can thus be used in order to further the body of knowledge on institutional change in regional sustainability transitions. In line with the conceptual approach, particular emphasis will be placed on the actors that foster these processes on the micro-level. This focus will also enable the generation of insights into the governance of transitions.

The **third aim** can therefore be formulated as following: to generate empirical insights into regional sustainability transitions and the underlying micro-dynamics on the basis of (comparative) regional case studies. An example for a region in transition is given, among others, by the city-region of Augsburg in Southern Germany, which received the German sustainability award for its broad transition process to sustainability (Stiftung Deutscher Nachhaltigkeitspreis 2013), and mainly inspired this dissertation thesis.

1.3 Research design of the dissertation project

The three aims of the dissertation will not be implemented separately from each other. On the contrary, their realization is deeply interwoven. This means that the conceptual approach will not be developed upfront in order to then be tested in empirical research. The thesis does not follow a purely inductive approach to theory-building either – although the starting point of this dissertation has been an observation in real life (in the Augsburg region). The research design, instead, corresponds more closely with what has been called an "abductive approach" (Timmermans and Tavory 2012, Meyer and Lunnay 2013). "*Abductive analysis constitutes a qualitative data analysis approach aimed at theory construction. This approach rests on the cultivation of anomalous and surprising empirical findings against a background of multiple existing sociological theories and through systematic methodological analysis*" (Timmermans and Tavory 2012: 169). Abduction is based on a form of logical reasoning, introduced by the pragmatist philosopher Charles Peirce, that aims to expand current knowledge about a phenomenon. The process starts with an empirical observation that seems "surprising" in light of existing theories (see Figure 2). In a next step, a theoretical explanation for this observation is formulated, for which the researcher draws on a broad array of existing theoretical knowledge. Thereafter the researcher searches for empirical facts that verify the theory and, if the empirical facts do not substantiate the initial theory, the process is repeated (Timmermans and Tavory 2012).

Abductive theory thus necessitates a constant back and forth between empirical and theoretical research in order for the two to amplify each other (Tavory and Timmermans 2014).

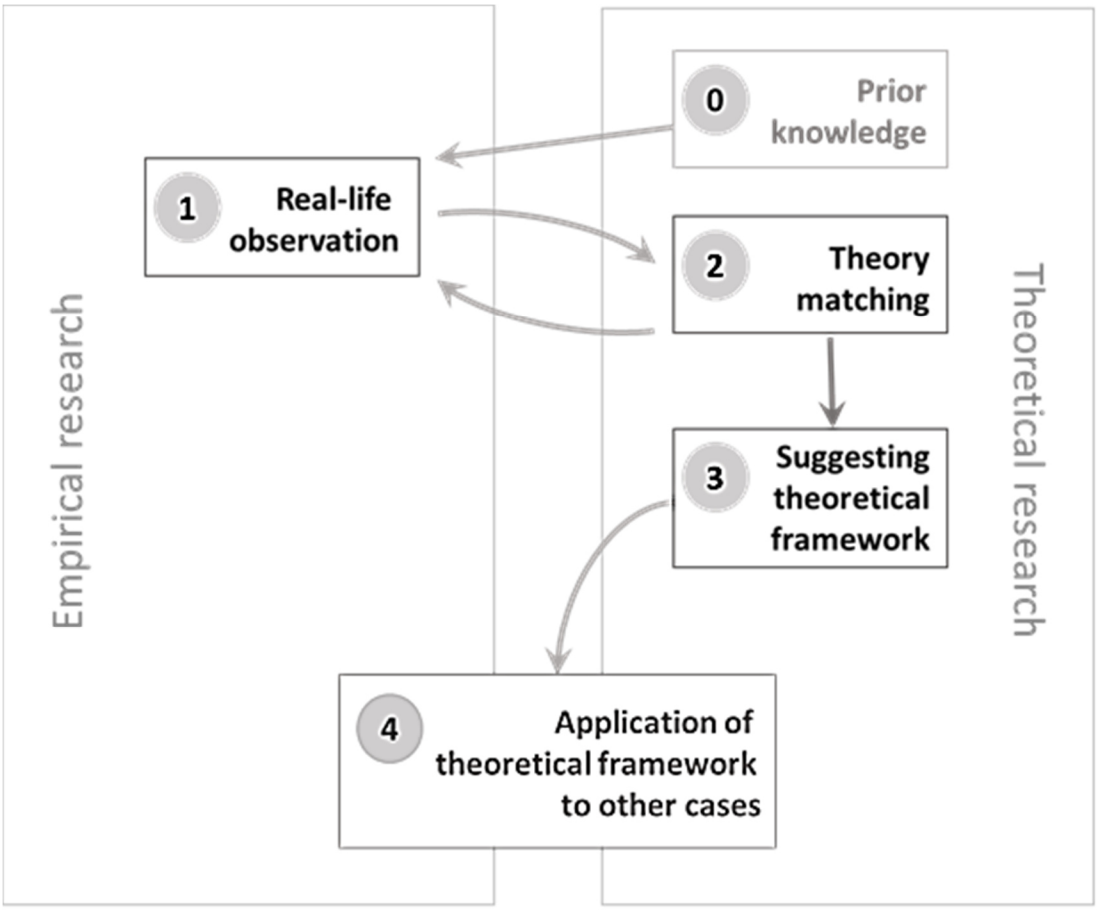

Figure 2: Abductive research cycle. (Adapted from Kovács and Spens 2005: 139.)

An abductive approach thus makes it possible to build on already existing theoretical insights about regional sustainability transitions and integrate theoretical approaches from other related fields. At the same time, however, it enables to "ground" theoretical ideas in the empirical data (Strauss 1998). Abductive research therefore draws on some methodological procedures, that are similar to those applied in grounded theory analyses (Tavory and Timmermans 2014). Revisits to the empirical phenomenon are supposed to enable the researcher to re-experience the phenomenon in light of new theoretical knowledge and also to perceive new aspects of an empirical phenomenon. Defamiliarization through taking "semantic distance" from real-world events (Timmermans and Tavory 2012: 177), for example by writing field notes, is also seen as important to enrich the researchers understanding of a phenomenon. Alternative casing, that is the analysis of empirical data in light of different theoretical approaches, is another way to enhance the potential of abductive research (Timmermans and Tavory 2012).

2 Institutional change in regional sustainability transitions

The aim of this chapter is to present the thesis's research problem in light of existing approaches from sustainability transition research: How do existing approaches already help to understand institutional change in regional sustainability transitions and what research needs become apparent? It furthermore sketches out the contours of a conceptual and methodological approach to analyze institutional change in regional sustainability transitions.

The first sub-chapter introduces the MLP, which is the most prominent approach in sustainability transition research. The MLP is an important reference point for the geographical perspective and the state of research on regional sustainability transitions, elaborated in the second part.[2] Based on the state of research, the third sub-chapter identifies a need for a more comprehensive regional approach to analyze institutional change in sustainability transitions and outlines the contours of such an approach. The chapter concludes with a short overview of key concepts from Neo-institutional Theory and EEG, which build the basis for the development of the new conceptual framework and the research conducted in this dissertation. The following sub-chapter discusses what a methodological approach to analyze regional sustainability transitions must be capable of and elaborates the foundations of such an approach.

2.1 A multi-level perspective on sustainability transitions

A range of different approaches to analyze sustainability transitions exist, many of which are based on a systemic understanding of transitions (Markard et al. 2012, Loorbach et al. 2017). The most prominent of these approaches is the MLP, which allows analysis of complex sectoral transition processes from a meta-perspective (Geels 2002 & 2004). The MLP builds on the work of René Kemp and Arie Rip on technological regimes (Rip and Kemp 1998) and was then developed further by Frank Geels (2002 & 2004). This latter elaboration of the MLP by Geels was inspired by insights from evolutionary economics, science and technology studies, structuration as well as neo-institutional theory (Geels 2010). The initial focus on technological innovations, their diffusion and social acceptance has, however, shaped MLP-based research for a long time (Affolderbach and Schulz 2016).

The MLP explains transitions as a result of the interplay of three analytical levels, which differ regarding their degree of structuration and their temporal characteristics (Geels 2002 & 2004). The central object of analysis is the so-called socio-technical system, which comprises all elements (such as technologies, knowledge, cultural meaning, capital, labor) necessary to fulfill a specific societal function (such as energy supply, housing or mobility). A socio-technical system is constituted by the activities of different actor groups (including firms, users, societal groups, authorities etc.; Geels 2002 & 2004). Coordination between these actor groups is enabled by the socio-technical *regime*, a relatively stable rule system comprising, with reference to Scott (2001), regulative, normative and cognitive institutional elements (Geels 2002 & 2004).[3] These rules at the same time enable and constrain the activities of actors and therefore usually change only incrementally over longer periods of time. They are thus characterized

[2] The MLP is the most frequently applied approach in the geography of sustainability transition research (Hansen and Coenen 2015). Compared to other approaches, such as TIS, the MLP also deals more explicitly with the role of institutions in transitions (Coenen et al. 2012).

[3] There exist different definitions of the term „regime". While some authors (like Geels 2002 & 2004) distinguish between socio-technical systems and socio-technical regimes, other authors apply a broader definition including also material elements in the regime definition (e.g. Smith et al. 2005). For a detailed discussion see Markard and Truffer 2008.

by a high degree of path dependency. The socio-technical regime can be understood as an organizational field (DiMaggio and Powell 1983) with a special focus on technologies and materiality (Fünfschilling and Truffer 2014), which consists of different broader societal regimes (such as policy, socio-cultural, science regime; Geels 2002 & 2004; see Figure 3).[4]

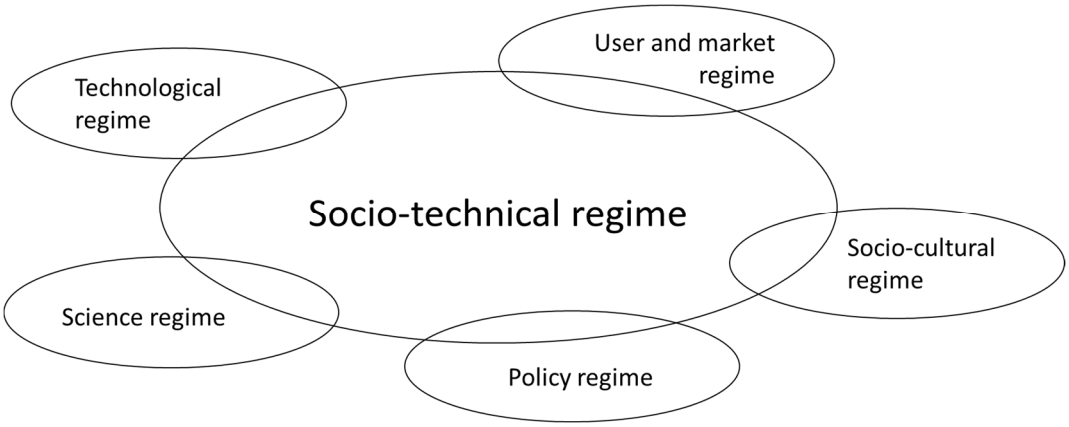

Figure 3: Meta-coordination through socio-technical regime.
(Source: Own graphic based on Geels 2004: 905.)

Socio-technical regimes interact with the so-called *landscape* level, deeper material or institutional structures that change only very slowly, as for example climate change or globalization. While the landscape level influences activities in the socio-technical regime, by making some actions easier than others, it can rarely be changed by actors or events at the regime level (Markard and Truffer 2008). Radical events, as for example natural catastrophes or political upsurges, can, however, lead to sudden changes on the landscape level, which then often further cascade down to the regime level. Simultaneously, socio-technical regimes also interact with *niches*, which are defined as spaces that are shielded from the dominant structures of socio-technical regimes (Smith and Raven 2012). Niches can be described as organizational fields as well, though ones that are still in their infancy (Geels and Schot 2007). Hence, niches are characterized by relatively loose institutional structures, which are constituted by loosely connected actor groups. In niches, actors can experiment with radically new technologies and social practices, build up new networks and gather resources necessary for the development of new socio-technical systems (Smith and Raven 2012).

The initial assumption was that transitions occur when tensions in the socio-technical regime develop due to events on the landscape level (see Figure 4). These tensions then open up opportunities for radical niche developments to disrupt and replace the regime (Geels 2002 & 2004). Over time, however, based on the timing and nature of interactions between the three MLP levels, a number of different pathways have been identified. Geels and Schot (2007) differentiate between the complete substitution of a socio-technical regime and cases in which modifications, re-alignments or adjustments in the regime take place. These ideal pathways all have in common that they model changes at the different levels primarily as a result of technological developments, while also acknowledging their interplay with institutional changes and shifting actor constellations.

[4] Geels (2004) calls them sub-regimes from the perspective of the socio-technical regime.

The advantages and disadvantages of the MLP have been discussed extensively across the last two decades (e.g., Berkhout et al. 2004, Smith et al. 2005, Genus and Coles 2008, Jørgensen 2012, Fünfschilling and Truffer 2014). This critical review of the MLP can be divided in a more general critique as well as criticism formulated from a geographical point of view. The former includes, among others the lack of consideration of the socio-political dimension of transitions (e.g., Shove and Walker 2007, Genus and Coles 2008), which shapes the direction, goals and priorities of these processes (Raven et al. 2016). Another closely related criticism is that the MLP has too strong a focus on technological aspects of transitions (e.g., Genus and Coles 2008), and that it does not sufficiently consider the activities of actors on the micro-level (e.g., Smith et al. 2005, Genus and Coles 2008). A criticism from a geographical perspective, was that the MLP, while allowing for an analysis of the interplay of different types of institutions across different societal regimes (policy, science, technology etc.) neglects the fact that institutions also have a geographical dimension (Truffer and Coenen 2012, Raven et al. 2012). It was furthermore pointed out that spatial variations regarding the perception and translation of landscape forces by actors, the internal coherence of socio-technical regimes as well as the effect of spatial institutions on niche developments, are therefore not considered in the MLP.

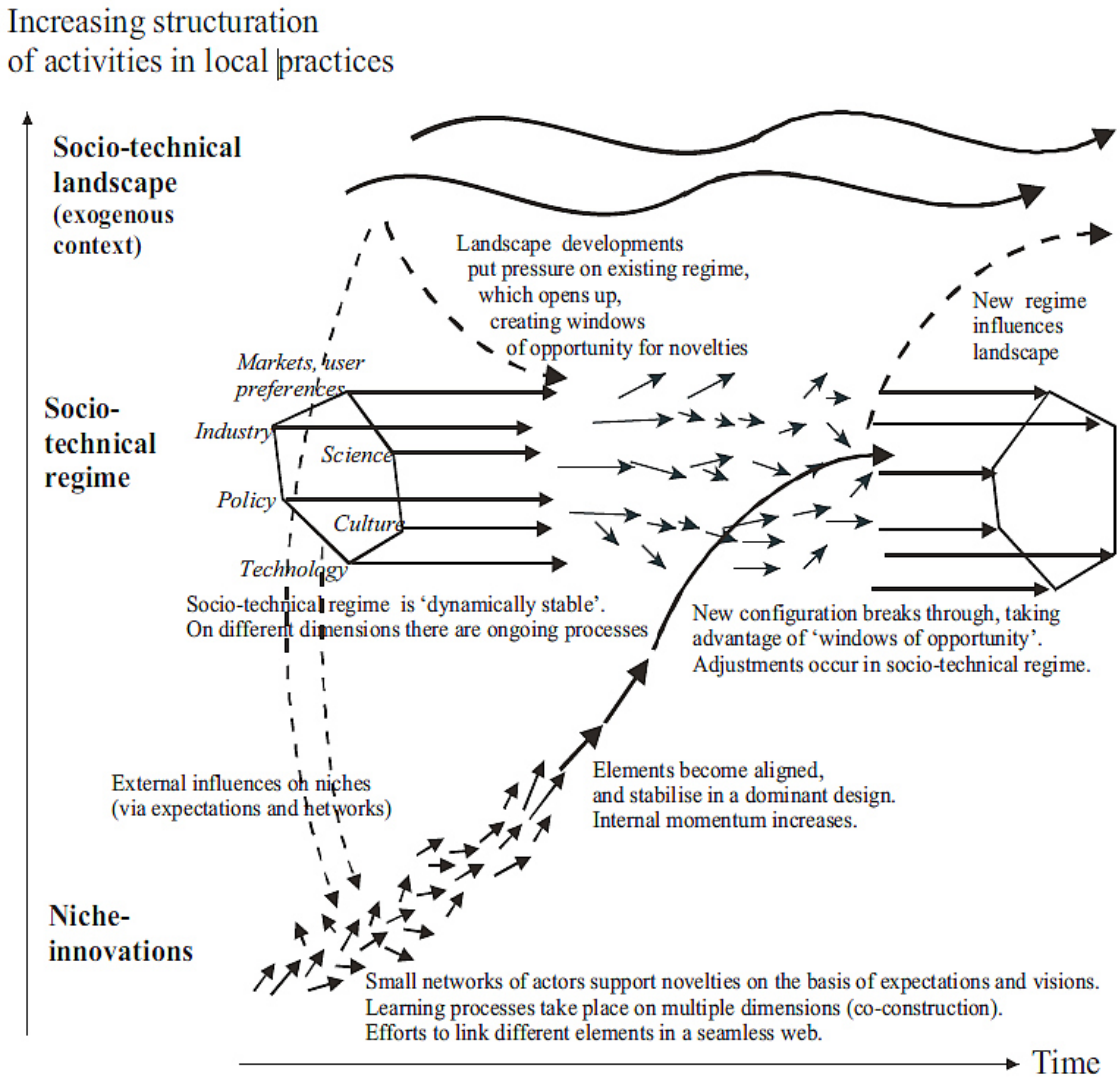

Figure 4: The multi-level perspective on transitions.
(Source: Geels 2011: 28.)

2.2 A geographical perspective on sustainability transitions

For a long time, space had only, if at all, been treated as a "*passive background variable*" in sustainability transition research (Coenen et al. 2012: 976). Most studies referred to the nation as a unit of analysis, while other geographical levels were rarely analyzed (Markard et al. 2012). This perspective changed only after some authors highlighted the need for a closer spatial analysis in order to explain the uneven transition dynamics across and between different spatial scales (Hodson and Marvin 2010, Smith et al. 2010, Cooke 2010, Coenen et al. 2010, Truffer and Coenen 2012, Coenen et al. 2012, Raven et al. 2012). These authors brought attention to a differentiated understanding of space and place, and pointed out how these two concepts are of relevance for the analysis of sustainability transitions. Place is defined in an absolute sense as a territory, which might contain specific institutions or other assets favorable for a transition to sustainability. In a relational understanding of space, niches and regimes are seen as socially constructed by actor networks that cut across territorial boundaries (Coenen et al. 2012, Raven et al. 2012). This differentiated understanding has also found its way into empirical research on sustainability transitions.

Research that explicitly deals with geographical aspects of sustainability transitions meanwhile comprises contributions from a variety of disciplines, including among others economic geography (e.g., Dewald and Truffer 2012, Carvalho et al. 2012), urban studies (e.g., Bulkeley et al. 2014), policy studies (Block and Paredis 2013), governance research (e.g., Hodson and Marvin 2010 & 2012) urban planning (e.g., Naess and Vogel 2012, Jenssen et al. 2015) and urban ecology (e.g., Kampelmann et al. 2016). Many authors combine their disciplinary perspective with systemic approaches from sustainability transition research and often use the MLP as a heuristic framework. The shared conceptual perspective has been an important basis for the development of this research field. Many studies show, however, that urban or regional transitions[5] cannot simply be equated with specific levels or sub-processes of the MLP. Sustainability transitions at the regional level are characterized by several particularities compared to sectoral transitions at the national level, which are not explicitly considered in the MLP. Against this background, the aim of the following overview is to show how the geography of sustainability transitions literature describes the particularities of sustainability transitions at the regional level.

It has become apparent that sustainability transitions at the regional level are strongly shaped by historically evolved *place-specific structures*. These structures comprise the region-specific formal and informal institutional environment, a region's technological and industrial specialization, its natural-resource endowments as well as the proximity to relevant consumers and market formation processes (Hansen and Coenen 2015). With regard to the institutional environment, DeLaurentis (2015) for example found that local informal institutions (in the form of cooperation practices, knowledge sharing etc.) in Wales (UK) enabled the development of a bioenergy niche, even in the absence of political aid for bioenergy crops. In a similar vein, Wirth et al. (2013) demonstrate, with the example of Austrian regions, that regional differences in the professional culture of farmers (such as e.g., their professional identity, their perceptions of what is appropriate) were responsible for the differing impact of national feed-in tariffs and subsidies for biogas plants. With regard to industrial and technological path dependencies, Carvalho et al. (2012) demonstrate, with the example of Göteborg (Sweden), Curitiba (Brazil) and Hamburg (Germany), how the development of specific clean-tech innovations was enabled

[5] Although there are differences between the urban and the regional scale, they are both characterized by spatial proximity. Therefore, despite the focus of this dissertation on regional transitions, studies about sustainability transitions at the urban scale (and smaller units, as communities or urban quarters) will be considered in the following chapters as well. The terms regional and urban will be used synonymously as from now on.

by previous innovation activities and the existence of a specific industry structure and labor force in the region. In a similar vein, Gibbs and O'Neill (2014) show how in Boston (USA) the green economy developed out of existing economic networks, and a long tradition of environmental leadership. Späth and Rohracher (2010) make apparent the influence of natural resource endowments on transitions at the regional level using the example of a small Alpine region in Austria. The authors illustrate how the availability of vast amounts of wooden biomass and the peripheral location of the Murau region built the basis for the development of a regional vision for the energy transition. Finally, Dewald and Truffer (2012) make apparent how the early formation of local markets through local solar initiatives can at least partly explain the uneven geography of the German photovoltaic market. Overall, these studies show that regions offer different conditions for sustainability transitions and that these conditions explain—at least to a certain degree—the multiplicity of sustainability transition pathways.

As already stated in the introduction, studies with a geographical perspective found *institutional changes* to play a central role in sustainability transitions at the regional level. Several studies have shown that these transitions often take their outset in institutional changes that motivate, legitimize and enable the implementation of sustainable solutions in specific socio-technical regimes (Carvalho et al. 2012, Späth and Rohracher 2012, Rohracher and Späth 2014, Uyarra and Gee 2013, Block and Paredis 2013, Hodson et al. 2017). Uyarra and Gee (2013) for example show how a strong regional political vision enabled a transition towards more advanced and sustainable waste solutions in the Greater Manchester region (UK), against the national trend. In a similar vein, Block and Paredis (2013: 181) illustrate how broader political visions in three cities in Belgium enabled innovative urban development projects that the authors regard as potential "*catalysts*" for urban sustainability transitions. Carvalho et al. (2012) demonstrate with the examples of Curitiba (Brazil), Göteborg (Sweden) and Hamburg (Germany), how the implementation of new green urban transport policies indirectly fostered the exploration of new clean-tech technologies, and experimentation with these new technologies, in the cities. Brown et al. (2013: 716) also show, using the example of the transformation of Melbourne's urban storm-water management, "*how the actual systemic changes ultimately were institutionally driven*". To conclude, these studies suggest that institutional changes are at the basis of sustainability transitions at the regional level.

Studies in the geography of sustainability transitions literature also highlight the role of *local actors* that act as forerunners in transition at the regional level by fostering change in specific local regimes, or in their broader institutional environments. Hodson and Marvin (2010 & 2012) for example observe that influential actors (e.g., policymakers, managers of utilities or NGOs) in global cities, often refer to broader landscape pressures (such as e.g., climate change, induced diseases or water scarcities) to create momentum for change (see also Rohracher and Späth 2014). These actors then build coalitions and foster the creation of shared visions (Hodson and Marvin 2010). In a similar way, other authors highlight the role of mayors, who are in a position to induce change and are able to convince other actors to join them (Block and Paredis 2012, Quitzau et al. 2013, Gibbs and O'Neill 2014). By referring to the literature on institutional entrepreneurship (DiMaggio 1988, Maguire et al. 2004), Block and Paredis (2013: 187) show, for example, how political leaders in the city of Kortrijk (Belgium) developed visions and broad discourse coalitions and networks to realize ambitious sustainability "*flagship projects*". Bulkeley and Castán Broto (2013) also highlight that political actors increasingly make use of experiments in order to foster transitions within cities.[6] Other authors have described institutional change in transitions at the regional scale, as distributed among a broader range of actors. By referring

[6] Urban experiments are understood here as: "*purposive interventions in which there is a more or less explicit attempt to innovate, learn or gain experience*" (Bulkeley and Castán Broto 2013:10).

to the institutional work approach (Lawrence and Suddaby 2006, Lawrence et al. 2011), Brown et al. (2013) have shown, for example, how a loosely coupled network of actors has fostered institutional change in Melbourne's urban storm-water quality management over a time span of 50 years. To sum up, these studies show that local actors are key drivers of sustainability transitions at the regional level and therefore also account for differences in transition dynamics.

Several transition scholars have observed *spatial proximity* between actors to be important in sustainability transitions at the regional level, as it enables the development and functioning of particularly heterogeneous actor networks (e.g., Späth and Rohracher 2010 & 2012, Mattes et al. 2015). Dewald and Truffer (2012) for example, found that early local market formation processes for photovoltaic technologies in Germany were primarily enabled by close interactions between suppliers and end-customers. Spatial proximity facilitated on-going feedback processes and enabled these actors to overcome innovation problems. Analyzing the regional energy transition in the city-regions of Emden and Bottrop (Germany), Mattes et al. (2015) also show how spatial proximity fostered network formation between actors from different societal subsystems (industrial, financial, political, administrative, scientific, civil society). The authors highlight in particular the informal personal ties between actors in the Emden region, through which activities were successfully coordinated and which substituted for more formal intermediary organizations. In the example of the Aquifer Thermal Energy Storage (ATES) niche in the Netherlands, Coenen et al. (2010) have also found the existence of different forms of proximity (cognitive, social, organizational, institutional, geographical) between actors (and also between projects) to be an important explanatory factor for the uneven development of niche processes across space. The authors show, that different forms of proximity became relevant in different phases of the development of niches. These examples illustrate that spatial proximity between actors from different societal sectors can facilitate the formation of heterogeneous actor networks for sustainability transitions.

Due to the proximity of actors with different interests, *conflicting perspectives* also become more easily visible at the regional level (Shove and Walker 2007, Coutard and Rutherford 2010, Hodson and Marvin 2012, Späth and Rohracher 2015). Empirical studies describe these conflicts and tensions with the example of concrete local projects (Bulkeley and Castán Broto 2013, Späth and Rohracher 2015). Späth and Rohracher (2015) illustrate for example how different sustainable solutions that had both been broadly supported by the public for a long time, suddenly became contested when being considered for implementation in a larger urban housing project in Freiburg (Germany). In a similar vein, Bulkeley and Castán Broto (2013: 22) observe that urban experiments generally rather: *"…provide grist in the urban mill, creating conflict, sparking controversy, offering the basis for contested new regimes of practice."* These conflicts and ambiguities can also become visible at the boundaries of different socio-technical regimes. As Späth and Rohracher (2015) point out: *"Projects of urban change often create new intersections between different socio-technical systems and bring certain conflicts and frictions to the fore."* While some studies show how conflicts and tensions can provide severe barriers to more fundamental transitions (e.g., Bulkeley and Castán Broto 2013), others found that tensions can also make actors develop new perspectives on existing problems and be important starting points for innovation (e.g., Jenssen et al. 2015). From an actor-network theoretical perspective, Jenssen et al. (2015) show, for example how conflicts can break up existing interdependencies between systems, infrastructures and practices in an urban context, and create new ones that are more conducive to a sustainable development. The authors demonstrate how the newly established harbor baths in Copenhagen (Denmark) and the practice of swimming in the harbor are the outcome of the intersection of conflicting perspectives of actors from different sectoral contexts. In the 1980s, traditional interdependencies, resulting from the use of the harbor as a corridor for commercial

shipping and a repository for waste water, became contested, as actors from other sectoral contexts put forward their perception of the harbor as a biological habitat and later also a recreational area. To conclude, these studies make apparent that place-specific tensions and conflicts within and between local regimes can have a substantial impact on the course of a transition.

It has also been shown that socio-technical transition processes at the regional level are *multi-scalar* and are influenced by institutional structures that are spread across different spatial scales, ranging from the city to the global level (Raven et al. 2012, Coenen et al. 2012, Truffer and Coenen 2012). This means that these processes are embedded in institutional environments with distinct features at different spatial levels (Raven et al. 2012). The embeddedness of regions in multi-scalar government networks also increases the complexity of sustainability transition at the regional level, and can spur tensions and conflicts (Smith 2007, Späth and Rohracher 2012). Hodson and Marvin (2012) for example illustrate using the example of the energy transition in Greater Manchester (UK), how multi-faceted national priorities and a variety of regional interests converged in the city-region and had to be negotiated. This case demonstrates how the embeddedness of regions in multi-level governance structures further increases the likelihood of a "clash of interests" and the complexity of sustainability transition processes at the regional level. Overall, these studies show that institutional structures and governance arrangements at other spatial scales also impact transition dynamics in the region.

Finally, several authors have emphasized the important role of *intermediaries* in sustainability transitions at the regional level that facilitate interactions between actors from different contexts. Hodson and Marvin (2010 & 2012) have for example highlighted the role of intermediaries between regime actors and different kinds of regional actors, which are often located outside the region. These intermediaries facilitated the coordination of often conflictual vision-building processes between these actors. In a similar vein, Brown et al. (2013) have shown how bridging organizations, which bring together key actors from the niche and regime contexts and formalize their interactions, were conducive in the transformation of Melbourne's (Australia) urban storm-water management regime. The authors also highlighted the importance of the networking between different bridging organizations throughout the transition process. Hamann and April (2013) investigated the potentials and challenges of intermediary organizations at the sub-city scale in Cape Town (South Africa). They show how these organizations were able to initiate cross-sector (government, business, civil society) collaboration, and influence the socio-ecological trajectory of the city. These studies make apparent that the existence of particular organizations that mediate between heterogeneous actor groups can facilitate sustainability transitions at the regional level.

To summarize, this chapter showed that socio-technical transitions within regions differ from sectoral transition processes at the national level that have usually been described with the MLP. Although this literature is highly fragmented due to the diversity of perspectives, concepts and starting points, some important issues can be distilled: institutional changes play a key role in sustainability transitions at the regional level, these processes are furthermore characterized by proximity between actors, which facilitates cooperation, but also enhances the likelihood of conflicts. Furthermore, they are influenced by place-specific structures and dynamics on other spatial scales. Overall, the multiplicity of actors and interests involved in these processes on different spatial scales as well as the different historically evolved institutional environments on these scales that mutually affect each other, make sustainability transitions at the regional level and their outcomes unpredictable. Therefore, these processes are often described as unplanned, non-linear and emergent (Block and Paredis 2013, Quitzau et al. 2013, Brown et al. 2013, Späth and Rohracher 2015).

2.3 Contours of a regional approach to sustainability transitions

The geographical focus on sustainability transitions, presented in the previous chapter, showed that transitions at the regional level differ in several regards from the sectoral transition processes at the national level that have previously been in the focus of MLP-based research. It also became apparent that the MLP perspective has its limits to investigate the complexities and particularities of sustainability transitions at the regional level.

A deeper analysis of regional transition paths to sustainability (RTPS) therefore has to go beyond "adding" spatial aspects to existing conceptual approaches (Hansen and Coenen 2015). Instead, an explicit regional approach is needed. In short, such a conceptualization has to make a shift from analyzing sustainability transitions *at* the regional level (i.e. the spatial expression of a sectoral transition) to analyzing regional transitions (i.e. the transition dynamics of a region with all its interdependencies, contradictories and messiness). To achieve this aim, such an approach has to rethink the basic concepts that define regional sustainability transitions. This section therefore elaborates on six notions that are essential to describe regional sustainability transitions, and outlines the conditions of a comprehensive approach to analyze these processes.

The first condition refers to the conceptualization of "**transition**". Transition scholars have described transitions as fundamental shifts in the development trajectories of systems (Geels 2004, Loorbach et al. 2017). It has been suggested that these processes are based on disruptive changes that result from the interplay of dynamics at the niche, regime and landscape level. This assumption has been supported by analyses of transitions of specific socio-technical systems at the national scale. Studies with a geographical perspective however, show that actors often do not develop radical innovations in niches, but rather interact directly with regime actors and existing socio-political structures. Spatial proximity and the support of intermediary organizations facilitate these processes. Regional sustainability transitions are thus not disruptive, as would be expected in the MLP, but proceed in a more gradual way (Rohracher and Späth 2014). *Therefore, an approach is needed that can explain transitions as a gradual change process.*

The second condition refers to the normative orientation of transition processes towards **sustainability.** Initial MLP-based studies usually focused on either historical transition processes (e.g., Geels 2005 & 2006) or the implementation of specific niche technologies that were assumed to be more sustainable than existing solutions (e.g., Raven and Verbong 2004, Van Driel and Schot 2005, Geels 2005 & 2006). The direction of these transition processes was more or less clear from the perspective of the researcher. However, the geography of sustainability transition literature has shown that the goal of sustainability in sustainability transition processes at the regional level is usually highly contested. What sustainability means in a specific local context is interpreted differently by different stakeholder groups (e.g., business, policy, civil society, science actors), and It is rather unlikely that local actors share a common vision for the future of the region. It is therefore also not possible for the researcher to have a precise vision in advance of what a regional transition to sustainability will look like (Naess and Vogel 2012). *Therefore, an approach is needed that acknowledges and deals with these conflicts and different perceptions of sustainability.*

The third condition refers to the **region** and the particularities of transition processes at this spatial scale. Transition scholars have been mainly interested in how the regional context shapes sustainability transitions in specific socio-technical regimes. Most of these studies have a sectoral interest, trying to establish to what extent a specific socio-technical regime becomes more sustainable at the regional level. In this vein, the geography of sustainability transition literature has already mentioned several particularities of sustainability transitions at the regional level. These particularities comprise relations

between actors, which are characterized by spatial proximity, the influence of historically evolved place-specific structures and the embeddedness in multi-scalar governance networks (see Chapter 2.2). It can be assumed that these particularities induce place-specific dynamics that significantly shape regional transition processes, which comprise multiple interdependent sectoral systems. *Therefore, a place-sensitive approach is needed that acknowledges the particular relations between actors, the place-specific contexts and the multi-scalar character of regional transitions.*

The fourth condition refers to the **path dependency** of transition processes. Transition scholars used this concept to describe stabilizations and lock-ins in sectoral development paths. Over time, the different elements in a socio-technical system (technologies, consumer preferences, lifestyles etc.) become highly interdependent. Self-reinforcing dynamics set in, which reduce the likelihood for radical change (Geels 2004). Scholars from Neo-institutional Theory (e.g., Streeck and Thelen 2005) and EEG (e.g., Strambach 2010, Tödtling and Trippl 2013) have, however, emphasized the existence of dynamics within path-dependent trajectories. These dynamic elements for example enable actors to use the plasticity of paths (Strambach and Storz 2008, Strambach 2010, Strambach and Halkier 2013) and initiate processes of "path renewal" (Martin and Sunley 2006, Coenen et al. 2015, Isaksen 2015) from within a region. *Therefore, an approach on regional transitions has to consider endogenous dynamics in regional development paths.*

The fifth condition refers to the role of **actors** in sustainability transitions. Although Geels (2004) mentioned actors and agency as important issues in sustainability transitions, MLP-based research has primarily focused on the broader system dynamics of transitions (Geels et al. 2016). Studies interested in the geography of sustainability transitions have shown that actors are central drivers of transitions at the regional scale. As outlined in the previous chapter, these drivers include highly engaged individual forerunners as well as more distributed forms of agency. These actors usually also coordinate with others by building coalitions, networks or other forms of organization. *Therefore, a regional approach has to pay attention to different kinds of actors and investigate the unfolding of dynamics at the micro-level of regional sustainability transitions.*

The sixth condition refers to **institutions** and institutional dynamics in regional sustainability transitions. In line with Neo-institutional Theory, institutions are understood as regulative, normative and cognitive elements that shape behavior beyond the individual (Scott 2001). While institutions have always played an important role in the MLP, MLP-based research has for a long time been characterized by a strong interest in technologies. The geography of sustainability transition literature has, however, shown that transitions at the regional level are mainly institutional transitions (Loorbach et al. 2017). On the one hand, institutional changes are often the initial impetus for socio-technical transitions at the regional level. On the other hand, broader regional transitions also comprise less technology-driven systems (such as health, education, finance or the economy), in which social and institutional innovations play a more dominant role per se (Loorbach et al. 2017). *Therefore, a regional approach must focus on institutions and institutional dynamics in sustainability transition pathways.*

To develop a more comprehensive approach to analyze micro-dynamics and institutional change in regional transitions path to sustainability, this dissertation draws on recent insights from two research fields. First, these are approaches from **Neo-institutional Theory**, which emphasize agency and more gradual institutional change processes. Secondly, these are approaches from **EEG**, which enable analysis of institutional change processes from a spatial perspective. The geography of sustainability transitions literature has, to some extent, already referred to evolutionary, institutional and relational perspectives in economic geography (Hansen and Coenen 2015). A comprehensive approach that combines these insights is, however, still lacking. In the following, it is elaborated how approaches

from Neo-institutional Theory and EEG can supplement insights from sustainability transition theory in order to fulfill the conditions of such a comprehensive regional approach.

Neo-institutional Theory

Neo-institutional Theory is a broad research field that inspired research in a variety of disciplines. Particularly relevant for this dissertation are recent insights from Neo-institutional Organization Theory and Historical Institutionalism. Both approaches see institutions as comprising both formal and informal rules, moral beliefs as well as cognitive schemes that help actors to decide which actions are legitimate and socially acceptable (Scott 2001). Neo-institutional Organization Theory has become a leading theory to study the relation between institutions and organizations (Greenwood et al. 2014). Relatively early, scholars in this research field started to pay attention to agency and processes of institutional change (DiMaggio 1988). Historical Institutionalism with its long-term perspective on the evolution of institutions, can supplement these insights.

Neo-institutional Theory can help to explain more gradual forms of change (condition 1) by taking into account the dynamic nature of institutional structures (condition 4). Recent approaches in Historical Institutionalism have focused on less abrupt forms of institutional change that, however, still have the potential to add up to more fundamental change over time (Streeck and Thelen 2005, Mahoney and Thelen 2010). This is based on the assumption that institutions are not seen as stable per se. It is instead assumed that institutional arrangements are never completely coherent, as they co-exist with other arrangements that have, for example, been established at another point in time. Institutions therefore always leave room for interpretation and in this way enable actors to test new behaviors inside existing structures (Streeck and Thelen 2005).

In a similar vein, approaches from Neo-institutional Organization Theory suppose that different actors perceive institutions differently (condition 2). This is based on the assumption that the behavior and perception of specific actor groups or institutional sectors (e.g., professions, nations and religions), is shaped by specific norms, values and cognitions, which are referred to as institutional logics (Thornton 2004, Thornton and Occasio 2008). While institutional logics generally stabilize behavior, they are also a mean to explain institutional change, as actors are often exposed to different institutional logics. As Thornton and Occasio (2008: 161) point out: *"Contact with institutional logics in multiple and different organizational fields increases the awareness of and experiences with contradictions in logics, which lowers constraints and embeddedness of actors and enables central actors to become institutional entrepreneurs".* In this concept, tensions and contradictions are thus seen as a resource for actors to induce change, for example by importing or exporting institutional logics from one field to the other, or pointing out contradictions to other actors (Thornton and Occasio 2008).

The concept of institutional logics is thus complimentary to approaches that focus on the micro-dynamics that drive institutional change (conditions 5 & 6), in particular the *institutional entrepreneurship* (Battilana 2006) *and work* (Lawrence and Suddaby 2006, Lawrence et al. 2011) approaches. While the concept of institutional entrepreneurship looks at individual actors that are usually in a powerful position and therefore able to change institutions, the institutional work approach is based on the assumption that institutional change is the result of the work of several actors that do not necessarily coordinate with each other (Lawrence and Suddaby 2006, Lawrence et al. 2011). As regional sustainability transitions are broad processes, which require changes in several societal regimes, distributed forms of institutional work are expected to be particularly relevant for these processes. The institutional work approach pays attention to the everyday work of actors, for example on how actors get in a position to engage in institutional work in the first place. It focuses on

the resources these actors need to conduct institutional work, including both more tangible ones (e.g., financial or political resources) as well as immaterial elements (e.g., narratives) that are needed to for instance de-legitimize a certain practice (Lawrence and Suddaby 2006, Lawrence et al. 2011). Institutional work can then also lead to the emergence of new institutional logics over time (Thornton and Occasio 2008).

To summarize, Neo-institutional Theory can fulfill most of the above-mentioned conditions of a regional approach to sustainability transitions. It does, however, not consider the spatial shaping of these processes (condition 3).

Evolutionary Economic Geography (EEG)

Another important basis for research in this dissertation are therefore insights and approaches from economic geography. In particular, evolutionary approaches (Boschma and Frenken 2006, Boschma and Martin 2010) with their focus on change enable better understanding of how geography shapes the institutional change processes described in the previous section. EGG does not simply explain differences in economic development through the existence of specific territorial institutions. As Boschma and Martin (2010) point out, EEG refuses such static analyses of institutions. From an evolutionary perspective, institutions cannot be treated as pre-given, but must be seen as dynamic, which according to Boschma and Martin (2010: 5): *"…refers to such features as emergence, convergence, divergence, and other patterns and trajectories that are rooted in real historical time."*

Hence, from an evolutionary perspective, institutions as such are not place-specific, but institutional dynamics. Institutions evolve in a path and place dependent way. Martin and Sunley (2006) point out that the concepts of path and place dependency are inherently related. A place produces a certain history; at the same time history leads to the development of a specific spatial structure over time. Place specificity is therefore the outcome of an evolutionary, contingent and irreversible process, while it also shapes the further development of this process (Martin and Sunley 2006).

Economic geographers have, moreover, also drawn on insights from Neo-institutional Theory (e.g., Strambach 2010, Grillitsch 2015, Evenhuis 2017). As outlined above, these approaches offer a more dynamic view on institutional settings and show that institutional changes can be evoked endogenously by actors on the micro-level, as well as by dynamics between different layers of institutional arrangements. In particular the concept of path plasticity (Strambach and Storz 2008, Strambach 2010, Strambach and Halkier 2013) can help to depict how the above-mentioned particularities (the relations between actors, the place-specific contexts and the multi-scalar character) shape institutional dynamics in regional sustainability transitions (condition 3). The concept of path plasticity considers how the proximity of actors within a region influences institutional dynamics (Strambach 2010). In addition, it also acknowledges that regional development paths can be shaped by path-interdependencies between several sub-paths in a region (Martin and Sunley 2006, Strambach and Halkier 2013). To explain the particularity of a regional development path, it is necessary to acknowledge that these sub-paths co-evolve in a path- and place-specific way over time (Martin and Sunley 2006). The path plasticity concept further draws attention to the multi-scalar character of institutional arrangements, and how this influences institutional change processes (Strambach 2010). Therefore, the concept can help to explain how the place-specific intersection of multiple institutional contexts (organizational, sectoral, spatial etc.) influences institutional dynamics at the regional level.

To conclude, all three research fields (Sustainability Transition Research, Neo-institutional Theory and EEG) contribute important insights for the analysis of micro-dynamics and institutional change in RTPS. Investigating the phenomenon of regional sustainability transitions with only one or two of these

approaches would always fall short of fulfilling at least one of the conditions outlined above. Sustainability Transitions Research provides a better understanding of the specificities of the object of study. Neo-institutional Theory helps to explain the core mechanisms behind agency and institutional change. EEG enables an understanding of how geography influences these mechanisms. Analyzing the interplay of processes on the micro- and the macro-level and their spatial shaping based on these three approaches will help to better understand the place-specificity and multiplicity (Hansen and Coenen 2015, Hodson et al. 2017) of regional sustainability transitions.

2.4 Contours of a methodological approach to analyze regional sustainability transitions

The previous chapter outlined several conditions that a regional approach to sustainability transitions has to fulfill. It showed that such an approach must:

- be able to capture more gradual change processes (condition 1)
- be sensitive to different perspectives on sustainability (condition 2)
- be place-sensitive in that it acknowledges the particular relationships between actors as well as the place-specific contexts and the multi-scalar character of regional transitions (condition 3)
- consider endogenous dynamics in regional paths (condition 4)
- pay attention to actors and micro-level processes (condition 5)
- focus on institutions and institutional dynamics (condition 6).

These conditions of the conceptual approach also provide a guideline for the development of the methodological approach. In the following, the six conditions will be used to specify of what a methodological approach to analyze regional sustainability transitions needs to be capable. Moreover, to what extent certain qualitative or quantitative approaches are able to fulfil these conditions will be discussed.

According to the first condition outlined above, the methodological approach must be able to capture gradual change processes in regional development paths. Therefore, a longitudinal approach is needed, as this is sensitive to smaller and less obvious changes and allows one to determine the extent of change in a path. Quantitative approaches, such as times series analyses or longitudinal networks analyses, allow one to determine the degree of change via indicators. Qualitative approaches are comparatively more sensitive to the characteristics of gradual changes. Using qualitative interviews or document analyses, different time phases in a regional path can be characterized and compared to each other to make gradual changes visible. Qualitative approaches might even be more sensitive to changes that quantitative indicators are not able to detect. The latter concerns in particular processes of change that take place on the micro-level and are not (yet) recognizable at the more aggregate level of a regional path.

Referring to the second condition, the approach needs to account for different perspectives on sustainability that co-exist in a regional context. Potential conflicts and tensions that result from such different perceptions, interpretations and opinions can only be understood through qualitative approaches. Qualitative interviews are particularly suited to comprehend subjective perceptions and interpretative patterns. In addition, group discussion could also be used in order to show how opinions are formed through social interactions and discourse analyses to depict the development of social interpretation frames.

The third condition requires the approach to be sensitive for place-specific regional context conditions and how these influence transition dynamics. The methodological approach must therefore be able to capture different place-specific aspects as well as how they affect regional sustainability transitions. In order to grasp this complex interaction, a triangulation of different qualitative approaches, for example interviews, document analyses and observations, seems indispensable. Mixed-method approaches that combine qualitative and quantitative methods (Creswell 2003) could be useful as well.

The fourth condition requires the methodological approach to pay attention to endogenous dynamics in regional paths. In doing so, the approach must be able to depict a regional path, that is, a sequence of events.[7] In order to reconstruct sequences of events, events need, first of all, to be defined and put into context. Furthermore, the origins of events need to be identified. Via the reconstructed sequence and the origin of events, it is possible to distinguish between endogenous and exogenous drivers of change. Only qualitative approaches are able to define and contextualize events. Document analyses, in particular, are useful to reconstruct longer sequences of events.

According to the fifth condition, the methodological approach must pay attention to micro-processes on the level of individual and collective actors. Hence, the approach has to be actor-centered and should be able to grasp the intentions, strategies, and actions of actors. It must also be able to determine how actors intentionally and unintentionally influence each other. Quantitative approaches, like agent-based modelling or social network analyses, can show how actors are related and influence each other. Yet, qualitative approaches, for example interviews, are better suited to uncover the intentions of relationships between actors and are able to account for the contextuality of micro-level interactions.

Referring to the sixth condition, the conceptual approach must pay attention to institutions and institutional dynamics at the system level of a regional path. The methodological approach therefore must be able to understand institutions and their change. Quantitative approaches can capture institutions and their change via proxies, while qualitative approaches can better determine the characteristics of institutional change and its sources.

Table 1 synthesizes the conditions of a conceptual and methodological approach to analyze sustainability transitions and the empirical approaches that are able to fulfill these conditions.

Table 1: Conditions of a conceptual and methodological approach to analyze regional sustainability transitions.

No.	The conceptual approach must be able to…	The methodological approach must be able to…	Empirical approach	Exemplary methods
1	conceptualize gradual change processes in regional paths.	capture changes within regional paths and the degree to which they change.	Both quantitative and qualitative approaches can fulfill this condition.	e.g., econometric analyses, document analyses, qualitative interviews

[7] Sequences of events are understood here, in line with Abbott (1995: 94), as „*an ordered list of elements*“. In the case of RTPS, the order is always temporal. The elements in a sequence can, but do not have to be connected to each other.

2	consider conflicting perceptions of sustainability in regional transitions.	account for different perspectives of actors, subjective perceptions and opinions.	Can only be fulfilled by qualitative approaches.	e.g., qualitative interviews, group discussions, discourse analyses
3	acknowledge place-specific regional context conditions.	capture the place-specific interaction of different processes.	Can mainly be fulfilled by triangulation of qualitative approaches.	e.g., case studies, mixed-method designs
4	consider endogenous forms of path renewal.	capture sequences of events and the origins of novelty therein.	Can only be fulfilled by qualitative approaches.	e.g., document analyses
5	pay attention to processes at the micro-level of regional paths.	grasp the intentions, strategies and actions of actors and how they influence each other.	Qualitative approaches are better suited to fulfil this condition	e.g., qualitative interviews, document analyses, group discussions
6	pay attention to institutions at the macro-level of regional paths.	capture regulative, normative and cognitive elements of institutions.	Both quantitative and qualitative approaches can fulfill this condition.	e.g., econometric analyses, document analyses, qualitative interviews

Most of the conditions described above necessitate a qualitative and not a quantitative approach. Therefore, the methodological basis of the conceptual approach on regional sustainability transitions must be qualitative. Yet, it is also apparent that several conditions require the capture of structural changes and regularities, which are difficult to determine with most qualitative approaches. Therefore, a qualitative approach that can cope with the complexity of regional sustainability transitions, but also enables a more structured analysis of the underlying processes, is needed. In addition, the table shows that no single method can fulfill all the conditions and that each method also has its strengths and weaknesses. A triangulation of different approaches is therefore required to analyze regional sustainability transitions. Such a procedure can provide a more comprehensive picture of the phenomenon, and be used to validate different findings against each other (Flick 2007). It is feasible to conduct this triangulation within the framework of a case study, as this methodological approach can describe individual processes, but is also able to capture the interplay of processes within their specific spatio-temporal context.

A case study approach to regional sustainability transitions

Case study research is suitable for analyzing complex social phenomena, which require an "*in-depth description"* of the object under study (Yin 2009: 4). Moreover, a case study approach is appropriate

when the boundaries between a phenomenon and its context are hard to define and when a large amount of potential influence variables needs to be accounted for (Yin 2009). Case studies are also appropriate when multiple levels of analysis (e.g., micro- and macro-level processes) have to be included (Yin 1984, Eisenhardt 1989). As has been discussed above, these preconditions all apply to the topic of regional sustainability transitions.

To handle this complexity, case studies use a triangulation of different data sources and methods, which can also comprise quantitative approaches (Yin 2009). In the following, three methods are presented, namely document analysis, qualitative interviews and participatory observation, that have been identified as suitable to analyze certain aspects of regional sustainability transitions in the previous section.

Document analysis refers to the review of documents in a systematic manner (Bowen 2009). Depending on the research question at hand, relevant documents can comprise personal documents (like e-mails, diaries, notes), documents related to meetings (such as agendas, protocols or announcements of meetings), administrative documents (like proposals, reports or strategy papers), formal studies that relate to the same research topic (such as master's theses or journal articles) and media contents (such as newspaper articles, press releases, or newsletters; Yin 2009). Document analyses are often used in combination with other methodological approaches (Bowen 2009, Yin 2009). The method has been found to be especially helpful for the following purposes: (1) to illuminate the context in which a phenomenon has been embedded, (2) to bring up relevant questions about the phenomenon (e.g., for subsequent interviews), (3) to supplement knowledge gained with other methods and determine specific details (e.g., exact dates or titles), (4) to detect changes over time by using documents that have been prepared specifically for this purpose (e.g., chronicles), by analyzing periodic documents (e.g., reports) or through tracking changes in different versions of a document, and (5) to validate findings that have been generated with other methods (Bowen 2009, Yin 2009). The strength of document analyses compared to other qualitative methods is that they usually yield relatively stable, unobtrusive, and exact results (Bowen 2009, Yin 2009). Document analysis is also comparatively efficient and cost-effective, while at the same time providing the broad coverage needed for comprehensive analysis of a phenomenon (Bowen 2009). However, the method also has its drawbacks. In addition to the difficulties to retrieve, access, and select relevant documents, disadvantages mainly result from the fact that documents have not been produced for the specific purpose of answering the research question at hand. It is therefore likely that documents lack sufficient information and that this has to be supplemented by other methods (Bowen 2009). Moreover, as Bowen (2009: 33) points out: "*It is necessary […] to determine the authenticity, credibility, accuracy, and representativeness of the selected documents*." When analyzing documents, the purpose and target group for which, and the intention with which these documents have been written must be considered (Yin 2009).

Qualitative interviews can provide specific insights into a topic that are not included in documents. They can also help to filter out unimportant aspects in the wealth of documents that exists on a topic. In particular, narrative interviews that aim at reconstructing social reality from the perspective of individual actors, are well suited to generate empirical material on the temporal unfolding of processes. As Küsters (2009) points out, narrative interviews can simultaneously be used to determine (1) how social reality presents itself from the perspective of an individual and (2) how the perspective of that individual is constituted. A precondition is that the interviewee has been involved in the process under study and has also paid it some attention (Küsters 2009). The main particularity of the narrative interview is that the interviewer only gives a stimulus at the beginning of the interview to trigger a relatively spontaneous narrative. The interview is thus characterized by a high volume of talking by the

interviewee. The interviewer only interrupts, if necessary, or poses further questions at the end of the narration. Narrative interviews are primarily used in biographical research but have also been applied to analyze the unfolding of innovation processes at the firm level (e.g., Butzin and Widmeier 2016). A regional transition process to sustainability is, however, thematically much broader than the biography of a person or a single innovation. Therefore, it will be of utmost importance that the stimulus at the beginning of the interview specifies precisely which aspects to focus on in the narration (e.g., certain events or milestones). As Butzin and Widmeier (2016: 225) phrase it, "*a straightforward 'narration corridor'*", with clear starting and end points, should be provided by the interviewer.

As the narrative interview produces a lot of data, a targeted and well-dosed application of the approach is necessary. Therefore, narrative interviews should be combined with problem-focused interviews (Witzel 2000), which are based on a more extensive interview guideline. Relying on the premise that theory can only be developed in an interplay of inductive and deductive procedures (Witzel 2000), problem-focused interviews comprise both narrative and more dialogical passages. In the latter, the researcher can guide the interview in a certain direction through previously developed questions (Witzel 2000). Therefore, narrative interviews are useful to establish an overview of the regional transition process, while more problem-focused interviews are needed to determine specific details in the process.

The quality of the material that is generated with qualitative interviews depends to a large extent on the choice of the interview partners. To reconstruct a regional transition process to sustainability, it is necessary to find interview partners who have a good overview of the processes, have been involved in the process for a long time, and who can be expected to have paid it a certain amount of attention. In this regard, Helfferich (2009) advises to define the group of potential interview partners as closely as possible and ensure a broad variation within that group when selecting the interview partners (Helferrich 2009). In terms of "*inner representativeness*" (Helferrich 2009: 173), the group of interview partners should include persons from different societal sectors in the region. Eisenhardt and Graebner further state that, "*….using numerous and highly knowledgeable informants who view the focal phenomena from diverse perspectives*" can also reduce biases, for example from "*impression management*" or "*retrospective sensemaking*" (Eisenhardt and Graebner 2007: 28).

Observations are frequently used in case study research to complement other qualitative methods (Weischer and Gehrau 2017). Observations provide a way to study social interactions directly and in a widely unbiased form. They can be differentiated into structured and unstructured, as well as participatory and non-participatory observations (among others; Gehrau 2013). For the analysis of regional sustainability transitions that stretch over decades, observations, which are confined to comparatively short sequences in time, can only make a minor contribution. Unstructured participatory observations, in which the researcher participates in events and interacts with other participants, can, however, be used (1) for explorative purposes, (2) to get access to interview partners and (3) to gather context knowledge, which can later be important for the interpretation of the results.

Visualization as a foundation for comparative research and theory-development

In most qualitative case studies, the results generated with different methodological approaches are integrated and presented in the form of a rich narrative. Although these dense descriptions are valuable in terms of exploring and illustrating the case, they usually do not make more general mechanisms visible (Geels 2011). In particular, geographical case studies have often been criticized for highlighting the idiosyncratic character of place-based processes, while generating little generalizable

knowledge about them (Hansen and Coenen 2015). The latter is, however, not a principle weakness of case study research. On the contrary, Eisenhardt and Graebner (2007: 25) call case study research "*one of the best (if not the best) of the bridges from rich qualitative evidence to mainstream deductive research. Its emphasis on developing constructs, measures, and testable theoretical propositions makes inductive case research consistent with the emphasis on testable theory within mainstream deductive research*." However, to draw more general theoretical conclusions from a case study, a rigorous procedure with regard to the overall design of the case study, the data collection, and the data analysis process is necessary (Yin 2009, Riege 2003, Gibbert et al. 2008). Yin (2009) proposes the following criteria for assessing the quality of a case study, which will be further elaborated on below: (1) construct validity, (2) internal validity, (3) external validity, and (4) reliability.

(1) Construct validity requires "*identifying correct operational measures for the concepts being studied*" (Yin 2009: 40). In the context of this thesis, this means that the main theoretical concepts (see Table 1), as well as their interlinkages, must be specified and translated into observable and measurable indicators. How can, for example, micro-dynamics and institutional change in regional transition paths to sustainability be investigated empirically? How can each of these concepts be measured and interpreted? How can linkages between these two concepts be made visible? The better the empirical measures fit the theoretical constructs, the higher the construct validity of the case study will be.

(2) Internal validity requires one "*to establish a causal relationship, whereby certain conditions are believed to lead to other conditions*" (Yin 2009: 40). In order to fulfill this criterion, the research must be designed in a way that it allows one to make causal interferences. Therefore, linkages between events in a regional transition path must be identified. By contextualizing these linkages, causalities can be determined, that is, that one or multiple events led to another event in the path at a later point in time. Ideally, these causal interferences should be verified by using different source of information.

(3) External validity requires "*defining the domain to which a study's findings can be generalized*" (Yin 2009: 40). This refers to analytical generalizations, which are the generalization of results to theory. They differ from statistical generalizations, which are the generalization of results to a larger universe (Yin 2009). Therefore, the theoretical domain to which the results apply needs to be specified. In the thesis at hand, the domain to which the results can be generalized are theories about regional sustainability transitions that comprise more gradual transitions in multiple sectoral domains. Ideally whether the conceptual approach has explanatory power for more than just one empirical case that matches this specification should be determined (Yin 2009).

(4) Reliability requires "*demonstrating that the operations of a study – such as the data collection procedures – can be repeated, with the same results*" (Yin 2009: 40). This criterion can be achieved through documenting the research procedure, for example in form of case study protocols and databases (Yin 2009).

To fulfill these quality criteria and the conditions of the conceptual approach, a **visualization** of the regional transition path to sustainability is highly conducive. Regional transition paths to sustainability rely on the interplay between several processes (see Table 1) within a specific spatio-temporal context. Only by reducing the complexity of these phenomena through visualization, the structures and underlying mechanisms of these processes can be identified and analyzed. In particular, the internal validity of a case study, which is often neglected in case study research (Gibbert et al. 2008), can be strengthened through visualization. Among others, the chain of evidence, that is how a researcher came to certain conclusions, can be made transparent. The latter is a precondition for validating the results by discussing findings with other researchers and with members of the study (also referred to as "*communicative validation*"; Flick 2007: 16-17).

In addition, the level of abstraction that is necessary to display the interplay of the above mentioned processes in a regional path is difficult to integrate into a rich narrative. Therefore, it makes sense to separate a more abstract analysis of the event sequence that constitutes a regional transition path to sustainability from a rich and illustrative description of the phenomenon. As Langley et al. (2013: 8) point out, in particular process-based research approaches profit from a combination of "…*rich narratives that enable the representation of nuance and ambiguity […] with more structured analytical approaches that favor the articulation and replication of more abstract theoretical ideas*."

3 Course of the dissertation

This section outlines the structure of the dissertation and gives a short summery of each chapter. Chapter 1-3 and Chapter 9 frame the research conducted in this dissertation. Chapter 1 introduced the reader to the topic, the aims and scope of the dissertation as well as the underlying research design. Chapter 2 presented the state of research on institutional change in regional sustainability transitions and identified the need for a comprehensive regional approach for the analysis of regional sustainability transitions. This chapter (Chapter 3) gives an overview of the course of the dissertation and the content of each chapter. The five chapters in between (Chapter 4-8) have been written in a cumulative way. Each paper (constituting one chapter) is guided by a specific research question and has been published in (or submitted to) an international peer-reviewed journal. Figure 5 shows how the individual chapters contribute to the three aims of the dissertation.

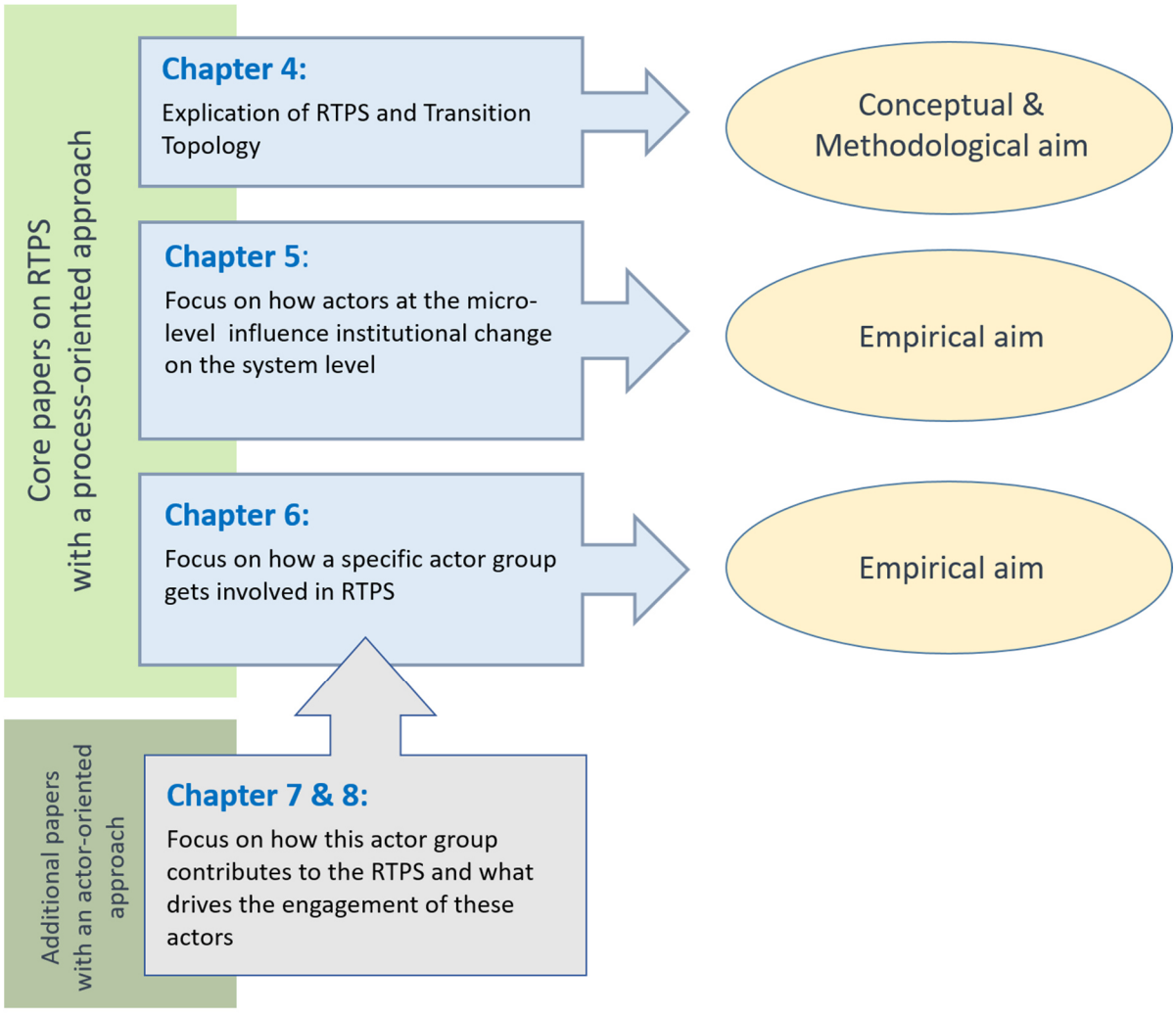

Figure 5: Contribution of the five chapters to the aims of the dissertation.

In the following, a short summary of each chapter is given. The five papers have been ordered in such a way that the reader can best follow the argument of this thesis. This order does, however, not display the actual course of research, which started with the empirical research presented in Chapter 5 and ended with suggesting the conceptual and methodological approaches presented in Chapter 4 (as

becomes apparent in the order of the papers). The course of research, following an abductive research approach, is described in more detail in Chapter 1.3 and 9.1.

Chapter 4 (paper 5), "*Transition topology: Capturing institutional dynamics in regional development paths to sustainability"*, outlines in detail the conceptual and methodological approaches that have been developed in the course of this thesis. The chapter starts by arguing that the MLP cannot sufficiently explain how more gradual and distributed changes add up to fundamental changes in a regional system over time. To enable a better understanding of the complex institutional dynamics in RTPS, the conceptual framework focuses on new organizational forms as enablers of both de-institutionalization and institutionalization processes. By elaborating the distinct impact of different types of new organizations on the interplay of stability and change in RTPS, a sound theoretical basis for the methodological approach of transition topology is created. The latter enables to reconstruct how micro-dynamics lead to changes at the system level of a path over time, by mapping institutional and different forms of organizational changes in their spatio-temporal context. The chapter outlines the methodological foundations of the transition topology and provides guidance on its practical application. It ends with an illustration of the potentials of the approach at the example of the transition topologies of the regions of Augsburg (Germany) and Linz (Austria).

Chapter 5 (paper 1), *"Micro-dynamics in regional transition paths to sustainability: Insights from the Augsburg region"*, focuses on how actors can impact institutional change towards sustainability in regional development paths. At the example of the Augsburg region in Southern Germany, the chapter analyzes (1) how actors use the plasticity of the regional path to induce institutional and organizational change, (2) how they overcome barriers in sustainable innovation processes caused by competing institutional logics, and (3) how incremental changes lead to more fundamental changes over the long run. Empirical findings are generated through qualitative interviews with key stakeholders in the region, document analyses and unstructured participatory observations. Based on the data gained, a transition topology is developed that maps the most important institutional and organizational changes in the Augsburg region, as well as their connections across different regional sub-systems over a time span of more than 30 years. The transition topology shows that RTPS do not originate in protected spaces. In the Augsburg case, actors used the interpretative flexibility given in existing institutional structures to initiate institutional and organizational changes within the path. Instead of distancing themselves from actors with different institutional logics, they established organizational proximity to these actors. The paper makes apparent that gradual institutional changes can also lead to more fundamental change in multiple regimes in a regional path over time.

Chapter 6 (paper 4) *"Developing Boundary-Spanning Capacity for Regional Sustainability Transitions: A Comparative Case Study of the Universities of Augsburg (Germany) and Linz (Austria)"*, focuses on how universities gets involved in RTPS. Several transition researchers have described universities as potential "change agents" for sustainability. The chapter however, starts from the premise that the participation of universities in RTPS is not a self-evident process. In order to adopt a developmental role in regional sustainability transitions, it is argued that universities need to develop a boundary-spanning capacity, which enables them to transcend disciplinary as well as sectoral boundaries. It is therefore investigated, (1) how boundary-spanning activities in the context of sustainability were initiated, (2) to what extent different drivers contributed to these activities, (3) how these boundary-spanning activities differ according to different drivers, and (4) what the latter means for the role of universities in sustainability transitions. The study is based on qualitative interviews and document analyses. Using the method of a transition topology, it is visualized how the universities of Augsburg and Linz developed relationships with actors in their surrounding regions over time. By comparing these two development paths, it becomes apparent that these processes are place-specific. The

analysis shows that a university's boundary-spanning capacity differs according to the actors involved and the central drivers of the process. The process in Augsburg, primarily bottom-up driven, was thematically quite broad and involved a range of actors. In Linz, the top-down initiated process was fragmented and more narrowly focused. It furthermore becomes apparent that actors within the region can be important drivers for a transition of the university.

Chapter 7 (paper 2), "*The role of Higher Education Institutions [HEIs] in Regional Transition Paths towards Sustainability: the case of Linz (Austria)",* argues that HEIs have the potential to initiate institutional and organizational change towards sustainability in a regional path. It is suggested that they can do this via the channels of teaching, research and outreach. The paper therefore asks (1) to what extent HEIs contribute to regional sustainability transitions and (2) how their role is influenced by institutional drivers on the organizational level (e.g., the HEIs' self-perception or mission statement) as well as field-level (e.g., HEIs legislation or funding programs). To analyze the influence of these drivers, the roles of the five HEIs located in the city of Linz and the region of Upper Austria are studied. The case study is based on in-depth expert interviews and a comprehensive document analysis. The investigation reveals that regulative drivers at the field-level, and normative as well as cognitive drivers at the organizational-level, affect HEIs' contribution to RTPS. Sustainability-related teaching activities are highly dependent on the bottom-up motivation of individual researchers and the support of the university management. With regard to research activities, field-level drivers such as national and international funding programs as well as regional allocation of contract research, turned out to play a more important role. It became apparent, however, that there is no contribution of HEIs as a whole to regional sustainability transitions. Their role is largely dependent on individual highly engaged "forerunners" as well as leadership from the university management.

Chapter 8 (paper 3), "*The Raise of Publications on Sustainability: A Case Study in Germany*", zooms in even further into the role of HEIs in sustainability transitions. Drawing on a broad range of conceptual approaches, potential motives of individual researchers to conduct sustainability-related research are outlined. Empirically, the study is based on the observation that the number of scientific publications containing the words "sustainability" or "sustainable" has increased tremendously over the last years in German HEIs. As the origins of these publications vary strongly across German regions, the aim of the study is to find out why sustainability research occurs strongly in some places and not in others. In a mixed-method approach, regression analyses are complemented by semi-standardized interviews with scientists from different disciplines. In addition to intrinsic motives, four potential external influences on the choice of a scientist's research topic are considered: (1) the interaction with the regional economy, (2) the attitude of the regional population, (3) path dependence in science as well as (4) the organizational circumstances provided by the university. The results show that the decision to conduct research on sustainability is in most cases based on a private intrinsic motivation of the researcher. The latter is, however, also influenced by the attitude towards sustainability in the broader public and in the researchers' regional surrounding. Compared to the other four chapters in the dissertation, this chapter approaches the topic from a different theoretical and methodological angle. Hence, the chapter did not contribute to the development of the RTPS approach and the transition topology. It shows, however, how these approaches can be complemented by variable-centered research, as well as research focusing on the level of individual actors.

Additional information on the methodological procedure underlying the case studies in Augsburg (Chapters 4, 5 & 6), Linz (Chapters 6 & 7) and the mixed-method study in German HEIs (Chapter 8) that have not been included in the published versions of the chapters (e.g. information on the interview partners, interview guidelines) can be found in Appendix 1. All other supplementary material is referenced in the respective chapters.

4 Transition topology: Capturing institutional dynamics in regional development paths to sustainability

(This paper has been submitted to Research Policy, Elsevier B.V..)

Abstract

A key challenge in sustainability transitions research is to better understand the huge variety and spatial unevenness of transitions paths. Institutions and institutional change have been identified as critical issues, as regional institutional settings significantly influence the pace and scope of sustainability transitions. However, the complex institutional dynamics underpinning 'Regional Transition Paths to Sustainability' (RTPS) are not well understood. Underexplored is in particular the link between short time gradual changes on the micro-level and long-term transformative change on the system level.

In order to add to a more profound understanding of these processes, a focus on organizational change is valuable. The basic argument made in this article is that the emergence of new temporary and more permanent forms of organization has the potential to enable de-institutionalization and new institutionalization processes simultaneously. As we will show, new organizational forms also serve as a means to make institutional dynamics visible.

The contribution of this paper is thus twofold: By combining insights from sustainability transition theory, evolutionary economic geography and neo-institutional organization theory, we develop an original conceptual framework. By developing and applying the methodological approach of a 'transition topology', the potential of this framework for comparative research on actors and processes in different regional transition path to sustainability is revealed.

4.1 Introduction

Recently, the institutional perspective on sustainability transitions has gained in importance. Various theoretical and empirical contributions have emphasized institutions and institutional change as a critical issue (e.g., Geels 2004, Brown et al. 2013, Wirth et al. 2013, Fünfschilling and Truffer 2014, Smink et al. 2015, Raven et al. 2019). However, although institutionalization and de-institutionalization have been identified as central processes driving sustainability transitions (Fünfschilling and Truffer 2014), the mechanisms of these complex processes and their interconnections over time are not well understood. What remains underexplored in particular is the link between short time changes on the micro-level and long-term transformative change on the system level (Hodson et al. 2017, Ehnert et al. 2018a). Many recent studies have underlined the important role of agency, in particular the contributions of institutional entrepreneurship and institutional work in changes made at the micro-level (Brown et al. 2013, Fischer and Newig 2016, Loorbach et al. 2017). Nevertheless, whether (and how) these micro-processes are stabilized and instantiate gradual changes in meso- and macro-structures is not considered in depth (Ehnert et al. 2018a, Hodson et al. 2017). Much research on sustainability transitions views institutional change and stability from a perspective called 'dualism' (Jackson 1999, Sydow 2018) where they are considered separate elements and even opposites – thereby underestimating the complexity of institutional dynamics in space-time paths.

This article contributes to this gap by focusing on two intertwined research questions:

- *"How do institutional trajectories which promote more sustainable action patterns and practices evolve in regional development paths over time?"*
- *"How can hidden institutional dynamics be captured in regional transition paths to sustainability?"*

From research on the geography of sustainability transitions, it is obvious that regional institutional settings significantly influence the pace and scope of sustainability transitions (e.g., Coenen et al. 2010 & 2012, Binz et al. 2012, Späth and Rohracher 2010 & 2012, Hansen and Coenen 2015, Hodson et al. 2017). In order to better understand the spatial shaping and the multiplicity of transition pathways, investigating in the transformation of regional systems towards sustainability is a key research challenge (Hansen and Coenen 2015, Hodson et al. 2017). Regional systems comprise multiple interdependent sectoral systems, which have developed in a place and path dependent way over time. These interdependencies lead to complex inter-system dynamics that tend to nudge rather gradual transformation processes. The institutional dynamics and more gradual change processes underlying 'Regional Transition Paths to Sustainability' (RTPS) (Strambach and Pflitsch 2018) can only insufficiently be explained with the niche-regime dichotomy that is usually applied in sustainability transitions research (Späth and Rohracher 2015, Geels et al. 2016). Gradual and distributed institutional changes that add up to more fundamental change only over time are especially hard to track and have largely remained a 'black-box' in transitions research.

Analyzing these complex processes, it is essential to unveil their temporality and to overcome the dualism understanding of stability and change as mutually exclusive, and not as intertwined elements that constitute each other. For the latter, the alternative term 'duality' is derived from Gidden's (1984) structuration theory, conceptualizing the duality of structure and agency.

In order to add to a more profound understanding of the way in which institutional change and stability are interrelated in transition pathways, a focus on organizational change is valuable. The basic argument made in this article is that the emergence of new temporary and more permanent forms of organization has the potential to enable de-institutionalization and new institutionalization processes simultaneously. As we will show, the investigation into the development of new organizational forms

(called “organizational archetypes”; Scott 2014) can also serve as a means to make visible the institutional dynamics in Regional Transition Paths to Sustainability (RTPS). To capture these processes, we have developed the methodological approach of a ‘transition topology’ – a directed graph that maps the most important organizational and institutional changes across different fields as well as spatial and social scales over time.

The contribution of this paper is twofold: By combining insights from sustainability transitions theory, evolutionary and institutional economic geography and neo-institutional organization theory, we intend to make a conceptual contribution to the geographical and the ‘socio-institutional’ perspectives on sustainability transitions (Coenen et al., 2012; Fünfschilling and Truffer 2014, Loorbach et al. 2017, Murphy 2015, Köhler et al. 2019). By developing and applying the methodological approach of a ‘transition topology’ (Strambach and Pflitsch 2018) empirically, the potential of this approach for comparative research on actors and processes in different Regional Transition Paths to Sustainability (RTPS) is revealed.

The article is organized in five sections: In Section two, we shed light on the interplay of institutional change and stability in RTPS by combining insights from sustainability transitions research and Evolutionary Economic Geography (EEG) on path dynamics. To better understand the place-specific character and the multiplicity of transition pathways, we take into account linked spatial and social scales. Grounded in new institutionalism and organizational theories, we outline how organizational change is an enabler of institutional dynamics in transition paths. The third section introduces the methodological approach of a transition topology. This is followed by an illustration of its application possibilities and potentials in Section four. We conclude by discussing the valued-added of the approach and sketching an outline for further research.

4.2 Institutional dynamics in regional transition paths to sustainability

In order to place emphasis on the distinct characteristics of regional transition processes and their underpinning institutional dynamics, we use the term Regional Transition Paths to Sustainability (RTPS) in differentiation to socio-technical transition paths to sustainability. For a long time, the research streams on sustainability transitions and EEG have evolved separately, although they share the evolutionary perspective and both use the concept of path dependency to explain processes of stability and change at the level of systems – of socio-technical and regional systems, respectively. Moreover, scholars from both fields have come to acknowledge the need for deeper investigation into forms of gradual change processes underlying more fundamental change over time. Asides from these commonalities, research on transitions has a normative starting point and addresses the grand societal challenges related to sustainability (Loorbach et al. 2017) whereas studies in economic geography and EEG have a prevailing focus on innovation and regional capabilities for developing new growth paths. Based on their respective perspectives both research streams conceptualize processes and mechanisms of stability and change in different ways. Evolutionary institutional economic geography has identified distinct mechanisms that are connected to spatialities and relationalities and that can potentially complement and refine niche-regime dynamics and the understanding of the multiplicity of transition pathways. In recent years however, both fields have entered into a stronger conceptual dialogue triggered by the emerging geography of sustainability transitions (Hansen and Coenen 2015, Boschma et al. 2017, Hodson et al. 2017).

4.2.1 Stability and change in socio-technical transition paths to sustainability

A core characteristic of the different approaches in sustainability transition research is the dualism understanding of stability and change (Geels 2004, Köhler et al. 2019). One of the most prominent approaches in this research field is the Multi-Level Perspective (MLP) introduced by Frank Geels. Within the MLP, change is allocated primarily at the niche and stability at the regime level. The underlying modeled dualism of these processes is pronounced for example in the separation of the micro- and macro-level analysis. More attention is currently paid to institutional work mechanisms and the stabilization processes at the niche level as well as on the incoherencies in regime structures as starting points for system transformation. This research, analyzing sustainability transitions from an institutional perspective (Loorbach et al. 2017, Raven et al. 2016), has made apparent that change processes can start at the niche as well as at the regime level.

From disruptive to more gradual forms of change

Transitions to sustainability are defined as large-scale changes in societal systems that emerge usually over decades (Geels 2010, Loorbach et al. 2017). The niche-regime-landscape dynamic s considered the main mechanism for the emergence of radical novelty at the system level (Geels 2002 & 2004). By focussing on path dependency of socio-technical regimes, transition research highlights primarily the stabilizing forces that contribute to the lock-in of unsustainable production and consumption patterns. Particularly emphasized is the path dependent co-evolution of institutions and technologies over time, leading to a persistence and rigidity of socio-technical regimes (Geels 2010). The concept of regime, understood as the dominant and stable configuration of a societal system, is the most central notion in transition studies (Loorbach et al. 2017). Its relative stability is explained by using the concept of a dominant institutional logic underpinning the strong alignment of practices, technologies and materiality over a long period of time. Here, in order to succeed in system change, radical and disruptive change is required (Geels 2002 & 2004). This change is located in niches, which are defined as protected spaces where actors are spared from prevalent institutional settings and can experiment with new technologies and social practices (Geels 2004). Initially, it was suggested that when developments at the landscape-level put pressure on the regime, niches are able to break through and replace the regime (Geels 2004, Markard and Truffer 2008). Thus, in order to bring about disruptive changes at the regime level, external sources of change played an essential role.
However, over time a more differentiated conceptualization of transition dynamics has occurred within the perspective of the MLP. Geels and Shot (2007) distinguished four different types of transition paths by taking into account the timing of changes at the niche and landscape levels and their (cooperative or competitive) relationship. By recognizing the resulting dynamics at the regime level, they identified the substitution, transformation, reorientation and reconfiguration path (Geels and Shot 2007, Geels et al. 2016). In particular, the reconfiguration path acknowledges less disruptive forms of change within socio-technical systems that nevertheless lead to more fundamental changes over time. Despite these advancements, the institutional mechanisms leading to these more gradual forms of change remained a largely open issue.

Advancements from a socio-institutional perspective

Institutions are a constitutive element of socio-technical regimes and thus have been a core component of the MLP from the beginning (Raven et al. 2016). Only recently, however, transition

scholars started to draw more extensively on institutional theories to better understand the complex institutional dynamics underlying sustainability transitions (e.g., Brown et al. 2013, Smink et al. 2015, Fünfschilling and Truffer 2014, Avelino and Wittmayer 2016, Geels et al. 2016, Jolly and Raven 2015 & 2016, Lockwood 2016, Raven et al. 2019). In this context, Geels, too, emphasizes shortcomings of the analytical focus on 'singular disruption' in the MLP (Geels et al. 2016, Geels 2018). Addressing system reconfiguration, he points out the necessity to pay more attention to other kinds of change mechanisms, which may in effect require some reconceptualization of the MLP.[8] To understand processes of system reconfiguration, he refers conceptually to historical institutionalism and the modes of gradual changes identified by Thelen (2002). In line with Thelen (2002), Geels (2018) points out that the modes of institutional drift, conversion, exhaustion, displacement, and layering have the potential to contribute to cumulative transformative change at the system level (Mahony and Thelen 2010).

In order to explain how opportunities for change develop at the regime level, other authors (e.g., Smith and Raven 2012, Brown et al. 2013, Fünfschilling and Truffer 2014, Binz et al. 2016, Jolly and Raven 2015 & 2016, Lockwood 2016, Markard et al. 2016) have recently started to draw on approaches from neo-institutional organization theory, such as institutional entrepreneurship, institutional work and the institutional logics approach (Battilana 2006, Lawrence and Suddaby 2006, Thornton and Occasio 2008). In order to focus more explicitly on the interplay of actors and institutions within system reconfiguration, Smith and Raven (2012), for example, highlight the need for niche actors to also stabilize institutional changes. After a phase of shielding and nurturing innovations in niches, there is a necessity to empower these innovations. Therefore, niche actors need to change deliberately the existing selection environment by conducting institutional work outside the protection of the niche. Complementary to this, Fünfschilling and Truffer (2014) show that institutional work that is not protected from existing structures can indeed be successful. Based on the institutional logics approach (Thornton and Occasio 2008), they argue that the regime also provides opportunities for change. From their perspective, empirical research has modelled socio-technical regimes as too monolithic and rigid (see also Ingram, 2015). In fact, the societal regimes that constitute a socio-technical regime might potentially develop in different directions or at a differing pace, leading to contradictions and tensions in the coherence of the regime. In this way, new competing field logics can emerge in the regime over time, for example when a specific sector logic becomes more dominant.[9] It is argued that different actors use these alternative logics for their purposes (i.e. maintain the status quo or induce change) (Fünfschilling and Truffer 2014, Geels 2018). These insights help to explain how more gradual changes in socio-technical regimes, such as layering, drift, conversion, exhaustion or displacement, come into being and how they have the potential to contribute to cumulative transformative change over time. Under which conditions these different forms of institutional change take place and, how they lead to system reconfiguration over time remains, however, in large parts an open question. Whether the purposive efforts at the micro-level are successful in changing institutions, have no effect on them, or have unintended outcomes, is often neglected.

[8] In particular, for addressing 'whole system' reconfiguration, which involves the interaction of multiple innovations and regimes, Geels (2018) considers necessary to broaden the MLP's focus on singular disruption.

[9] The potential for incoherencies in regimes has already been mentioned by Geels (2004), but the issue has somehow gotten "lost" in subsequent MLP-based empirical research.

4.2.2 Stability and change in regional transition paths to sustainability

The geography of sustainability transitions has become a major topic in sustainability transitions research in recent years (Loorbach et al. 2017). In this line of research, studies often combine the MLP with insights from urban studies and economic geography. These studies have highlighted several particularities that characterize sustainability transitions at the urban and regional level. The niche-regime dichotomy of the MLP can, however, only insufficiently capture the complex dynamics underpinning sustainability transitions at the regional level (Rohracher and Späth 2014, Hansen and Coenen 2015). Particularly, the ways in which short term changes at the micro-level lead to the reconfiguration of a system over time and how these processes are shaped by the spatio-temporal contexts in which they take place cannot fully be explained by the MLP. We therefore refer to recent approaches from evolutionary and institutional economic geography that focus on more gradual forms of change underlying fundamental changes within regional paths (Evenhuis 2017, Grillitsch and Sotarauta 2018, Grillitisch and Trippl 2016, Miörner and Trippl 2017, Wink et al. 2017, Zukauskaite et al. 2017). In particular, the concept of path plasticity can enhance the understanding of the interplay between stability and change and its spatial shaping (Strambach 2010, Strambach and Halkier 2013).

Particularities of sustainability transitions at the regional level

For long time, sustainability transition research has focused on transitions at the national level. However, with the emerging geographical perspective the subnational level and the particular local dynamics characterizing transition processes in cities and regions have received increasing attention. In this line of research, several authors have found interactions between heterogeneous actors in the context of sustainability transitions to be fostered by spatial proximity (Coenen et al. 2010, Späth and Rohracher 2010 & 2012, Dewald und Truffer 2012, Mattes et al. 2015). At the same time, it has been shown that conflicting perspectives, due to their manifestation in concrete projects, are more likely to become visible at the regional level (Shove and Walker 2007, Coutard and Rutherford 2010, Hodson and Marvin 2012, Späth and Rohracher 2015, Fastenrath and Braun 2018). The diversity of perspectives and interests is further increased by the embeddedness of regions in larger multi-scalar transition processes, whereby actor networks are spread across different spatial scales (Raven et al. 2012, Coenen et al. 2012, Truffer and Coenen 2012). Several authors have also argued that interdependencies between regimes are particularly pronounced at the regional level (Wolfram and Frantzeskaki 2016, Frantzeskaki et al. 2017a, Fünfschlilling 2017, Strambach and Pflitsch 2018). Such interdependencies can be the result of input-output relationships or structural couplings between different regimes, potentially leading to coupled transformation dynamics (Raven 2006, Raven and Verbong 2007, Konrad et al. 2008).

In addition to the particularities that distinguish sustainability transitions on the regional scale, the literature has highlighted the place-specific character of sustainability transitions. Regional transition processes have been found to be affected by the region-specific formal and informal institutional environment that has developed in a path dependent and co-evolutionary way along with the region's technological and industrial specialization, its natural-resource endowment as well as the proximity to relevant consumers and market formation processes (Hansen and Coenen 2015). Therefore, transition scholars have pointed out that regional sustainability transitions develop in an idiosyncratic way (Shove and Walker 2007, Coutard and Rutherford 2010, Hodson and Marvin 2012, Späth and Rohracher 2015, Affolderbach and Schulz 2016, Gibbs and O'Neill 2017).

Path plasticity and multiplicity - the interplay of stability and change

The substantial body of work from the geographical perspective has contributed to uncovering the huge variety and spatial unevenness of sustainability transitions, and has led to the recognition that one of the challenges for future research is to better understand this multiplicity. Scholars with a focus on socio-technical transitions point out that the MLP requires reconceptualizing to address both transitions in infrastructure systems as well as transitions in urban forms (Hodson et al. 2017). In order to integrate the multiple manifestations of transitions in the MLP, a preliminary framework called 'contextual reconfiguration of urban sustainability transitions' has been developed (Hodson et al. 2017).

Scholars from the geography of sustainability transitions also highlight the undertheorized sources of spatial differences in transition dynamics. Seeking to better understand the place-specificity of transition processes, the unexploited potentials of theoretical advancements made in evolutionary and institutional economic geography are emphasized (Hansen and Coenen 2015). In order to enhance the more generalizable knowledge on the geography of sustainability transitions, an approach is needed that can explore the duality of institutional change and stability in space-time paths. In this context, scholars in EEG have recently started to investigate into a better understanding of path dependency as a dynamic process caused by regionally endogenous factors interacting with exogenous forces simultaneously (Asheim et al. 2017, Evenhuis 2017, Grillitsch et al. 2018, Martin 2010). As institutional mechanisms in particular stabilize regional paths over time, this research has started to address more explicitly the plasticity of well-established institutional settings and institutional dynamics within paths. By exploring those mechanisms at the macro- and micro-level that enable gradual cumulative institutional changes, the path plasticity approach focuses on the interrelationship of stability and change (Butzin and Rehfeld 2013, Halkier and Thelsken 2013, Strambach and Halkier 2013, Strambach and Klement 2013, Vissers and Dankbaar 2013, Notteboom et al. 2013, Evenhuis 2017, Wink et al. 2017).

By identifying sources of plasticity at the macro-level, the path plasticity concept refers to institutional complementarity and coherence (Casper et al. 2005, Campbell 2011), which have been recognized as essential mechanisms for providing stability of place-specific regional paths. Institutional complementarity links together different institutions situated at distinct spatial scales and modes of organization into an architecture where institutions become more efficient through their interaction with and reinforcement of each other. In this way, institutional complementarity creates coherence, generates disincentives to radial change and contributes to the reproduction and maintenance of their spatial shaping. What is rarely taken into account, however, is that the mechanism of institutional complementarity plays an ambiguous role, in that it feeds into the plasticity of paths at the same time and may provide dynamics for institutional change (Strambach 2010, Strambach and Halkier 2013). Place-specific complementary institutional settings are not static compositions and the change of particular institutions within such configurations does not necessarily lead to destabilization of the coherence of a whole architecture. Conversely, institutional change in one sphere can increase pressure and have a snowball effect on complementary institutions, leading them to change gradually. Moreover, related to institutional hierarchy, change at a lower level has the potential to contribute to institutional change at higher levels.

Transferring these insights to regional sustainability transitions, it can be assumed that complementarities between different regimes within a region stabilize the coherence of the whole regional institutional architecture. However, these complementarities or institutional interdependencies can also induce a dynamic of change across multiple-regimes. They can lead to

incoherencies in the regional system and thus open up opportunities for actors at the micro-level to induce change (Strambach and Pflitsch 2018).
At the micro-level, institutional ambiguity is an important source of plasticity, considering that a scope of interpretative flexibility in their meaning is a permanent feature even where rules are formalized (Mahoney and Thelen 2010). The action-guiding function of institutions are dependent on their assessment by the relevant actors. Particularly cultural and cognitive components of institutions provide scope for divergent perceptions among various agents (Powell and DiMaggio 1991, Scott 2014).
In summary, emphasizing the duality of institutional change and stability, unlike dualism, appears paradoxical at first, however it allows for exploration and investigation into the complex institutional dynamics from a processual point of view. It has the advantage of envisaging a thoroughgoing interdependence of these conceptually distinct elements (Jackson 1999) and may, thus, be useful for disentangling the spatial variations in socio-technical transitions.

4.2.3 Organizational change and institutional dynamics in RTPS

In this section, we will elaborate on our main argument that a conceptual approach with a procedural view focusing on the emergence and the evolution of new organizational forms in spatio-temporal contexts can contribute to a deeper understanding of institutional dynamics and the multiplicity of RTPS. Based on new institutionalism of organization theory and insights from both EEG and sustainability transitions research we will explicate how the unfolding of new organizational archetypes (Scott 2014) has the potential to enable stability and change in RTPS simultaneously.
Although the central role of agency in institutional entrepreneurship and institutional work is commonly highlighted (Geels 2004, Boschma et al. 2017, Sotarauta 2017), institutionalization processes, understood as those actions through which social structures produce and reproduce obligations and constraints (Tolbert and Zucker 1996: 185), are seldom the focal point of attention. Yet, new social practices in sustainability transitions require being institutionalized in order to produce legitimacy and to establish a higher level of structuration (Giddens 1984). By framing problems differently and providing new solutions, institutional entrepreneurs play a key role in identifying the plasticity of prevailing institutional arrangements. However, actions of institutional entrepreneurs alone are not sufficient for structuring new institutional fields that promote more sustainable action patterns in RTPS over time. In order to change unsustainable practices and the existing institutionalized social structures that govern the entrenched behavior patterns, collective resources have to be mobilized, other actors convinced and a common understanding of the appropriateness and values of the new social practices established. To date, related to institutional dynamics, there is a lot more knowledge on self-reinforcing mechanisms stabilizing existing institutional settings than on the early processes of institutionalization and their spatial shaping. Not fully explored are the ways in which new meanings and innovative framings of problems evolve, gain legitimacy (Suchman 1995, Deephouse and Suchman 2008), and are amplified and stabilized in such a form that these micro-processes instantiate gradual changes of meso- and macro-structures at later points in time.
We argue that the emergence of new organizational forms (Scott 2014) has the potential to enable both stability and change in institutionalization processes. In order to identify the relationship between organizational change and institutional dynamics in RPTS, we differentiate organizations as ‘the players’ and institutions as ‘the rules’ of the game (North, 1990) comprising regulative, normative and

cultural-cognitive elements (Scott 2014).[10] Beside the broad agreement that both formal and informal institutions constitute organizations, the goal-oriented nature of organizations is a distinct difference between them and institutions (Scott 2014). Organizations are purposefully created to achieve specific goals through the consciously regulated coordination of the members' actions based on routines and the use of tangible and intangible resources. Organizations as entities are embedded in institutional environments, causing a need to find legitimacy for their actions (Suchmann 1995). Based on this key perspective of organizational institutionalism and in line with Greenwood and Suddaby (2006: 30), we define a new organizational form as "*an archetypal configuration of structures and practices that give coherence by underlying values regarded as appropriate within an institutional context*." A focus on transience and a limited expected duration of organizational forms are valuable since their distinct impact on the interrelationship of institutional change and stability can be assumed to be a natural consequence. We propose a theoretically founded differentiation between temporary and more permanent forms of organizing.

Temporary organizational forms

Scholars in transition research have recognized that temporary organizing plays a critical role in sustainability transitions (Köhler et al. 2019). The organizing of transition arenas, urban living labs as well as forms of experimental spaces for niche developments have been extensively explored (see Loorbach 2007, Torrens 2018). It is argued that such forms of temporary organization enable the coming together of actors with different perspectives over a limited period of time to develop radically new solutions whilst being protected from existing structures.

Research in economic geography highlights somewhat different mechanisms at work in temporary spaces and events by focusing on different forms of proximities and their reciprocal conditioning in the knowledge dynamics that underpin innovation. For one, trust-building is considered an important precondition for the exchange of distance-sensitive tacit and symbolic knowledge between actors and is promoted through co-presence and face-to-face interactions (Mattes 2012). Temporary organizational forms offer opportunities for the de- and realignment of normative and cultural-cognitive elements of institutions in particular, by giving participants the chance to get to know actors with different institutional logics. In this context, the intersection and combination of geographical and relational proximities (Boschma 2005, Gertler 2010, Ibert 2010) support complex communication and learning processes. Scholars in economic geography have demonstrated that in actor constellations with a high degree of cognitive diversity and with a minor degree of institutional overlap, temporary spaces facilitate the exploration of knowledge complementarities, the allocation of meanings and of collective sense-making (Ibert 2010, Strambach and Klement 2013). Consequently, these insights underline the fact that transient organizational forms of limited duration promote non-routined and creative behaviour (Eksted et al. 1999).

Additionally, the approach of field configuring events in organizational studies, as recently transferred to economic geography research, points out that temporary events have the potential to configure institutional fields (Lange et. al 2014, Henn and Bathelt 2015), as they can act as catalysts of institutional and evolutionary change (Schüssler 2013, Suwala and Micek 2018). However, very little is known about the specific conditions that allow such change to occur over time, as only few studies

[10] Neither institutional approaches nor organizational institutionalism constitute unified paradigms. The debates cannot be depicted at length here. For detailed discussions in economic geography on organizations and institutions see Gertler 2010, Bathelt and Glückler 2003 and Zukauskaite et al. 2017.

have connected field-configuring events with new path creation (Sydow and Koll 2017, Suwala and Micek 2018). Research in economic geography has provided significant insights into how organizational forms of limited duration are spatially shaped and inextricably interwoven with their enduring environment (Grabher 2004, Torrens 2018). The accumulation of temporary unique events anchored in place specific institutional settings – and their temporal and sequential unfolding in particular – can result in path dependent processes, thereby contributing to further structuration and stabilization of new practices.

New organizational networks

Network forms of organization are placed between markets and hierarchies (Coase 1937, Wiliamson 1985) and are considered a distinct mode in coordinating interactions and transactions while comprising elements of both. Economic exchange is always embedded in particular social contexts (Granovetter 1985), however, these forms are more dependent on social relationships, mutual interests and reputation and less guided by formal structures of authority (Powell 1990). Even though there is a wide range of network forms, their relationships have specific characteristics in common. As a stylized form of organization, the mutual orientation of the individual or collective members engaged in reciprocal, beneficial actions is highlighted and grounded in the expected gains of pooling resources together and exploring complementarities (Powell 1990).

We argue that the establishment of new organizational networks may also promote dynamic movement within prevalent institutional logics, particularly by forming structural overlaps across systems (Thornton and Ocasio 2008). In such forms of organization with loose coupling, the choices of participating actors remain largely independent. However, since they have overlapping interests, they tend to temporarily collaborate and coordinate their activities. In this way, actors are exposed to different norms and cognitive framings and experience competing or conflicting logics. When grounded in organizational learning processes, networks enable the translation and adaptation of new social practices between organizations operating in different fields and on different spatial scales.

Research in economic geography and innovation studies has provided substantial insight not only into the pivotal role of networks as mechanisms that drive innovation and new path development but also their intertwined spatialities and relationalities. In recent years, scholars challenged the prevalent local-global dichotomy by demonstrating the increasing multi-scalarity of network across sectors and geographical scales during processes of knowledge combination and innovation (Crevoisier and Jeannerat 2009, Asheim et al. 2011). Based on these findings, the formation of organizational networks has the potential to foster institutional dynamics such as the translation of institutions across social and spatial scales and bricolage – the rearrangement or recombination of institutional principles and practices in new and creative ways (Campbell 2011). Moreover, out of loosely coupled networks more permanent forms, such as formal organizations, can emerge at a later point in time, contributing to the stabilization of new practices and their further institutionalization (Strambach and Klement 2013).

New formal organizational entities

The important role of formal organizations and particularly the essential functions of intermediaries in transformation processes have already been pointed out in the research on sustainability transitions and innovation systems (Howells 2006, Hodson and Marvin 2012). Nevertheless, a processual and temporal perspective on interactions between multiple levels and across organizations and contexts is rare – but a pertinent issue for exploring institutional dynamics nonetheless. This gap has also become

evident in the findings of a recent systematic review of the studies of intermediary organizations in transition contexts. Kivimaa et. al (2018) demonstrate that there is a vast variety of intermediary actors that are facilitating transitions or that take over such a mediating role in the process of socio-technical change. These ecologies of intermediaries condition the ways in which knowledge is translated and learning takes place. The reviewed studies, however, neglect to clarify to which processes and between which elements intermediaries are crucial, and how their roles within the ecology of intermediaries change over the course of a transition (Kivimaa et al. 2018). Furthermore, how these ecologies of intermediaries fulfil roles in the crossing and connecting of geographical and administrative scales is hinted at as an important future research avenue (Kivimaa et al. 2018).

To grasp the complex institutional dynamics in RTPS, the focus on a single organizational population such as intermediaries is, in our view, too limited. In line with Lawrence and Suddaby (2013), we argue that a narrow concentration only on actions that purposefully aim at affecting institutions inhibits the recognition of other practical effects of institutional work. Kivimaa et al. (2018) for example, have figured out that many important intermediary functions in transitions have been performed by emerging rather than specifically established intermediaries. Thus, we propose an alternative approach to exploring the emergence of new organizational archetypes that span institutional boundaries by incorporating hybrid logics.

Organizations as collective actors manifest the institutional logics of their enduring environment. They may contribute to the stabilization of dominant institutional logics or have an interest in altering the place specific institutional contexts in order to promote their own specific purposes (Zukauskaite et al. 2017). However, when organizations challenge established institutionalized action patterns with new practices and the creation of competing or contradicting logics, they have to find a certain degree of legitimacy for their actions in their environment. Consequently, they have to combine aspects of established institutional logics and their associated practices and organizational forms with new elements and fuse different logics, thereby creating a new type of organization underpinned by a hybrid logic. From a micro-foundational perspective, new organizational forms are mechanisms that foster the institutionalization process of new practices, as cognitive framings are more easily transmitted in organizations than in other contexts (Zucker 1987). From a macro perspective, new forms of organizations enhance the diversity of pre-established place-specific institutional settings and might promote changes in the selected environment by contributing to the further institutionalization of new practices. Such a focus is particularly promising for gaining further insights into the spatial shaping of short-term changes on the micro level and the instantiation of gradual change on the meso- and macro-level at later points in time.

In summary, a conceptual approach with a processual perspective focusing on the emergence as well as the sequential and parallel unfolding of new temporary and more permanent organizational forms within space-time contexts can contribute to an improved understanding of institutional dynamics. Due to their inherent potential to affect both institutional change and stability, they are important generic mechanisms, which, in their interplay, simultaneously contribute to and reproduce the large multiplicities of transition pathways. On the surface, the impression might be created that we investigate mainly structural and relational changes; however, we consider organizational archetypes as an indicator for changes in normative and cultural-cognitive elements of institutional logics through the constitutive achievements of institutional work.

4.3 The Transition topology – a methodological approach to analyze and map organizational and institutional changes

4.3.1 Methodological foundations of the transition topology

The transition topology aims to visualize the 'hidden' institutional dynamics that occur over time. The goal of such a topology is to identify the processes that generate these changes by focusing on the timing and sequencing of events as well as the interconnections between processes over time. In this regard, the topology enables capturing the outcomes of the underlying micro-dynamics at the macro-level along the transition path.

The topology is a directed graph that maps the most important institutional and organizational changes and their connections in form of concrete events in time across different institutional fields and spatial scales. The distinct features, which differentiate the transition topology from the already well-known network topologies, are twofold: the causal reconstruction and the process analysis. A network topology is usually a systematic description of a set of actors or nodes, along with a specific set of ties that link them together. The pattern of the ties in a network yields a particular structure, and nodes occupy positions within this structure (Burt 2004, Borgatti and Halgin 2011, Wassermann and Faust 1994). The reproduction of network structures is explained using the properties of networks reflected in the network topology itself. However, the causal processes generating the structural properties remain largely underexplored (Giuliani 2013). The transition topology seeks to go beyond the acknowledged drawbacks of network topologies by taking into account the social characteristics of actors, their institutional embeddedness and the agency involved in change processes.

The topology follows a process ontology that considers the existence of entities not independently from the processes. However, although both are mutually constitutive, we analytically distinguish them. The causal reconstruction strives to explain a given social phenomenon (such as an event, structure, or development) by identifying the processes through which it is generated. Unlike a flat process ontology that does not differentiate between levels of analysis, the transition topology is based on a tall process ontology where micro-level activities are conditioned and dependent on macro structures or systems (Seidl and Wittington 2014). Such a perspective considers structures not as fixed but as emerging in the ways actors draw on them in their agency. According to the structuration theory (Giddens 1984) and the duality of structures and actions, the tall process ontology focuses on both stability and simultaneously on the unfolding of change across space.

Process research requires mostly longitudinal and contextualized deep and rich data in order to examine how social phenomena evolve over time (Langley et al. 2013). Since process studies rely on emergence and openness, they have no clearly defined variables at the beginning of the research process. In terms of research methods, a mixed method approach builds a suitable basis for process studies integrating qualitative and quantitative data.

Process methodologies are applied with the aim to understand sequences of events and their underlying complex patterns of causation as well as their potential effects in a specific time period. Therefore, process studies require to move from detailed empirical observations to more abstract models that capture the underlying generative mechanisms of a process (Langley et al. 2013). The basis of the empirical research in the transition topology builds the sequence of events that is displayed as a directed graph. An event sequence is understood here as a list of elements that follow a temporal order and which can, but do not have to be, connected to each other (Abbott 1995). As the topology is grounded on a tall process ontology, it connects the micro- and macro-levels of a regional path. In tall process ontologies, the previously defined macro-theory facilitates the identification of the key

mechanisms that connect both levels. The micro level is considered as the site of structural reproduction and gradual change and defined macro theories give guidance to investigate empirically on the causality (Seidl and Wittington 2014). Based on new institutional organization theory, the transition topology has been investigated empirically on the emergence of new organizational forms in a regional system.

The event sequences only constitute the visible basis of interaction processes that are structured by the enduring institutional settings in which they take place. For contextualizing and interpreting the findings visualized with the topology, a more detailed narrative description of the investigated phenomenon is therefore indispensable. A deeper understanding of the complexities and particularities of the case is necessary to define clearly the theoretical domain to which the findings can be generalized (Langley et al. 2013). Hence, the methodological approach of transition topology combines a structured analysis with a thick description and interpretation of the phenomenon.

4.3.2 Establishment of the transition topology

The transition topologies presented in the following chapter rely on qualitative longitudinal case studies, which involve the triangulation of different methods and data. The specific composition of the latter can change depending on the particular research question and the accessibility of data. The selection of methods is thus closely linked to the objective of the study and the theoretical preconception of the research object. Yet, the mix of methods and data must fulfil some basic requirements in order to meet the needs of the conceptual approach. The conceptual approach aims to explain the emergence, as well as the sequential and parallel unfolding of new organizational forms connected to institutional dynamics within regional paths. The methodological approach must therefore enable the researcher to capture sequences of organizational and institutional changes (i.e. event sequences). For this purpose, it is necessary to (1) identify events that have been relevant for the regional transition process, (2) to locate these events in time and space and (3) to establish causal connections between them. In order to explain these connections and sequences, one must furthermore gather additional qualitative information about these event sequences.

Figure 6 illustrates the procedure underlying the establishment of a transition topology. The first explorative phase enables the researcher to familiarize with the case and to prepare the subsequent data collection phase. Methods that can be used to conduct initial explorative research are for example document analyses, media analyses, desk research, participatory observations or explorative interviews. These methods can help to identify interview partners or prepare a more structured document analysis.

In the second phase, a mix of different methods is used to collect data. Ideally, these methods are not applied sequentially, but in parallel, so that they can complement each other. Different types of interviews with actors that had been deeply involved in the regional transition process in combination with document or media analyses make it possible to capture event sequences. Narrative interviews (e.g., Küsters 2009) can for example enable the identification of events that have been relevant from the perspective of regional actors. Document and media analyses (e.g., Flick, 2009) can provide additional information on these events. Problem-centered and semi-structured interviews (e.g., Witzel 2009) enable the deeper investigation of particular parts of the process or of specific details. Moreover, participatory observations or group interviews can be deployed to gain additional context knowledge, which is important for the interpretation of the topology in the research process at later points in time.

In the third phase, the data needs to be analyzed, integrated and validated in order to establish a solid basis for the transition topology. The data analysis aims at determining the most important

organizational and institutional changes as well as their connections. For this purpose, one needs to deduce certain categories from theory, as e.g., new organizations, networks and institutionalized temporary events. In order to maintain an openness for new findings, additional fine grained or subordinated categories can be generated in an inductive way. In a next step, the findings must be integrated and cross-validated. For this purpose, it is necessary to establish a database, which contains information about all events, their temporal and spatial location, their connections and additional qualitative information on each event. In case the findings contradict each other, additional field research is necessary to resolve these contradictions and investigate their causes. The database (or an initial visualization therefore) can also be used for communicative validation with interview partners (Flick 2007).
In the fourth phase, the findings are visualized in form of a directed graph. This graph should at the same time represent the complexity of the process, while also making its main process dynamics transparent (Langley et al. 2013).

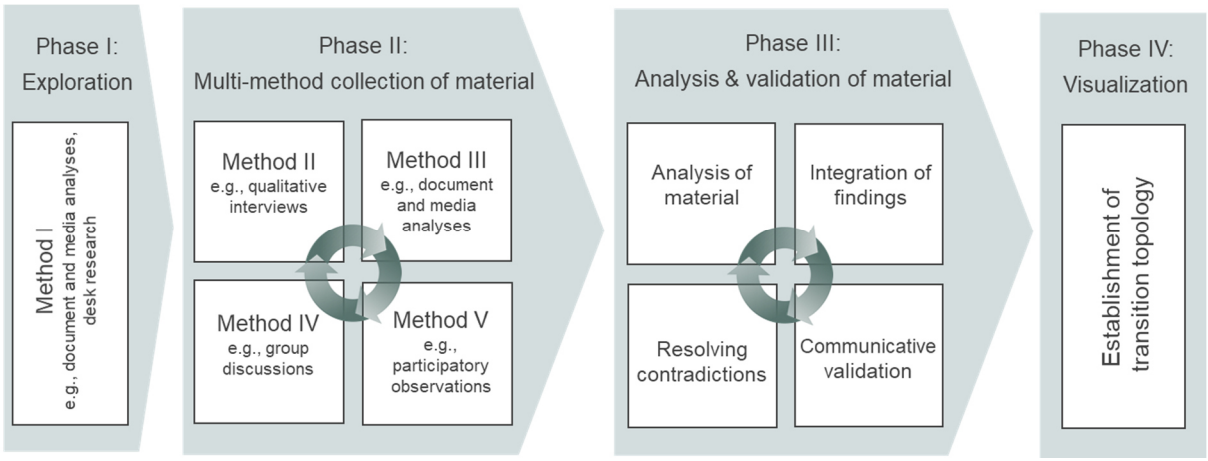

Figure 6: Establishment of the transition topology.

4.4 Illustrating the potentials of the transition topology

In this chapter, the application possibilities and potentials of the transition topology are illustrated. The chapter is subdivided into four different topics, which exemplify the range of application possibilities of the approach. The first three sections draw on an in-depth case study of the sustainability transition in the Augsburg region (Germany) (see Strambach and Pflitsch 2018). The latter has been increasingly recognized for its frontrunner role in the transition towards sustainability, e.g. by being awarded the German sustainability prize in 2013. The Augsburg region provides a particularly suitable example, as the transition process there spans different regimes, including technology-based regimes (e.g. mobility, energy, housing) as well as regimes from the social infrastructure sector (e.g. health, education, food). The fourth section illustrates the application of the topology to analyze the role of a specific actor type in regional sustainability transitions. It draws on a comparative case study about the involvement of the universities of Augsburg and Linz (Austria) in the transition process towards sustainability in their surrounding regions (see Pflitsch and Radinger-Peer 2018). Although the Linz case is comparable to that of Augsburg (e.g. population size, industrial history,

student numbers, study program), the approach towards sustainability of both regions differed substantially.[11]

4.4.1 The nature of organizational and institutional change in different transition phases

The topology (see Figure 2) makes apparent that Augsburg's transition process is characterized by a dynamic institutional and organizational change. Through the analysis of the empirical material, three different phases in the transition process were identified. These phases become visible immediately when studying the pattern of the topology: In Figure 2, these phases can be distinguished by the varying quantity of events in the different time periods. A closer examination shows that the three phases also differ regarding the nature of organizational and institutional changes.

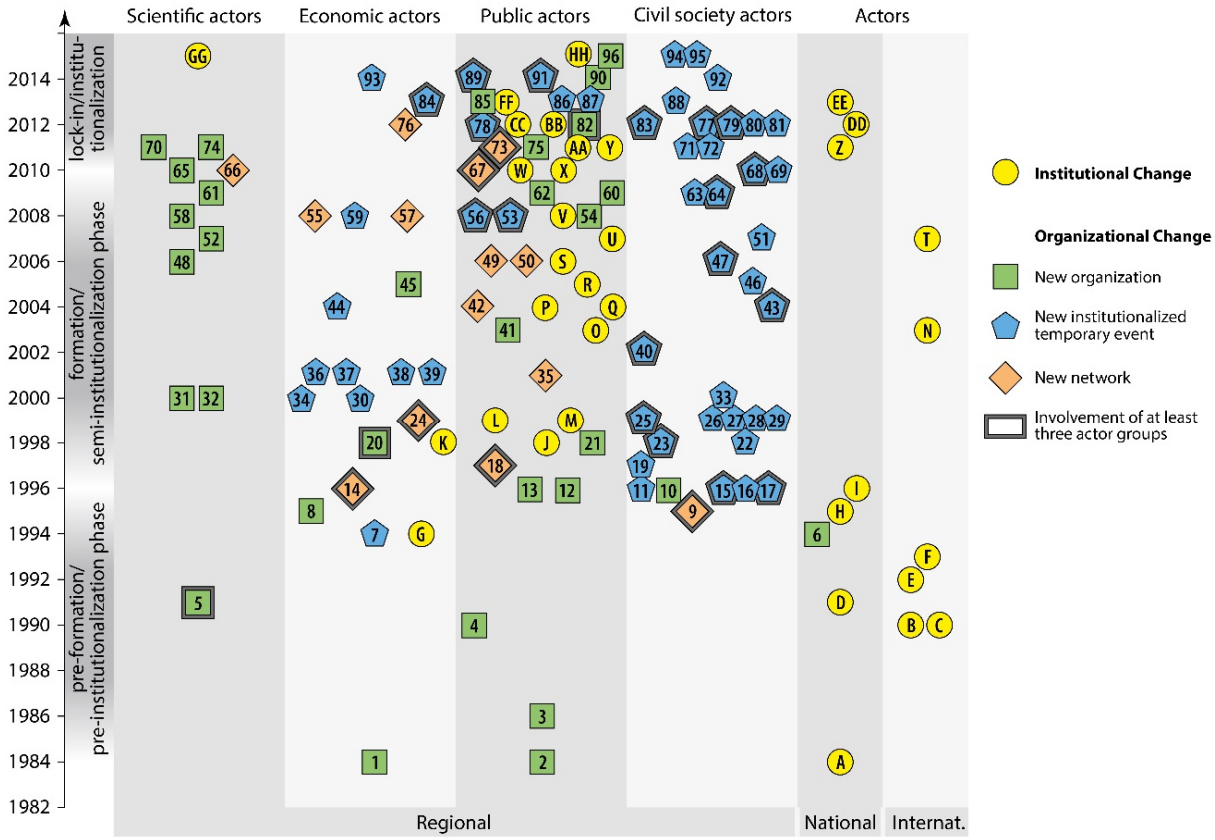

Figure 7: Transition topology for the Augsburg region.
(Cartography: Christiane Enderle.)

The pre-institutionalization or pre-formation phase

From the mid-1980s until 1996, there are relatively few events in the topology. Institutional changes, which gave impetus for the regional transition process, mainly took place at the national and international level (see right column in Figure 7, letters A-H). Simultaneously, some initial organizational changes happened at the regional level, mainly in the public field (2-4). Taking a closer

[11] Tables which contain all events displayed in the topologies can be found in the Appendix. For Figures 7 and 8, see Appendix 2, Table 17. For Figure 9, see Appendix 3, Table 18. For Figure 10, see Appendix 3, Table 19.

look at these early organizational changes, an important characteristic of this phase becomes apparent: here, no organizations which cut across different institutional settings were established. Actors thus mainly operated within their institutional field and had not been confronted with conflicting field logics, yet.
However, from the interviews we know that many informal interaction processes had already taken place, which becomes visible in the organizational changes in the second phase. In addition, it became apparent that despite some value-driven individuals, most collective actors in the region did not have an understanding of sustainability yet. Changes in this early phase happened due to a regulatory push at the national and international level.

Semi-institutionalization or formation phase

The second phase is characterized by a strong increase in organizational changes across different institutional fields. The emergence of three collective actors (9, 14, 18) that had explicitly aimed at fostering change towards sustainability also marks an important point of change and serves as the initiation of the second phase. These networks bring together actors from different institutional fields with different interests and logics and therefore foster the establishment of cognitive proximity. The double framing of the events indicates that all three organizations bring together actors from at least three different institutional fields. Hence, the emergence of organizations that break up institutional consolidations are a new phenomenon, characteristic for this second phase. It also becomes apparent that after the formation of these three main actors, a large number of new institutionalized temporary events were established. All the while, several institutional changes happened in the public field.
The interviews revealed that throughout this second phase the focus on environmental issues broadened and a more holistic understanding of sustainability was established, particularly in the city administration. However, at the beginning of this phase, actors in the public field and the economy were still sceptical about sustainability. In order to convince actors of the purpose of these activities, individual boundary spanners played an important role. Moreover, the importance of temporary events was emphasized, which fostered the exchange of ideas and different perspectives between actors across organizational boundaries.

Institutionalization or positive lock-in phase

Since 2010, a further intensification of institutional and organizational changes can be observed, particularly in the public domain. Most importantly, institutional changes occurred that reinforced or strengthened developments which took place in the second phase. Examples are two decisions of the city council: to continue the sustainability advisory board that was set up at the beginning of the second phase (AA) and to update and expand its sustainability program (BB).
From the interviews, we know that positive feedback effects had set it, e.g. through a recognition of the process from outside. Compared to the beginning of the second phase, the concept of sustainability started to guide social practices in different institutional settings and thematic fields in the third phase. At the same time, the interview partners however raised concerns about a certain “abuse” of the sustainability term and an uncontrolled proliferation of the process.

4.4.2 Connections between organizational and institutional changes

The topology can furthermore be used to uncover connections between organizational and

institutional changes (see Figure 8). In this way, it also enables the identification of important actors and events (as critical junctions) in the transition process.

Figure 8 shows that there are two collective actors (10, 20), which had induced a substantial number of further organizational and institutional changes along the path at later points in time. This central position in the topology indicates that these actors played a particularly important role in the regional transition process to sustainability.

As expected, the topology shows that most connections between organizational and institutional changes exist within particular institutional fields. There are, however, connections which cut across these boundaries as well. In a multi-scalar process, institutional changes at the supra-regional level (e.g., F, H, I) had induced change processes in several institutional fields within the region. An organizational actor in the economic field (20) (co-)initiated several organizational changes at the university (31, 32, 52, 58). In the case of Augsburg, these connections can be found in particular between actors form civil society and the public field. In this case they even go back and forth between these fields (e.g., 40, Q, Y, 83). Different forms of connections become apparent in the topology as well, such as temporary events in civil society, that have given many impulses for institutional changes in the public field (e.g., 40, Q). The topology also reveals that one of the two central actors had been a hybrid organization (10, 12) that cut across the public and the civil society fields.

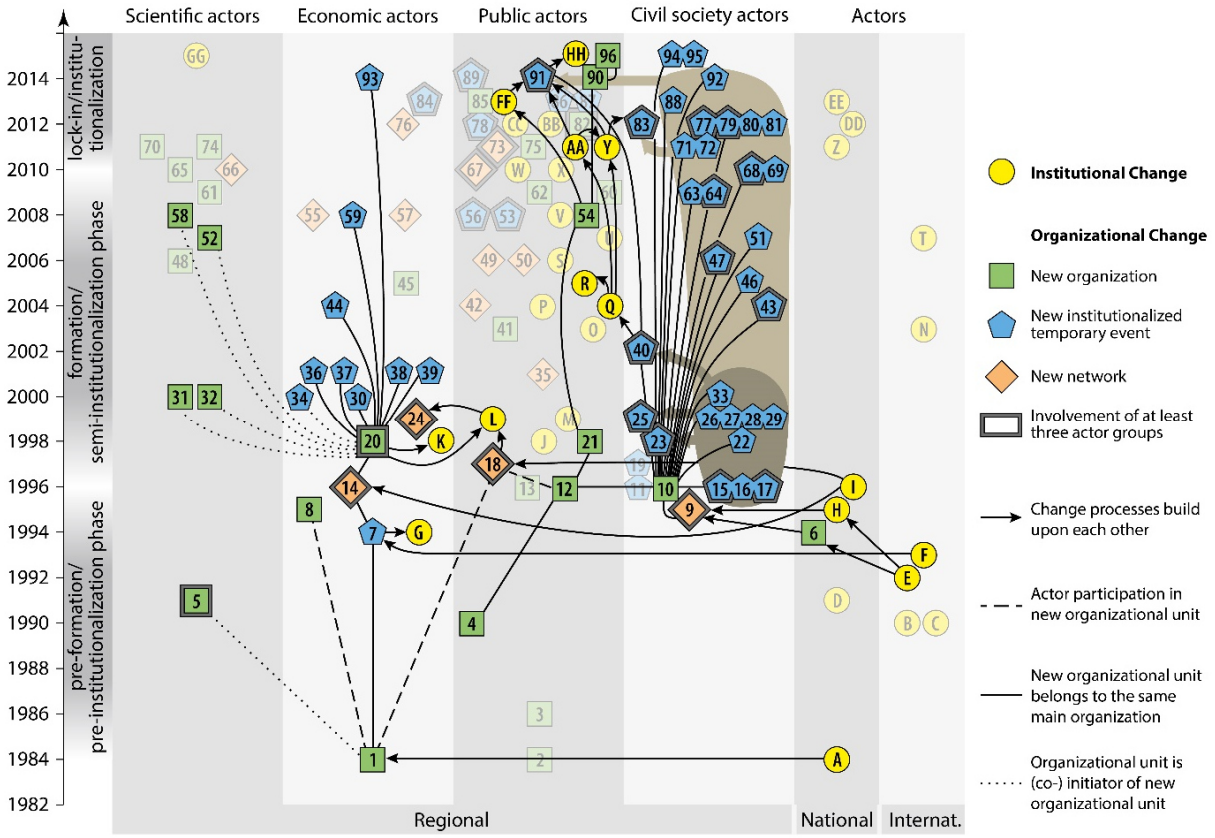

Figure 8: Main actors in Augsburg's RTPS.
(Cartography: Christiane Enderle.)

From the interviews we know that the collective actor (10) that fostered a holistic understanding of sustainability in Augsburg over time had moved from a peripheral to a more central position within

the path. It turned out that this actor was able to strengthen their position mainly due to its hybrid organizational form. Through establishing permanent organizational proximity to actors from the public field, this collective actor was able to bridge the two different institutional logics and foster a more holistic understanding of sustainability in the city administration.

4.4.3 The effects of events in their specific temporal and spatial context

Through the topology, impacts of events can be analyzed in their specific temporal and spatial context by putting the focus on their timing and sequencing. Thus, change processes can be reconstructed and the underlying causalities become visible based on the underlying empirical qualitative data analysis.
The topology (Figure 8) shows that the main actors in the process are established due to the same developments at the supra-regional level. It becomes apparent that at an early point in time impulses from outside the region were necessary in order to spur the process, which then went on to develop mainly within the region.
It also shows that specific events at later points in time sometimes build on long sequences of foregone events. In this way, it can be seen that an event that had happened in the mid-1980s (1) would lay a foundation for an event that took place nearly two decades later (93). Another example is a new organization (1), which built the basis for a network (14) that was not to be established until twelve years later. Two years after its foundation, the network would then transform into a more permanent organizational form (20).
The topology illustrates that the transition path of the Augsburg region relies on a substantial amount of organizational and institutional changes. It shows how different forms of organizational changes interrelate, e.g. when loosely coupled networks are turned into more permanent organizational forms with resources and clear structures (14 & 20, 9 & 10).
Based on the qualitative data analysis, we know that a few value-driven actors lay important foundations for the transition process. They used windows of opportunity in order to start institutional work processes. Temporary events enabled them to react spontaneously to changes in context conditions. Through these events they were able to convince other actors of the need to act and develop more sustainable practices. In this way, these actors continuously involved new actors groups and thematic topics in the process.

4.4.4 Comparing dynamics and actor roles in different transition paths

The topology also builds a basis for a systematic comparison of cases. The example below shows that it can be used to compare the roles of a particular types of actors in the regional transition process and to make different place-specific dynamics visible. The following figures display the relationships of the universities of Augsburg (Germany) and Linz (Austria) with their surrounding regions in the context of sustainability. By comparing the two topologies, different ways of how particular actor types get involved in the transition process and how that affects their role in these processes become visible (see Pflitsch and Radinger-Peer 2018).
In this example, the left columns (in Figures 9 and 10) differ from the other columns, as they display the university's internal organizational and institutional dynamics. In this column, the actors at the university responsible for the largest amount of organizational changes within their contexts can be identified.
In Augsburg it is one collective actor in particular (f) that induced many further organizational changes within the university. The topology (Figure 9) shows that this actor was established due to impulses

from regional actors/events. The process within the university and the process in the other regional institutional fields then developed simultaneously. As indicated by the arrows in the topology, the collective actors from the university (f, z) recently gave important impulses for organizational changes in the region (r, aa).

In the interviews it became clear that in Augsburg many relationships between university members and regional actors developed in a bottom-up way. University actors tend to have direct relationships with actors from all other institutional fields. In addition to these sectoral boundary spanning activities, a variety of actors from different disciplines are involved in the transition process. Although these activities are only managed by a relatively small unit within the university, the process involves a large amount of actors and spans a variety of different topics.

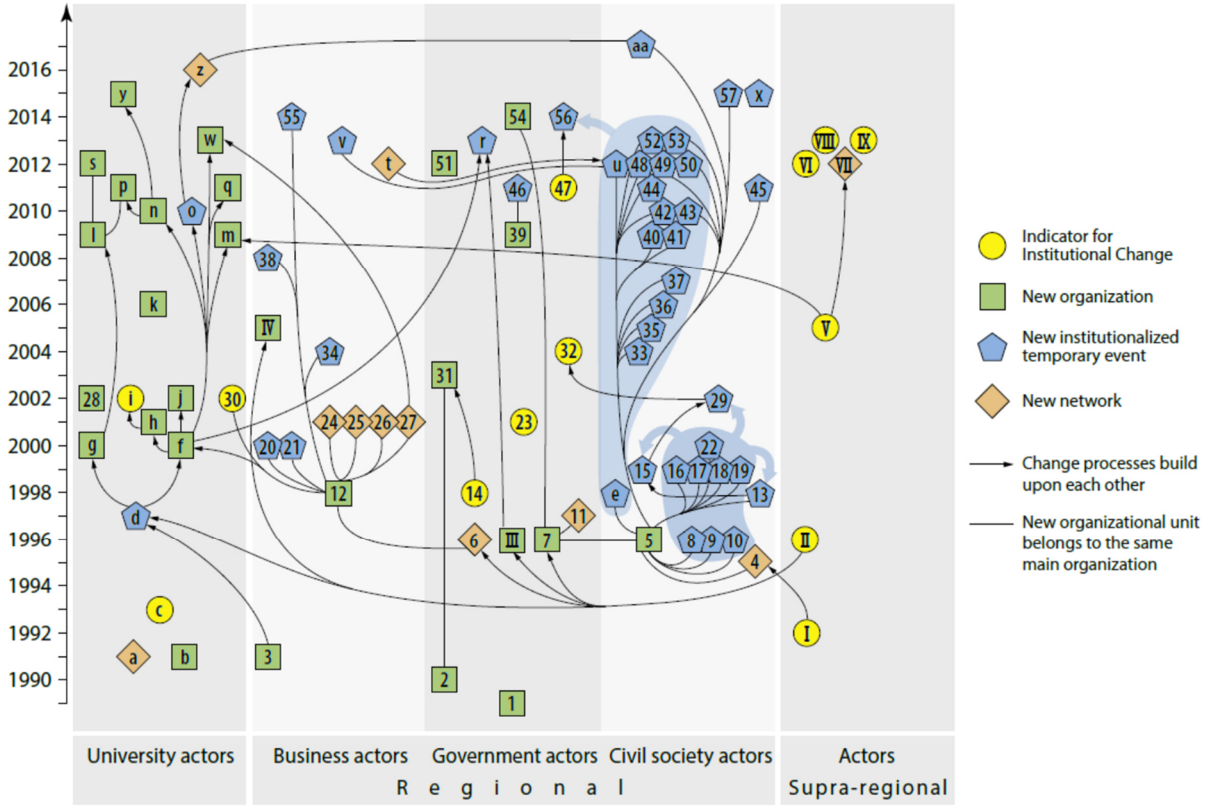

Figure 9: The role of the University of Augsburg in the RTPS.
(Cartography: Christiane Enderle.)

There are few sequences of events in the topology of the Linz region (Figure 10) like the ones seen in the topology of the Augsburg region. In Linz, both the processes within the university and in the other regional fields look very differently. A dynamic process had set in neither in the university nor within the region. At several points in time, there had been impulses from the supra-regional level that initiated organizational changes within the university. However, there are few actors in the region that these organizational units at the university could cooperate with.

Through the qualitative analyses, it became apparent that actors from the university work in close cooperation with actors from the federal government. Relationships to actors from civil society and the economic field exist only indirectly through the participation of university members in advisory boards and working groups of the federal government. Boundary spanning activities within the

university are also relatively rare. Overall, the current role of the university in the transition process is rather fragmented and passive, but nonetheless more focused on specific topics that are perceived as relevant by the federal government.

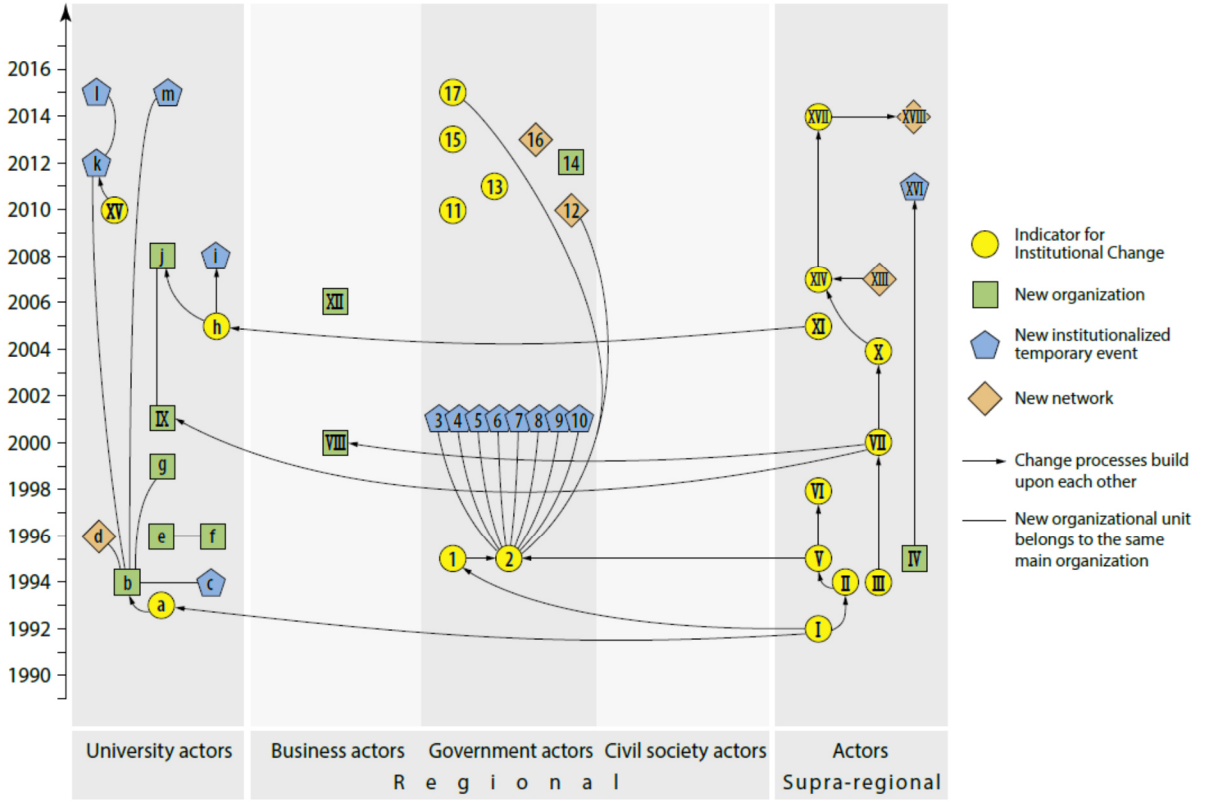

Figure 10: The role of the University of Linz in the RTPS.
(Cartography: Christiane Enderle.)

4.5 Conclusion and outlook

This article intended to contribute to two recently emerging fields in sustainability transitions research, i.e. the geographical and 'socio-institutional' perspectives. From an institutional viewpoint, it stressed the importance to analyze how changes on the micro-level instantiate change on the system level. From a geographical perspective, it identified the need to investigate the spatial shaping of these processes to explain the variety and unevenness of transition pathways. For this purpose, an original conceptual framework was developed that combines insights from sustainability transitions research, EEG and new institutional organization theory. The approach considers mechanisms at the regional level that shape the interplay between stability and change and enable gradual institutional changes. It focuses on new organizational forms as enablers of the complex institutional dynamics underpinning RTPS. With the transition topology a methodological approach was introduced to capture interrelated organizational and institutional changes within their spatio-temporal contexts. The transition topology enables the causal reconstruction of temporal processes and allows navigating between different analytical levels (Köhler et al. 2019). The empirical examples of two city-regions illustrated how the topology allowed to identify (1) different phases over time, (2) important actors and critical junctions, and (3) long-term effects of micro-level activities. The examples also showed how the topology can be used to compare these patterns across different regional contexts.

The empirical illustrations support the theoretical assumption that new organizational forms indicate changes in normative, cognitive, and even in rule-based elements of institutions in long-term sustainable transitions at the level of regional systems. In particular, in the Augsburg case, sequences of interlinked organizational changes often culminated in tangible institutional changes. That calls for more research on the development of new organizational forms and extends thinking on institutional entrepreneurship since without organizational change at former points in time later institutional changes would not take place. The transition topology enables to shed light on the complex relationship between institutional logics and organizational forms.

The transition topology can indeed contribute to gain a more accurate idea of how institutionalization processes evolve in sustainability transitions. The empirical examples also showed that the approach is able to consider the spatial shaping of these institutionalization processes. In particular, the comparative case study of the two city-regions made apparent that the approach allows identifying different patterns of organizational and institutional changes. It also helps to reveal the path and place dependent mechanisms that cause these patterns. Therewith, the transition topology provides a suitable basis for developing typologies of different processes underlying transition pathways. Such typologies could make an important contribution towards a better understanding of the multiplicity of sustainability transitions (Hodson et al. 2017).

There are of course shortcomings of our approach and situations where other frameworks are better suited. A framework such as presented by Hodson et al. (2017) is for example more appropriate to generate detailed insights into the transformation of specific sectors or socio-technical regimes at the regional level. Our approach has also drawbacks in that it does not analyze the link between changes in institutional and material structures, a general strength of MLP-based studies (Geels 2002 & 2004). However, we think that the focus of our approach on institutional transformations of regional systems provides a perspective that is neglected in other approaches.

The transition topology can be used also to explore new research fields. One promising avenue for further research is the investigation of multi-regime dynamics. In the sustainability transition literature, multi-regime dynamics mainly gained attention in the context of broader sectoral transitions (e.g., the utility sector), which involve multiple interdependent socio-technical regimes (Raven 2006, Raven and Verbong 2007, Konrad et al. 2008, Papachristos et al. 2013, Geels 2018). Multi-regime dynamics can either reinforce or dampen each other and are therefore regarded significant from the perspective of a whole sector (Konrad et al. 2008). Multi-regime dynamics are key mechanism in regional transitions that require changes in multiple interdependent regimes. With the transition topology, it would be possible to make these dynamics visible, e.g. by assigning events in the topology to specific regime contexts and to more general regional governance institutions. In this way, one could analyze how different parts of the system influence each other in their transition dynamic over time.

Another topical issue that could be investigated with the topology is ‘tipping points’ in transition pathways (Köhler et al. 2019). A quantitative evaluation of the topology would allow identifying such qualitative shifts in the process dynamics of a regional transition path, while qualitative research could explain such changes. The topology provides a suitable tool for investigating these and other current issues in sustainability transitions research further. When using the transition topology to conduct comparative research, it would also be possible to automate the establishment of the graph (see e.g., Spekkink and Boons 2016).

5 Micro-dynamics in regional transition paths to sustainability – Insights from the Augsburg region

This chapter is a reprint of:

Strambach, S. & G. Pflitsch (2018): *Micro-dynamics in regional transition paths to sustainability – insights from the Augsburg region.* Applied Geography 90: 296-307.

Abstract

While there has recently been an increased interest in urban and regional transitions to sustainability, there are little profound insights about the emergence, design and enforcement of regional transition paths to sustainability (RTPS). The latter are characterized by organizational and institutional dynamics that affect multiple regimes and cannot fully be captured with the niche-regime categories of the multilevel perspective (MLP). This paper is therefore based on recent approaches from evolutionary economic geography (EEG) that focus on how actors at the micro-level use the plasticity of paths to enact change. The transition path and underlying micro-dynamics over more than 30 years in the Augsburg region revealed in an empirical study are visualized in the form of a transition topology. The results show that RTPS do not exclusively originate in protected spaces. Actors use the interpretative flexibility of institutions and establish organizational proximity between different institutional logics thereby eroding institutional consolidations and allowing new configurations within the path. Gradual institutional changes lead to more fundamental changes in social practices over the long run.

[12] For this chapter, additional material that has not been published in the original paper can be found in Appendix 1. See Table 12, interviews 1-12; interview guidelines for narrative and problem-centered interviews; Table 13; Table 14; Figure 22.

5.1 Introduction

In light of the global acceleration of anthropogenic climate change, the increasing resource scarcity and social fragmentation, cities and regions are confronted with the challenge to develop in a more sustainable i.e. nature and human compatible direction. This requires a fundamental change towards more sustainable social practices and a transformation of their socio-technical infrastructure (Hodson and Marvin 2010, Bulkeley et al. 2011). Researchers from the field of urban studies therefore increasingly refer to Geels' (2004) prominent multilevel perspective (MLP), which offers a tool to capture socio-technical change processes in their entirety, and the related approaches of strategic niche (SNM) and transition management (TM). At the same time, spatial aspects have received more attention in the sustainability transition literature after some seminal contributions (e.g. Coenen et al. 2012, Raven et al. 2012, Truffer and Coenen 2012) pointed out the influence of the spatial institutional environment on socio-technical transitions and their multi-scalar character (Wolfram and Frantzeskaki 2016). Both research streams – sustainability transitions and urban studies – recognize the need for new forms of governance activities that involve a diversity of societal actors to solve the complex sustainability challenges mentioned above (Loorbach 2010, McCormick et al. 2013, Bulkeley et al. 2014). With more management oriented approaches researchers try to deliberately initiate and steer these governance processes at the regional or sectoral level (Loorbach 2010, Loorbach and Rotmans 2010). Based on their involvement and experiences over the past ten years in transition management, Loorbach and Rotmans (2010: 243) emphasize that *"every transition project is unique in terms of context and participants and therefore requires a specific contextual and participatory approach"*. They conclude that there is no "standard recipe" for how to manage transition projects. This is in line with evolutionary theory that regards regional development as a contingent and path dependent process. The long-term outcome of transition processes is hard to predict, as they are shaped by both purposeful and unintentional mechanisms.

Empirical studies have also shown that urban and regional transition processes are based on complex dynamics on the micro-level. However, a largely open question is how these micro-dynamics are connected with long-term transition processes at the aggregated urban or regional system level. To gain insights into this connection we suggest an evolutionary institutional framework to identify the endogenous unfolding of regional transition processes. We therefore introduce the notion of regional transition paths to sustainability (RTPS) and examine three important aspects that have not been explored in depth in the above mentioned research streams that focus explicitly on the geography of sustainability transitions. First, by shifting the focus to RTPS, the implementation and integration of new sustainable solutions in many different regimes is acknowledged. The focus of most transition studies on specific socio-technical regimes, primarily from the utility sector, does not fully encompass the thematic breadth of sustainability in a regional transition process. In particular, the social dimension of sustainability is rarely recognized. Second, it is argued that change does not only develop in protected, deliberately created spaces but that regional paths offer actors opportunities to initiate change from within. Regional paths are characterized through the overlap of institutional settings, multi-regime dynamics and place specificity and thus provide diverse possibilities for adjustment and recombination of existing institutions. Third, although transition scholars have emphasized the long-term character of transitions (Loorbach and Rotmans 2010), many empirical studies focus on the initial stage of a transition process (Brown et al. 2013, Hansen and Coenen 2015) and thus do not capture the outcome of micro-dynamics at later points in time. If and how changes are stabilized is not considered in depth.

In agreement with scholars from institutional theory, we argue that we need to acknowledge the *"contingent and emergent nature"* of institutional change and *"adopt a broad, processual understanding of strategy"* in order to better understand the interplay of actors and structure in RTPS (Lawrence and Phillips 2004: 708, Gertler 2010). In the empirical part of this paper, a longitudinal and process-oriented approach is followed to reconstruct the dynamics actors induce with their activities and what outcomes these activities have in the long run. For this purpose a transition topology is developed, which captures the RTPS of the Augsburg region across different institutional fields over a time-span of more than 30 years. The transition topology establishes a link between major institutional and organizational changes over time and thus brings dynamics to the fore which have remained largely hidden in transition research so far. Our framework and analysis show how social agency is shaped by the place-specific institutional environment and in turn how agency maintains, modifies and shapes this institutional environment in regional paths. It not only contributes to the newly emerging field of the geography of sustainability transitions (Hansen and Coenen 2015), but might also be informative for policy-makers and public actors as well as actors from civil society who want to initiate a transition in their city or region.

The article is structured as follows: Section 5.2 specifies our concept on RTPS and possible sources of change on the micro-level. In the focus of Section 5.3 is the methodological procedure and the development of a transition topology to chart a RTPS. The empirical results are presented in Section 5.4, followed by a discussion and an outline of further research issues.

5.2 Sources of organizational and institutional change in regional transition paths to sustainability

Sustainability transition research has highlighted the need for a radical transformation of existing socio-technical regimes in order for society to develop in a more sustainable direction (Geels 2004, Geels 2011).[13] From a regional or urban perspective it is the challenge to implement and integrate multiple new sustainable solutions in different socio-technical regimes and adapt them to the specific local circumstances. The region can be conceptualized as an open system, which contains a wide range of socio-technical regime configurations that have developed in a co-evolutionary and place-specific way over time. Rohracher and Späth (2014) have shown that in order to initiate and stabilize transition processes in the region's socio-technical infrastructure, a broader organizational and institutional change in the regional system is necessary. Studies from the field of urban transition research show that these organizational and institutional changes are usually not targeted at a specific socio-technical regime, but strongly influenced by more general regional goals (as e.g. carbon reduction or economic growth targets) (Hodson and Marvin 2010, Loorbach and Rotmans 2010, Dielemann 2013, Hamann and April 2013, Higgins 2013, Khan 2013, Ryan 2013, Rohracher and Späth 2014). Nevertheless, they pave the way for changes in many socio-technical regimes over the long run. We therefore argue that the emergence of the regional transition path cannot be fully explained with the niche-regime categories of the MLP (Block and Paredis 2013, Rohracher and Späth 2014). Changes in RTPS are thematically broader, more complex and hard to capture. They do not only emerge in protected spaces, where heterogeneous actors are spared from prevalent institutional structures.

How actors use existing institutional settings for new purposes, or how institutions are re-combined and provided with new social practices, has not received much attention in the literature so far.

[13] For a detailed discussion about the concept of socio-technical regimes see Markard and Truffer (2008).

Regimes are seen as relatively stable institutional settings, which have formed over a long time span and which guide actor's behavior. The plasticity and changeability of institutional settings through individual and collective actors are underestimated (Quitzau et al. 2013, Fünfschilling and Truffer 2015). We therefore refer to recent approaches from evolutionary economic geography (EEG) that argue for a more differentiated understanding of path dependency, path creation and dynamics within established paths (Boschma and Martin 2010, Strambach 2010, Strambach and Halkier 2013, Trippl and Tödtling 2013). The basic argument is that regional paths leave room for creative and reflexive actors at the micro-level to enact change (Strambach and Halkier 2013). *"Path plasticity provides a certain scope for variation within a well-established institutional setting of a path. This characteristic of paths is rooted in the interpretative flexibility of institutions and incoherence of paths themselves due to the interconnectedness of institutional settings at different* [spatial] *levels."* (Strambach and Klement 2013: 69). At the regional level actors are often involved in multiple regimes at the same time, which offers them many opportunities to combine or adjust existing institutional elements from peripheral regimes for new purposes. Due to proximity economies, institutional complementarities between different regimes in a regional system exist. These function as a stabilizing mechanisms, while they might at the same time be the source of multi-regime dynamics through initiating gradual change processes in other structurally connected regimes. Even if these change processes are not radical, but rather gradual at first, they do have the potential to lead to more fundamental changes over the long run (Mahoney and Thelen 2010). The latter underlines the argument that it usually takes a considerable amount of time until regional transition processes become visible at the macro-level.

In particular, sustainable innovations that require the combination of knowledge of actors from different institutional fields are often connected with path plasticity (Strambach and Halkier 2013, Strambach and Klement 2013). Innovation processes aiming at sustainability, in which actors' ecological, economic and social needs and aims must be considered and balanced, necessitate complex search, evaluation and negotiation processes between different actor groups. The cooperation of different stakeholders from the economy, but also of political, intermediary and civil society actors, is necessary (Loorbach and Rotmans 2010, McCormick et al. 2013). These actors need to combine their resources, competences and their cumulative knowledge. This causes diverse tensions, and controversial interests need to be overcome. Combinatorial knowledge dynamics thus require *"the transformation, recombination or creation of institutions at the micro-level, as they imply coping with many different cognitive, technological, organizational and institutional interfaces"* (Strambach and Klement 2013: 67). Recent approaches in economic geography have shown that these processes can be facilitated through the setup of specific organizational structures. In particular, temporary forms of organization such as trade fairs, conventions, conferences or festivals have been highlighted in economic geography as an opportunity for actors from different institutional settings, even competing organizations, to interact and develop their ideas (Bathelt and Schuldt 2008, Rychen and Zimmermann 2008, Torre 2008, Cohendet et al. 2014). According to Cohendet et al. (2014), temporary events enable actors to exchange tacit knowledge with other cognitive proximate actors or with actors from competing organizations that have similar or opposing interests. The authors conclude that a regional environment which provides these spaces for interaction is therefore particularly fruitful for the development of radically new ideas. It is however still a largely open question how existing practices are deinstitutionalized and replaced with newly developed more sustainable social practices in regional paths.

Seeing path plasticity and combinatorial knowledge dynamics as a source of change in RTPS leads us to the following questions: (1) How do actors use the plasticity of pre-existing institutional configurations given in the regional path to enact organizational and institutional change towards

sustainability? (2) How do they overcome the barriers in sustainable innovation processes given by competing institutional logics? (3) How do incremental changes at early points in time induce more fundamental changes over the long run?

5.3 Methodology and case

5.3.1 Methodological procedure

A qualitative research design with a mixed methods approach was applied, in order to track the transition dynamic over time and to gain insights in the research questions. In a first step, a document analysis was conducted in order to set up a data basis, which collects the most important organizational and institutional changes in the regional transition process and their connections over time. Afterwards, two narrative and ten problem-centered interviews with actors from different organizations that were deeply involved in the transition process and a second more targeted document analysis were applied to complement the data basis and cross-validate the findings. In total 130 events were identified (see Appendix). Seven unstructured participatory observations (during workshops, project meetings and public fairs) and several telephone calls helped to clarify and enhance empirical findings. In the final stage the results were validated by discussing them with some of the interview partners as well as the members of the city's sustainability advisory board.

As a research heuristic, the actor-centered institutionalism approach was used for detecting and ordering empirical facts (Mayntz and Scharpf 1995, Scharpf 2000). The basic assumption is that social phenomena are the results of interaction of intentional acting actors. These interactions are structured by enduring institutional settings in which they take place. Based on the structuration theory and the duality of structures (Giddens 1984) it is assumed that results of interactions in turn have impacts on institutional settings by contributing to gradual institutional changes over time. The central analytical categories of this approach are actor constellations as well as the action orientations and outcomes of interaction processes in time. These key features enabled us to explore empirically the connection between actors and systems and to reconstruct causal processes in RTPS. Outcomes of interactions were analytically differentiated as organizational and institutional changes, defined as events in time and mapped in what we label a transition topology (see Figure 11 in the next chapter). The aim of such a directed graph is to identify the processes through which these changes are generated.

Institutional changes were operationalized as events, which reflect a change in rules, norms or cognition related to sustainability, as e.g. the implementation of a new formal regulation or the official announcement of new voluntary standards, which legitimize new social practices in favor of sustainability or de-legitimatize unsustainable behavior. Organizational changes are events, which indicate the establishment of a new organizational form. According to their temporality and their degree of formalization, we differentiated three distinct forms: 1) an entirely new body of organization, 2) networks and 3) institutionalized temporary events. A new organization (1) can refer either to the foundation of a new independent organization or a new department within an existing organization. Responsibilities and competencies are clearly defined in formal organizations. Organizations are further characterized by a clear rule system and hierarchical structures. Compared to networks and temporary organizations, they are more stable and have their own administrative, technical and financial resources. Networks (2) are defined as a loosely coupled group of independent actors with a common interest. They are organized in a non-hierarchical form, do not have their own resources and are more fluid than formal organizations. Finally, new institutionalized temporary

events (3) were operationalized as the start of a series of events, where actors meet repeatedly for a specific purpose over a limited time.
The transition topology is of course not exhaustive. There were clearly practical constraints to processing the large amount of information available. It was however also not the goal to map every single event in the region, but to identify the main development strands with the data triangulation.

5.3.2 The Augsburg case: a broad shift towards sustainability

Two years ago, Augsburg was awarded with the German sustainability prize to appreciate the city's remarkable engagement in the fields of climate protection, economic and demographic change. According to the jury, it was not Augsburg's outstanding performance in one specific field, but the diversity of achievements and their increasing integration into one overall process that led to this decision (Stiftung Deutscher Nachhaltigkeitspreis 2013). The city of Augsburg has a sustainability program compiling 75 goals in the social, economic, ecological and cultural dimensions, as well as indicators which make achievements measurable (Stadt Augsburg 2016). The breadth and depths of this program show in how many different areas sustainable practices have diffused and are monitored today. Augsburg therefore provides a particularly suitable case for analyzing a regional transition process, which spans many different regimes. In particular, the cultural dimension, which was added only recently after an intensive discussion process involving actors from different institutional fields in 2014, is an indicator for an explicit attempt to achieve a fundamental change in values.
In the social and cultural dimension of sustainability, Augsburg's achievements regarding the integration of migrants are worth mentioning. In 2007 the city council adopted 20 binding core principles for its future integration policy, which were developed in a broad participatory process. These principles are accompanied by several civil society projects. A study on civic commitment in Germany showed that Augsburg's citizens are among the ten most engaged of all 97 German regions (Generali Holding AG A.M.B. and Prognos AG 2009). Taking the example of the ecological dimension, the outcomes of the transition process in Augsburg become visible in several regimes already. The city of Augsburg has e.g. increased its production of renewable energies amongst others by the installation of several hydropower stations or bioenergy plants. In 2009, Augsburg fed in far more renewable energy into the grid than other comparable cities in Germany (as e.g. Freiburg, Münster or Heidelberg) (Stadt Augsburg, 2013). Augsburg has also reduced its CO2 emissions e.g. by shifting all its buses to regenerative biofuels e as the first city in Germany. In parallel, Augsburg's economy has undergone a significant structural change towards a more resource efficient and environmentally sound economy (BMWi, 2014). The latter has been accompanied by the establishment of an excellent research and education infrastructure in this field (Thiel et al. 2015). Moreover, the districts in the Augsburg region have officially recognized sustainability as a strategic goal for Augsburg's regional economic development agency.
This is all the more remarkable as Augsburg's economy was affected by a dramatic economic downturn in the 1960/70s caused by the decline of the textiles industry, which had shaped Augsburg's economy for centuries. Employment numbers in the textiles industry declined rapidly since the 1960s, while the machinery industry managed a structural change.[14] However, as a classical production site with relatively weak research infrastructure and a resource-intensive machinery industry, the region was at

[14] Calculation based on monthly industry reports from the Bavarian Statistical Office by the office for Statistics and Urban Research in Augsburg. This information was assessed through personal communication with the latter.

a comparatively disadvantage to manage the grand challenges posed by climate change and resource scarcity. This makes the initiation of this broad transition process towards sustainability in the region even more interesting.

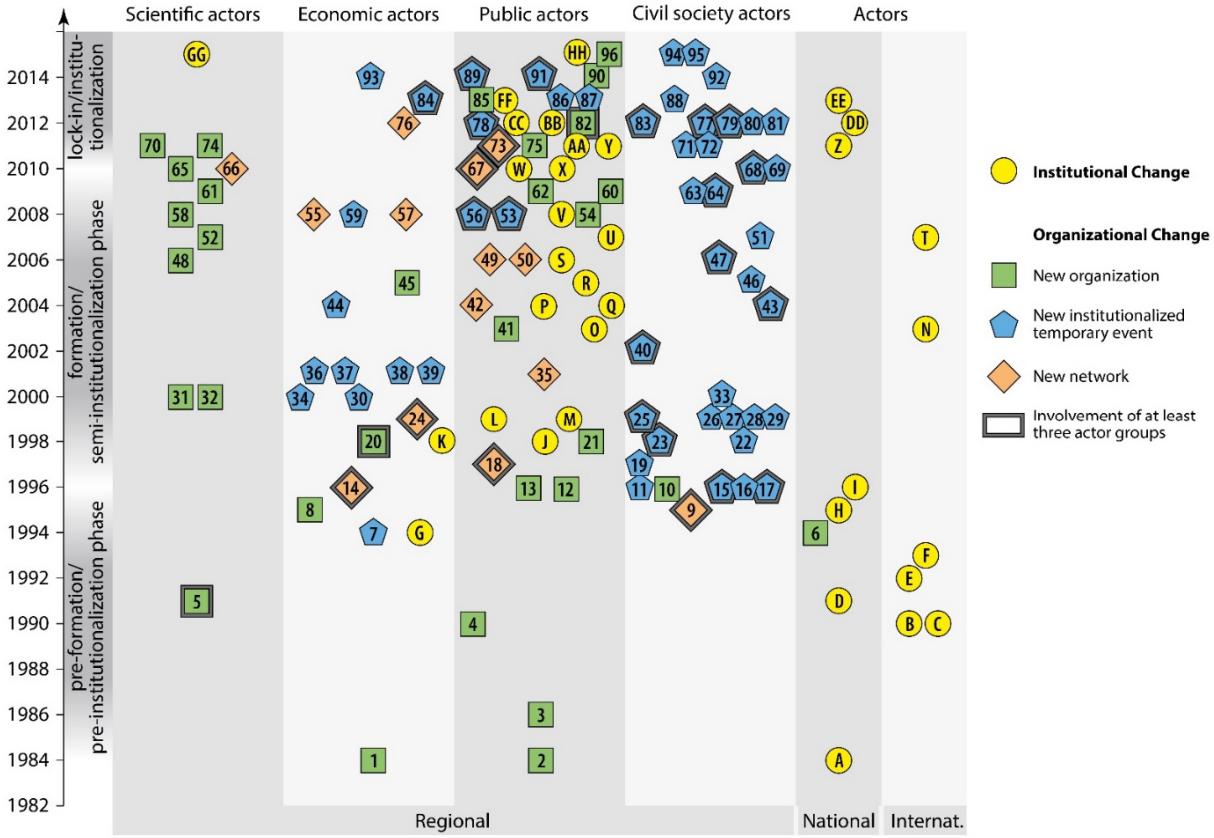

Figure 11: Transition topology of the Augsburg region.
(Cartography: Christiane Enderle.)

5.4 Actors and micro-dynamics in Augsburg's transition path towards sustainability

Through the analysis of the empirical material, three different phases in Augsburg's transition process could be identified that are characterized by a different degree of institutionalization of sustainable practices. In the pre-institutionalization or pre-formation phase (1) there is no broad understanding for sustainability and environmental protection yet. The semi-institutionalization or formation phase (2) is characterized by the emergence of the main actor groups and an increasing legitimation of sustainability. In the institutionalization or positive lock-in phase (3) sustainability becomes a guiding principle in different thematic fields and self-reinforcing dynamics set in. These phases also become visible in the transition topology through the quantity and type of organizational and institutional changes (see Figure 11).

The transition topology also shows that there are many actors from different institutional settings that contributed to the regional transition process with varying intensity. The main actors, which induced a considerable number of organizational and institutional changes over time, are the LA 21, the city's environmental advisory board and an environmental competence center called Kumas (see Figures 12-

14). The following therefore focuses on these three actors and their contribution to the transition process.

5.4.1 Regulatory push and institutional plasticity

Augsburg's LA 21 was established due to impulses from outside the region, starting with the Rio conference on sustainability in 1992 (this event is represented by character E in Figure 12).[15] In Germany the LA 21 process fell within the responsibility of the Federal Environmental Agency (BMU) and was therefore strongly focused on environmental aspects. Inspired by the first LA 21 processes in Munich and Berlin (6), actors from the 'Werkstatt Solidarische Welt', an organization active in the field of developmental issues, started networking and communicating with the most influential environmental groups in Augsburg, a loose group of solar engineers as well as with the city's environmental office (9).

Shortly before the local elections in 1996, the Bavarian conservative government declared Augsburg an 'environmental competence region' and announced that it would move its state department for the environment to Augsburg. The oil shock in 1973 had put Augsburg's resource intensive industry under massive pressure. Helping the region to gain back its economic prosperity through the development of an environmental industry became the key for success for the local conservative party in the elections in 1996. When the decision was made official, the later head of Kumas immediately brought together all relevant stakeholders from the economy, the scientific and public field to define what this label should mean for Augsburg. At the same time, the newly established LA 21 used this 'window of opportunity' for their purposes by initiating a discussion in civil society about appropriate strategies and actions for an environmental competence region. The speaker of the LA 21 explained: *"So we became the legitimization or concretization of the expectations that the general populace had for an environmental competence region."* As the topology reveals, the group's exertions finally led the city in 1998 to establish a permanent part time position for the LA 21 in the city's environmental office (21) and to set up an environmental advisory board (18).

While taking advantage of the new environmental orientation of the region, the LA21 tried to raise attention for a holistic understanding of sustainability including social and economic aspects right from the beginning. Initially, however, this met with little understanding in the public field, where the topic was regarded as purely environmental. As the head of the environmental office explained: *"It took years until colleagues from other areas came to the meetings and until they also felt responsible for what happened in this process."* The progress the LA 21 has contributed to over a time span of more than 15 years becomes apparent in the renaming of the environmental advisory board as agenda (O) and later as sustainability advisory board (BB). The renaming and the associated thematic expansion of the advisory board in 2003 could only be achieved, because the LA 21 had by then worked out concrete sustainability guidelines (Q) with other relevant actor groups. The thematic expansion also becomes apparent in the establishment of an increasing number of LA 21 forums that explicitly focus on social, cultural or economic aspects of sustainability as e.g. a partnership between generations (29), civic commitment (33) or corporate responsibility (77). Another indicator for the broader understanding of sustainability in the city administration is the separation of the LA 21 from the environmental office in 2014. Since then it functions as a stand-alone unit in the department for the environment, sustainability and integration.

[15] See Appendix 2 for the concrete content of the topology.

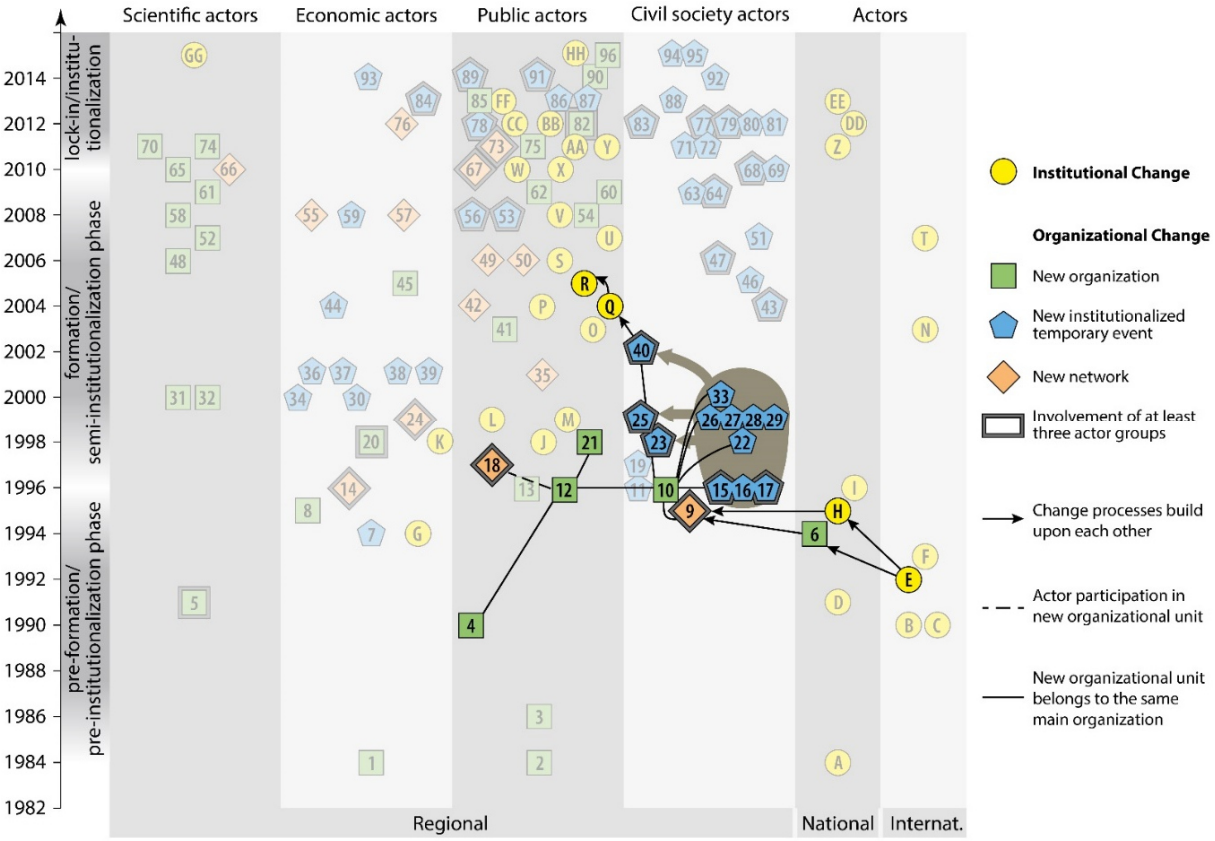

Figure 12: Local agenda (phase 1-2).
(Cartography: Christiane Enderle.)

5.4.2 The connection between organizational and institutional change

As the topology (see Figure 13) shows, the LA 21 induced many organizational changes, which facilitated further organizational and institutional changes at later points in time. The establishment of expert forums where sustainable practices were discussed in certain thematic fields such as energy, urban development or mobility (15-17) and where concrete project ideas were developed is worthy of particular mention. Each forum was led jointly by a thematic expert in the relevant field and a moderator, who organized and structured the meetings. The aim was to bring together actors with different capabilities and specialized knowledge who were already working on or were interested in a specific sustainability-related topic and provide them with the necessary resources. With a few exceptions, all forums brought together actors from at least two different institutional fields. The first forum on energy issues e.g. was led jointly by the head of the city's environmental office and a solar engineer and contained several actors from the economic and public field, as well as from civil society. Like the other forums, it was of a temporary and rather fluid nature as composition of the members fluctuated strongly from time to time. Often smaller subsidiaries developed on a current topic or problem that quickly disappeared again when the problem was solved. Over the last years, the energy forum began to dissolve as the topic is already implemented by rules and laws and now more intensely and efficiently dealt with in formal organizations from the public, economic and scientific field as e.g. the chamber of industry and commerce or the regional energy agency. Nevertheless, some core members of the energy forum are still active in order to point out gaps and give innovative impulses to these organizations and thus challenge them to take the process to the next level.

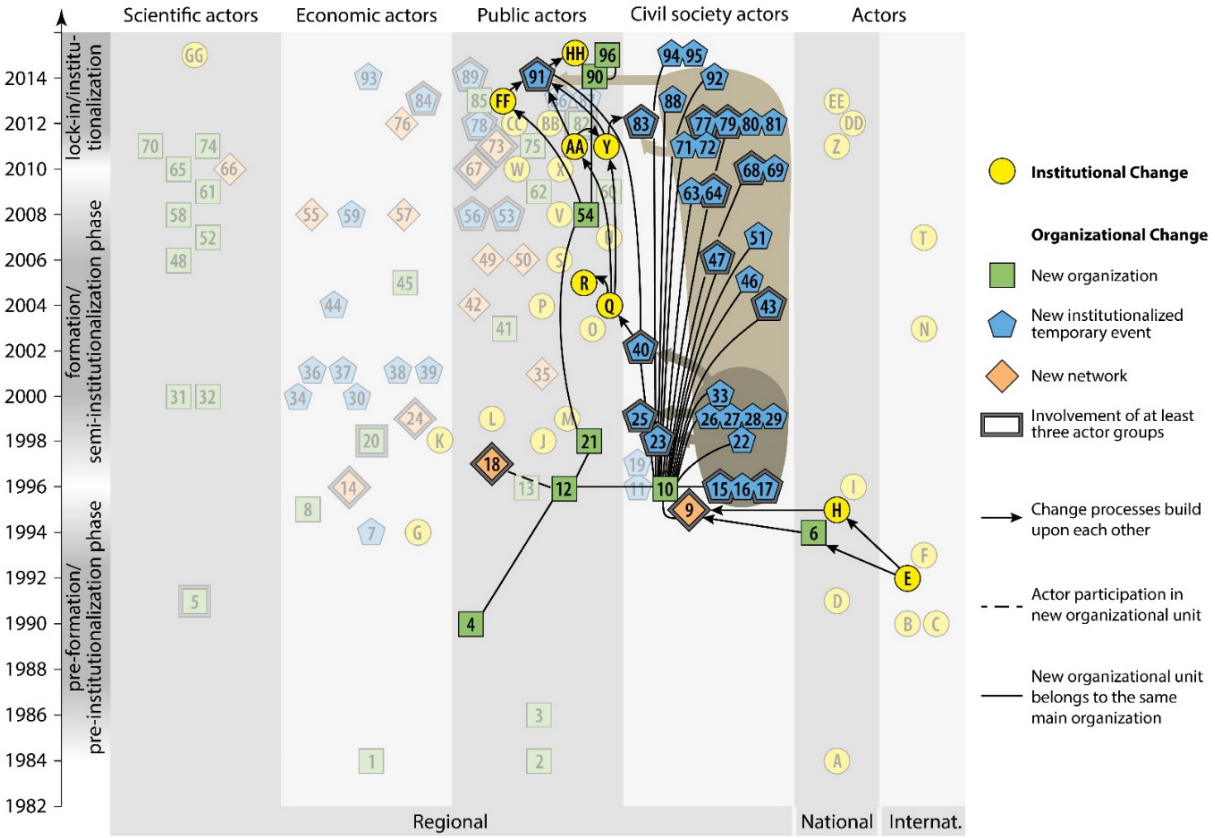

Figure 13: Local agenda (phase 1-3).
(Cartography: Christiane Enderle.)

Through the topology, it becomes apparent what outcome the combinatorial knowledge dynamics generated in these forums induced over time in other institutional fields. The knowledge generated in the forums provided the basis for the establishment of sustainability principles and, later, for the development of indicators to measure the achievements (23, 25). Moreover, in 2002 when the political situation shifted from a conservative to a social-democratic government, the LA 21 also initiated the creation of concrete goals for Augsburg in a series of public workshops with representatives from civil society, public organizations, the city administration, politicians as well as actors from the economic field (40). In 2004, these sustainability goals (Q) were handed over to the city council. As the head of the environmental office stated: *"I think that a whole lot of contacts came out of this. I always found it amazing how some actors who I had always thought coordinated with each other, didn't do that at all. Having a round table like that – regardless of what the specific topic was – really helped the exchange of ideas – In fact even was the starting point for that."*

In 2011, the city council instructed the LA21 to expand and update their sustainable action program (AA) to use it as a basis for an integrated urban development concept (Y) as well as a sustainability assessment (FF) for all further city council resolutions.[16] The latter means that both the actors in the city administration that develop a proposal, and the members of the city council that decide about it, have to adhere to the sustainability guidelines. The provisional implementation of the assessment in

[16] When the city council in 2011 decided to update the sustainable action program, it also recommended to use it as a basis for the sustainability assessment. In 2016, the assessment was implemented in about one quarter of the city's departments. It is currently in a test phase. The final decision to use the new action program as a basis for the urban development concept was taken in 2015.

2011 makes it particularly apparent that the incremental changes at early points in time have meanwhile led to transformative change in the path.

The topology (see Figure 14) also shows the important role of the advisory board (18), through which many ideas developed by the LA 21 forums got access into the city council. The latter transformed several of these proposals into binding legal decisions, so that actors in the city administration had to implement them. As the topology illustrates, the ideas to join the climate protection alliance of European cities and to establish an energy agency, both of which emerged in the LA 21 energy forum, were introduced to the city council through the advisory board. By joining the climate protection alliance of European cities, Augsburg committed to concrete CO2 emission reduction goals (J). A CO2 reduction concept was developed which included an action plan, forming the basis for all further climate protection measures throughout the following years. In 2002/3, the city of Augsburg also set up a new climate protection office (41) with the main goal to foster networking activities between different regional actors and to initiate the development of a municipal climate protection concept. At a regional development conference (53) the department also introduced the idea to establish a regional climate protection concept (CC) as well as a regional energy agency (75), which lay the ground for many changes in multiple regimes as e.g. the setup of biomass heating plants by the local utility company or the implementation of a smart metering pilot project in several private households.

The environmental advisory board also built an important platform for intensive communication and learning processes between actors from different institutional fields. It consists of up to 25 important individuals or organizations from the economic, political, scientific and civic fields and meets four times a year. Since the advisory board is not focused on a specific dimension of sustainability, as are many of the forums, conflicts between the ecological, economic, social and cultural dimensions can be identified and discussed. Due to the relatively stable membership, an understanding for the perspective of actors from other institutional settings has been developed over time. Through the support of actors from the economic and scientific field in the advisory board the ideas developed in the forums were taken more seriously by the city council. The manager of the LA 21 office explained: *“The director of Kumas provided a bridge into the traditional industry and trading sector.* [...] *When we needed a city council resolution and the advisory board supported this, the issue was taken far more seriously by urban politicians.”*

The hybrid organizational structure of the LA 21 was another important organizational prerequisite in order to initiate further organizational and institutional changes in the city of Augsburg. In addition to its position in the city's environmental office, occupied by a member of the city administration, the LA 21 maintained their civil society based organizational units and speakers right from the beginning. In 2005, the former civic speaker of the LA 21 took over the direction of the city's local agenda office. Through taking over this strategically important position, the LA 21 was able to enforce their institutional logic in the administrative field. Described by the manager of the LA 21 office: *“The fact that I came from the outside world gave me a lot more freedom within the city administration. They knew that I was passionate about what I did, and when I was a bit too direct they also understood that I didn't come from an administrative background.”*

In parallel two new civic speakers were chosen, assuring that the LA 21 would not get “too mainstream.” The manager of the LA 21 office always made sure that the civic speakers were integrated in important decision processes. At the same time, the civic speakers could, when needed, exert pressure on the city administration or politics from outside. It becomes apparent from the topology (see Figure 13), since this change in personnel the number of expert forums further increased, indicating an expansion of the topic of sustainability into several thematic fields. Moreover, from inside the administration the new manager of the LA 21 office was able to initiate a transformation of the

advisory board, so that its members evenly represented all dimensions of sustainability. The interviews showed this hybrid structure to be a critical success factor in Augsburg's transition process.

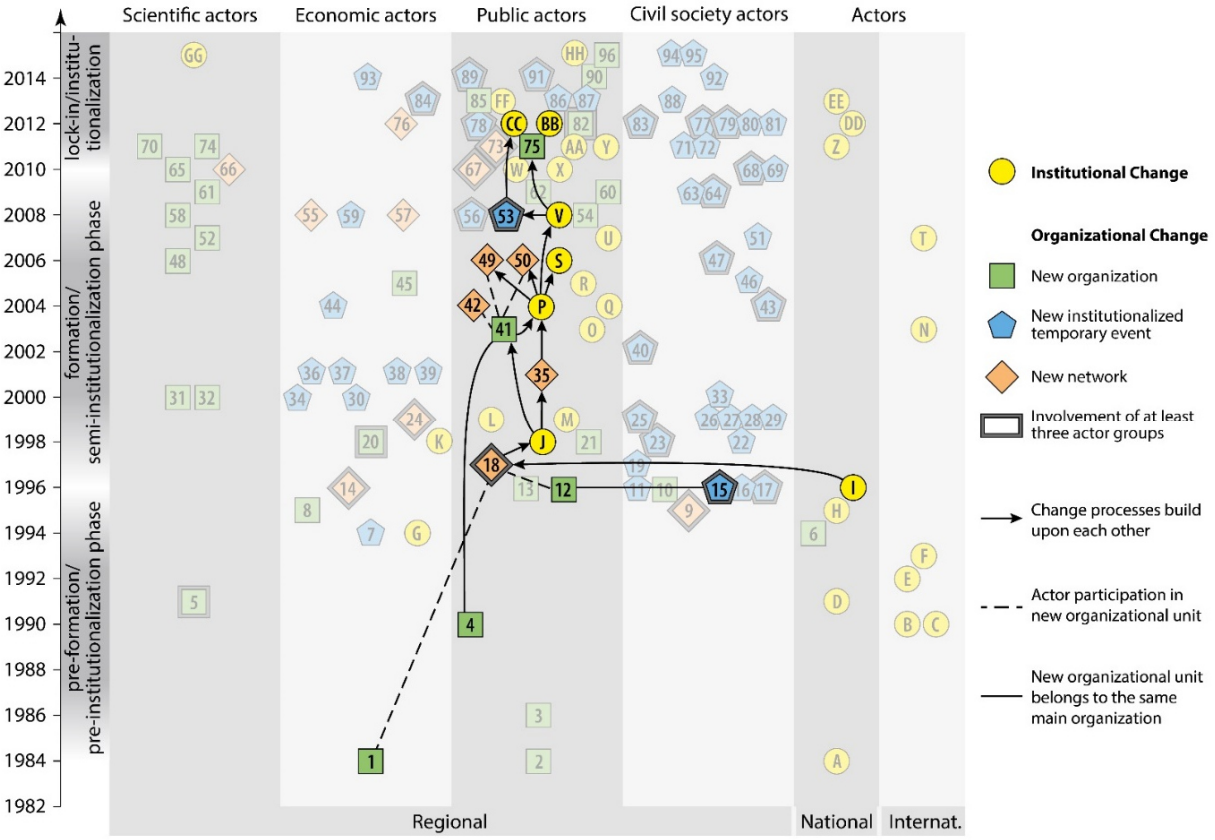

Figure 14: Advisory board. (Cartography: Christiane Enderle.)

5.5 Discussion

With the aim to understand how micro-dynamics are connected with long-term transition processes at the aggregated urban or regional system level, in the following, the three questions developed in the conceptual part are discussed: (1) How do actors use the plasticity given in the regional path to enact organizational and institutional change towards sustainability? (2) How do they overcome the barriers in sustainable innovation processes given by competing institutional logics? (3) How do incremental changes at early points in time induce more fundamental changes over the long run?

The emergence of the main actor groups in Augsburg's transition path underlines the argument that RTPS do not only emerge in protected spaces where actors are shielded from existing institutional structures. The LA 21 is a good example for an actor that initiates a fundamental change in values and cognition in a region by using the interpretative scope of existing institutions. In the case of Augsburg it successfully attached new elements to the environmental focus of the region over the course of time. What becomes apparent from this example is that actors, when making use of the plasticity of institutions, do not distance themselves from others with contrasting views but rather try to establish cognitive proximity to these actors. This helps them to legitimate their actions when they have no relevant reputation yet. In this way actors with a peripheral position in the well-established context of a path can nevertheless initiate significant changes over the long run. The role of personal networks between actors that are key persons in different organizations, networks and regimes simultaneously

is important in this regard (Brown et al. 2013). Particularly in an early phase, highly reputed actors can function as boundary spanners by establishing acceptance for the ideas of more peripheral actors in their respective institutional setting.

Through changing and broadening existing institutions, a new spectrum for action is established in which more sustainable practices can be developed. For this purpose, actors find collectively organizational forms which enable further collective learning processes. New organizations facilitate the integration of actors from different institutional fields with divergent perspectives and interests. In particular temporary institutionalized organizations provide an opportunity for mutual problem framing and knowledge combination between actors with very different cognitive frameworks and intentions and thus are the places where new sustainable practices are developed (Strambach and Klement 2013). In line with Cohendet's (2014) argument, it can be stated that in the Augsburg case these temporary institutionalized organizations enabled the integration of new ideas from a more informal urban milieu into the formal organizations in the public, economic and scientific fields. Mutual agreement on new practices is then expressed by the establishment of new permanent organizations that are equipped with resources to enact these practices as e.g. the energy agency. Being composed of actors from different institutional settings who interact on a continual basis, permanent organizations facilitate trust building and reduce cognitive distances. They also contribute to the legislative formalization of new social practices. Therefore, new permanent organizations are crucial in order to stabilize institutionalization processes in the region over the long run.

Another mechanism for overcoming institutional barriers in the case study has been the hybrid organizational structure of the LA 21 and thus the establishment of permanent organizational proximity between different institutional logics. Thereby a growing understanding and responsibility for the process was created in the city administration. At the same time, the LA 21 was provided with financial resources and stability, which Hodson and Marvin (2010) also found to be a decisive success factor for intermediary organizations. However, the example also shows that it is important that different institutional logics do not merge, but that actors keep their roots in their respective institutional field in order to continuously supply the process with fresh ideas, critically reflect on its development and exert pressure if necessary.

The example of the LA 21 and Kumas also make apparent that through the ongoing integration of new groups, intermediary organizations are able to constantly expand and update their knowledge base. This enables the organization to keep pace with the dynamic nature of sustainability and to adapt to changing circumstances (Hodson and Marvin 2010). This way, over the years, sustainable thinking has penetrated a considerable amount of different regimes (e.g. mobility, energy supply, housing) and thematic areas (e.g. integration, religious tolerance, freedom of art and culture). This also stabilizes the transition process when transition dynamics slow down in a particular field. Rohracher and Späth (2014) have illustrated how quickly such a dynamic can lose momentum, if the process is too narrowly focused or solely connected to a specific group of actors.

The topology shows how temporary institutionalized organizations pave the way for the implementation of more sustainable technologies and the development of more sustainable consumption patterns in different regimes at later points in time. Even if additional impulses from outside were necessary, many of the developments in Augsburg today could not have been implemented so easily without the previous, pioneering work of these organizations.

The transformation of the normative sustainability principles into binding regulations in the Augsburg case indicates how over time an alignment of regulative, value-based and cognitive forces is taking place. In a first step, cultural-cognitive proximity between actors is established that enables the development of a common understanding of sustainable practices. Normative principles are then

formalized into binding legislative rules that become an action orientation for a broader set of actors in the region. In Augsburg, this process was enabled through the establishment of the advisory board. Such a network which spans actors from different institutional fields and thematic areas provides the opportunity of taking a holistic perspective on sustainability.
However, speaking of fundamental changes in the path, it was not our intention to evaluate the progress in the transformation of specific socio-technical regimes. Although changes in regimes have taken place, it would afford more research in order to assess how far reaching these changes are. As transition scholars have shown, the ability of cities and regions to change a regime are clearly limited (Hodson and Marvin 2010, Rohracher and Späth 2014). Moreover, we did not analyze feedback mechanisms to these changes on other spatial scales. These dynamics could receive more attention in the future. However, the topology provides a useful basis for such analyses.

5.6 Conclusion

In order to shed light on the micro-dynamics of RTPS, a longitudinal case study in the Augsburg region was conducted, in which a particularly broad transition process is taking place that spans many different regimes. A main aim of the study was to analyze how actors use the plasticity given in a regional path to initiate the development and diffusion of sustainable practices across multiple socio-technical regimes over time. For this purpose, a transition topology was developed to chart a RTPS and its underlying micro-dynamics. The latter were captured in the form of major institutional and organizational changes.
The study makes apparent that actors who want to initiate or support a transition in their region should focus on the potential that is already given in the regional path. The example of Augsburg shows that even regions that do not have favorable preconditions for a transition to sustainability on first sight, might be very successful in this regard. Despite the spatial proximity of actors from different institutional settings in a region, opportunities for exchanges and encounters between these actors need to be created. While the establishment of temporary organizations is important to lift the creative potential in a region and to allow new interpretations of existing institutions to emerge, it is also necessary to stabilize these new practices in form of more permanent organizations. Our framework and analysis encourages political actors to look beyond their specific field of action and foster combinatorial knowledge dynamics between thematically overlapping fields. By supporting actors that are involved in different thematic fields, multi-regime dynamics can be initiated that stabilize the process dynamic over time.
While most frameworks in the sustainability transition literature focus on actor dynamics and institutions within specific sociotechnical regimes, the RTPS framework and the transition topology grasp regime-overarching dynamics as intended and unintended outcomes in a specific place. By showing how spatially bound institutions affect the activities of actors in a transition process, an issue is addressed that has been pointed out as a main research gap in the geography of transition literature (Hansen and Coenen 2015). Moreover, a type of multi-regime dynamics becomes visible that is based on spatial proximity and has not been considered in the sustainability transition literature so far (Raven 2006, Konrad et al. 2008, Raven and Verbong 2007). The approach also offers a differentiated view on organizational forms as governance instruments in a regional or urban transition process that might be informative for transition management. In line with Brown et al. (2013), we conclude that there is a need to get more profound insights into institutional work and localized institutional changes in

future research. The transition topology provides a promising tool that enables to conduct systematic comparisons with other regions in the future in order to come to more generalizable results.

(For better readability of this dissertation, acknowledgements were deleted here, but can be looked up in the original paper.)

6 Developing boundary-spanning capacity for regional sustainability transitions – A comparative case study of the universities of Augsburg (Germany) and Linz (Austria)

This chapter is a reprint of:

Pflitsch, G. & V. Radinger-Peer (2018): *Developing Boundary-Spanning Capacity for Regional Sustainability Transitions – a Comparative Case Study of the Universities of Augsburg (Germany) and Linz (Austria).* Sustainability 10: 1-26.

(Minor changes were made to adjust the text to the layout of the present dissertation.)[17]

Abstract

The potential of universities to become 'change agents' for sustainability has increasingly been highlighted in the literature. Some largely open questions are how universities get involved in regional sustainability transitions and how that affects their role in these processes. This paper argues that universities need to develop a boundary-spanning capacity, which enables them to transcend disciplinary as well as sectoral boundaries in order to adopt a developmental role in regional sustainability transitions. It is investigated how universities develop this capacity within a particular regional context, using the method of a transition topology. Comparing how the relationships of universities with their surrounding regions developed in Augsburg (Germany) and Linz (Austria), the paper shows why these processes are place-specific. A university's boundary-spanning capacity develops over time and differs according to the actors involved. The primarily bottom-up driven process in Augsburg was thematically quite broad and involved diverse actors. In Linz, the top-down initiated process was fragmented and more narrowly focused. Individual value-driven actors that made use of their personal networks played an important role in both regions.

[17] For this chapter, additional material that has not been published in the original paper can be found in Appendix 1. See in particular Table 12, interviews 15-22; Table 15, interviews 1-4, 9-11; and interview guideline "universities".

6.1 Introduction

Current challenges such as climate change, impending resource scarcity, demographic change, and migration patterns confront regions with the task to develop in a more sustainable direction. This requires deep structural changes in multiple areas of daily life (e.g., mobility, energy supply, housing), that have changed only incrementally over a long period of time (Geels 2004). Due to their multidimensional character, these transformations are extremely complex. They can only be achieved through the participation of a broad range of heterogeneous actors that contribute their specific knowledge, competencies, and perspectives (Truffer and Coenen 2012, Hodson et a. 2017). Universities are seen as particularly relevant actors in these processes (Stephens et al. 2008, Zilahy and Huisingh 2009, Mader et al. 2013, Peer and Stoeglehner 2013, Sedlacek 2013, Trencher et al. 2013, Blume et al. 2017, Radinger-Peer and Pflitsch 2017).

In the scientific literature, universities are expected to be highly responsive to the concept of sustainability and the problems and questions it brings up, due to their long-term perspective and their societal mandate (Mader et al. 2013, Sedlacek 2013). Stephens et al. (2008) and Zilahy and Huisingh (2009) argue that they could even take a leading role in regional sustainability transitions through developing strategic long-term visions and goals. Moreover, due to their interdisciplinary structure, universities are expected to have the capability to bridge different types of knowledge (Caniëls and van den Bosch 2011). According to Sedlacek (2013), this is particularly important in order to solve complex sustainability challenges. Universities have therefore recently been described as a 'change agent' for sustainability (e.g., Stephens et al. 2008, Peer and Stoeglehner 2013).

In line with these authors, we assert that universities can indeed take an important role in regional sustainability transitions. We do not, however, want to imply that their role is more privileged than that of other actors and that they necessarily act as a frontrunner in these processes. Referring to what has been labeled a developmental role in the literature on universities and regional development (Gunasekara 2006), we suggest that universities can actively engage in regional governance activities and, in doing so, contribute to direct a region's development trajectory towards sustainability. Sustainability challenges and the opportunities for approaching them are highly place-specific (Truffer and Coenen 2012, Hansen and Coenen 2015, Murphy 2015). In the context of sustainability transitions, the regional focus of a university's research and education activities, which is seen as a key element of a developmental role, becomes even more important. At the same time, the integration of the university in and its contribution to regional networking activities and institutional capacity-building become particularly significant.

Most existing studies that explicitly focus on the role of universities in regional sustainability transitions show that universities need to interact with a more diverse range of regional actors – Including actors from the economy, the public field, and civil society (e.g., Zilahy and Huisingh 2009, Trummler et al. 2011, Mader et al. 2013, Trencher et al. 2013, Trencher et al. 2014). At the same time, they have to integrate knowledge, perspectives, and methods from different disciplines within the university (e.g., (Stephens and Graham 2010, Sedlacek 2013, Trencher et al. 2014). How universities can develop this boundary-spanning capacity is, however, largely an open question. Most existing studies take a *"snapshot"* of the activities of universities at the point the research was conducted (Stephens and Graham 2010: 615). We argue that boundary-spanning capacity results from a place-specific and temporal process.

Analyzing the involvement of universities in regional sustainability transitions therefore necessitates a long-term approach. For this purpose, the paper uses the methodology of a transition topology, which makes it possible to map the emergence, unfolding, and stabilization of institutional and organizational

change processes towards sustainability over time (Strambach and Pflitsch 2018). It reveals how the universities under study developed and institutionalized their boundary-spanning capacity and how this in turn shaped the regional transition towards sustainability. The comparative case study setting showed how these processes differ across regions. It became apparent that the thematically quite broad approach towards sustainability in Augsburg was driven primarily from the bottom up and involved diverse actors, while the top-down process initiated in Linz was fragmented and more narrowly focused on specific topics. By examining how place specificities shaped these different pathways, we shed light on the question of why transitions differ between regions and contribute to the emerging research field on the geography of sustainability transitions (Hansen and Coenen 2015).
The paper is structured as follows: The theoretical part elaborates how a developmental role in the context of sustainability transitions relies on the institutionalization of boundary-spanning activities to a more diverse range of actors (Section 6.2). After the methodological approach (Section 6.3), the two case studies are presented (Section 6.4). This is followed by a detailed presentation of both regional development paths to sustainability (Section 6.5). The discussion synthesizes the similarities and differences in a comparative form (Section 6.6). We conclude with policy recommendations and suggestions for further research (Section 6.7).

6.2 The role of universities in regional sustainability transitions

6.2.1 Universities and regional development

Within the last decades the interest in universities' roles within their regional contexts, as part of a so-called 'third mission' or 'task', emerged (Goddard and Chatterton 2003, Cooke and Piccaluga 2004). The scientific efforts associated with this role produced two bodies of literature, that is, (a) the role of universities in promoting regional economic activities through academic entrepreneurialism (e.g., triple helix model, entrepreneurial university) (Leydesdorff and Meyer 2003, Etzkowitz and Leydesdorff 2017), in comparison to (b) university engagement in a broader understanding focused on the long-term development of a region (e.g., engaged university) (Chatterton and Goddard 2000, Charles et al. 2003). Gunasekara (2006) differentiates these roles into 'generative' or 'developmental'.
The generative role refers primarily to the provision of knowledge by the university in response to business or institutional demands (Gunasekara 2006). The developmental role, in contrast, implies that the university interacts with broader regional governance structures which seek to purposefully shape future development trajectories and network topologies (Boucher et al. 2003). The developmental role considers that universities contribute to the long-term socio-economic development of a region by adapting their research and teaching activities more closely to regional needs. Moreover, universities play an important role in enhancing the regional institutional and social capacity, as well as fostering the creation of new intra- and interregional relationships (Gunasekara 2006).
Benneworth et al. (2009) showed with the example of Lund University that taking over a developmental role helped to *"construct advantage"* (Benneworth et al.: 1660) through (a) deepening, that is, creating institutions which were conducive for technology transfer; (b) widening, in the sense of broadening regional networks and establishing relations to external actors, and (c) integrating, that is, bringing together various sectors and in this way creating a stronger integration of the formerly fragmented activities of regional actors. Thus, the university engaged in activities spanning industrial sectors, which created new innovative capacity and avoided lock-in.
Taking over a developmental role does not happen independently and autonomously from the universities' specific regional environment, however. Instead, it is influenced by the regional

absorptive capacity (e.g., industrial base, human capital), the regional culture and tradition of university-region linkages, as well as national and regional political framework conditions (Gunasekara 2006, Benneworth et al. 2009). In this vein, it must be considered that both universities and regions are complex systems, which are unlikely to work together on a rational, linear regional development process (Pinheiro 2012, Pinheiro et al. 2012). Universities are multidimensional, loosely structured communities of scholars who are active in wider knowledge production, transformation, and transfer processes. Regional engagement is just one of multiple agendas, and the regional scale merely one of multiple scales (Arbo and Benneworth 2007). Regions are complex systems themselves with different actors who consciously (e.g., policy makers, regional development agencies) or unconsciously (e.g., entrepreneurs, businesses) shape the development path of a region. The (developmental) role of the university thus has to be seen as the outcome of complex process dynamics that are shaped by intended and unintended actions of multiple actors from both the university and the region over time. While existing literature has developed a nuanced understanding of the interdependencies between universities and their regional environment, it privileges the role of universities to support economic growth and regional competitiveness. It is largely an open question of how universities can contribute to a reconfiguration of the regional system in a more sustainable direction by taking over a developmental role.

6.2.2 Universities and regional development in a context of sustainability transitions

Sustainability transitions are generally understood as fundamental changes in socio-technical systems (such as energy, transport, or housing), which comprise changes in technologies, infrastructures, policies, consumer practices, and cultural meanings (Geels 2004). These processes differ substantially from purely technological, economically motivated innovations, particularly due to the much more complex knowledge dynamics and actor constellations involved (Strambach 2017). They also have long-term orientations and their outcomes are often unclear (Geels 2004). Additionally, sustainability transitions and the opportunities for approaching them are highly place-specific (Truffer and Coenen 2012, Hansen and Coenen 2015, Murphy 2015, Strambach 2017).

This increased complexity affects the roles of universities in regional development processes, in that they become more diverse and complex (Sedlacek 2013, Trencher et al. 2013). In addition to combining knowledge from different disciplines (e.g., Stephens and Graham 2010, Sedlacek 2012, Trencher et al. 2014), universities need to establish new linkages and relationships between actors, build coalitions, and enable negotiations among regional stakeholders (Stephens and Graham 2010, Karatzoglou 2011, Trummler et al. 2011, Mader et al. 2013, Sedlacek 2013, Trencher et al. 2013, Trencher et al. 2014). Stephens and Graham (2010) therefore see the primary task of universities in the context of sustainability transitions in the formation and guidance of cross-sectoral initiatives. The authors argue that universities have the potential to provide leadership, long-term orientation, and reflection on the progress of transitions. Sedlacek (2013) also highlights these facilitating and mediating functions of universities. She suggests that universities have to generate knowledge together with societal and political actors by *"bridging the gap"* between these actor groups (Sedlacek 2013: 75). She thus considers universities mainly as 'bridging institutions', which initiate and facilitate interaction among different societal sectors in the region. In a similar vein, Trencher et al. (2014) argue that universities do not transfer knowledge to regional actors or advise regional decision-makers anymore, but instead aim at co-creating knowledge with a diverse range of societal actors.

What can be deduced from these studies is that a fundamental and inevitable process underlying the role of universities in the context of regional sustainability transitions is to transcend a broad range of

disciplinary and sectoral boundaries. The latter can in this context be defined as the establishment and management of interactions between different organizations, professional groups, or sectors (Marrone 2010, Williams 2010). Many authors model universities as 'change agents' or 'frontrunners' that mobilize regional actors and initialize transitions in their surroundings (e.g., Stephens and Graham 2010, Trencher et al. 2014). By analyzing best-practice examples, they highlight the importance of leadership by the university management and the existence of a strong mission towards sustainability (e.g., Stephens and Graham 2010, Sedlacek 2013). These studies have in common that they derive these conclusions based on the investigation of single sustainability-related projects or initiatives. In doing so, certain aspects, such as regional embeddedness, leadership, and their 'change agent' role are assumed as given.

We are of the opinion that the concept of a developmental role provides a more holistic approach to understand the roles of universities in sustainability transition, their long-term emergence, and the establishment of new relationships to and between formerly separated actors. The concept has to be broadened, however; in the context of sustainability, relationships between a much broader range of actors must be established. Based on these considerations, we expect the ability of the university to fulfill a developmental role in regional sustainability transitions to be highly dependent on the institutionalization of the university's boundary-spanning activities.

6.2.3 Developing boundary-spanning capacity for sustainability transitions

Few insights are available in the literature about how boundary-spanning activities develop and how universities build up a boundary-spanning capacity in the context of sustainability. Most studies focus on the role universities and their individual members play in specific regional sustainability projects at a certain point in time (Stephens and Graham 2010), where relationships between diverse actors are already present. Benneworth et al. (2009) used the example of the University of Lund to demonstrate that it required a time-intensive and elaborate organizational learning process to engage in boundary spanning between different economic sectors in the region. Referring to insights from institutional theory, we argue that the institutional environment of a university plays an important role in this regard.

Institutions comprise regulative, normative, and cultural-cognitive elements that, together with associated activities and resources, provide stability and meaning to social life (Scott 2001). At the same time, they enable and constrain agency (Giddens 1984). The institutional environment in the context of the university can be described as an organizational field (Pinheiro 2012), which is composed of all those organizations that *"*[…] *in the aggregate, constitute a recognized area of institutional life"* (DiMaggio and Powell: 148).

Traditional institutional contexts of universities do not offer particularly favorable conditions for boundary spanning. Examples are very pronounced disciplinary cultures and unwritten rules, which hamper interdisciplinary cooperation, as well as a focus on specialization in the current academic system. Regarding external stakeholders, there are, for example, much stronger incentives to cooperate with economic actors than with other actors in the region, as researchers are strongly dependent on third-party funds from industry. Therefore, the question is how a favorable institutional context develops which triggers or at least supports boundary spanning across disciplines and sectors.

Two general mechanisms can be distinguished which can induce institutional changes: (1) incentives and support from different levels of government and/or the university management, and (2) activities and efforts of individual actors.

(1) The government has an important role due to its regulative influence on universities via rules, laws, evaluations, and sanctions. In addition, it can also provide incentives for certain activities via political programs, subsidies, and funding programs. Over the last years, many political programs have tried to spur the involvement of universities in regional sustainable development (Sedlacek 2013, Radinger-Peer and Pflitsch 2017). Via funding programs or the establishment of intermediary organizations, politicians from the national or federal level have tried to foster the formation and/or institutionalization of relationships between university members and regional actors to foster sustainability transitions (Trencher et al. 2013). In addition, DiMaggio and Powell (1983) emphasize the influence of the academic profession, which at large, as well as within a given national context, exercises a considerable normative influence. Examples are the implementation of transdisciplinary approaches towards research and teaching in certain scientific fields, or on the other hand, their negligence. Another factor within the organizational field which exerts influence on universities are other Higher Education Institutions (HEIs) and their function as role model and cooperation partner, but also competitor. Finally, we expect the regional institutional environment to exert influence on the boundary-spanning capacity of universities. Regional governance and network structures with their own power relations, dynamics, culture, and trust (Coenen et al. 2012) offer proximity between actors (Boschma 2005) and can be important facilitators of (transdisciplinary) cooperation.

The university management may exert influence on other university members to engage in boundary-spanning activities via their normative and cultural-cognitive influence. Examples are the incorporation of sustainability-related networking activities with other disciplines and regional actors, the incorporation of sustainability into the university strategy and mission, or commitments to specific charters or declarations (e.g., Copernicus Charter). Furthermore, the support for new organizational units, such as interdisciplinary platforms or new institutes with a respective focus, can foster boundary-spanning activities. Overall, however, interventions from the 'top' are not as effective in universities as in other organizations (Musselin 2007). Universities are 'loosely-coupled' (Weick 1976) organizations that are subdivided into departments and institutes, which each possess a certain extent of autonomy regarding their teaching, research, and outreach activities (Arbo and Benneworth 2007).

(2) Clark (1983) suggests that the basic change or adaptation mechanism within 'bottom-heavy' organizations like universities is grassroots innovation, with little interference or steering from managerial structures located at the top. Therefore it is also likely that actors from the university and/or region initiate new relationships due to a shared interest in a topic or a shared concern for a particular sustainability challenge in a more informal way. Actors 'at the bottom' are usually better informed about regional needs than politicians at the federal or national level and can therefore better tailor their activities to the region's demands (Croog 2016). Moreover, these relations can be expected to be driven by a stronger intrinsic motivation. Relationships that are initiated bottom-up are often based on existing social relationships that are not purely of a professional character. Thus they already build on trust and shared experiences and therefore function more smoothly (Rutten and Boekema 2007), while top-down initiated interactions still must be socially embedded. At the same time, this strong personal-boundedness can come into conflict with the long-term nature of relationships necessary for sustainability transitions.

More recent approaches from institutional theory (Streeck and Thelen 2005, Mahoney and Thelen 2010) suggest that actors on the ground can also induce change in the university's institutional environment. The institutional work approach considers that individual or collective actors can purposefully enact or prevent change through maintaining, disrupting, and creating institutions. Institutional changes are often the result of the purposeful or unintended coordination of actions of multiple actors (Lawrence et al. 2011). In the same vein, Strambach (2010) argues that existing

institutions always leave actors *"room for manoeuvre"* (Strambach 2010: 421). By using the interpretative flexibility of institutions, particularly creative and reflexive actors can enact changes in existing cognitions, values, and rules (Strambach 2010, Strambach and Halkier 2013). Even gradual institutional changes can have a radical result over the long run (Mahoney and Thelen 2010). This implies that even 'less powerful' actors at the bottom of the hierarchy, such as students, can achieve substantial institutional changes (Lawrence et al. 2011).

We expect that boundary-spanning activities need to be institutionalized within the university in order to have a positive effect on long-term regional sustainability transitions. Institutionalization is understood as a process which goes through various stages (Fünfschilling and Truffer 2014). An increasing degree of institutionalization becomes apparent through formal and informal rules, standards and standardized routines, and structural changes (e.g., new organizational units), as well as the supply of human, financial, and infrastructural resources (Scott 2001, Olsen 2001, Colyvas and Powell 2006). While formal institutions and organizational changes can be implemented relatively quickly, it is much more time-consuming and difficult to change cultural-cognitive institutions such as habits or cultural meanings. The latter, however, is seen as the most developed form of institutional change, as it means that actors have internalized these new institutions and take them for granted (DiMaggio and Powell 1983). Nevertheless, new organizational structures might also induce learning processes between actors, as in the case of Lund University (Benneworth et al. 2009), and thus induce cognitive-cultural changes. The mechanisms and dynamics are very complex and little is known about what kind of institutional and organizational changes effectively initiate and sustain boundary-spanning activities in the context of sustainability.

From our conceptual considerations, we therefore derive the following questions which will guide our empirical analysis:

(a) How were boundary-spanning activities in the context of sustainability initiated?
(b) To what extent do different drivers contribute to these boundary-spanning activities?
(c) How do these boundary-spanning activities differ according to different drivers?
(d) What does that mean for the role of universities in sustainability transitions?

6.3 Methodological procedure

Institutional change processes and their underlying dynamics are hard to grasp due to their often diffuse and gradual character. The approach of a transition topology makes it possible to capture the emergence and outcome of institutional and organizational change processes over time. It helps to understand how intended or unintended activities of actors on the microlevel induce gradual changes and how these add up to a more fundamental change on the aggregate level of a path. The transition topology also makes interactions between different sectors in the region and between spatial levels visible. It therefore provides a useful tool to identify which institutional and organizational changes were important for the emergence and development of boundary-spanning activities, which actors induced these changes, and how these activities in turn shaped the regional sustainability transition (Strambach and Pflitsch 2018).

A comparative case study was conducted in order to show how the development of boundary-spanning capacities of universities for sustainability transitions differs among regions. A main criterion for the selection of the cases was a similarity regarding some basic framework conditions, which made it easier to determine other place-specific influences. The Johannes Kepler University (JKU) as well as the University of Augsburg are both relatively young, mid-sized universities with a broad disciplinary spectrum. They are located in the medium-sized cities of Augsburg (Germany) and Linz (Austria). The

surrounding regions have both been classical production sites and therefore had rather difficult preconditions for a transition to sustainability. A further criterion was that the two universities are not 'best practice' examples of sustainable universities (as it is the case for the Leuphana University in Lüneburg or the Karl-Franzens University in Graz). With a recent recognition for sustainability, they rather constitute 'normal practice' among universities and thus provide a realistic picture on the topic. The data was collected through a qualitative mixed methods methodology. In each case, seven interviews with actors from the university as well as key stakeholders from the region were conducted. A mix of narrative and more problem-focused interview techniques was chosen in order to stimulate the interviewees to reconstruct the evolution of the transition process. Specific details in the process were investigated via telephone or e-mail. In parallel, a thorough document analysis was conducted, which included strategic papers, annual reports, websites, newsletters, etc. The juxtaposition of different perspectives on the topic and the methodological and data triangulation helped to verify and deepen the results. Additionally, both authors had already conducted research in the case study regions.[18] The knowledge gained through previous interviews, participant observations, and document research was important for the interpretation of the results and their integration into the overall context. The authors did not, however, participate in the processes themselves, which enabled them to remain in a neutral and objective position.

In a first step, the data was analyzed in order to establish the transition topology, a directed graph which maps the major institutional and organizational changes in the region and the connections between them in a chronological order (Strambach and Pflitsch 2018). In addition, political programs or initiatives at the supraregional level that had an impact in the region were taken into account. In total 135 events were recorded (see Appendix 3). Institutional changes were operationalized as events, which indicated a shift in regulative, normative, or cognitive elements (Scott 2001). Organizational changes refer to the establishment of a new organization, which includes new independent organizations as well as new departments in existing organizations, more fluid as well as more permanent organizations.[19] The connections between the events are of a genealogical nature. They either indicate an organizational affiliation or an impulse from one event to another that has been vital for the latter's establishment. This impulse can be of a material (e.g., financial support) or non-material nature (e.g., founding idea, transfer of personnel). The topology covers a time period of more than two decades, capturing institutional and organizational changes within the university and their relation to the regional development paths to sustainability (Strambach and Pflitsch 2018). It enables the identification of the main organizations and most influential events in the transition through the number of changes they induced in the path. In the next step, a qualitative content analysis of the interviews was conducted. This enabled the detailed analysis of the boundary-spanning activities that the main organizations identified in the first section engaged in and how these influenced the role of the university in the transition process.

[18] While one author investigated the role of LA21 in the sustainability transition of the Augsburg region (Strambach and Pflitsch 2018), the other author conducted a research project on university engagement in the Linz region (Goldstein et al. 2016).

[19] For a more detailed description of the methodology, see Strambach and Pflitsch (2018).

6.4 The case study regions

6.4.1 Augsburg

After Munich and Nuremberg, Augsburg is the third largest city (with 286.374 inhabitants in 2015), as well as the third largest economic center in Bavaria (together with the districts of Augsburg and Aichach-Friedberg). After a long economic crisis due to the decline of the textiles industry and rationalization measures in the machinery industry, the city of Augsburg recorded a positive trend in employment numbers over the last years (Stadt Augsburg 2017). With the help of political support programs, Augsburg's production-intensive industry managed a structural change towards a knowledge-intensive and more environmentally sound economy. Today, Augsburg hosts many leaders as well as a cluster organization and a competence network in the field of environmental technologies. In 2011, the city of Augsburg officially adopted a resource efficiency 'Leitbild' (mission statement) in order to jointly promote the leading sectors in the region: automation and mechatronics, information and communication technologies, fiber composite and lightweight technologies, aerospace and environmental technologies. At the same time, a comprehensive research infrastructure with a similar focus was built up at the two higher education institutions in the region (Thiel et al. 2015). In 2014, Augsburg was even ranked among Germany's top five innovation regions, particularly due to its networking activities in the field of resource efficiency (BMWi 2014). Parallel to this development, the city of Augsburg received the German Sustainability Award in 2013 for its broad range of achievements in the fields of climate protection, economic and demographic change. The jury emphasized the success of Augsburg's local agenda 21 (LA 21) process and its outcomes in multiple thematic fields. The broad participatory process through which the holistic sustainability concept of the LA 21 was developed was seen as particularly valuable (Stiftung Deutscher Nachhaltigkeitspreis 2013).
The University of Augsburg was founded in 1970 with a focus on the social sciences, law, and economic studies. Only in the mid-1980s was the faculty of the natural sciences established, which then expanded quickly during the 1990s. 20,386 students were enrolled at the university in the winter term of 2017 (Universität Augsburg n.d.). The University of Augsburg is referred to as one of the first 'Reformuniversitäten' (reform universities) in Germany. The societal relevance and applied character of study programs were thus emphasized right from its establishment (Lengger 2004). The only other HEIs in the region that delivered specific expertise for the regional transition was the University of Applied Sciences.[20] Professors and students at universities of applied sciences therefore usually have comparatively strong ties to the local industry (Wissenschaftsrat 2010).)

6.4.2 Linz

Linz, the capital of Upper Austria, has a population of 201,595 (in 2016). The city of Linz with its surrounding region, the Central area of Upper Austria, has around 580,000 inhabitants (including the districts of Linz, Wels, and Steyr). The city of Linz acts rather autonomously within its field of competence due to its size as well as political and economic significance. Between the end of World War II and the 1970s, Upper Austria became the leading industrial region in Austria with the highest export and employment rates. Small but innovative firms grew to become internationally known enterprises (e.g., Voestalpine, BMW-Motorenwerk Steyr, KTM, Bombardier-Rotax, etc.). More recently

[20] The German system of higher education comprises universities and universities of applied sciences. The latter are required by law to conduct more applied research than universities and offer an education with a strong practical orientation (e.g., through long internships, degree theses written in companies).

a 'green economy' has developed and, supported by the state government, a number of clusters have been set up, representing the Green Tech Region Upper Austria. While Linz had the image as a grey industrial city for several decades, restoration and reutilization projects of former industrial sites (e.g., the Tabakfabrik) as well as social and economic programs led to the declaration of Linz as European Capital of Culture in 2009.

The Johannes Kepler University (JKU) was founded in 1966. 19,406 students were enrolled at the university in the winter term of 2015/16. Like the University of Augsburg, the JKU offers a broad thematic spectrum ranging from law studies and the social and economic sciences, to the technical and natural sciences. First attempts to found a university in Linz date back to 1962, when the city and the federal-state government of Upper Austria founded the 'Linzer Hochschulfond' (Higher Education Fund Linz), a public corporation between the city of Linz and the federal country Upper Austria in order to raise the financial capital needed to found the university. This corporation, besides financing the infrastructural and operational needs of the university, also influenced the development of the study program, the appointment of the professorships and departments, and thus the self-perception of the university and its role within its regional environment. Compared to Augsburg, in Linz a broad range of HEIs is located in the region, ranging from public universities, private universities, and universities of applied sciences, to two colleges of education. These universities are also engaged in sustainability-related activities (see Radinger-Peer and Pflitsch 2017) but are not in the focus of this paper.[21]

The regions as well as the universities of Augsburg and Linz share many similarities. It is important, however, to consider that the region of Linz accounts for a large proportion of Upper Austria and is its main economic center. Augsburg is the third largest of three economic centers and only accounts for a much smaller proportion of the Bavarian population.

6.5 Developing boundary-spanning capacities for the regional sustainability transition – The cases of Augsburg and Linz

The empirical analysis is organized into two subchapters in which the case studies are presented separately. Each subchapter is further divided into (1) a description and analysis of the transition topology and (2) a qualitative analysis of the boundary-spanning activities of the main organizations that have been identified in the first section, as well as their outcomes.

6.5.1 The Augsburg case

6.5.1.1 Emergence of boundary-spanning organizations

The topology (see Figure 15) captures the genealogical relationships in the regional development path to sustainability. The university's internal dynamics are displayed on the left side. Those of the other regional subsystems can be found in the three columns in the middle. On the right side, events that happened on other spatial scales, but had an impact on events within the region, are displayed.

The topology makes it possible to identify the most important actors in the regional transition. It makes apparent that in the university, the interdisciplinary Research Center for the Environment (WZU) (f), founded in 2000 with the aim to explore the sustainable use of substances, materials, and energy, initiated several institutional and organizational changes towards sustainability. Amongst others it gave impulses for the establishment of new sustainability-related interdisciplinary study programs (j,

[21] If no reference is mentioned, the information was acquired through the interviews.

m, q), the establishment of a global non-profit organization advancing sustainable business practices (h), a chair for resource strategies (n) and two working groups on sustainability among researchers, administrative staff (o) and students (z) with the aim to foster sustainability in the operation of the university and generally raise awareness for sustainability within the university. With the User Center for Material and Environment Research (AMU) (g) and the Center for Material Resource Management (MRM) (l), a second 'strand' developed. In contrast to the WZU, the MRM follows a technology-oriented approach focused on the exploration of new materials for a resource-efficient economic development.

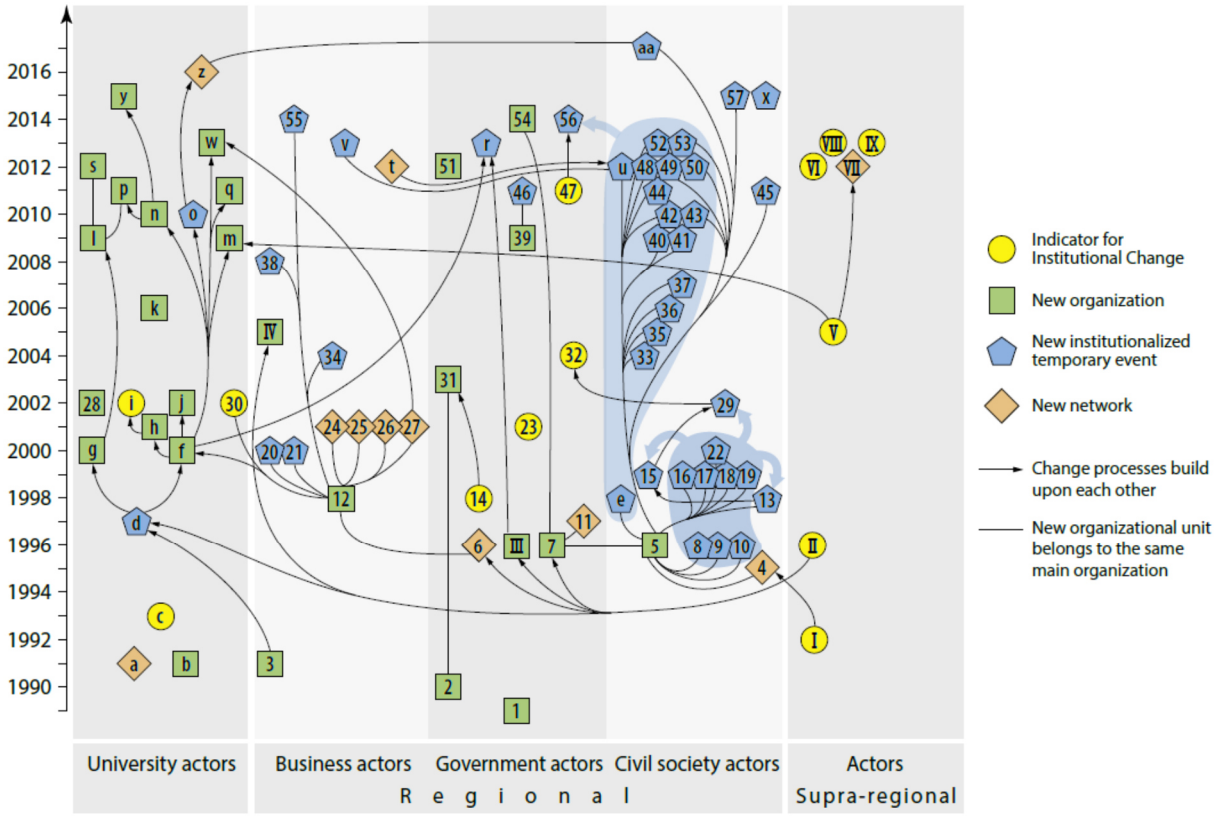

Figure 15: Transition topology for the University of Augsburg and the surrounding region. (Cartography: Christiane Enderle.)

In the region, several important actors, which induced many further institutional and organizational changes, become visible as well. The Environmental Competence Center Augsburg-Schwaben (Kumas) (12) initiated several networks and exhibitions on the topic of environmental technologies (20, 21, 24-27, 30, 34, 38, 55). The LA 21 (5) continuously established new institutionalized temporary events on specific topics, in which more sustainable social practices were developed (7, 8-10, 13, 16-19, 22, 33, 35-37, 40-45, 48-50, 52, 53, 57, e, u, aa). It also initiated the city's environmental advisory board (11), where all relevant organizations from the region regularly come together to advise the city council on environmental and sustainability-related questions.

The topology also helps to understand how these main actor groups emerged. After the first organizational changes at the university (a, b) and in the public field (1-3), the declaration of Augsburg as an environmental competence region by the Bavarian government in 1996 gave an important stimulus for the emergence of Kumas, the LA 21, the WZU, and AMU. The LA 21, which had been

founded by actors from civil society (4), used the new label to secure a permanent position in the city administration (7) and to initiate the city's environmental advisory board (The advisory board was later renamed into agenda and then sustainability advisory board) (11). Kumas was established shortly after the declaration by actors from the IHK, the university management, and the city of Augsburg in order to formulate concrete strategies and actions for the environmental competence region. Amongst others it recommended the establishment of applied research centers on environmental topics at the university to support the emerging environmental industry in Augsburg. In this vein, the Bavarian government provided seed funding for the WZU (f) and the AMU (g) at the university.
The interviews show, however, that it was due to the personal interest of the founders of the WZU, three professors from the natural and social sciences, as well as the manager of the WZU, that the organization's intended focus on environmental topics expanded and a holistic sustainability perspective developed. The latter was based on previous research activities of these actors and impulses by colleagues from the institute of geography, which had already engaged with the topic of sustainability.
In both the region and the university, new foundations generated foundations themselves. In this way, the number of actors working on the topic of sustainability steadily increased. Over time, two different strands developed in the region: a technology-oriented approach focused on the transformation of Augsburg's resource-intensive machinery industry into a more environmentally sound and resource-efficient economy, and a strand which engaged in broadening the understanding of an environmental competence region towards a holistic sustainability 'Leitbild'. This dynamic recently even started to cut across regional subsystems, e.g., with the establishment of a new LA 21 forum (aa) through the Green Office, a student initiative from the University of Augsburg (z).

6.5.1.2 Boundary-spanning activities driving sustainability transition

This section describes the boundary-spanning activities, how they were influenced by the key organizations and events that have been identified in the previous section, and how they contributed to the regional transition process. Hence, the focus is on interactions between organizations or individual actors on the microlevel that do not directly become visible in the topology.
Through the WZU, boundary-spanning activities across diverse disciplines and sectors were established. The network of the WZU meanwhile involves 74 researchers from seven faculties (covering both the natural and social sciences) and several external organizations. Members of the WZU cooperated repeatedly with regional actors, such as members of the Bavarian Institute for Research into Waste Disposal (Bifa), the chamber of crafts (HWK) and the IHK, the association of landscape management, the city's environmental office, and the public utility company. They also participated in several LA 21 forums, enabling students to do internships and practical projects, e.g., in the city's environmental education station. The working groups on sustainability and the Green Office frequently cooperate with regional actors such as the LA 21 and other actor groups from civil society, e.g., Cityfarm Augsburg or Foodsharing e.V., as well. The Bavarian State Ministry for the Environment (LfU), which had been moved to Augsburg in the course of its declaration as an environmental competence region, also became a close cooperation partner of the WZU.
While the WZU has built up a very heterogeneous actor network, the sectoral boundary-spanning activities of the AMU and MRM are primarily focused on actors from industry and government. Although the MRM also engages in knowledge transfer to the broader public, for instance, by conducting workshops in education facilities, the activities are mainly targeted at the techno-economic

development of the region. Boundary spanning between disciplines is also taking place in the MRM, but with a narrower focus on material sciences and resource strategies.

The boundary-spanning activities of the WZU were not initiated top-down but emerged through a shared interest of persons in a specific topic, often in an informal way. It was important for the stabilization of sectoral boundary-spanning activities that members of the WZU were integrated into regional organizations, such as Kumas, the city's environmental advisory board and some LA 21 forums right from the beginning. This was actively fostered by the founders of Kumas and the LA 21, who were not commissioned by the city of Augsburg but had their own agenda and mobilized a variety of actors in the region in order to realize their personal vision for the Augsburg region. In this way, the network relationships with regional actors became relatively stable and are no longer dependent on specific actors. At the same time, institutionalized temporary events, including regular meetings at the WZU, the Kumas' networks, and the LA 21 forums, where actors met repeatedly for a limited amount of time, enabled the initialization of new relationships and the creation of new ideas for joint projects.

The university management is not perceived as a strong driver of boundary-spanning activities in the context of sustainability. Although it mentioned the aim to network with regional actors in the field of environmental technologies in the university's development plan in 1990 and signed the Copernicus Charter in 1993, it has not proactively fostered interdisciplinary networking or the establishment of relationships to a broader range of regional actors. Most researchers that have entered the WZU's network seem to be mainly interested in finding new cooperation partners or getting new impulses for their research and teaching activities. However, without the support of the university management and the engagement of individual committed actors at the federal-state level, the increasing institutionalization of the bottom-up driven activities would not have been possible.

On the contrary, third-party funds and research programs have given strong incentives for boundary-spanning activities with industry actors in the field of resource and material efficiency. Particularly in the Augsburg region, with its carbon industry, these activities have been strategically promoted by the city of Augsburg and the federal-state government, e.g., through the establishment of the new innovation park on resource efficiency. The regional development agency also fostered cooperation between researchers from different disciplines with industry actors by initiating a platform for resource efficiency in 2011. Through regular meetings, inter- and transdisciplinary projects or joint project applications developed, which would—according to an interview partner—not have been established automatically through the spatial or even organizational proximity of these actors in the region or the university.

In this way, university actors have contributed to the regional transition in various ways. Through its boundary-spanning activities, the WZU absorbed impulses from a broad range of actors from different disciplines and societal sectors with different perspectives on sustainability. Thus members of the WZU were able to identify topics that are particularly relevant for the region in the context of sustainability and develop more extensive research approaches, e.g., the comprehensive approach 'Stoffgeschichten' (material histories).

Since the foundation of the WZU, a total of 25 research projects with an explicit regional focus were conducted. The contributions range from the legitimation of sustainability measures (e.g., the implementation of an environmental zone) in the region, the choice of potentially sustainable technologies for the local transition (e.g., through the establishment of a heating atlas), the identification of conflicts between different aspects or dimensions of sustainability (e.g., in an open lecture series on the renaturation of the local river), and impulses for the future development of the region (e.g., the development of a concept for an environmental department at the new university clinic), to a critical reflection of the progress and direction of the regional transition process (e.g., by

taking a critical stance on the implementation of the resource efficiency 'Leitbild' in the local economy). By integrating sustainability into the university's teaching activities and by extensive educational work in the region, the WZU also raises awareness for sustainability topics and their multidimensional character among students.
The establishment of relationships between university members and regional actors not only enabled the university to contribute to the transition process, but also gave impulses for a transformation process within the university. Both working groups on sustainability have received impulses and support from the LA 21, for instance, to implement ecological standards in several buildings or to start a campaign to reduce the use of paper at the university. More recently, the Green Office even received funding for its foundation from the LA 21 and financial support to take part in international networking activities with other student initiatives.
The AMU and in particular the MRM are involved in various cooperation with industry actors and the latter takes over an important role in the regional innovation park on resource efficiency. Actors affiliated to these organizations moreover participate in various projects, which often have a huge impact on the external image of the region. One example is a project financed by the German government with the aim to analyze how a region with an energy-intensive industry like Augsburg can deal with the volatile energy supply from renewables and this way manage the 'Energiewende' (energy transition).

6.5.2 The Linz case

6.5.2.1 Emergence of boundary-spanning organizations

The topology (see Figure 16) shows that at the Johannes Kepler University (JKU) Linz, the actor which induced the largest number of further organizational and institutional changes towards sustainability, is the Institute for Environmental Law (b). Besides establishing an association with the aim to support the institute financially but also to involve other stakeholders from the region (d), the institute initiated an event series (c), a new specialization in the study program law (g), and an international conference (k), as well as the future lecture series (m). Two other organizational changes provided a basis for further changes at the JKU, the Institute for Environmental Management in Companies and Regions (UWI) (e) and the Energy Institute (IX), which both started new study programs in their respective fields of expertise (f, j).
In the region, there seem to be no main actors which fostered the topic of sustainability. The main changes towards sustainability which have been initiated by regional actors, such as the eco-energy cluster, have received comprehensive support from the federal government. The LA 21 (2) is the only actor which induced a number of further organizational changes in the form of working groups around different aspects of sustainability (3-10). The latter do not, however, initiate further changes over time, as they have not been continuously supported by the city government.
Regarding the emergence of the main actors, the topology shows that the Rio Conference in 1992 was an important impulse for several changes at the national and regional level. Inspired by this event, the JKU Linz, as one of the first universities in Austria, signed the Copernicus Charter (a) in 1993, which provided the basis for the establishment of the Institute for Environmental Law (b). However, from the interviews we know that the establishment of the Institute for Environmental Law and the UWI, founded in 1998, was also strongly promoted by the subsequent heads of the institutes.
Inspired by the UN conference in Rio de Janeiro (I), the federal-state government of Upper Austria decided in 1994 as the first federal country in Austria on a sustainability concept (II). Stimulated by

these same developments, in 1995, the city of Linz became a member of the Local Governments for Sustainability Initiative (ICLEI) (1), which resulted in the resolution of the municipal council to start an LA 21 process (2). In 2012, due to changes of the governing political parties, the LA 21 process slowed down, however, and was transformed into a non-binding process.

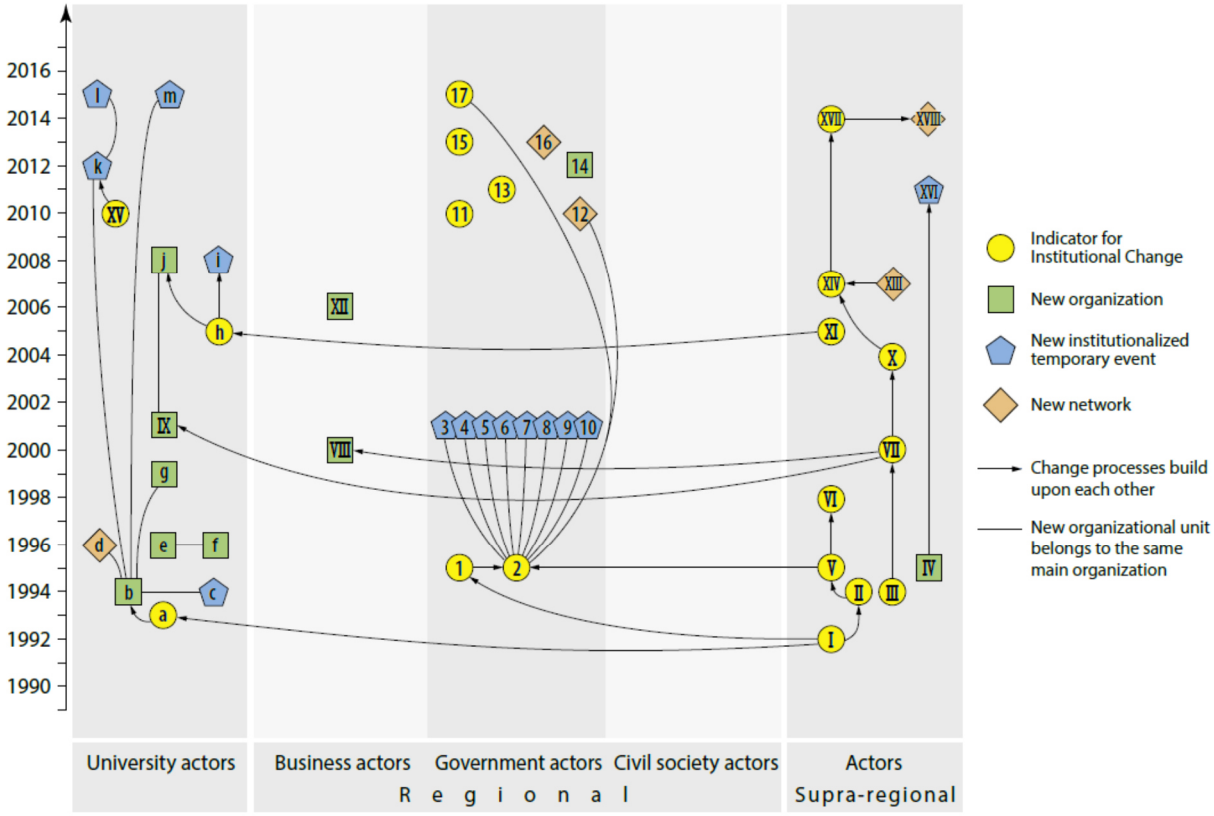

Figure 16: Transition topology for the JKU Linz and the surrounding region. (Cartography: Christiane Enderle.)

In 1994, the government of Upper Austria decided on an energy concept (III), formulating precise targets and measures until 2010, as well as the decision on an environmental program for Upper Austria (IV) in 1995. In 2000, this energy concept was updated, which supported the establishment of the Energy Institute in 2001 (IX). The institute was founded by the government of Upper Austria, the Energiesparverband Upper Austria, the Energie AG, Linz AG, the Upper Austrian Ferngas AG, the Chamber of Labor, and the Chamber of Commerce, with the purpose to conduct inter- and transdisciplinary applied research projects in the fields of energy law, energy economics, and energy technology, and to support politics and the regional economy in energy-related issues with scientific evidence. The Energy Institute was founded as an independent organization, although two of the three directors of the Energy Institute also hold positions at institutes of the JKU.

Overall, the government of Upper Austria induced a large number of political programs that gave strong impulses for the emergence of all the key actors at the university, both in the form of financial funding and thematic orientation. Regarding the dynamic of organizational and institutional changes, it becomes apparent that there are only a few second-stage foundations compared to Augsburg. There are no connections between events which cut across different regional subsystems.

6.5.2.2 Boundary-spanning activities driving sustainability transition

The sustainability-related network in Linz mainly consists of a number of highly engaged university members and actors from the public field. The Institute for Environmental Law has been in ongoing cooperation with the federal-state government of Upper Austria in the form of joint events, project cooperation, informal knowledge exchange, and lecturing activities. Most of these activities were informal and not institutionalized. The members of the Institute for Environmental Management in Companies and Regions (UWI) served in different transdisciplinary working groups or advisory boards, established by the federal-state government, to whom they voluntarily applied or were invited. Examples for these are a working group for the development of measures in the frame of the Upper Austrian energy concept or the Upper Austrian 'Zukunftsakademie' (future academy). The working groups, which included actors from the economy, science, civil society, and the public field, were usually set up for a limited time. The managing directors of the Energy Institute also actively participated in these working groups, in particular in those focused on energy-related topics. They also cooperated regularly with the public body as well as with energy suppliers.

The relationships of the institutes to actors from the city of Linz are less pronounced than those to the federal-state government. Particularly noteworthy is that the UWI has not been in contact with the city of Linz or their LA 21 process, although the latter is clearly in the field of expertise of the institute. Only one scientific representative from the Energy Institute at the JKU has been involved in the air, climate & energy working group. Only recently, initial talks have taken place between these actors regarding the start of a smart city process. Overall, the relationships to the city administration have not been that manifold and close as those to the federal-state government. Only the Institute for Environmental Law is well connected to the city of Linz, especially to the city counsellor from the Green party, who is, among others, responsible for nature and environment-related issues.

In the interviews, it turned out that rarely any boundary-spanning activities between disciplines at the JKU have been taking place, and the mentioned institutes rarely cooperated with each other. All of the mentioned institutes, however, integrated interdisciplinary sustainability topics into their teaching activities despite the fact that, apart from the Energy Institute, the institutes themselves are not interdisciplinary in nature. They also do not coordinate with other Higher Education Institutions (HEIs) in the region of Linz that focus on sustainability-related issues.

It became apparent that it have been mostly the same individuals (mainly the department heads of the presented institutes as well as the rector) at the university that have shown a strong engagement in regional activities over the years. The appreciation of the city or federal-state government has been pointed out as a main motivation for these individuals.

Overall, the sustainability-related activities of the JKU to other societal sectors have been strongly shaped and incentivized by the federal-state government of Upper Austria. The initial environmental focus of the UWI was altered to a more holistic sustainability perspective only through a request of the federal-state government to conduct an evaluation of the LA 21 processes in Upper Austria. The interview partners furthermore pointed out two recent developments regarding the research activities of the institute, which are again influenced by the strategies and therewith funding programs of the government of Upper Austria, as well as by national funding programs: (a) the holistic focus on sustainability is altered into a more thematically specified one (e.g., mobility, climate change, demographic change) and (b) the discourse on sustainability is no longer focused on rural regions but moves towards urban agglomerations (e.g., smart cities). The Energy Institute also had the clear mission, right from its foundation, to support the energy transition of the energy-intensive industries, a topic which was and is high on the agenda for the federal-state government.

The low amount of boundary-spanning activities between the institutes and the city of Linz is due, among others, to the fact that there is no actor responsible for the topic of sustainability in the city administration. Moreover, the LA 21 working groups were initiated and strongly dominated by representatives from the municipal administration, which outnumbered participants from other public bodies, companies, and associations, as well as representatives from political parties.

The high fragmentation of activities seems to be due, amongst others, to the lack of leadership by the university management. Although the rectorate signaled awareness for the topic of sustainability at a very early point in time by signing the Copernicus Charter and later the Graz declaration, there has been no continuous engagement by the university management since then.

Outcomes of sectoral boundary-spanning activities of the UWI initiated by the government of Upper Austria include the identification of 'hot spots' for the environmental policy program of Upper Austria up to 2030, the design of a regional plan on using biogenic resources for food, energy and raw material, a synergetic concept for sustainable energy strategies in regions, the increase of material efficiency by means of environmental management accounting tools, and a feasibility study for solar fuels, to name only a few examples.

The Energy Institute strongly shaped the technological, legal, and economic spheres of the energy transition within the region, for example, by comprehensively supporting the Ecoenergy and the Environmental Cluster and by taking part in broader political discussions. One interview partner also mentioned that sometimes researchers have raised their 'critical voice' to point out unsustainable directions of development. The JKU thus mainly induced awareness for sustainability issues in a 'classical' way through knowledge transfer, expertise, and consulting. The contributions of the institutes and their individual members are overall fragmented and show a high level of thematic specification.

6.6 Comparative discussion: Different development trajectories in Augsburg and Linz

The questions of interest of the present paper referred to the connections between the emergence, drivers, and type of boundary-spanning activities and the roles of the universities in the regional sustainability transition. Comparing the cases, we can now deduce some more general mechanisms and results.

In the case of Augsburg, boundary-spanning activities in the context of sustainability are based on a lot of bottom-up work by individual actors in the context of the WZU and from the region. A dynamic process was initiated through the continuous foundation of new organizations, in which, over time, an increasing number of heterogeneous organizations and individuals within the university and in the region became involved, covering different thematic aspects of sustainability. This dynamic was spurred by institutionalized temporary events, where actors came together for a limited amount of time and where new relationships could emerge. At the same time, more permanent organizations enabled the development of trustful long-term relationships between actors from all regional subsystems (Strambach and Pflitsch 2018).

As shown in Figure 3, the WZU, which is the nucleus of most sustainability-related activities at the university, has absorbed impulses from different actor groups and on this basis defined its own research focus and priorities. As such it succeeded to cross organizational, disciplinary, and sectoral boundaries. In this vein, the University of Augsburg is currently transitioning from its more passive and restrained position into a more active, independent, and developmental role. This does not mean,

however, that sustainability has penetrated the self-perception of the whole university. The WZU and individual engaged institutes are relatively small organizational units within the university. Apart from the WZU, the MRM has emerged as a strong player, although mainly targeting the industry and techno-economic development of the region. This makes apparent that there is no unitary role of the university in the regional sustainability transition process (Croog 2016).

In Linz, the network constellations around sustainability built on the already existing historically evolved network relations and relational proximity (Boschma 2005) of individual actors at the university and in the region. The long-term study revealed that these networks around sustainability did not change significantly over the years. Boundary-spanning activities with actors from civil society and the economy are taking place only indirectly, through the participation of university members in the transdisciplinary advisory boards and working groups set up by the federal-state government (see Figure 17).

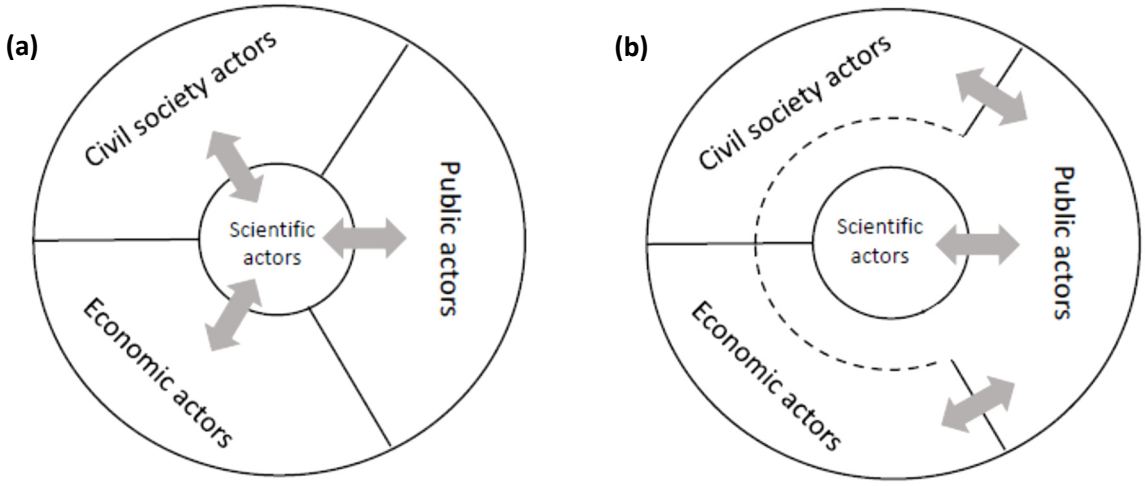

Figure 17: Relationships of the WZU at the University of Augsburg (a) and the Institute for Environmental Law, the UWI and the Energy Institute at the JKU Linz (b) to other regional actors.

Disciplinary boundary-spanning activities within the university are limited to the interdisciplinary Energy Institute. The Energy Institute, however, is organized as an association and organizationally decoupled (Meyer and Rowan 1991) from the university, preventing the institute from initiating further changes within the rest of the university. Moreover, a platform or organizational unit which bundles and institutionalizes sustainability-related research and teaching activities within the university is missing. Therefore, selected university institutes act in a rather fragmented fashion, independently of each other. Regional organizations which engage in boundary-spanning activities are largely missing in Linz. Therefore, a different, more top-down-oriented approach, which made use of the historically-evolved close relationships between the university and actors at the federal-state level, was more effective. Overall, the role of the JKU is rather fragmented and passive today due to this development. In addition, it is more narrowly focused on topics which are particularly relevant for the region from the perspective of the federal-state government.

In the two examples, differences regarding the actors involved and their interaction mechanisms become apparent, which have been shaped by place-specific path dependencies. The latter can be differentiated into (a) socio-spatial and socio-economic characteristics (pre-existing industrial base,

natural resource endowment, human capital), (b) relational aspects (networks, power relations, roles of specific actors, proximity between actors), and (c) the institutional environment (regulations, policies, visions, norms, culture) (Bathelt and Glückler 2003, Boschma 2005, Gunasekara 2006, Coenen et al. 2012, Hansen and Coenen 2015). Although the two case studies share some similarities with regard to the size of their location city, the history of their industrial basis, and the age of the universities, they took over a different role in the regional sustainability transition. Differences mainly refer to relational and network aspects as well as the institutional environment.

In Augsburg, the state played the classical role of providing financial resources (Farla et al. 2012) and thus supported the foundation of the WZU, which was initiated by the university management and regional actors. The holistic sustainability approach of the WZU is, however, primarily a result of the engagement and ideas of individual researchers at the university. The WZU also supported the institutionalization of already existing bottom-up-driven boundary-spanning activities from other researchers. In parallel, a bottom-up-driven sustainability process in the region developed, which gave impulses for actors at the university and also spurred sectoral boundary-spanning activities. The example of Augsburg confirms that regional sustainability transitions are, to a great extent, also driven by business communities and civil society actors (Seyfang et al. 2010). The cooperation of frontrunners from these different sectors was key in order for these actors to generate momentum.

While in the case of Augsburg the state government was an enabler via opening a window of opportunity, the federal government of Upper Austria was a strong agenda-setter right from the beginning, not only by providing funding for the relevant research institutes at the JKU, but also by influencing their research focus and boundary-spanning activities. Policies and regulations stated important pull factors (Hansen and Coenen 2015) in the case of Linz. Interestingly, the national Austrian University Law, which clearly outlines the role of universities to contribute to a sustainable societal and environmental development, is not really in the consciousness of the university members. It is mainly the policies, regulations, and funding programs of the federal government of Upper Austria which moderate the engagement of the JKU. The self-perception of the JKU and its members is that of a demand-oriented service provider for politics and the regional economy. This seems to be historically imprinted through the 'Linzer Hochschulfond' (Higher Education Fund Linz), an Austria-wide unique cooperation between the municipal government of Linz and the federal-state government of Upper Austria. The Higher Education Fund Linz enabled the foundation of the JKU via its financing, but at the same time consolidated power constellations, with the regional and city government expressing clear expectations towards the JKU. The top-down approach, however, profited from the strong engagement of individual actors at the university, who often participated in sustainability activities in addition to their normal working hours.

The case studies illustrate the two different mechanisms through which boundary spanning is institutionalized that have been discussed in the theoretical part. They reveal their advantages and disadvantages and make apparent that a mixture of bottom-up and top-down approaches is probably the most feasible path for most universities.

In both cases, the intrinsic motivation of individual university members was essential to induce institutional and organizational change towards sustainability. In most cases, these individuals felt a normative obligation to engage in sustainability topics due to the position they held (institute head, rector) or their personal convictions. As such, they have been 'frontrunners' (Brown et al. 2013) and role models for other institute members. Apart from this, the interviews revealed that there was also a personal interest to contribute to the region they are living in. It has been confirmed in one case (Institute for Environmental Law, JKU) that this personal engagement works at the expense of international cooperation and publishing activities. The cases thus underline the important role of

individual frontrunners or 'champions' at the university and in the region that has frequently been emphasized in the transition literature (Brown et al. 2013).

The cases, however, make it apparent that support from the university management and from the federal-state is necessary to develop organizational and institutional structures which facilitate and sustain relationships to regional actors and between disciplines (Stephens and Graham 2010, Ferrer-Balas et al. 2008). The latter is particularly important when highly engaged individuals leave the university (Hoover and Harder 2015, Radinger-Peer and Pflitsch 2017,). Contrary to the finding of Feldman and Desrochers (2003), Sedlacek (2013) or Lozano et al. (2015), we found, however, that even without a strong leadership by the university management, university members as well as regional actors can initiate boundary-spanning activities and foster their institutionalization. On the other hand, the missing (continuous) leadership of the university management also prevents universities from taking a leading role in regional sustainability transition, as no strategic long-term vision and goals are formulated (Stephens et al. 2008, Zilahy and Huisingh 2009).

Both case study regions are characterized by a strong industrial basis, which leads policy makers and other actors from the top to favor economic development and economically relevant aspects within sustainability-related activities over others such as societal and environmental ones (Gibbs and O'Neill 2014). According to Croog (2016), this implies the danger that sustainability endeavors are tailored to policy and funding cycles and thereby more holistic, long-term, and systemic approaches are marginalized (see also Hoover and Harder 2015). Universities are expected to take into account the plurality of perspectives, remain in a neutral position, and stay open for criticism. This expectation of being a 'guardian' of a holistic understanding of sustainability on the one hand and on the other hand being dependent on industrial and public funding makes the tension for universities apparent. This is part of the reason why there is no unitary role of the university in the regional transition process (Croog 2016), but different university units and members have different perceptions of their regional (developmental) role and are also influenced by proponents of competing visions for the region's future development (Murphy 2015).

6.7 Conclusions

Taking the examples of two mid-sized university cities and their surrounding regions, the paper shows different ways of how universities can be involved in regional sustainability transitions. It makes apparent that the ability of taking over a development role in these processes relies on their boundary-spanning capacity, which needs to be understood as the capacity to transcend both disciplinary and sectoral boundaries. In particular, the long-term perspective and the comparative approach were key in order to realize which actors and events shaped the boundary-spanning activities of the university and how that influenced the role of the university in the regional sustainability transition. The transition topology showed that developing a boundary-spanning capacity is the outcome of a long-term process of institutional and organizational change, which can only be driven to some extent by actors from the top. In particular, cultural-cognitive changes have to be induced, which are more effectively driven by actors on the ground.

Different roles of the universities in the regional sustainability transition became apparent. The roles we found in our examples can be distinguished on the basis of two dimensions: their depth and autonomy. Regarding the first dimension, we found the roles to be (1) comprehensive, involving diverse actors and approaching sustainability with a holistic perspective, and (2) more fragmented and passive, but also more focused on specific topics (Trencher et al. 2014). Regarding the second dimension, the roles were (1) autonomous, the university defining its own focus and priorities through

interacting with a broad range of regional actors, and (2) more directed, the university working on topics that are relevant from the perspective of the regional or federal-state government. These categories can be seen as different manifestations of a developmental role in the context of sustainability.

As such it became evident that not only are sustainability transitions highly dependent on their geographical and spatial surrounding (Truffer and Coenen 2012, Hansen and Coenen 2015, Murphy 2015), but so are the roles specific regional actors and organizations play within these transition processes. By focusing on two normal practice examples of universities and their sustainability engagement, we have been able to identify internal dynamics as well as external influencing factors which shape their boundary-spanning capacity. It turned out that it is not a self-evident process that universities become change agents for sustainable development, but it is the result of interrelated aspects of bottom-up engagement, top-down consolidation, and regional embeddedness. We therefore conclude that to foster the involvement of universities in regional sustainability transitions, it is not sufficient to support actors at the university or in the region. Political programs should be targeted at both sides in order to stimulate a productive interaction between the university and its regional environment. There is no 'one-size-fits-all' strategy (Tödtling and Trippl 2005). When designing policy approaches, the place- and path-dependent character of these processes needs to be considered.

More systematic, comparative, case study research is needed in order to shed light on the question of why the role and involvement of universities in regional sustainability transitions differ across places (Hansen and Coenen 2015). The transition topology provides a good starting point for that. It could be used in further research to establish a typology of different regional transition paths to sustainability. This typology could, for instance, be based on variations in key actors, the nature of their interactions with each other, and the organizational dynamics that develop over time.

(For better readability of this dissertation, acknowledgements, declaration of author contributions and conflict of interest were deleted here, but can be looked up in the original paper.)

7 The role of higher education institutions in regional transition paths towards sustainability

This chapter is a reprint of:

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Abstract

The present paper investigates the role of the located Higher Education Institutions (HEIs) in the transformation towards sustainability of the city of Linz as well as the region of Upper Austria. We argue that HEIs have the potential to spur a regional transition towards sustainability via the channels of teaching, research and outreach. We furthermore take into account that organisational- and field-level drivers influence the role of HEIs within the regional transition paths towards sustainability (RTPS). We chose an explorative research design in order to give a realistic picture of the potentials and limitations of HEIs' involvement in regional transitions to sustainability. The role of the five HEIs located in the city of Linz is studied through in-depth expert interviews and a comprehensive document analysis. The investigation reveals that there is no contribution of HEIs as a whole to RTPS, but that the impact is dependent on individual highly engaged "frontrunners" enacting change and at the same time on leadership from the university management. Moreover, regulative drivers at the field-level and normative as well as cognitive drivers at the organisational-level affect HEIs' contribution.

7.1 Introduction

Various political agendas, programs and supra-national initiatives have emphasized the role of Higher Education Institutions (HEIs) in spurring sustainability and sustainable development throughout the last decades. In 1987 the Brundtland Report (WCED 1987) introduced sustainability as a concept which strives for a balanced social, ecological and economic development on different spatial scales. Launching several new principles such as:

a) increasing significance of the local and regional level,
b) public and stakeholder participation and
c) integrative, holistic approaches to regional and local challenges (Peer and Stoeglehner 2013),

the concept of sustainability confronts considerable complexity and emphasizes the need for systemic, multi-dimensional and transdisciplinary approaches. Sustainability transition research integrates technological, market and behavioral perspectives by considering the co-evolutionary development of these different elements in specific socio-technical systems (STRN 2010). The latter fulfil basic human needs such as energy supply, mobility, and housing, and are also referred to as 'sociotechnical regimes'. How to break up these path dependent structures and initiate a fundamental change in the architecture of these systems is the central question in sustainability transition research and receives increasing political attention (e. g. WBGU 2011).

Cities and regions in particular have been identified as a key for sustainable development (McCormick et al. 2013). Proximity advantages at the urban and regional levels facilitate the mobilization and integration of various actor groups and initiatives (Truffer and Coenen 2012). Empirical research has shown that sustainability transitions are highly place-specific and that some regions offer a particular favorable institutional environment for such processes (Hansen and Coenen 2015). The concept of Regional Transition Paths to Sustainability (RTPS) explains how specific institutional environments develop that favor the development of sustainable innovations and pave the way for changes in multiple socio-technical regimes (Strambach and Pflitsch 2017).

The changing political and scientific discourse has influenced the engagement of HEIs in regional development in general, and sustainable development in particular. HEIs have developed and continue to develop from their "traditional" role as mere educational infrastructure and research institutions, to "new" roles as drivers for innovation and as stakeholders in public and private partnerships, as well as in planning processes (Chatterton and Goddard 2000). This "3rd mission" depicts a broader and more adaptive role for HEIs, and their contribution to social, cultural and environmental development based on regional needs (Chatterton and Goddard 2000, Gunasekara 2006).

Lozano et al. (2015) outline seven spheres where HEIs may engage in implementing sustainability:

1. institutional framework,
2. campus operations,
3. education,
4. research,
5. outreach and collaboration,
6. on-campus experience,
7. assessment and reporting.

Stephens et al. (2008) deepen the definition of sustainable development by not only focusing on the activities of universities, but also by taking the content of teaching and research activities into account. They apply the term "change agent" to describe four paths of university action supporting sustainable transitions:

1. providing a model of sustainable practices for society;

2. teaching students how to deal with complex problems and exercise system-thinking;
3. performing practice based research-activities; and
4. promoting and enhancing engagement between individuals and universities situated as transdisciplinary agents.

While sustainable development related educational changes as well as HEI management and campus operations are quite prominent in the literature (Lozano et al. 2015), evidence – with few exceptions (e. g. Sedlacek 2013) – Is yet rare on the role of HEIs in RTPS.

The present paper aims at shedding light on the role HEIs play in the regional transformation towards sustainability using the example of Linz (Austria) and the five HEIs located therein. The two research questions of interest are:

1. what are the contributions of HEIs to RTPS via teaching, research and outreach,

and

2. how is the role of HEIs within RTPS influenced by organizational- and field-level drivers?

The paper is organized in six sections. Section 7.2 elaborates the conceptual framework on the role HEIs might be able to play in RTPS by referring to state of the art scientific literature. Section 7.3 outlines the methodology of the explorative case study. Section 7.4 presents the case study of Linz and the located HEIs, and gives a concise overview of the transition towards sustainability in the city of Linz as well as the region of Upper Austria. In Section 7.5, the results of the empirical investigations are presented and are further discussed in Section 7.6, taking into account the existing literature. The final section concludes the main findings.

7.2 Conceptual framework – Regional transition paths to sustainability and the role of HEIs

It has recently been highlighted that socio-technical transition processes are strongly influenced by the territorial institutional environment in which they take place (Coenen et al. 2012, Truffer and Coenen 2012). From a regional perspective, it has to be considered however that a transition to sustainability encompasses the implementation and integration of transformations in multiple socio-technical regimes. Introducing the concept of RTPS, Strambach and Pflitsch (2017) argue that regional transitions are based on more complex dynamics than transitions of specific sociotechnical regimes due to the co-evolution of their institutional environments over time and the interdependencies resulting from them. The concept of RTPS therefore refers to recent approaches from Evolutionary Economic Geography (EEG) that allow a more differentiated view on path dependent developments, focusing in particular on how actors at the micro-level use the plasticity of the regional institutional environment to enact change (Boschma and Martin 2010, Strambach 2010, Strambach and Halkier 2013, Trippl and Tödtling 2013). Empirical studies show that at the regional level actors initiate more general institutional and organizational changes that lay the foundation for changes in multiple socio-technical regimes and thematic areas. Over time, incremental changes can this way lead to a more fundamental change in direction of a regional path towards sustainability (Rohracher and Späth 2014, Strambach and Pflitsch 2017).

Different elements necessary for a socio-technical transition including actors, knowledge, materials, power etc. are usually spread over various geographical scales (Murphy 2015). Therefore Truffer and Coenen (2012: 11) have pointed out that: *"*[...] *a critical examination of transition spaces would not stop at the administrative borders of territorial units (regions, nations) but would require attention for spatial dimensions and implications of sustainability transitions 'wherever they may lead'."* This is

based on a relational understanding of space, in which territorial scales are constituted through actor relations and not through simple geographical hierarchies (Coenen et al. 2012, Rohracher and Späth 2014). Hence in a regional transition actors may interact on multiple geographical scales, leading to a momentum of "interlocalization" (Geels and Deuten 2006), that is, *"a point in the transition when formerly local actors are able to exert greater influence on a regime as the scope and extent of their influence consolidates and institutionalizes"* (Coenen et al. 2012: 975). In other words, agency and particular conditions enable the interventions by individual actors to trigger more structural evolution (Gibbs 2006, Genus and Coles 2008).

Arbo and Benneworth (2007) pinpoint that a significant part of HEIs' regional potential lies in the fact that they are often not purely regional bodies but are multi-scalar in nature, integrating the global, national and regional scale. They localize elements of both, "local nodes" and "global networks" (Späth and Rohracher 2012). Thus, HEIs are expected to fulfil a bridging and brokering function between international research communities and the needs of regional stakeholders for tailor-made knowledge. In a more general understanding, the model of the "engaged university" attempts to conceptualize the comprehensive role HEIs may play for their location region, thus going beyond mere recognition of economic impacts – as argued by the Regional Innovation System Model as well as the "entrepreneurial model" – of HEIs activities. The "engaged university" characterizes HEIs as active "animateurs" (Shiri et al. 2012), which are capable of providing tailor-made solutions to region-specific challenges and problems (e. g. urban development, transport, health, sustainable development). Also the term "change agent" (Stephens et al. 2008) raises the expectation that HEIs have the potential to take agency and thus trigger institutional and organizational changes in the regional path. This is facilitated through the channels of teaching, research and outreach.

At the same time, we argue that the HEI-region interface is highly context- (Peer and Penker 2016) and place-specific, hence, HEIs will not shape RTPS autonomously but are influenced by and depend on their local and regional environment. We propose a conceptual framework that combines two perspectives:

1. the contribution of HEIs to RTPS via the different channels of "Teaching", "Research" and "Outreach", and
2. the drivers influencing the roles of HEIs in RTPS, thus taking into account the place-specificity of the regional transition path.

In doing so we distinguish between field-level and organizational-level drivers.

7.2.1 Contribution of HEIs via different channels

Teaching. Sustainability might be integrated as theoretical content in different lectures or provide the starting point of practical student projects. New didactic methods, such as service learning, or organizational settings, such as inter- or transdisciplinary seminars, can be implemented. While a theoretical consideration of sustainability issues helps to raise awareness, practical student projects in collaboration with regional stakeholders can have a direct impact on the regional transition path. Moreover, new study programs might be initiated which have their inception in specific regional sustainability challenges and which enable the combination of existing disciplinary contents in order to deal with complex sustainability challenges (Wickson et al. 2006). Teaching activities can be seen as an important driver of long-term institutional change in the region, as graduates and their awareness for sustainability represent a multiplier and possess the capacity to deal with such complex challenges. This process might be accelerated through additional vocational training courses or customized education programs that are tailored to specific regional needs (Peer and Stoeglehner 2013).

Research. Research on sustainability might be conducted in individual disciplines or in the context of transdisciplinary research platforms that integrate researchers from different disciplines as well as practitioners. Sustainable transdisciplinary research differs from multi- and interdisciplinary approaches through its strong problem focus, evolving methodologies that are tailored to the specific problem under investigation and collaborative knowledge generation between researchers and stakeholders – not only in the problem solution phase but already in the stage of problem definition (Wickson et al. 2006, Radinger-Peer et al. 2015). Compared to co-research and cooperative research projects, all project members work together on all aspects of the project and not in parallel on different aspects, which are then synthesized at the end (Hord 1986). This enables environmental and social problems to be approached from a systemic perspective that is not obstructed by disciplinary knowledge boundaries (Russell et al. 2008). As a result, transdisciplinary projects are much more likely to generate practical knowledge directly applicable to the region.

Outreach. Outreach builds on the two former roles of the HEI. Such activities include spontaneous or occasional encounters of actors as well as more frequent and broad-based interactions with their regional environment. More permanent forms of association enable trust building and foster the development of social and cognitive proximity between actors (Coenen et al. 2012). Outreach activities may be passive, active, or proactive. A passive role means that HEIs (re)act on demand (for e. g. expertise, external consultation, presentations), while an active role subsumes the initiation of new platforms and discourses in the region, (voluntary) participation in advisory boards or also political engagement. Another contribution could be the formation of networks and alliances with key actors both inside and outside the region in order to influence political decision processes that affect the RTPS and acquire resources such as financial support for pilot projects in the region. In a proactive role, HEIs realize their brokering and bridging function, thus utilizing their international networks to serve the regional need or even take agency and set the agenda.

7.2.2 Organizational and field level influences on the role of HEIs in RTPS

HEIs are loosely structured organizations, whose sub-units and individual members interact on multiple scales and are influenced by regulative, normative and cultural cognitive drivers from the organizational- as well as field-level. The “field” in this understanding comprises the local, regional but also national HEI-related environment. The latter is especially interesting because HEIs in Austria, their legal framework and financing are a competence of the nation state.

Internal rules, strategies, mission statements and guidelines influence the behavior of individuals because they seek the attendant rewards or wish to avoid sanctions (Scott 2001). On the field level, regulative mechanisms entail first of all university and higher education legislation, funding organizations and programs, policy strategies, and programs in adjacent fields such as regional, science and innovation policy, which may exert coercion or offer incentives.

Normative drivers entail both values and norms. While some values and norms are applicable to all members of the collective body, others apply to selected types of actors or specified social positions. Hence members of the rectorate or department heads might be confronted with the expectation to act as role models and contribute in various ways to the RTPS. This includes also the self-perception of the role of the HEI and its communication towards HEIs members. Norms and values may also be operationalized as certifications, awards or accreditations.

Cultural-cognitive drivers focus on the role of ideas, beliefs and assumptions. Taken-for-granted assumptions are among the most powerful drivers in the interaction and debate among different types of stakeholders (Colyvas and Powell 2006). Cultural cognitive elements entail, for example, routines in

the interaction with regional stakeholders. We point out that this theoretical separation of the different driving mechanisms might not be found to reflect reality, where boundaries may blur.

7.3 Methodology

The HEIs in Linz are perceived as being among the most regionally engaged throughout Austria (see also Goldstein et al. 2016). It was therefore of interest to the authors if these HEIs also play a significant role in RTPS. A further reason for choosing the city of Linz and the region of Upper Austria as a case is their transition from an industrial city and region towards an Austrian-wide leader of transition towards sustainability. They have been the first throughout Austria in various sustainability related fields e. g. first to join the ICLEI–Local Governments for Sustainability Initiative, first province with a sustainability concept and strategy, first diocese in Linz powered by 100% green electricity, first province to transform the energy system. The question to what extent the regional HEIs contributed to these processes was open from the beginning. Although we limit our investigations to the case of Linz, we aim towards deducing some general mechanisms which shape the role of HEIs in RTPS. This explorative research design was chosen in order to give a realistic picture of the potentials and limitations of HEIs' involvement in regional transitions to sustainability. The latter is particularly important considering the high demands placed upon HEIs from the political side.

Table 2: Presentation of the interview partners, their affiliation and role within RTPS.

Role of the interview partner within their organization	**Reasons for choosing the interview partner – connection to RTPS**
Officer of the City of Linz	Environmental Department, initiator of the membership in the ICLEI - Local Governments for Sustainability Initiative of the city of Linz as well as the Local Agenda 21 process Linz
Sustainability Coordinator of Upper Austria and among others in charge for the Local Agenda 21 process	Working for more than 20 years for the government of Upper Austria in sustainability-related initiatives, projects
Deputy Head of the Institute for Environmental Management in Companies and Regions (JKU)	Supported the establishment of the sustainability focus of the institute; very well known as member of manifold regional sustainability-related initiatives
Head of Institute of the Institute of Environmental Law (JKU)	Established sustainability as core topic in research and teaching; main organizer of the event "Austrian Days of Environmental Law"; well known in the city of Linz for sustainability-related voluntary engagement
Rector of the PH (PH)	Rector since 2005; main advocate for the participation in the ÖKOLOG network as well as the establishment of the further education program BINE
Former rector of the KTU and Head of the Institute Moral Theology (KTU)	Institutionalized sustainability in the EMAS - Eco Management and Audit Scheme during his

	period as rector. First to introduce sustainability as content of university lectures as well as in establishing an interdisciplinary course setting
Professorship for Public Management (UoAS)	Introduced sustainability in the study program Public Management through various lecture as well as student projects. Well known in the city of Linz for sustainability-related projects and research focus
Study program manager and Head of the Institute for Design and Space (UAL)	First to introduce lectures on sustainability in the study program Architecture. Initiated transdisciplinary student projects on sustainable wood construction. Co-initiator of the further education program "Sustainable wood construction", initiator of the Austrian-wide award on "sustainable wood construction"

The case study is based on eight in-depth interviews with actors at the university as well as key stakeholders in the region (see Table 2). A snowball-sampling technique helped to identify all relevant actors for the purpose of this study. It consisted on the one hand of the investigation of historical documents to reconstruct the RTPS and the actors involved. On the other hand, the rectors of the respective HEIs were contacted and recommended us to the most active HEI members in this regard. A narrative interview technique was chosen in order to stimulate the interviewees to reconstruct the transition process in a chronological order and emphasize those aspects that they regarded as particularly important. The narratives were then complemented by some more specific and reflexive questions. All interviews have been transcribed and forwarded to the interviewee for approval. Afterward a comprehensive document research was conducted, in order to complement and confirm the statements in the interviews. The documents investigated range from protocols from sessions of the provincial parliament, legislative texts, political concepts and programs (including a documentation of their genesis and the actors involved), protocols of the LA21 process in Linz, and press releases, but also university-related documents such as development plans, mission statements, the research databases and profiles of selected researchers, etc. Moreover, one of the authors has been involved in other thematically related projects in the case study region and thus already possessed contextual knowledge which was helpful for approaching the interview partners and the selection of the material of interest.

The empirical material was then analyzed using inductive and deductive categories derived from the conceptual framework presented in Section 7.2 Here we follow the methodological approach of Strambach and Pflitsch (2017) to reconstruct the most important institutional and organizational changes in the regional transition process. We conducted a document analysis on the empirical material at hand in order to extract the contributions of teaching, research and outreach activities on the one hand and the stated drivers on the other. The interview partners were available for further questions and clarifications, and provided information on complementary documents.

7.4 Case study description and research setting

Linz, the capital of Upper Austria, has a population of 201,595 (2016), and is Austria's third-largest city. Linz is one of the main economic centers of Austria with the highest rate of employment to population. The largest sector is manufacturing, in which 17% of all employees work. Between the end of World War II and the 1970s, Upper Austria became the leading industrial region in Austria with the highest export and employment rates. Small but innovative enterprises grew to become internationally known enterprises, e. g. Voestalpine (metal production); BMW Motorenwerk Steyr, KTM, Bomardier-Rotax, Rosenbauer (vehicle construction and suppliers); Lenzing AG, Borealis AG, AMI (chemistry and paper production).

For several decades Linz had the image as a grey industrial city. Restoration and reutilization projects of former industrial sites (e. g. Tabakfabrik) into culturally interesting locations, an economic program which strived for a diversification of the local economy (supporting tourism and trade), as well as a comprehensive social program have all contributed to changing the image of Linz to a culturally active and economically aspiring city. In 2009 Linz was nominated European Capital of Culture.

Various HEIs are located in Linz, ranging from public universities, private universities, and universities of applied sciences to two colleges of education (see Table 3). The Anton Bruckner Private University, the Private University College of Education of the Diocese of Linz, and the University of Applied Science for Health Professions did not enter the study due to a lack of relevance to the topic.

In the 1990s, in line with and influenced by the United Nations conference on Environment and Development in Rio de Janeiro in 1992, the city of Linz as well as the state country of Upper Austria started in parallel to elaborate on their sustainability agendas. The understanding of sustainability was a holistic one, aiming for a balanced ecological, societal and economic development and thus a high quality of life for both current and future generations. On the municipal level, the program Local Agenda 21 (LA21) was initiated. Meanwhile, the government of Upper Austria took several initiatives, such as establishing the LA21 as a state-wide program, the incorporation of sustainability into the Upper Austria Spatial Planning Act, the specification of an Energy Concept for Upper Austria as well as the elaboration of a Sustainability concept and furthermore a Sustainability Strategy for Upper Austria. *"The government of Upper Austria is characterized by a strong proactive power with regard to sustainability and environmental related issues"* (interview partner). The 1990s are hence characterized by a political go-ahead and a high commitment to sustainability issues.

Two types of developments can be observed from 2000 on: a thematic prioritization on energy related issues and a shift of the sustainability agenda to the economic sphere. This resulted among other developments in the foundation of the Ecoenergy cluster (renamed into Cleantech-Cluster in 2016 http://www.energiesparverband.at/info-service/cleantech-cluster.html), a network of green energy businesses which support renewable energy and energy efficiency businesses. Subsequently, and supported by the state government, a number of other clusters have been set up, representing the Green Tech Region Upper Austria. Furthermore, the government of Upper Austria decided on a second phase of the energy concept, renaming it into "Energy 21". It comprises the targets till 2010, including an increase in energy efficiency, reduction of energy consumption, development of new energy technologies as well as support of R&D in the field of energy. At the same time, the initial euphoria on the local level came to a halt due to a change of the political power and the consequent transformation of the LA21 process "Linzer Agenda 21" into a nonbinding process.

Within the last decade, the topic of sustainability has broadened and diffused from the environmental department to other departments of the Linz city administration, with the consequence that the undertaken activities are no longer communicated under the label of sustainability. The initiated LA21

process was altered into a smart city initiative, while the city council agreed on eco-guidelines to promote the consumption of Fairtrade goods. The "Linzer Sozialprogramm" (social program for Linz) emphasizes the social pillar of sustainability. In addition the Local Development Concept imposes a sustainable urban development model with a focus on environmental protection and therefore "internal development before outer development" (Stadtplanung Linz 2013).

Table 3: HEIs located in the city of Linz.

HEI	**Year of foundation**	**Number of students (2015/16)**	**Faculties / Institutes**
Johannes Kepler University Linz (JKU) *(public university)*	1966	19,406	Faculty of Social and Economic Sciences, Faculty of Law, Faculty of Technical and Natural Sciences, Medical Faculty (since 2014)
University of Arts and Industrial Design Linz (UAL) *(public university)*	1947	1186	Art and Education, Media Design, Space and Design
Catholic-Theological Private University Linz (KTU) *(private university)*	1978	463	Faculty of Theology, Faculty of Philosophy and Arts
University of Applied Sciences Upper Austria Campus Linz (UoAS)	2001	823	Medical Technology , Applied Social Sciences and Non- Profit Management, Aging
College of Education Upper Austria (PH)	2007	3000	Training of teachers in the fields of educational science, language education, mathematics and informatics, natural science, social science, economics, arts and sports.

(Source: uni:data 2016.)

In parallel, the government of Upper Austria was the first state in Austria to adopt the Global Marshal Plan, and thus gave the sustainability discussion an economic direction. The activities of this worldwide initiative comprise, for example, consciousness-raising activities, the cataloguing of measures for communities, and trainings for companies. The most recent activities on the state level comprise the Environmental Program Upper Austria, which was elaborated in a comprehensive transdisciplinary participatory process and adopted by the government in 2014.

This presentation illustrates that the local as well as state government have been strong agenda setters. While the RTPS process of the city of Linz was an administrative process, initiated and conducted by the department for environmental affairs, the government of Upper Austria tackled sustainability and its challenges from a transdisciplinary perspective, thereby involving numerous

stakeholders from the beginning on. While there is a clear emphasis on the ecological and, to a lower extent, the economic pillar of sustainability at the regional level, this cannot be confirmed for the city level. Another interesting difference is the level of self-commitment: while the government anchors sustainability in binding programs and law, it is embedded at the city level in a more non-binding nature. The local as well as the regional process are characterized by numerous institutional and organizational changes shaping the respective transition path (see also Appendix 4).

7.5 Results

In accordance with the conceptual framework, the result section is split up into two main chapters, investigating on the one hand the role HEIs play in RTPS via teaching, research and outreach activities, and on the other hand the organizational and field-level drivers influencing these roles.

7.5.1 The role of HEIs in RTPS via teaching, research and outreach

The investigation of the channel "teaching" reveals that only the JKU offers whole study programs with a clear focus on sustainability: namely the master program "Operational and Regional Environmental Management" with its respective specializations, the specialization Environmental Law within the study program law as well as the bachelor program "Economic Law" and the further education program "Energy Management" (see Table 4). Nevertheless the topic of sustainability enters numerous lectures also within the other HEIs, ranging from "Good governance", "Ecological sustainability in moral theology", "Solar architecture", and "Fashion and Sustainability", just to mention a few (www.jku.at (Johannes Kepler University Linz 2017), https://www.fh-ooe.at/campus-linz/ (University of Applied Sciences Upper Austria Campus Linz 2017), https://ph-ooe.at/ (University College of Education Upper Austria 2017), http://www.ufg.ac.at/ (University of Arts and Industrial Design Linz 2017), http://ku-linz.at/ (Catholic-Theological Private University Linz 2017)). *"As sustainability is multidimensional in nature, there are various topics which may be assigned to this concept"* (interview partner). Furthermore, practical student projects with a clear focus on sustainability are conducted, mainly at the UoAS Linz (study program Public Management), and the UAL (Institute for Space and Design) (e. g. concepts for inter-municipal cooperation, concept to counter youth out-migration of rural communities, design for regional wood construction projects, urban renewal and development projects). They are often implemented in inter- and transdisciplinary settings with representatives from the public administration, local businesses, regional management, the local population or representatives from various chambers. All of the interviewees stated that they have strong personal networks, which make these kinds of transdisciplinary student projects possible. Due to its organizational characteristics and founding idea, the UoAS in particular has a strong focus on bridging teaching content and regional practical demand. All of the investigated HEIs point out that the students and their awareness for the topic of sustainability are important multipliers at the local and regional scale. This becomes especially important as – according to information provided by the interview partners – the majority of the students enter the labor market in Linz or Upper Austria after their studies.

With regard to research, sustainability is on the agenda of selected institutes of the investigated HEIs, for which it is a basic principle or even taken for granted, or as one interview partner states *"sustainability is our umbrella brand, under which various thematic specializations are subsumed"*. The investigation of the HEIs' research activities reveals that following Rio in 1992 there was a strong focus on environmental issues as well as on sustainability in a holistic sense, whereas in the last decade a

separation into the topics of energy, demography, climate change etc. has taken place (see also research documentation of the JKU: http://www.jku.at/content/e263/e16099/e16086/ (Johannes Kepler University Linz 2017), UAL: https://ufgonline.ufg.ac.at/ufg_online/, (University of Arts and Industrial Design Linz 2017), UoAS: http://research.fh-ooe.at/ (University of Applied Sciences Upper Austria 2017)). The research topics covered in the investigated HEIs are manifold, ranging from climate change, environmental technology, energy law and economics to sustainable lifestyle, sustainable nutrition and food, sustainable transport concepts, etc. (see Table 3). Although inter- and transdisciplinary research settings are taken for granted in all of the investigated institutes, no institutionalized transdisciplinary research platform has been set up so far. Contacts to partners from the public policy arena, industry and the regional economy, and other regional stakeholders are informal and selective, and strongly dependent on each individual's networks.

Table 4: Teaching, research and outreach activities towards RTPS of the investigated HEIs.

HEI	Teaching	Research	Outreach (selection)
JKU	"Environmental Law" (Austrian-wide unique specialization within the study program law) Graduate program "Energy management" "Future Lectures" series Study program "Environmental-, Resource and Quality Management" Further education program "Energy Management"	*Institute of Environmental Law*: research on diverse fields of environmental law, e.g. legal frameworks of carbon capture and storage, hydropower in Natura2000 areas, light pollution, legal issues of the energy certificate. *Institute of Environmental Management in Companies and Regions*: research in the field of climate change, environmental protection, renewable energy, environmental technology, sustainable technologies, sustainable economic activity, and environmental politics. *Energy Institute*: applied research in the field of energy law, energy economics as well as energy technology Students master thesis in the mentioned research fields	Public event series "Days of Environmental Law" Public event series "Education for sustainable development" Participation in the LA21 working group on air, climate and energy of the city of Linz Participation in the elaboration of the regional energy concept "Energy 21" Participation in the elaboration of the Environmental Program Upper Austria 2030, Upper Austrian Energy concept, Upper Austrian Future academy and further current political discussions
KTU	Ecological sustainability in moral theology Interdisciplinary lecture on sustainability in arts and moral theology Further education opportunities in	Research projects on sustainable lifestyle, sustainable nutrition and food, regionalization and greening of agriculture etc.	Former rector is active as environmental spokesperson of the dioceses Linz (supported the dioceses becoming 100% powered by green electricity) Initiatives like "abandon the car", fair trade days etc.

	sustainability issues for members of the KTU		
PH	Sustainability as inherent principle of most lectures BINE – further education program for teachers on innovations in education for sustainable development	*Research pillar in development*	Participation in the ÖKOLOG network Cooperation with the Austrian Youth Red Cross and Austrian Students Union for the integration of refugees via cultural and language courses Projects with Ars Electronica (e.g. museum of the future) on the elaboration of an OTELO – open technology lab
UoAS	Sustainability is anchored as topic in various lectures in the study program "Public Management": "Public Governance", "Good governance", "Regional development and inter-municipal cooperation" Transdisciplinary study projects	Research in the field of participatory community planning, good governance; strategies to encounter out-migration from rural communities; labor market integration of people with disabilities; inter-communal cooperation in various fields (infrastructure, education, childcare) Transdisciplinary research settings Master thesis in cooperation with regional stakeholders (e.g. sustainable transport concepts, sustainable location development)	Event series "Public management impetus" Fair Trade Days Transdisciplinary cooperation (various associations, different departments of the government Upper Austria, Austrian Chamber of Labor, Austrian Chamber of Commerce, Regional management)
UAL	Lectures "Solar architecture", "Ecology", "Fashion and sustainability" Student projects on sustainable wood timber construction Further education program "Überholz" (sustainable timber construction)	Research with focus on regional sustainable timber construction Project "ins Blaue" on the elaboration of a sustainable fashion label Endowment professorship on "Sustainable and Spatial Tactics"	Initiation of the Upper Austrian Wood construction price; Public lectures, presentations and media work (local, regional and national) to raise awareness for the topic "sustainability" in architecture, construction and design

(JKU Johannes Kepler University Linz, KTU Catholic Theological Private University, PH College of Education, UoAS University of Applied Sciences Upper Austria, UAL University of Arts Linz.)

Interestingly, the investigated institutes vary in the degree of regionalism of their research focus and partners. While an interview partner from JKU points out that *"unfortunately often the results from basic research projects do not find their way into practice"*, interviewees from the UoAS emphasize the impact through inter- and transdisciplinary research settings with local and regional stakeholders. The Energy Institute at the JKU shows a high local and regional focus regarding research projects as well as partners (http://www.energieinstitut-linz.at/v2/projekte/ (Energy Institute 2017)). This is also true for the Institute of Environmental Law, the Institute of Environmental Management in Companies and Regions at the JKU as well as the UoAS. The KTU and the UAL, on the other hand, show in general a low degree of research activities with a regional focus. The research and student projects throughout Upper Austria in the field of sustainable wood construction conducted by UAL are a notable exception. The PH as a rather young HEI is still in the development phase of its research pillar. It was pointed out that a strong regional focus does not necessarily conflict with the distinct national and international perspective of the HEI. The investigated HEIs confirm that contacts through teaching and research with stakeholders on the regional level outnumber the contacts with the local level, especially the city government of Linz.

When it comes to outreach activities, all of the investigated HEIs are very active: ranging from annual public events (Austrian Days of Environmental Law, Public Management Days), participation in Austrian-wide cross-organizational activities (e. g. Future Lectures), volunteer involvement (e. g. environmental spokesperson in the diocese Linz), numerous presentations and speeches, provision of expertise in regional bodies (e. g. advisory board of the Ecoenergy cluster), initiation of awards (e. g. Upper Austrian Wood construction prize) and participation in working groups (e. g. elaboration of the regional energy concept "Energy 21"). One interview partner put individual engagement in a nutshell *"*[...] *recently we conducted a pilot study in the field of sustainable transport and e-car sharing for a regional partner, because we have been interested in the topic and considered it important, it was not important for us to receive funding for it"*.

Taking again into account the spatial dimension of the contribution of HEIs to RTPS via the channel of outreach, the contacts with the city government of Linz are occasional and informal, and often take place on the personal level between single individuals, rather than on the level of the organization. While the Institute for Environmental Law as well as the UoAS and PH outline good and regular contacts to the city government Linz, other interviewees highlight that requests from the municipality level are rare. The picture is a different one for the role of the HEIs on the regional level, where all of the investigated HEIs are in ongoing collaboration and contact with departments of the state government and other organizations (e.g. Chamber of Commerce, Climate Alliance Upper Austria). *"The contribution of our institute to a transition towards sustainability is more regional than local. In my perspective it is a well-known problem, that the potential in front of one's own door is not valued"* (interview partner, referring to the scarce contacts to the city government).

7.5.2 Organizational and field-level drivers influencing the role of HEIs within RTPS

The legally defined 'type' of organization influences the share of teaching versus research and the self-perception of HEIs towards their regional mission. While the focus on teaching and research is rather balanced at public universities (JKU, UAL), private universities (UAL) and UoAS have a strong emphasis in teaching as the number of students has also financial implications. The UoAS is the only type of HEI with an inherent and explicit regional mission.

On the organizational-level the university management can exert coercive power via the regulatory framework (e. g. development plan) and/or undertake voluntary activities such as mission statements, memoranda, or participate in international networks, which spur normative and cognitive change.
The development plan is the strategic instrument of the university, outlining personnel related developments, foci of study programs, teaching and research, as well as societal goals, following the template from the performance agreements with the national ministry (Österreichischer Wissenschaftsrat 2016). The development plans of the universities are elaborated by the rectorate and enfold a self-binding character for the university management and a guiding normative framework for faculty members. The JKU outlines sustainability within the development plan 2006–2012 (Johannes Kepler University Linz 2009), as one component of the fields of excellence "environment/energy/ sustainability" as well as "management/economic politics/environmental law". In 2013 it is further emphasized as a main thematic focus of the excellence fields "management and innovation", "biotechnology" as well as "social systems/welfare state" (Johannes Kepler University Linz 2013). On the other hand, sustainability is not mentioned in the mission statement of the university. The UAL emphasizes and acknowledges sustainability as a thematic focus of selected teaching and research activities in the development plan 2014–2018 (University of Arts and Industrial Design Linz 2014). The UAL does not have a separate mission statement. The UoAS Upper Austria outlines in its mission statement and strategy: *"Through regional and global interlinkages with economy, society, public bodies, research and education institutions we create education opportunities, innovation, knowledge and sustainability"* (University of Applied Sciences Upper Austria Campus Linz 2016). Special emphasis is given to ecological sustainability. The KTU does not have a mission statement, nor a development plan. The PH as youngest HEI does not emphasize sustainability in its overall strategy, but highlights in the description of the single areas and study programs of the PH that *"sustainability is taken into account on all levels of education and further education programs for teachers"*. In sum, it turns out that:

a) there was/is not a continuous commitment towards sustainability throughout the last decades,
b) any attention given to these issues is not always communicated under the label of sustainability (e. g. the KTU mentions in its environmental mission statement the environmental responsibility of the KTU) and
c) the way in which sustainability is grounded and mentioned in the investigated documents implies no obligation.

Apart from these formal frameworks several HEIs engage in voluntary activities influencing the institutional framework:
In 1996, the KTU committed itself to the environmentally friendly management and operation of the university, and – under the leadership of the rector – has bundled their activities in the field of sustainability in the EMAS (EcoManagement and Audit Scheme) from 2009 on. The JKU was one of the first Austrian Universities to sign and endorse the Copernicus Charter in 1993 (Campus Sustainability Centre 2005), thereby committing themselves to featuring sustainability prominently in curricula, institutional management and service. It was in 2005 when the JKU, as part of the European University Association, signed the Graz declaration (European University Association 2005), and therewith renewed its commitment towards sustainability. The PH Upper Austria was the first to join the ÖKOLOG network. ÖKOLOG is an initiative of the Austrian Federal Ministry for Arts and Culture to support sustainability as educational content. The HEI management as well as other HEI boards exert authority and induce organizational change in form of the foundation of new university institutes, professorships or the establishment and (re-)orientation of study programs: the rectorate of the JKU, together with the city of Linz and state government Upper Austria founded the Institute for Environmental Law in

1994 and the Institute for Environmental Management in Companies and Regions in 1998, along with respective study programs and specializations. Another example is the endowment professorship on "Sustainability and spatial tactics" at the UAL in 2010. Managerial incentives of this kind to legitimate sustainability related activities were not found at all of the investigated HEIs. Faculty members in some of the HEIs took action or made use of the opportunities afforded by their position (e. g. as head of an institute, study program manager). This was, for example, the case at the UOA: *"I brought the topic of sustainability to the HEI. In the environment where I was working before joining the HEI it was taken-for-granted to take sustainability and its dimensions into account. Therefore, it was somehow self-evident for me to bring this topic to the HEI and implement it into the curricula in my role as study program manager. I initiated this process 20 years ago and it was not until the last years that I have the feeling that it also reached the university rectorate"* (interview partner).

Two further examples which have been already described, were certain personalities in their role as rectors have initiated institutional change, are the EMAS (Eco Management and Audit Scheme) at the KTU and the participation in the ÖKOLOG by the PH. The crucial role of individual faculty members incorporating sustainability issues into the content of their lectures, or even setting up whole courses around it, should not be underestimated. The driving mechanism evident here is a normative one: it is the personal values of faculty members as well as their personal perception of their role and position at the HEI which generates a commitment to sustainability and thereby shapes the overall role of HEIs in RTPS. *"It is part of my understanding of science to bring also controversial topics such as sustainability into the public debate"* (interview partner). *"Numerous lectures, presentations and other types of engagement in the field of sustainability are conducted based on personal convictions. It is this kind of engagement which is special to researchers in the field of environmental protection and sustainability. I have seen and learned this from my former head of the institute"* (interview partner). The latter statement captures another important organizational-level driver: role models. Several interview partners mentioned their mentors and former heads of institutes or departments as role models when it comes to engaging with sustainability related topics. It was also pointed out that due to the small size of institutes focusing on sustainability related issues, limited personnel and time resources are a barrier to engagement. Apart from the described normative driver, different forms of incentives may activate engagement within RTPS. Such incentives at the organizational-level include awards, funding programs, official recognition of output besides teaching and research contributions, or oral appreciation. For the investigated HEIs it is especially oral appreciation from the rectorate that was confirmed as important.

For reasons of precision, we differentiate the field-level drivers into national, local as well as regional ones. The national level exerts a strong regulative power on HEIs. That is on the one hand due to the fact that much of the relevant legislation lies within the purview of the national government (Ministry of Science, Research and Economy, Ministry of Education), as does the basic financing (except for private universities). The investigation of the respective legal basis (Universitätsgesetz 2002 (2017), Hochschulgesetz 2005 (2017), Privatuniversitätengesetz 2011 (2017), Fachhochschulstudiengesetz 1993 (2017)) revealed that only the University Law 2002 mentions "sustainable resource use" as one of the guiding principles and furthermore outlines that *"universities* [...] *are responsible to contribute to the beneficial development of society and the natural environment"*. Although sustainability is therefore part of the legal framework, one interview partner states, *"*[...] *as there are no sanctions for not taking sustainability into account, it has not yet entered all areas of the university"*. According to the interview partners, the performance agreements between the ministry and the universities on the one hand, as well as the national funding programs on the other hand, exert more influence on the sustainability focus and activity of the HEIs than the legal framework. The ministry provides a general

template for the performance agreements but leaves sustainability dependent on voluntary compliance.

What exerts a stronger influence are the nationwide funding programs, specifically the FFG (the Austrian Research Promotion Agency for applied research) and the FWF (the Austrian Research Fund for basic research), but also the Austrian Climate and Energy fund – a special program to foster research and development for sustainable energy technologies and climate. The FFG has also developed special programs, in line with international EU programs and agendas, with a focus on energy and environmental studies (e. g. smart city, city of the future, e-mobility, etc.). As third party funding is an important source of income for all of the mentioned HEIs (becoming even more important following the University Law 2002 (2017)), these programs and funding schemes influence research foci and raise awareness among researchers and HEI management.

Through prizes and awards, appreciation is expressed and further awareness raised. The interview partners confirmed that such incentives have more of an indirect effect than that of a direct driver. One of the best known is the "Austrian Sustainability Award" (BMWF, BMLFUW 2010, 2012, 2014). The Institute for Environmental Law has received this award multiple times (2010, 2012, and 2014) for their event series "Austrian Days of Environmental Law", the project "Carbon Capture Storage – technical requirements and legal frameworks" and the project "Legal issues of the energy certificate". The PH was also nominated for this award in 2014 for their activities in the ÖKOLOG network, and also in 2016 for the further education program "BINE". By expressing appreciation, this award aims at incentivizing HEI members, while raising awareness and legitimizing their initiatives.

At the regional level of the state of Upper Austria as well as City of Linz several driving mechanisms are rather similar to those of the national level, namely funding programs, political strategies and agenda setting, as well as awards.

Through various activities by the government Upper Austria in the early 1990s (elaboration of a sustainability concept, Sustainability Strategy Upper Austria, program Local Agenda 21) sustainability was activated at the state and local level. *"For us the topic of sustainability became interesting in research, because it was activated by the state politics"* (interview partner). An interview partner pointed out that these initial holistic attitudes towards sustainability was replaced by a thematically focused one: *"While a holistic understanding of sustainability was on the agenda in the early 1990s, the political and also scientific discourse specialized into different spheres such as energy, climate, demography etc."* (interview partner).

The government of Upper Austria influenced the research agenda, e. g. through the regional Energy concept "Energy 21" and the elaboration of "Environmental Program 2030", as well as associated funding schemes and research contracts. *"With regards research projects and funding for research projects, we are highly dependent on the demand raised by local and state politics. Most of the time we are contacted personally and asked to conduct research on a special issue. This demand also influences our research agenda"* (interview partner) Furthermore the Government of Upper Austria influences forms of collaboration in an innovative way: for the two mentioned programs, inter- and transdisciplinary working groups have been set up to jointly elaborate on measures and targets in defined areas (e. g. electricity, health, mobility). The process for the elaboration of the "Environmental Program 2030" even entailed a broad participatory process with citizens and youth councils in addition to experts from the public, private and scientific sectors. Apart from legitimizing and awareness rising, these approaches shape regional network structures and influence future interaction and cooperation between different stakeholders. While the state government implemented incentives for HEIs to join local and regional initiatives, the city administration steered sustainability related initiatives quite autonomously.

Apart from these changes in the institutional environment, certain activities leading to organizational change within the HEIs deserve mention. That are the already mentioned foundations of the Institute of Environmental Law as well as the Institute of Environmental Management in Companies and Regions which institutionalize and legitimate of the sustainability focus at the HEIs. Again in 2001, the City of Linz and the Government of Upper Austria jointly founded the Energy Institute, an independent association that is located at the campus of the JKU. This inter- disciplinary research institute focusing on economic, legal and technical aspects of energy related issues is intended to support local and regional industry with cutting edge applied research and thereby support the state-wide energy transition.

The "Upper Austrian Award for Environment and Nature" which was renamed into "Upper Austrian Award for Environment and Sustainability" in 2012 is intended to function as an indirect driver for HEI's activity in RTPS. Appreciation is also expressed face to face or through financial support of certain activities (e. g. the City of Linz financially supports the journal "Environment and Law" from the Institute of Environmental Law and certain events).

7.6 Discussion

The present paper elaborates on the questions of:

1. which roles HEIs play in the regional transformation towards sustainability via the channels of teaching, research and outreach, and
2. by which organizational- and field-level drivers these roles are influenced.

The results underline that the investigated HEIs have not been engaged in RTPS in a holistic organizational sense, but a selected number of institutes and individual HEI members are active, thereby confirming the multilevel structure (Arbo and Benneworth 2007) of these highly complex silos (Denman 2009) with numerous autonomous subunits.

The contribution of teaching activities to RTPS is seen in consciousness raising, legitimization and provision of knowledge for regional needs. Activities to incorporate sustainability into teaching are highly dependent on the bottom-up motivation of single faculty members and the top-down consolidation of the university management. While a theoretical incorporation of sustainability into teaching contents may raise awareness, the investigations reveal that a certain degree of institutionalization (Olsen 2007), e. g. in terms of whole study programs as well as student projects and final thesis on sustainability issues in cooperation with regional actors have long-term effects on RTPS. HEIs are learning organizations (Benneworth et al. 2009) and, as such, an increased institutionalization of sustainability can be confirmed as also being a result of the interaction with the regional environment. The highest impact is attributed to the graduates and their function as regional multipliers.

In contrast, research activities in the field of sustainability are strongly affected by national and international funding programs and their respective focus as well as contract research placed by regional actors. In the case of Linz, research activities have been transformed from a holistic approach in the 1990s to a thematically specified one (especially on renewables and climate change). The contribution of research to RTPS is dependent on the regional focus of the research endeavor and, above all, the correspondence of research foci with local and regional demands (Chatterton and Goddard 2000). The members of the investigated institutes show strong person-bound networks with policy makers and other stakeholders at the regional and local levels. Through their relationships and networks they are 'well placed' to encourage support (Eisen and Bartlett 2006) which has allowed the

elaboration of expertise in the field of sustainability and the development of a dedicated research focus. This includes personal contacts to the municipal council, to the government of Upper Austria, as well as to industry partners and other research institutions outside the region.

Their relational proximity influences their behavior at a number of different scales (Coenen et al. 2012) and shapes also the opportunities they are offered. In line with Saxenian (2000) we reveal that these relationships are not purely economic: culture and trust are also important facilitators of cooperation. Furthermore, the absorptive capacity of the regional environment and the research approaches affect the contribution of research towards RTPS. Inter- and transdisciplinary research settings anchor research projects and support the implementation of results. This has also been confirmed for applied research versus basic research projects (Fritsch and Slavtchev 2010). Overall the contribution of research to RTPS can be seen in the shaping of public opinion and discourse, scientific substantiation of political strategies, expert know how, and concrete scientific contributions to process or product innovations (e. g. in the field of renewables).

With respect to outreach activities, mostly those HEI members who are already active in research and teaching also engage in this field, showing a high amount of voluntary and private engagement in fostering RTPS. This engagement cannot be reduced exclusively to their personal interest in the topic but also has the strategic dimension of ensuring future funding and contract research or taking agency to trigger structural change (Genus and Coles 2008). Most of the time outreach activities are demand driven and based on invitations from respective regional stakeholders. Exceptions are the initiation of event series at the HEI (e. g. Austrian Days of Environmental Law), the taking over of honorary appointments (e. g. environmental spokesperson for the Dioceses), and the initiation of awards (Award for sustainable wood construction), where individual HEI members took the lead. The value of outreach activities lies in consciousness and awareness raising, legitimization of sustainability issues in the region, support of political strategies as well as serving as role models for other HEIs and HEI members.

Overall, the contribution of HEIs in Linz to RTPS via teaching, research and outreach is manifold but also fragmented. We agree with Denman (2009) that many of the efforts for transitions towards sustainability address only one or two aspects, thus focusing on the institutional framework, education, teaching, campus operation, outreach *or* assessment and reporting.

One reason for this is the role of the HEI management: while organizational changes (such as the foundation of institutes, study programs, professorships) which set the frame for further sustainability-related activities have been implemented, we observe a lack of leadership. Goldstein et al. (2016), Sedlacek (2013) and Hamann and April (2013) emphasize the crucial role of leadership to promote sustainability within the HEI, but also within the regional context. Leadership of the university management in sustainability transitions entails visioning, laying out long-term system-level goals and objectives, and establishing the structure and context for social change in a strategic way (Stephens and Graham 2010). Although several rectors engage themselves in sustainability related activities in the region, sustainability as a leading principle has not yet found its way – with few exceptions – into the mission statements, development plans or strategies of the investigated HEIs.

A further reason for the fragmented contribution of the HEIs towards RTPS is the high level of person-boundedness of the depicted activities, and, at the same time, the rather low level of institutionalization, respectively temporal institutionalization. This raises the question of whether these activities would continue if the relevant individuals were to leave the HEI.

As elaborated in detail in Section 7.5, a strong influence on RTPS is exerted by single HEI individuals who have taken agency afforded by their particular position at the HEI. Agency provides for a consideration of the role of power in institutional processes, thus referring to an actor's ability to have

some effect on the social world, altering the rules, relational ties or distribution of resources (Scott 2001). They have furthermore also been role models for engaging in sustainability-related activities in the local and regional context. It is their intellectual engagement with environmental and broader sustainability issues, as well as their worldviews and beliefs (Barlett 2008), which have influenced other members of the HEI. Furthermore, through their relationships and networks they have been able to provide necessary financing which has allowed the elaboration of expertise in the field of sustainability and the development of a dedicated research focus. These committed individuals, so called 'champions' (Hoover and Harder 2015), or 'frontrunners' (Brown et al. 2013), are central to institutional and organizational changes towards sustainability (Wright and Wilton 2012).

In sum, the investigated HEIs show manifold contributions via teaching, research and outreach activities, which are mainly influenced by highly engaged single individuals and their role model effect, regional/national and international funding programs as well as the place-specificity of their region. While our investigation reveals that leadership of the HEI management in sustainability related issues is not a mandatory prerequisite for HEI members to become engaged, it might enhance the degree of engagement within various disciplines and institutes at the HEI. In the lack of leadership of the investigated HEIs we see one reason for their fragmented contribution, for the continuing reservations between the different types of HEIs and, consequently, the lack of interdisciplinary collaborations between members of HEIs located in Linz and focusing on sustainability. Overall we observe that the role of the investigated HEIs towards RTPS is rather a responding than active one. While in regions with poorly developed governance structure and weak regional leadership *"it is often necessary for HEIs to* [...] *set the development agenda"* (Goddard and Puukka 2008, p. 21) in our case the state government set a strong top-down initiative what regards the research agenda, funding programs, as well as the role of the HEIs within RTPS.

7.7 Conclusion

The present paper revealed that HEIs have the potential to enact institutional and organizational change and thus spur a regional transition towards sustainability via the channels of teaching, research and outreach. Activities to incorporate sustainability into teaching are highly dependent on the bottom-up motivation of single faculty members and the top-down consolidation of the university management. Research activities in contrast are shaped by field-level drivers such as national and international funding programs as well as regional allocation of contract research. We revealed that those individuals who are engaged in respective research and teaching activities are also active in outreach activities within RTPS. The latter is not part of the core functions of the HEI but an important channel to raise awareness for one's one research and contributes to political and public opinion forming. Especially outreach activities have proven to have also a strategic dimension of ensuring future funding or taking agency to trigger structural change. Although the contribution of the HEIs in Linz to the RTPS over time is remarkably, their role can be regarded as rather responsive than active. Subsequently we would like to summarize how our findings can be transferred to other regions.

First and more generally, the case underlines the place specificity of the role of HEIs in RTPS which is shaped by the historically developed governance structures in the region and the already existing relationships between HEIs and their regional environment. It also becomes apparent that the mix of HEIs in the region influences their role in RTPS. It might be that in regions with only one main HEI the activities can be bundled and coordinated more easily. In regions with many HEIs, the role of HEI is

spread over different actors. While this might result in a loss of efficiency, it might also be conducive for the process, as different types of HEIs set different kinds of impulses.

Second, we can generalize from our findings that there is no role played by HEIs as a whole in RTPS, but as a multi-level organization, different spheres within the HEI ranging from HEI management to individual researchers have become active. So called 'champions' and 'frontrunners' are characterized by holding key positions at the HEI (e. g. rector, study program manager, head of institute) which allow them to take agency and precipitate organizational and institutional change within the HEI. Apart from their position, their personal multi-scalar networks and their relational proximity to public and private stakeholders influences the awareness of the region for the contribution HEIs can make.

Third, we can deduce that the role of HEIs in RTPS has to be regarded as the result of the dynamic interplay of HEIs, regional and state level actors. It becomes apparent that, regardless of the specific regional circumstances, no one actor can initiate this process on its own. We also revealed that both bottom up activities (as in the case of the universities) as well as more top down approaches (as in the case of the region) can successfully trigger change within the university or the region. An alignment of both initiatives as well as strengthening of interdisciplinary cooperation among the various HEIs seems to be ideal to realize the full potential of HEIs in RTPS.

Fourth and finally, a certain level of institutionalization enables trust building and the development of relational proximity. We hypothesize that in order to take over a more active role within RTPS HEIs have to fully exploited their potential as brokering and bridging organizations. That entails their potential for bringing together various stakeholders in institutionalized transdisciplinary settings, which would allow HEIs to enter into a continuous process of dialogue instead of providing their expertise sporadically and on demand.

In order to deepen these results, it would be necessary to conduct more comparative research in the future. We think that the combined analysis of organizational and field level drivers provides a good starting point for systematic comparisons with other regions.

(For better readability of this dissertation, acknowledgements, information about funding and open access publishing were not included here, but can be looked up in the original paper.)

8 The raise of publications on sustainability – a case study in Germany

This chapter is a reprint of:

Brenner, T. & G. Pflitsch (2017): *The raise of publications on sustainability – a case study in Germany.* Review of Regional Research 37: 189-225.

Reprinted with kind permission of Springer Nature. (Minor changes were made to adjust the text to the layout of the present dissertation.)[22]

Abstract

The number of scientific publications containing the words “sustainability” or “sustainable” has increased tremendously over the last years, but their origins in Germany are not equally distributed in space. The aim of the paper is to find out why sustainability research occurs strongly in some places and not in others. Four potential external influences on the choice of a scientist’s research topic are considered: 1) the interaction with the regional economy, 2) the attitude of the regional population, 3) path dependence in science as well as 4) the organizational circumstances provided by the university. In a mixed-method approach, regression analyses are complemented by qualitative interviews with scientists. The results show that the decision to conduct research on sustainability is in most cases based on a more private level. However, the perceived attitude towards sustainability in the broader public and in the researcher’s local surrounding also seem to be important.

[22] For this chapter, additional material that has not been published in the original paper can be found in Appendix 1. See Table 16 and interview guideline “sustainability publications”.

8.1 Introduction

The last decades have seen a strong increase in the perception of the relevance and importance of sustainability in society, politics and science. Plenty of policy programs and political and societal events have been conducted with an explicit connection to sustainability.

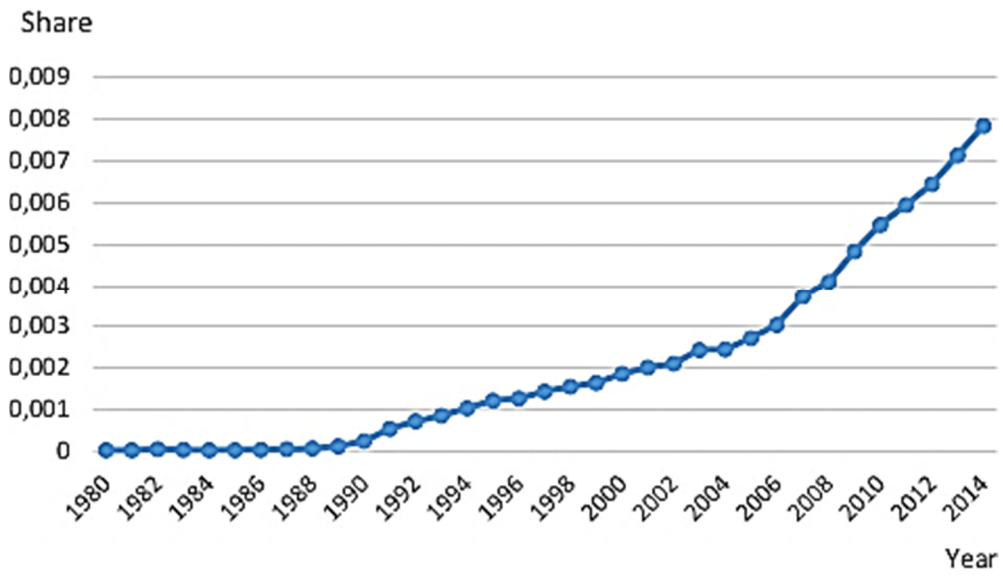

Figure 18: Share of world-wide publications (WoS) that contain the word "sustainability" or "sustainable" as keyword, in title or abstract.

In line with this, the use of the words "sustainability" and "sustainable" has increased tremendously in the last years in scientific publications (see Figure 18). This phenomenon affects not only one discipline but can be observed in many research fields.

However, sustainability research is not equally distributed in space. While at some universities more than 5% of all publications contain the words "sustainable" or "sustainability" in title, abstract and/or keywords, less than 1% or even none of the publications fall into this category at other universities in Germany.

The literature on regional innovation systems (e. g., Cooke et al. 1997), the triple helix (e. g., Etzkowitz and Leydesdorff 2000) and the third mission of universities (e. g., de Rassenfosse and Williams 2015) has shown that universities strongly interact with their surroundings. Hence, whether or not extensive research on sustainability is conducted at a university can be expected to also influence other activities in the region. Therefore, it is not only of academic but also of societal and political interest where research on sustainability is conducted. Especially in regard of the increasing interest in sustainability in society and politics, academic research in this field might contribute to a sustainable regional development (e. g., the special issue edited by Zilahy et al. 2009).

This leads to the question of why research on sustainability occurs strongly in some places and not in others. Of course, research at universities does not only have an influence on other activities in the surrounding region, but might also be influenced by these regional circumstances. However, while the theoretical literature clearly states that universities and their surroundings influence each other mutually (Etzkowitz and Leydesdorff 2000), there is little empirical research on this issue. The paper at hand studies the relevance of the regional context for university research on sustainability.

Of course, this is embedded in the larger question of why certain research is undertaken in certain places. Part of the answer refers to the individual scientists' motives and goals to pursue specific research activities, which have already been discussed in the literature for a long time (see e. g., Gustin 1973). In this paper, the focus is on the external circumstances that influence the research agenda at universities. Sustainability research was chosen as a case for our study because it is considered of key importance for the transition to sustainability. The latter is urgently necessary in face of the increasing ecological and societal problems that our societies are facing (Geels 2011). Moreover, sustainability research has a number of characteristics that make it especially suitable in order to give a differentiated answer to the more general question stated above: 1) Sustainability is a topic with a strong increase in publications in recent years. 2) Research on sustainability occurs in a wide range of disciplines, so that we are able to examine differences between disciplines. 3) Sustainability plays a strong role in society, politics and the economy. Hence, it is one of the very few topics that might be influenced by societal, political and economic circumstances.

The aim of the paper at hand is to examine what kind of regional circumstances influence the intensity of sustainability research at German universities measured by the occurrence of the words "sustainability" and "sustainable" in respective publications (title, abstract and/or keywords). A mixed method approach is applied. On the one hand, we analyze publication data in order to examine statistically the relationship between sustainability publications and various regional circumstances. On the other hand, German researchers who used the word "sustainability" or "sustainable" in their publications are interviewed in order to examine their reasons for conducting this kind of research. In total, 19 interviews with researchers from two meta-disciplines (engineering and social sciences) were conducted.

In the following section, we outline the theoretical concepts from which we derive our hypotheses. In Section 3, the different methodological approaches used in this study and the purpose of the triangulation are elaborated. Afterward, the results are presented. The conclusion (Section 8.5) contains some more general statements on the question of why certain research is undertaken in certain places.

8.2 Theoretical background

Which topic is studied in research is first of all decided by the individual researcher. Public researchers enjoy quite some freedom in deciding about their research topic, especially in the German university system. Therefore, although we are not directly interested in the motives of scientists – which are extensively researched in the literature –, we have to take a closer look on these motives to identify the ways in which regional circumstances influence the choice of research topics.

Hence, in this section we discuss the various individual motives of researchers (Section 8.2.1) and take a more specific look at their interaction with the economy (Section 8.2.2), their interaction with policy and society (Section 8.2.3), path dependence in science (Section 8.2.4), and the organizational circumstances provided by the university (Section 8.2.5).

8.2.1 Motivation of researchers

Psychologists see motivation as an outcome of external incentives and the fulfillment of internal individual needs. Both types of motives are in most activities closely interwoven and some researchers therefore see scientist's motives rather lying in a continuum between extrinsic and intrinsic motivation (Lam 2011). For analytical reasons it makes sense however to distinguish between an extrinsic and

intrinsic motivation. Intrinsic motivation of researchers is mainly associated with an aspiration for self-determination and competence as well as a strong interest and involvement in a specific activity (Rheinberg 2011). While extrinsically motivated actions either have a material (e. g., financial reward) or social outcome (e. g. reputation), intrinsically motivated activities either lead to an affective or social result. An affective result means that the action as such leads to personal satisfaction. A social result means that persons are rather focused on the outcome of an intrinsic action, with which they want to achieve a normative goal or benefit others (Grant 2008).

Compared to other professional groups, researchers can act relatively autonomously within their organization. Universities have flat hierarchies and decentralized governance structures, which give professors a lot of freedom in their choice of topics and their activities in general. This lack of control by the organization is usually compensated by a strong intrinsic motivation of scientists. The academic career path with its extremely long training phase functions as a selection mechanism in this regard (Minssen and Wilkesmann 2003). The fact that scientists accept significantly lower wages compared to what they could earn in other fields (Stern 2004) indicates that most scientists indeed have a high intrinsic motivation (Bruneel et al. 2010).

However, studying the impact of local and regional circumstances on researchers' choice of topics implies that we have to look mainly on extrinsic motives. Extrinsically motivated social as well as material goals also play an important role in the academic community. Studies show that recognition in the academic community through publications, citations and prizes is extremely important for most scientists (Lam 2011). At the same time, material incentives have become more important. Recent years have seen an expansion of the role of universities and the researchers therein. Besides teaching and research, nowadays public researchers are more and more expected to also interact with their surrounding by doing research for companies and taking an active role in society. Policy has supported the interaction between science and economy strongly and universities have increased incentives and pressure on researchers to receive third-party grants in recent years. Empirical studies that analyze the personal motivation of scientists to pursue such commercial activities come to different results. As Lam (2011) shows in her empirical study, intrinsic and extrinsic motives are closely interwoven in this context. Independent of whether a researcher aims at personal satisfaction, raising her/his reputation or receiving more money (and other economic advantages), there are four ways in which the choice of research topic can help to reach these aims:

- Choosing a research topic that is well publishable (fashionable or relevant topic)
- Choosing a research topic that is often mentioned and aimed by funding programs
- Choosing a research topic with practical relevance, so that third-party money can
- be obtained from companies or governments
- Choosing a research topic that is highly appreciated within the university.

It can be assumed that the different types of motivation mentioned above are closely interrelated and that an activity is often motivated by more than one goal. While it might be the case that two types of motivation co-exist, they can also dampen each other.

When asking why scientists choose to conduct research on sustainability, we also have to consider the specific characteristics of this topic. Sustainability differs from other research topics due to its extreme broad and interdisciplinary character, as well as its normative component. The definition of the concept gave rise to many debates in the scientific literature. A very general definition was given in the Brundtland report (1987: n.p.), which defined sustainability as meeting the *"needs of the present without compromising the ability of future generations to meet their own needs"*. The concept has received much criticism due to this broad and also vague definition. At the same time, this broadness

also enabled its transfer to various fields and its attractiveness to and acceptance by actors with different perspectives and interests (Kajikawa et al. 2007).
Due to its normative character, it is likely that research on sustainability is seldom an end in itself or conducted for the sole purpose of expanding knowledge on the topic but rather with the goal to solve urgent societal problems. Also in the other categories mentioned above, topics which are (perceived as) relevant for society have a higher probability to be selected. Hence, the perception of the relevance of a topic for society seems to be a particularly important factor. The latter might influence researchers directly or indirectly, e. g. through the promotion of such topics by policies.

8.2.2 Interaction between economic activity and scientific research

The interaction between economic activity and scientific research is mainly an issue within the literature on regional innovation systems (e. g., Cooke et al. 1997) and the triple helix (e. g., Etzkowitz and Leydesdorff 2000). The main argument in the literature is that scientific research provides the underlying knowledge and inventions for the generation of innovations. Hence, the basic argument is that regional research activity supports the innovation activities of firms.
However, here we are interested in the opposite direction of influence. The linear understanding of the above relationship has been criticized and alternative models have been developed since quite some time (e.g, Kline and Rosenberg 1986, Stokes 1997). A more bi-directional and systemic perspective on the interaction of universities and the regional economy has been established (e. g., Uyarra 2010). Hence, it is assumed that not only scientific research provides a basis for the respective economic activity, especially innovation activity, but that scientific activity is also influenced by the surrounding economy.
The main mechanism behind this interaction is third-party money. Companies subcontract research to universities and public research institutions in order to tap into the specific knowledge and competences existing there (Sarabia-Altamirano 2016). In addition, private and public researchers often cooperate (D'Este and Patel 2007), especially in the context of applying for research grants, that are in Germany often given conditional on an interaction between companies and public researchers. Hence, conducting research that is relevant for companies' innovation activities increases the options to receive third-party money and, thus, provides an incentive for choosing such research topics (D'Este and Perkmann 2011). In an empirical study, Blankenberg and Buenstorf (2016) show the co-evolutionary character of public research and private activity in the laser industry.
The literature provides ample evidence that such interaction between companies and public research is much more likely to occur within a region due to easier interaction, the possibility of frequent face-to-face interaction and respective search processes (e. g., Jaffe 1989, Arundel and Geuna 2004, Broekel and Binder 2007, D'Este and Iammarino 2010). Hence, it can be expected that a higher innovation activity in the region increases the motivation for and, thus, the occurrence of the respective research activity in universities. The potential to obtain third-party money from companies or in cooperation with companies is especially high in the natural sciences and engineering. Therefore, we hypothesize:
Hypothesis 1: A higher share of respective regional innovation activities is related to a higher share of research on sustainability at the universities in the region. This holds especially for research in natural sciences and engineering.

8.2.3 Political and societal circumstances and scientific research

The literature on the interaction of universities with their regional environment has for a long time focused on the contribution of universities to the region's economic development. Recent approaches argue, however, that universities also contribute to the social, environmental and cultural development of their region (e. g., Chatterton and Goddard 2000). At the same time, these approaches assume that universities are more responsive to regional needs.

The regional innovation system and the triple helix approaches mentioned above indicate a closer interaction of universities with actors from the public field, in order to better tailor the activities of the university to regional (economic) goals (Gunasekara 2006, Trencher et al. 2013). This greater responsiveness to regional needs is usually referred to as the 'third mission' of universities (Trippl et al. 2012). The literature on the 'engaged university' or the university as a regional system builder (e. g., Caniëls and van den Bosch 2011) extends this 'third mission' to a broader set of regional goals (Uyarra 2013). According to this approach, universities are stakeholders that are actively involved in regional governance activities with actors from the economic and public field as well as from civil society (Chatterton and Goddard 2000, Boucher et al. 2003). Empirical case studies indicate that a number of universities in Europe are indeed taking such a proactive role with regard to the broader development of their region (Boucher et al. 2003). Through the participation in cross-organizational regional networks, steering committees or conferences, the university or individual researchers are motivated to conduct research on topics that are particularly relevant for the region from a societal or political point of view (Gunasekara 2006, Trippl et al. 2012).

In addition, faculty and students usually live in the university region and are thus also informed about the local socio-political discourses through the media or direct communication with their peers. It is therefore likely that they perceive topics, which are high on the political and societal agendas in the region, as particularly relevant. The perceived societal relevance of a topic can be an important driver for conducting research on a specific topic (see Chapter 2.1). This leads us to the following hypothesis:

Hypothesis 2: In regions in which the society is more oriented to environmentally friendly and sustainability activity a higher share of research at universities is conducted on sustainability issues. This holds for all subjects, but might apply more to law, economics and social sciences because of the higher connection to topics in the society.

8.2.4 Regional path dependence

The concept of path dependence became popular through the seminal contributions of David (1985) and Arthur (1989), who argued that small, random events in an early stage of a technological path have long-lasting effects on the further development of this technology. Although these events do not determine the technology's development trajectory, they narrow down the number of available options for future development once positive feedback effects (e. g., through increasing returns, network externalities or institutional adaptation processes) have set in (Martin and Sunley 2006, Strambach and Halkier 2013).

Meanwhile, path dependence has become a central concept in regional studies and economic geography to explain the relative continuous industrial development and technological focus of regions (Henning et al. 2013). In line with this, it has been argued that endogenous change in a regional path mainly occurs through branching processes into related industries, which are based on similar skills and knowledge bases (Boschma and Frenken 2011). Several empirical studies have confirmed that the existence of related industries or a certain related variety in a location provide an advantage

for the further development of nations or regional economies (e. g., Hidalgo et al. 2007, Boschma et al. 2013). In Section 8.2.2, we argued that the thematic focus of the regional economy effects the choice of research topics at universities (e. g., through third party funding). Based on this argument, we expect that the occurrence of path dependence and branching processes into related fields in the regional economy also show an effect at the university.

At the same time, research in organization and management studies suggests that these mechanisms can also occur at the level of the university itself (Sydow et al. 2009). Existing incentive systems and organizational set ups in universities (e. g., funding programs, mission statements, prizes, chairs, study programs etc.) that have co-developed with certain research foci are expected to show a certain degree of persistence over time. Similar to our argument in Section 8.2.5, we suppose that the occurrence of path dependence on the level of the university leads to a certain continuity in the choice of research topics on the individual level.

It can however also be assumed that these mechanisms apply directly to the career trajectories of individual researchers. On the one hand, a researcher will not radically change her/his research field, as she/he will try to build on her/his existing knowledge and use her/his existing networks. On the other hand, a certain thematic scope is conducive and in most fields even required for an academic career. Therefore, it is likely that researchers diversify their research portfolio over time by doing research on thematically related topics, which necessitate similar capabilities.

Path dependence that leads to relative continuity and rather gradual changes in the research conducted in a region can thus occur on 1) the regional, 2) the organizational and 3) the individual level. All three cases (as long as persons do not switch their
working place) lead to path dependence in the research topics that are studied in a location. Hence, we hypothesize:

Hypothesis 3: Research on sustainability occurs mainly in places in which research on sustainability and related topics was studied before. This holds for all subjects.

8.2.5 University characteristics and research

Compared to other occupations, the direct influence of the university on the activities of researchers is relatively small. Under the German constitution, researchers are free in their choice of research topic. They are usually strongly motivated by intrinsic goals and by receiving recognition within their disciplinary community (see Section 8.2.1). Nevertheless, there are ways through which the university might have an influence on the research conducted by individual scientists.

Although researchers are strongly oriented towards their disciplinary communities, it can be assumed that they are also committed to the social objectives of their university. A high appreciation of a specific topic in the organization can thus be expected to motivate research in this area. This appreciation can, e. g., be expressed in form of specific awards or through a respective mission statement or ‘Leitbild’ (Ferrer-Balas et al. 2008, Lozano 2006). In the context of sustainability, researchers might also become aware of sustainability issues through activities concerning the sustainability of the own workplace, as, e. g., environmental reports, labels or management programs and the ongoing communication of the progress that has been made. Coaching persons in how to participate in such activities might help to build up a respective culture in the organization. Leadership is seen as an important driver of sustainability activities at universities in the literature. This means that the university’s top management has to position itself clearly, e. g. through a mission statement or the establishment of the position of a sustainability manager (Lozano 2006). Empirical research has shown that a lack of

leadership and funding for sustainability activities from the university's top management slow down sustainability initiatives of individual scientists in the university (Velazquez et al. 2005).
The most direct way through which a university might influence research activities of individual researchers is the establishment of positions, which are linked to a specific research field. The university can also facilitate and/or foster specific research activities by establishing links between researchers from different disciplines that are interested in related topics through the set-up of specific organizational platforms, e. g. networks or thematic research centers. This way redundancies can be reduced, resources can be bundled, the efficiency of such projects can be increased and new ideas in this area are likely to emerge (Ferrer-Balas et al. 2008). Impulses for research into specific topics can also be given through the invitation of guest lecturers from other research institutions or practitioners.
Hypothesis 4: Universities are able to increase the amount of research conducted on sustainability by various activities that provide motivation for the researchers to conduct such research. This holds for all subjects.
In contrast to hypotheses 1–3, which are tested by an approach detecting causality, the available data on university activities does not allow for testing hypothesis 4 in the quantitative approach. All we can do in this paper is to test the following hypothesis:
Hypothesis 4´: Universities that are more active in providing motivation for the researchers to study sustainability are also those universities at which more research on sustainability is conducted. This holds for all subjects.
However, the test of hypothesis 4´ and the qualitative research conducted here also give some hints on hypothesis 4. A more elaborated test of hypothesis 4 has to be done in future research.

8.3 Empirical approach

In this paper a mixed methods approach is applied. Regressions were used to examine whether the spatial distribution of publications can be explained by various regional circumstances. In parallel, researchers were interviewed for an in-depth understanding of their motives to conduct research on a certain topic. This *"concurrent triangulation strategy"* (Creswell 2003: 217), combining quantitative and qualitative methods, was chosen in order to cross-validate and complement the findings. In the following, the characteristics and sources of the data used for the regressions and the identification of suitable interview partners are described. This is followed by a discussion of the two types of regression approaches conducted as well as a description of our qualitative research design.

8.3.1 Data characteristics and sources

In order to test the above deduced hypotheses 1–4, regression analyses were used to examine whether the number of publications on sustainability in universities is related to local circumstances. Figure 19 shows that the share increased tremendously in recent years and that the share differs strongly between subjects. There are three subjects that show shares clearly above average: agriculture, law, economics and social sciences, and engineering. Furthermore, natural sciences (including mathematics) show high absolute numbers of publications on sustainability, although the shares are below the value for all subjects. This is caused by a high share of sustainability publications in geography and biology, while in physics and chemistry the shares are rather low. Therefore, four subjects, agriculture, law, economics and social sciences, engineering, and natural sciences were explicitly studied here, although only the first three of them show an above average share of sustainability publications.

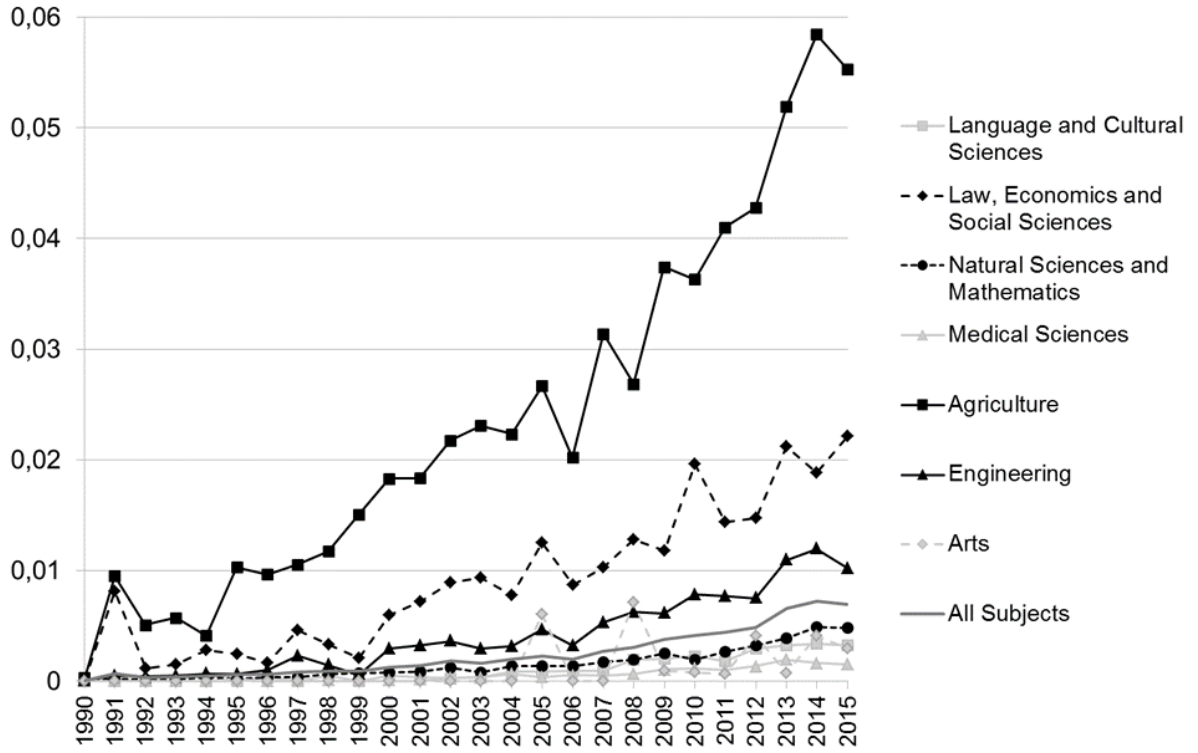

Figure 19: Share of publications (WoS) with at least one author from a German university that contain the word "sustainability" or "sustainable" as keyword, in title or abstract.

As Figure 19 shows, excluding natural sciences would have excluded a significant share of the publications on sustainability. The remaining subjects that were not explicitly studied contribute very little to the publications on sustainability in most universities (see Figure 19). Different subjects might show a different dependence of research topics on local circumstances (as assumed in hypothesis 1 and 2). Therefore, all analyses were conducted separately for different subjects. Sustainability research has also different histories in the various disciplines, so that connections to different other research topics and different other aspects could be expected.

The Web of Science was used as database for the analysis of publication data. All publications that have at least one author from a German university and contain the words "sustainability" or "sustainable" in either title, abstract or the list of keywords were counted as publications addressing sustainability.

The identified publications addressing sustainability were used in two ways. First, the researchers that we approached for interviews were randomly drawn from all German authors of such publications in the years 2011 to 2014 (see Section 8.3.4).

Second, the publication data was used in regression analyses. To this end, for each German university the total number of publications and the number of publications on sustainability were counted (applying fractional counting in case of more than one author) for the years 1990 till 2014. This resulted in a panel data set on the ratio between sustainability and total publications with individual universities and years as observation units. All universities with sufficient publications before 2005 (to calculate the share of sustainability publications, at least 100 publications in total are assumed necessary) and no fundamental changes during the considered time period, such as mergers and new locations, were

considered. Figure 20 depicts the universities and the respective share of sustainability publications. A complete list of the 85 considered universities is given in Appendix 5.

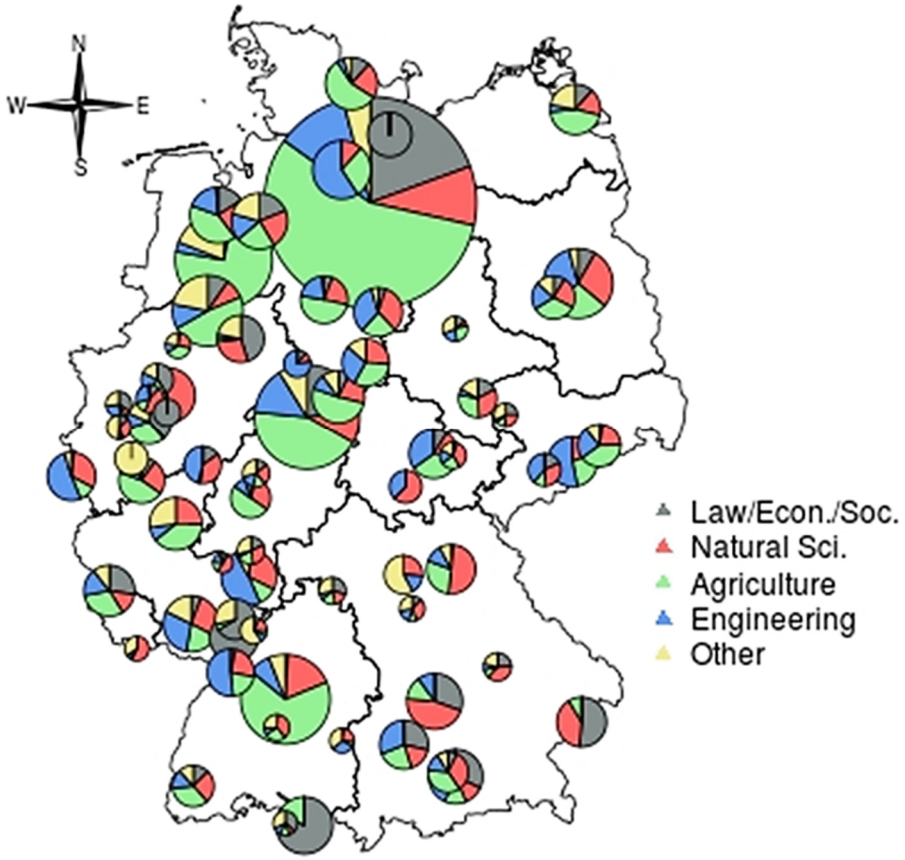

Figure 20: Location of considered universities and the share of sustainability publications (size of total bubble) and its distribution among the disciplines. (In case of more than one university at the same location, only the university with the highest share is depicted.)

Hypothesis 3 states that regional research is path dependent. This means that research on sustainability occurs in locations where research on similar topics has been conducted before. To this end, topics that are related to research on sustainability had to be identified. We define relatedness in this context by the Term Domain Specificity with the domain defined by all publication that contain the words “sustainability” or “sustainable”. The Term Domain Specificity was calculated for nearly 1.8 million keywords that are used as keywords in publications. The 24 keywords with the highest Term Domain Specificity for the publications on sustainability were used here as defining related research topics. Due to an insufficient number of cases before 2004 wo keywords had to be eliminated. Furthermore, multicollinearity problems made it necessary to build keyword groups. To this end, a cluster analysis was conducted for the 22 keywords using their shares in the publications of the universities considered here (the resulting dendrogram is presented in Figure 23 in Appendix 5). Since the clustering was used to deal with the multicollinearity problem in regression, the number of clusters was reduced one by one until no multicollinearity was detected any more (all VIF values are below 5). This procedure led to eight clusters (which is also a good breakpoint looking at the dendrogram), two

of which are groups of keywords and six represent single keywords. These keywords and keyword groups are presented in Table 5. To calculate the number of respective publications from each university the same approach as for the sustainability publications was applied, creating again shares of all publications originating from the universities.

Hypothesis 4 states that the university itself might well have an impact on the research topic of its researchers. However, in the context of Germany it has to be kept in mind that university professors are quite independent in the choice of their research topics. Nevertheless, universities might have direct impact by defining chairs and deciding about study programs and might have indirect impact by motivating researchers (see hypothesis 4). In order to check for direct impacts we looked on the web page of the universities for such activities. In total we defined six kinds of activities as listed in Table 6. The web pages of the 85 universities were searched for such activities and respective dummies were build. This data faces three serious problems: First, we did not have information about the starting of these activities, so that for these activities it is unclear whether the initiative came from the university board or bottom up. However, at least, the university has to support the initiative for such activities to be conducted on the university level. Second, this approach faces the problem that the activities might not be adequately represented on the web pages of the universities. However, this also signals the attention that the university pays to these activities. Third, for most of these activities it was not possible to find out when they have started. This limited the use of these variables in the regressions as described below.

Table 5: Descriptive statistics for the share of publications as used in the cross-sectional regression.

	Mean	Min	Max	Standard deviation
Sustainability publications (before 2005)				
Law, economics and social sciences	0.000402	0	0.008153	0.001222
Natural sciences	0.000383	0	0.006469	0.000897
Agriculture	0.000342	0	0.006644	0.000884
Engineering	0.000103	0	0.00082	0.0002
Sustainability publications (2007 and later)				
Law, economics and social sciences	0.001294	0	0.025585	0.003134
Natural sciences	0.00138	0	0.01186	0.001584
Agriculture	0.002623	0	0.07427	0.008493
Engineering	0.001199	0	0.014378	0.001948

Keywords or Keyword groups (before 2005, as used in the cross-sectional regression)				
Agriculture-social group: “livelihood”, , “farming system”, “agricultural systems”, “food security”, “land management”, “water management”, “renewable energies”, “renewable resource”, “cycle assessment”, “future generations”, “social responsibility”, “social-ecological” and “cropping system”	0.000567	0	0.007716	0.001053
Agricultural production group: “agricultural production”, “soil fertility”, “crop production”	0.000464	0	0.012280	0.001625
“natural resources”	0.000295	0	0.008153	0.001150
“ecological systems”	0.000106	0	0.004859	0.000544
“resource management”	0.000281	0	0.006447	0.000835
“environmental impacts”	0.000277	0	0.003224	0.000566
“forest management”	0.000182	0	0.006469	0.000775
“renewable”	0.000363	0	0.004985	0.000808
Regional variables				
Share of Y Patents (2004)	0.131294	0.069742	0.231777	0.028761
Share of green voting in EU election (2004)	16.990588	3.4	36.8	6.315544

Hypothesis 1 states that respective regional innovation activity is related to a higher share of research on sustainability. It is difficult to define innovation activity that is related to sustainability. Two problems arise: the measurement of innovations and the identification of innovations that are related to sustainability. We applied the most simple method: using the number of patents that are classified into the category ‘Y’ in the CPC classification (patent data and the respective information from the PATSTAT database by the European Patent Office is used). By this, we followed the usual approach in the literature to measure innovations by patents, although this has a number of shortcomings (see, e. g., Deyle and Grupp 2005). Furthermore, the Y class does not clearly match the topic of sustainability, because it is defined to contain new technological developments and cross-sectional technologies. However, the Y class especially contains patents on renewable energies, resource efficiency and climate change and hence the patents related to sustainability. Developing a more detailed and exact

definition of patents relating to sustainability is beyond the scope of this paper, although we are aware of this shortcoming and take it up in the interpretation of the results.

Table 6: Considered university activities and their frequency.

University activity	Number of universities with this activity (out of 85)
Chair containing “sustainability” or “sustainable” in the title or	34
Chair with teaching activity on sustainability	79
There are talks on sustainability organized at the university	75
Awards are given for sustainability research or projects	27
A network on sustainability exists at the university	56
The university hints for more sustainability in its operation by providing respective instructions and/or coaching	36

As usual in the literature, patents were counted at the place of inventors. Inventors might live in administrative districts different from the districts they work in. Labor market areas take commuting into account, so that for each university all Y patents that fall into the same labor market area (according to Binder and Schwengler 2006) were counted. This was done for each year, so that panel data was obtained.
Hypothesis 2 states that the opinion of the society has an impact on the research topics in universities. The political parties in Germany offer a way to measure the attitude towards sustainability: the Green party is the main representative for such a political aim. Hence, the share of votes for the Green party can be used as reflecting their influence. Elections take place in Germany every four to five years. Hence, using one kind of election would not provide data in panel form. Therefore, we build for each university and each year the average of the last German and European election (the votes of the respective city inhabitants are used; data is obtained from the German Statistical Office). In the cross-sectional analyses only the EU election was used because the EU election is the election least influenced by strategical considerations. In local and national election the expected shares of parties and potential coalitions play a much stronger role as well as the specific candidates. For the panel data the votes in German election was used in addition to obtain data that is changing more often (a robustness check with only EU election data showed that the result become more robust by this). The voting shares of the Green party can be interpreted as an indicator of the local attitude towards environmentally friendly and sustainable policies. Descriptive statistics for all regional data that was used is presented in Table 5.

8.3.2 Cross-sectional regression

Due to the different nature of the various data used here two different statistical approaches were applied. One is a vector auto-regression regression, which requires panel data (Section 8.3.3). The data on university activities cannot be obtained in panel form, since the starting date for each activity

cannot be obtained easily in most cases. Therefore, a cross-sectional regression was conducted with each university representing one observation. We used the share of sustainability publications in the four subjects agriculture, law, economics and social sciences, engineering, and natural sciences and mathematics as dependent variables. All other variables were used as independent variable, so that all variables on the university and regional level were simultaneously considered. For the university activities dummies were used, reflecting whether the universities conducted the different activities in 2016. This approach faces the problem that causality could not be studied for the university activities. Except for the university activities, we have panel data for all variables. Furthermore, the share of sustainability publications increased strongly from 2007 onwards. Hence, most publications on sustainability are published 2007 and later. This fact was used to define two periods of time, namely before 2005 and from 2007 till 2015. The dependent variable consists of the sustainability publications counted for the latter time period, while for all other variables only the time before 2005 was considered (for publications and patents all activity before 2005 was considered, for the other regional variables their value in 2004 was used). A gap between the two periods was used to reflect the fact that publications usually require two to three years to be published. This approach allowed to use a cross-sectional regression including all our variables and, at least, exclude, except for the university activities, that the revealed correlations stand for causal effects in the opposite direction. It is unlikely that sustainability publications from 2007 and later influence any of the publication or patent activities or any of the other measures before 2005. Furthermore, including the sustainability publications before 2005 as independent variable takes account of other unobserved university effects that influence sustainability publications, although not all of them. Hence, the cross-sectional approach provided some first insights and was the only way to include university activities in the analysis. Nevertheless, a VAR approach was necessary to detect causality in a reliable way.

Checking the conditions for conducting an OLS regression showed that a normal distribution of residuals is not given due to outliers. Therefore, a robust regression (using the Huber-k estimator; see Wilcox 2005) was applied. Checks for heteroscedasticity and multicollinearity (after aggregating related research fields as stated above and eliminating, in addition, one keyword group in the case of agriculture and engineering) revealed no problems.

8.3.3 VAR approach

An additional vector auto-regressive (VAR) approach was used for two reasons. On the one hand, a VAR approach allows for causal statements. In addition, the VAR approach allows to study whether there might be causal effects in opposite directions. In our case it was especially interesting also to test whether research on sustainability at a university influences the local economy (Y patent activity) and the local attitude (green party votes).

The usual VAR approach restricts immediate causal effects by theoretical arguments. Here, it was an explicit intention to examine whether sustainability publications influence or are influenced by regional economic activities or attitudes. Therefore, the recently introduced VAR-LiNGAM approach was used (Moneta et al. 2013), which contains a data-driven identification strategy for the direction of causality. This approach has already been used in a number of studies (e. g., Coad et al. 2012, Brenner and Duschl 2015, Brenner et al. 2017).

In those studies median regressions (least absolute deviation (LAD) method) were used within the VAR approach (for details see Brenner and Duschl 2015). Median regressions focus on the center values of the variables. In the case of publication activities many universities were inactive in many years. Hence, the distribution is quite skewed and the interesting cases are not located near the median. A normal

distribution is also not given (as anyhow required by the VAR-LiNGAM approach). As for the cross-sectional regression the robust regression turned out to be the best choice: It takes into account the more extreme cases without overweighting them, which led to very robust results in the VAR analysis. The assumptions behind the VAR-LiNGAM approach were tested using the Shapiro-Wilk normality test (distributions have to be non-normal), kernel estimates of the distance between the joint densities and the product of the marginal densities (independence assumption) and the robustness of the causal ordering (acyclicity assumption) (see Brenner and Duschl 2015 for details). While the first two conditions were satisfied, the acyclicity assumption was used to determine how many keyword clusters were build and used. The different publication variables on the related topics were too much correlated, so that the causal ordering was less robust. The clusters used in the cross-sectional approach were not sufficiently aggregated. The keywords were further aggregated – reducing the number of clusters according to the result of the cluster analysis (see the dendrogram in Appendix 5) – until the causal order was most robust (the same causal order appears most often in a repeated bootstrap calculation compared to the expected repetition). Four keyword groups resulted for natural sciences and agriculture, which are presented in Table 7. There is one large group (related to agricultural and social aspects), one clearly focused group (agricultural production) and one combination of two keywords (related to natural resources) and one keyword that remains alone (renewable). In the case of law, economics and social sciences and engineering a reduction to three keyword groups, combining the last two clusters, turned out to be more adequate. The choice of the number of lags was based on the Akaike Information Criterion (see Brenner and Duschl 2015 for details) and resulted in a 1-lag model.

Table 7: Keyword groups considered in the VAR approach.

Keyword groups	**Contained keywords**
Agricultural & social systems	“livelihood”, , “farming system”, “agricultural systems”, “food security”, “land management”, “water management”, “renewable energies”, “renewable resource”, “cycle assessment”, “future generations”, “social responsibility”, “social-ecological”, “cropping system”, “ecological systems”, “resource management” and “environmental impacts”
Agricultural production	“agricultural production”, “soil fertility” and “crop production”
Renewable	“renewable”
Natural resources	“forest management” and “natural resources”
Natural resources	“renewable”, “forest management” and “natural resources”

Furthermore, using the VAR-LiNGAM approach required that the underlying processes were the same for all observations (here universities). This homogeneity could not be directly tested. However, in order to eliminate part of the unobserved heterogeneity, fixed effects were used in the robust regressions within the VAR approach. Beyond this, we had to assume homogeneity in the underlying processes, which is a general shortcoming of such an approach.

Table 8: Status and discipline of interview partners.

Status	Discipline		
	Natural Sciences, Engineering and Agriculture	**Economics and Social Sciences**	**Overall**
Professor	3	3	6
Post-doc and lecturer	4	5	9
PhD student	4	-	4
Overall	11	8	**19**

In total six or seven variables were used in the VAR-LiNGAM approach: the sustainability publications, the Y patents, the Green party votes and the publications belonging to the three or four keyword groups (Table 7). The panel data on the green votes is available from 1994 onwards. Publication and patent data would have been available also for earlier years but the number of publications on sustainability becomes sufficiently large also around the year 1994. Patent data is completely available up to the year 2012 (using the PATSTAT database from Spring 2016). Conducting the VAR approach on a yearly basis was problematic for two reasons: First, elections take place every four or five years. We used the average of the green vote in the last German and EU election, but nevertheless this implies that the values often do not change from year to year. Second, publication and patent numbers fluctuate a lot from year to year. Therefore the analyses were conducted using two-, three- and four-years time periods. Using two-years time periods still did not completely solve the issues. Using four-years time periods reduced significances due to a lower number of observations. Three-years periods (for 1995 till 2012) were found to lead to the most robust results and are therefore presented and interpreted below. Nevertheless, all analyses were also run for two- and four-years periods as a robustness check and the confirming or deviating findings are mentioned in the discussion of the results. Again we had to check whether sufficient publications and patents are present in each time period in order to calculate the shares of interest. In order to deal with the different period definitions in the same way, all universities that have, at least, in one year no publication or no patent in the surrounding labour market area were excluded. This reduced the number of universities for this analysis from 85 to 79.

8.3.4 Interviews with researchers

For the identification of interview partners, five publications per year in each discipline were randomly selected from all sustainability publications in which the main author worked at a German university at the time of publication. It was furthermore checked that the word “sustainable” or “sustainability” referred to the concept of a responsible use of resources and not only to the original meaning of the word, i. e. long lasting. This way a broad sample representing different status groups as well as disciplines was selected (see Table 8). This diversity among interview partners was considered important, as it was not the purpose of this part of the study to come to representative results, but rather to identify a particularly broad range of perspectives on the topic.

Overall, 19 problem-centered interviews (e. g., Witzel 2000) were conducted. A semi-structured interview guide was used, in order to give the interview partners room for open narration but also enable the interviewer to focus the interview on the specific research question. A short biographical questionnaire could in most cases already be filled in before, based on internet research. The telephone interviews lasted from 15 to 30 minutes and were either recorded or (if requested by the interviewee) only documented by a second person.
In the first part of the interview the individual understanding of sustainability and its role in the interviewee's own research, as well as her/his discipline in general, was determined. Then the interviewee was asked to recollect and explain in detail why she/he started her/his research on sustainability. If necessary, additional questions were asked by the interviewer, in particular to be able to differentiate between the motivation for conducting research on sustainability and for the mere use of the word in publications and grant applications. The interviews were finally analyzed using deductive and inductive categories.
This open, exploratory design of the qualitative study enabled us to determine if there are other influences that we were not aware of or not able to consider in the quantitative study.

8.4 Results and discussion

In the following the results from the two regression approaches and the interviews are presented and discussed separately. The findings are then integrated in a subsequent section.

8.4.1 Cross-sectional regressions

The cross-sectional regression was done for the four subjects Law, Economics and Social Sciences, Natural Sciences, Agriculture and Engineering separately. However, the overall results show a lot of similarities. The regression results are presented in Table 9. The similarities concern especially the findings for the groups of independent variables. In all four subjects there is a significant dependence on the publication activity on sustainability before 2005. This was expected and the variable was included in the analyses rather as control variable to take care of this endogeneity. Nevertheless, it also shows that there is path-dependence in studying the subject of sustainability, which confirms the first part of hypothesis 3.
The second part of hypothesis 3 states that research on a new topic occurs mainly in places where research in related fields has been conducted before. This hypothesis is also clearly confirmed. In all four subjects we found clear evidence for such a path dependence.
For all studied disciplines we found a positive significant relationship between overall publications on forest management before 2005 and discipline-specific sustainability publications in 2007 and later. It is rather surprising that publications on one specific keyword are relevant in all disciplines. However, this might represent the fact that sustainability played a role already very early in forestry and there seems to be a spread of the issue from this to other disciplines within universities.
In law, economics and social sciences also publications on "ecological systems" precede sustainability publications. This is well in line with the strong connection of sustainability with ecological considerations in these disciplines. In agriculture we found, besides the relationship with forest management, a path dependence on previous research within the large keyword group on agricultural and social issues connected to sustainability as well as on environmental impacts. Sustainability research has a long history in agriculture already before sustainability became fashionable. The results seem to reflect this. In natural sciences and engineering no further preceding keyword besides forest

management showed a significant relationship with the sustainability publications. Robustness checks with other keyword groupings showed that there might be preceding topics also in these fields but they are buried in the largest keyword group above and the results of robustness-check regressions are not reliable due to multicollinearity problems.
For the regional factors, no significant relationship with the share of sustainability publications was found. The strong occurrence of sustainability research at some universities from 2007 onwards seems not to be triggered by respective innovation activity in the regional economy. It has to be taken into account in this context that the measurement of sustainability-related innovation activity by Y-class patents might not be adequate. We did also not find evidence for an impact of our regional attitude variable, green votes in the EU election, on sustainability research. It was difficult to measure the regional attitude towards sustainability and the indicator we used has its limitations. Nevertheless, it was expected that voting for the Green party is related to research on sustainability. Hence, hypothesis 1 and 2 are not supported by the findings. However, the cross-sectional regression has its limitations and the VAR approach below offers deviating findings.
Finally, hypothesis 4´, stating that university activities come together with research on sustainability, is only confirmed in one case by our findings: In natural sciences, talks on sustainability are an indicator for sustainability research conducted there. This result can be interpreted as follows: First, in all other disciplines besides natural sciences no significant relationship is found, so that no confirmation of hypothesis 4´ is obtained. If university would have an impact on sustainability research (hypothesis 4), the weaker hypothesis 4´ should hold. Hence, we might conclude that the influence of the university is, at least, rather limited. In the case of the significant finding for natural sciences it seems rather plausible that research conducted on sustainability in a university triggers the organization of talks there.
To sum up, we did not find evidence for an impact of regional circumstances on the choice of research topics at universities considering the case of sustainability research. In addition, no clear evidence for an influence of the university administration was found. The main explanation of the location of sustainability research seems to be scientific path dependence.

8.4.2 VAR analyses

As in the case of the cross-sectional regressions, the VAR analysis was conducted for the four disciplines separately. As a result, we obtained the coefficients for the dependence of each variable from all other variables in the same time period and the period before. All results that refer to sustainability publications are presented in Tables 10 and 11. The complete results are presented in Appendix 5.
The first observation is that in all subjects, except law, economics and social sciences, sustainability publications in one time period depend on the sustainability publications in the time period before. This is in line with the findings in the cross-sectional analysis and confirms path dependence in research (hypothesis 3).
In contrast to the findings in the cross-sectional analysis, we found significant dependence of sustainability publications on the share of Y patents and the share of green votes in the region before. The dependence on the green votes was found for natural sciences and engineering, while the dependence on the Y patents is only significant for engineering. Hence, the more short-term causal analysis detected some influence of the regional circumstances. The findings for the green votes are also found in the robustness check analyses of two-years and four-years periods. Hence, there is clear causal evidence for a dependence of sustainability research at universities on the attitude of the surrounding city population, at least in two subjects. Hypothesis 2 is partly confirmed.

Table 9: Results of the cross-sectional regressions for the four studied subjects.

Regional factor	**Dependent variable: Share of university publications containing the words "sustainability" or "sustainable" (title, abstract or keywords) in the subject**			
	Law, Economics and Social Sciences	**Natural Sciences**	**Agriculture**	**Engineering**
Constant	5e-04 (0.386)	0.000851 (0.182)	0.000192 (0.821)	0.0007 (0.184)
First lag of dependent variable	*0.61**** *(0.000)*	*1.16**** *(0.000)*	*1.04**** *(0.000)*	*3.65**** *(0.000)*
Related research fields:				
Agriculture-social group	0.11 (0.558)	0.00516 (0.98)	*0.777**** *(0.000)*	0.046 (0.604)
Agricultural production group	-0.13 (0.237)	0.0102 (0.933)	-	-
"natural resources"	0.0688 (0.732)	-0.0399 (0.744)	0.223 (0.181)	0.102 (0.331)
"ecological systems"	*0.416* (0.017)*	0.331 (0.086)	0.271 (0.281)	-0.0592 (0.704)
"resource management"	-0.134 (0.297)	0.106 (0.435)	-0.077 (0.665)	-0.0768 (0.495)
"environmental impacts"	-0.182 (0.339)	0.231 (0.287)	*0.8** (0.004)*	0.232 (0.223)
"forest management"	*3.14*** (0.000)*	*0.558* (0.012)*	*2.35*** (0.000)*	*1.55*** (0.000)*
"renewable"	0.162 (0.345)	-0.0103 (0.954)	-0.362 (0.113)	-0.123 (0.4)
University activities:				
Chair on sustainability	-0.000027 (0.913)	-0.000139 (0.604)	0.000498 (0.161)	0.000212 (0.324)
Teaching on sustainability	0.000098 (0.824)	-0.000252 (0.605)	0.000059 (0.926)	0.000202 (0.606)
Talks on sustainability	0.000302 (0.412)	*0.000847** *(0.035)*	0.000336 (0.521)	0.000116 (0.716)
Awards for sustainability research	4.9e-05 (0.807)	-0.000264 (0.24)	-0.0001 (0.735)	-0.00019 (0.285)
Network on sustainability	0.000074 (0.79)	0.000098 (0.743)	-0.000259 (0.514)	-0.000172 (0.478)
Instructions and/or coaching	-0.000131 (0.579)	-0.000056 (0.83)	-0.000027 (0.938)	-0.000119 (0.569)

Regional factors:				
Y patent share	-0.002774 (0.367)	-0.004609 (0.176)	-0.000549 (0.905)	-0.001751 (0.518)
Green party votes (EU election)	-0.00001 (0.494)	0.0000000 (0.981)	-0.000012 (0.58)	-0.000026 (0.06)
AIC	-802.2	-908.7	-573.5	-889.0
Number of observations	85	85	85	85

(P-values in brackets with the significance levels indicated by ***(<0.001), **(<0.01) and *(<0.05).)

In the case of the Y patents a dependence has been expected for natural sciences and engineering (hypothesis 1). Significant dependence is found for engineering. Hence, the results are partly in line with the expectations. Taking into account that research on sustainability in the natural sciences is mainly done in geography, the missing evidence for this discipline is understandable. A stronger connection to innovations in the economy would be expected for physics and chemistry. The significant dependence in engineering was also found for two-years periods. Hence, in line with our expectation (hypothesis 1) sustainability research in engineering positively depends on related innovation activity (Y patents) in the surrounding labor market region.

An interesting fact is that we did find little significant dependence in the opposite direction (Table 11). Usually the literature assumes that university research has an impact on the economic activity in the region (Uyarra 2010). Only in the case of natural sciences some positive dependence of green voting on the share of sustainability publications was found. In the case of agriculture even some negative effect of sustainability publications on the respective innovation activity was found. Both findings are only significant on the 5%-level, so that they should not be over interpreted. More recent approaches (e. g., Chatterton and Goddard 2000) expect universities to take a broader role in regional development, also contributing to the social, cultural and ecological development of the region (Uyarra 2010). Some authors even regard universities as a 'change agent' for sustainability in society and particular in their regional surrounding (e. g., Stephens et al. 2008, Sedlacek 2013). We found only very weak evidence for a positive dependence of the local attitude in the region on sustainability research at the university.

Finally, the results of the VAR analyses clearly confirm hypothesis 3: Related research topics have a causal impact on sustainability research. The keyword group "Natural resources" (including forest management) shows the strongest impact. In addition, other research fields also have an influence. Only in the case of agriculture, no dependence on other related fields was found. Probably the reason for this is that in agriculture sustainability research has a longer history, so that the internal path dependence dominates here.

However, we also found causal dependence in the opposite direction. Therefore, there seems to be less of a one-way causal effect and more of a general path dependence in science with a number of keyword-defined topics involved.

To sum up, in contrast to the cross-sectional analysis, the VAR analysis confirms the expectations that sustainability research is more likely to receive increasing attention in a university if the local attitude towards sustainability (measured by green votes) and the economic interest in related technologies (measured by Y patents) increases, although this is confirmed only within one and two disciplines, respectively. Besides this, the strong path dependence within science is again confirmed.

Table 10: Results for the dependence of sustainability publications on the other variables.

Other variables	**Dependent variable: Share of university publications containing the words "sustainability" or "sustainable" (title, abstract or keywords) in the subject**							
	Law, Economics and Social Sciences		**Natural Sciences**		**Agriculture**		**Engineering**	
Temporal ordering	*Same period*	*Period before*	*Same period*	*Period before*	*Same period*	*Period before*	*Same period*	*Period before*
Sustainability publications	-	0.0405 (0.4359)	-	*0.2497** (0.002)*	-	*0.7899 *** (0.0000)*	-	*0.4775* (0.0177)*
Y patents	-	0.0000 (0.9488)	-	0.0000 (0.9534)	-	0.001 (0.2633)	-	*0.0008* (0.0229)*
Green votes	-	0.0000 (0.9461)	-	*0.0012** (0.0059)*	-	0.0007 (0.0875)	-	*0.0004* (0.014)*
Publications in related research fields:								
Agricultural & social systems	-	-0.0203 (0.2297)	-	*0.051* (0.0493)*	-	0.0212 (0.5679)	-	0.0259 (0.3269)
Agricultural production	0.1972 (0.1231)	-0.2504 (0.0653)	0.0517 (0.5436)	0.0143 (0.9046)	-0.113 (0.8085)	0.2613 (0.6181)	-	0.0073 (0.8212)
Renewable	-	-	*0.4733 *** (0.0000)*	-0.2015 (0.3729)	-	0.5976 (0.0525)	-	-
Natural resources	*0.4169 *** (0.0006)*	*-0.1423* (0.013)*	*0.1474* (0.0203)*	-0.0076 (0.9445)	0.0516 (0.6103)	-0.0675 (0.5578)	-	*0.1146* (0.0254)*
Number of observations	79		79		79		79	

(P-values in brackets with the significance levels indicated by ***(<0.001), **(<0.01) and *(<0.05).)

8.4.3 Interviews

Our qualitative study was guided by the question of what motivates researchers to choose a certain research topic. The results and discussion are structured according to the main drivers that became apparent in the interviews. These categories sometimes overlap, which supports our assumption that different types of motivation are closely interrelated and the choice of a research topic is often motivated by more than one goal.

Table 11: Results for the dependence of the other variables on sustainability publications.

Other variables	**Independent variable: Share of university publications containing the words "sustainability" or "sustainable" (title, abstract or keywords) in the subject**							
	Law, Economics and Social Sciences		**Natural Sciences**		**Agriculture**		**Engineering**	
Temporal ordering	*Same period*	*Period before*	*Same period*	*Period before*	*Same period*	*Period before*	*Same period*	*Period before*
Y patents	-0.8363 (0.4669)	-0.0005 (0.9998)	1.9811 (0.1316)	-0.3398 (0.8792)	0.8899 (0.4169)	*-2.8107 * (0.0341)*	-0.1778 (0.9444)	3.8234 (0.2441)
Green votes	0.494 (0.4816)	0.6577 (0.4122)	0.8918 (0.335)	2.7532* (0.0372)	0.2572 (0.6557)	0.4137 (0.7233)	1.2601 (0.3416)	4.259 (0.1058)
Publications in related research fields:								
Agricultural & social systems	*0.4581* (0.0165)*	-0.0326 (0.8997)	0.3088 (0.1636)	-0.0119 (0.9209)	*0.5269* (0.0163)*	0.2266 (0.3754)	*0.9757* (0.0281)*	0.508 (0.4239)
Agricultural production	-	0.0000 (0.9963)	-	0.0000 (0.9945)	-	0.0000 (0.9951)	0.1291 (0.1051)	-0.0616 (0.2316)
Renewable	-	-	-	0.0001 (0.9956)	*0.2027* (0.0396)*	-0.1423 (0.1421)	-	-
Natural resources	-	-0.0785 (0.1926)	-	0.0255 (0.5806)	-	0.0251 (0.8256)	*0.8971*** (0.0004)*	0.2992 (0.3383)
Number of observations	79		79		79		79	

(P-values in brackets with the significance levels indicated by ***(<0.001), **(<0.01) and *(<0.05).)

8.4.3.1 Personal interest and perceived societal importance

The interviews showed that the motivation of most persons to conduct research in the field of sustainability is rooted in a private interest in that topic. For some interviewees the thoughts and questions that the concept of sustainability brings up even constitute a fundamental motivation for their research activities. An interview partner from the social sciences explained: *"I think the concept of sustainability is particularly valuable. The idea was first expressed by the Club of Rome in the 1970s: Do we use this globe in a sustainable manner? And this is something which fundamentally motivates me to be a scientist."*

This private interest usually developed before the person even started his or hers studies. Therefore, some persons already chose a sustainability related subject for studying. Most interview partners did not become aware of the urgency of the topic suddenly through a specific event, but rather gradually through the emerging public discourse about the concept in the 1980/90s.

Some interview partners stated that the main goal of their research activities was to broaden their own knowledge on the topic. Nearly all of the interview partners mentioned the intention to advance scientific knowledge on sustainability in general or to raise awareness for the importance of the concept in their discipline, among students and/or in the broader public. Several interview partners also stated that right from the beginning they had the aim to foster sustainable development through cooperation with practitioners and giving advice to policy makers.
In some cases, this personal interest was further spurred by a particular project or seminar during the person's studies. As one interviewee from the field of engineering reported: *"I have always been interested in this topic and have already chosen environmental science as a minor subject during my engineering studies. I still have a seminar in mind that was particularly outstanding in my opinion, in which we had to reduce the energy demand of a building by implementing a photovoltaic system."*
The interviews thus support the assumption that scientists are driven by a high intrinsic motivation when choosing a sustainability related research topic. This is usually an intrinsic motivation that not only leads to personal satisfaction, but also to a social result (Grant 2008). The interviews also indicate that intrinsic motivation seems to substantially increase the likelihood that external influences (as e. g., teaching offers at the university) have an impact on a researcher's choice of topic at later points in time.

8.4.3.2 Organizational and disciplinary context

In the literature, rewards and role models are seen as a driver of sustainability-related activities (e. g., Ferrer-Balas et al. 2008). Some persons indeed mentioned role models or specific seminars or initiatives at their university during their studies which either initially aroused, but most often, supported their already existing intrinsic motivation to conduct research on the topic (see section above). These persons then usually searched for a PhD supervisor or an institute with a sustainability focus for their PhD, not necessarily at the same university, however.
It also became apparent in the interviews that research on sustainability can be (further) spurred by a research focus on sustainability in a job description. One researcher, e. g., holds a chair endowed by a company, which is focused on sustainability research. Although this person had worked on related topics before, it was the job description, which substantially spurred publication activities on sustainability.
Other influences from the organizational context, as e. g. leadership of the university management, that is frequently highlighted in the literature (e. g., Velazquez et al. 2005, Lozano 2006), were not mentioned in the interviews. It rather became apparent that recognition from the disciplinary community and from the broader public can be (additional) motives to conduct research on sustainability. One interviewee reported that it was the high appreciation in his community that encouraged him to continue his work in the field of sustainable construction. For some interview partners it was rather the intention to change the unsustainable and undifferentiated public image of their research.
The latter supports our assumption that extrinsically motivated social and material goals also play an important role as (additional) drivers for sustainability research. Universities seem to be able to further spur sustainability research. They do, however, rather not give the initial impetus for conducting sustainability research.

8.4.3.3 Interaction with practitioners

The interviews show that cooperation with practitioners in the region was seldom a reason or additional trigger to conduct research on sustainability for our interview partners. In particular in the natural sciences, some researchers stated that industrial companies are not so interested in their research, as the procedures or products which they develop are not profitable yet. As one interviewee, who develops chemical recycling procedures, stated: *"The problem is that the industry is not interested [in our research], because oil is much too cheap at present.* [...] *Therefore our work ends up in a drawer somewhere, so to say. But we will hopefully be able to use that in ten years or so."* Another interview partner from the field of steel production and processing reported that he finds it extremely difficult to bring his research results into practical application due to the "inertia" of the steel industry.
However, researchers from other fields reported that they do indeed cooperate with companies and policy makers. This does, however, not necessarily occur in the region and in fields where patents are involved, but rather, e. g., in the field of sustainable supply chain management or corporate social responsibility. In particular in the social sciences researchers from the fields of philosophy and ethnology reported that they participate in national political committees and programs. In their field the topic of sustainability is even seen as a chance to conduct applied research, which is normally rather unusual in these disciplines.
Our assumption, that innovation activities by firms in the region increase the motivation for and, thus, the occurrence of the respective research activity in universities, in particular in the natural sciences and engineering (hypothesis 1), is thus not supported by the results from the interviews. Political or societal influences from the regional surrounding (hypothesis 2) were not explicitly mentioned in the interviews either. These mechanisms can if at all be found on the national level. However, the interviews indicate that in most cases these cooperation activities were just an additional trigger and not the initial impetus for conducting sustainability research.

8.4.3.4 Path dependence and relatedness

In the interviews, it became apparent that researchers did not radically change their research focus in order to conduct research on sustainability. An interview partner from the field of engineering stated two possible mechanisms that explain continuity in research very clearly: one is that researchers build on already existing knowledge bases and competences and focus more strongly on sustainability aspects now (1) and another is that they just label or embed their research differently but still study the same (2).
Regarding the first case, one interview partner from economics explained that at a certain point in one's career it becomes difficult to switch from one topic to another. In some cases smaller events at an early point in a person's career (e. g., a lucrative job offer) had thus a major effect on the person's later career. However, there are still some persons that took up the topic of sustainability relatively late in their career. These persons often stated however that they already had a private interest in the topic before. The latter makes apparent that intrinsic motivation is often not sufficient, but that other factors need to be given in order for a researcher to realize his or her aims and ideas. This applies in particularly to research in the natural sciences and engineering, which depends on high levels of public or private funding.
In line with the second explanation given above, several researchers explained that the sustainability perspective only led to a different framing of the research that had been conducted before. In particular interview partners from the natural sciences and engineering reported that the topic of

sustainability just provided a new opportunity for legitimizing their research and was thus only mentioned in the introduction and conclusion of a paper or PhD thesis. Others mentioned that sustainability in its general meaning is and has always been an inherent goal in their research field (e. g., the aim to make a process or product more energy or material efficient or the aim to reach equilibrium states in socio-ecological systems) and that it is mainly the wording which has changed.
Hence, path dependence and branching into related fields (hypothesis 3) indeed play a role on the individual level. These mechanisms might also occur on the organizational level. As described in the previous section, researchers are sometimes influenced by colleagues/supervisors in the choice of research topics. These persons do however not necessarily have to come from the same organization, but can also be part of the researcher's disciplinary network. Job offers at a university with a sustainability focus that were also mentioned as a driver of sustainability researchers could also indicate path dependence on the organizational level. This is however only an assumption as this has not been explicitly mentioned in the interviews.

8.4.3.5 Public funding and 'hypes'

Funding opportunities are across all disciplines perceived as particularly good in the field of sustainability. Most interview partners stated explicitly that they use the word "sustainability" in research applications to legitimize their research and that they have the impression that their colleagues do the same. They also reported that sustainability topics or at least a reference to the concept are explicitly requested in research programs in their discipline. However, for many researchers there seems to be a conflict between increasing their funding chances and their reputation in the scientific community.
The broadness of the concept makes it possible to apply to a broad range of funding programs and publish in a broader range of journals. As one interview partner from the social sciences explained, it can however have a negative effect on one's career when one solely works with these *"bridging concepts"* and not with core concepts of the own discipline.
The interview partners also had the impression that the interest in sustainability research is strongly subjected to 'hypes'. The latter are usually initiated by a sudden rise in public awareness through scandals or natural catastrophes followed by a comparably steep decline of attention (Ruef and Markard 2010). These hypes led to an over- and unspecific use of the concept. Therefore, many researchers do not want to use the term anymore and try to distance themselves from the political connotation of the concept.
A way out of this dilemma seems to be the replacement of sustainability with more precise terms and concepts. The latter is important as one interview partner from economics explained, the scope of the concept of sustainability is steadily broadening, increasingly also including ethical and cultural issues.
We can conclude that material incentives in the form of public and third party funding indeed have an effect on publication activities in the field of sustainability. This can however conflict with social incentives, in particular reputation in the scientific community. Moreover, the interviews indicate that funding leads to an increased use of the term of sustainability but does not necessarily change the content of the research conducted.

8.4.4 Integration of findings

Bringing together the results of the two quantitative approaches and the qualitative study not only increases the validity of the study, but also enables a more nuanced and differentiated interpretation and reveals some further connections.

Regarding our first hypothesis on the effect of regional innovation activities on university research, we receive different results. The more short term statistical analyses reveal a significant influence for the fields of engineering. The cross-sectoral regression and the interviews rather indicate that the influence of regional innovation activities is negligible or not significant. The contradicting results for engineering might be explained in one of the following ways: 1) If joint projects between universities and companies are conducted, the companies often want to patent the results first and publications are done (maybe 2–3 years) later. The VAR might be able to detect the effects of such projects, while they are not sufficient in number to show up as a general explanation of overall publication activities by patent activities before 2005. 2) A general increase in the awareness of sustainability-related issues in the economy might also trigger the latent intrinsic motivation of researcher to move into this direction in their research. The researchers would rather see this as a trigger (as formulated in some interviews) and the effect would not be visible in the long run, but the VAR analysis would identify this triggering. Hence, we conclude that the general focus of universities on sustainability research cannot be explained by the technological interests in the region, but that in the short term changes in focus in the discipline of engineering might be connected to changes in the regional technological profile.

Regarding the opposite direction, i. e. the effect of university research in specific disciplines on innovation activities in the surrounding region, we did not find any statistical significance. This finding is in line with the statements of the interview partners from the natural sciences and engineering, which suggest that it is difficult for researchers to bring their results into practical application as the pressure on most industries to substitute certain resources is not strong enough yet. The cooperation activities with practitioners mentioned by the interviewees from the social sciences do not become visible in patent activities and could therefore not be detected in the quantitative study. However, also here the interviews indicate that these activities usually rather take place at the national or international scale.

Concerning our second hypothesis, the more short term regressions support the assumption that in regions in which the society is more oriented towards sustainability there is also more research into this topic at the university. In the interviews the perceived societal relevance in the region in which the scientists work today was not explicitly mentioned. However, it became apparent that the perceived societal relevance in general indeed plays an important role. It can be expected that the perception of the relevance of a topic for society is a result of influences from the media and from social interactions. It is likely that persons do not consciously differentiate between influences from the national and the regional level. However, from the interviews we can also conclude that persons are often shaped early in their career or before this career even started. Therefore, this influence does not have to come directly from the region in which these persons work today. It might, however, be that many researchers still live in the region in which they grew up or moved to a region where they are able to conduct sustainability research. Hence, we can conclude that the perceived societal relevance of sustainability in general and in the local surrounding seem to have a strong influence on scientists when choosing their research topic.

Our third hypothesis stated that research on sustainability occurs mainly in places in which research on related topics was studied before. This assumption was clearly supported for (nearly) all disciplines in both statistical analyses. As discussed in the theoretical part, there can be different mechanisms

leading to this result. The interviews provide additional information in this regard. They make apparent that path dependence occurs mainly on the individual and to some degree also on the organizational level. Path dependence on the individual level does not necessarily lead to regional path dependence. However, we can assume that researchers stay in a location for several years and from the interviews we also know that they give impulses to their colleagues and students, which would explain why sustainability research persists in some places over time.

Regarding our fourth hypothesis, the findings from the quantitative and qualitative studies are rather contradictory. The interviews suggest that universities are able to and do foster research on sustainability, in particular by the creation or declaration of respective jobs and chairs. They also indicate that an already existing interest in sustainability can be further spurred through seminars or larger working groups that are already working on the topic. Awarded research can also lead to role models for younger researchers and influence the choice of their research topic. The results of the statistical analyses on the contrary show that the activities of universities are not significantly related to the amount of research conducted on sustainability. An explanation could be that the mechanisms mentioned in the interviews are simply not strong or frequent enough to be statistically significant. Another explanation could be that the activities of universities are themselves caused by the researchers working there, so that in the statistical analyses these effects are represented in the identified scientific path dependence. It would be necessary to consider university activities in the VAR approach to finally detect the causal dependencies in this context.

The qualitative study also shows that influence factors on sustainability research are closely interwoven. They can either spur or dampen each other. The effects of the external influences mentioned in the hypotheses seem to be strongly dependent on the principle personal attitude of a researcher towards the concept of sustainability.

The interviews also brought up some additional issues that have to be considered when interpreting the quantitative results and drawing further conclusions. They indicate that good funding opportunities and the perceived societal relevance of the topic might have led to a very broad use of the terms “sustainability” and “sustainable”. The interviews thus let us expect that in some places, where a lot of research was conducted in a discipline or topic in which sustainability issues have always been inherent, the term was used more frequently because it became politically ‘en vogue’ and not because of a change in the research conducted. At the same time, it became apparent that other researchers avoid these terms, although they are still conducting research that we are interested in. Many researchers from different disciplines stated their concern regarding the use of the word in the scientific context due to its unspecific nature and over-use. Hence, the identification of sustainability research is not straightforward. The definitions of sustainability and the motivation of researchers to use the word “sustainability” seem too differ strongly between researchers.

8.5 Conclusions

A mixed method approach was used here to examine what determines the spatial distribution of sustainability research in Germany. We obtain four main results: 1) Regional innovation activities matter less than expected. They only seem to serve as an additional triggering factor in engineering, but do not fundamentally shape the orientation of university research. 2) However, regional circumstances do matter in form of an influence of regional attitudes (Green party votes) on sustainability research, which is found here for natural sciences and engineering. Our interpretation is that researchers are influenced by their surrounding and that the surrounding might trigger them to

put an already intrinsic motivation into research practice. 3) Path dependence is strong in scientific research in all disciplines, mainly based on path dependence on the personal level and inter-personal influences. 4) The influence of the university administration on the researchers' choice of topic seems to be rather low. Among all disciplines the intrinsic motivation of scientists seems to be the main driver of choosing a sustainability related research topic. However, despite motivation, researchers are of course dependent on financial resources from the university as well as from national and European funding programs.

Although we have studied only the specific topic of research on sustainability, some insights might also hold beyond that. First, regional path dependence in science can well be expected in other fields. Second, the university administration does not seem to have a strong impact on the topics studied, at least in the German system. Third, the influence of the attitude in the local society on research topics in university might hold also in other research fields. However, this is an interesting insight that requires further research, especially on the question of what are the exact mechanisms and of how universal this finding is. We did not find a relationship in all of our analyses, which suggests that the mechanisms behind are not universal.

A motivation for this study was the assumption that academic research into sustainability contributes to a sustainable regional development. Although we did not analyze this topic in depth, some results of our study indicate that the influence of sustainability research on the region is rather low. In order for academic research to contribute to sustainable regional development, it might thus not be sufficient to spur sustainability research, but also to strengthen exchange between researchers and various regional stakeholders. The interviews indicate that the motivation to do so is generally given on part of the individual researchers.

9 Conclusion

This dissertation contributed to the geography of sustainability transitions literature by analyzing micro-dynamics and institutional change in regional transition paths to sustainability (RTPS). In this way, a better understanding of the multiplicity and place-specificity of sustainability transitions should be gained. The central research questions were:
How do institutions, which foster sustainable practices in multiple thematic domains, develop in a region over time? And how do actors drive the development of these institutions on the micro-level?
An extensive review of the existing literature revealed the need for a conceptual and methodological approach to analyze the complex institutional dynamics underpinning regional sustainability transitions. Consequently, three main aims for this dissertation were formulated (see Chapter 1.2). While the first two aims referred to the development of a conceptual and methodological approach to analyze regional sustainability transitions, the third aim focused on the generation of empirical insights to answer the above research questions.
The following section synthesizes the main contributions of this thesis and explicates the research design that has been used for developing theory and method. The next section elaborates on the central empirical findings that have been generated with the newly developed conceptual and methodological approaches. This is followed by a detailed reflection of these approaches as well as suggestions for future research. The chapter will conclude with practical implications for policy makers and other actors that want to foster regional sustainability transitions.

9.1 Contributions of the dissertation

(1) It was a central aim of the dissertation to "*develop a conceptual framework that models the regional particularities of institutional change as a basis for regional sustainability transitions*" (see Chapter 1.2).
This aim was based on the observation that regional transition processes differ substantially from sectoral transitions. They cannot be adequately captured with existing frameworks like the MLP, which are primarily focused on dynamics within specific sectoral contexts. The RTPS framework developed in this dissertation acknowledges the particularities that influence transitions at the regional scale and models change not as disruptive, but as evolving in a gradual way. The approach suggests that new organizational forms are important enablers of institutional dynamics in regional transition paths to sustainability (see Chapter 4).
(2) Another aim of the dissertation was to develop "*a methodological approach that enables the systematic mapping and analysis of the complex institutional dynamics underlying regional sustainability transitions, and that provides a basis for (comparative) case study research*" (see Chapter 1.2). This aim was based on the finding that existing approaches to the analysis of sustainability transitions focus either on "the bigger picture" *or* zoom in on the micro-level (Köhler et al. 2019). These approaches do not establish the connection between developments at the micro-level and the system-level. The methodological approach of a transition topology developed in this dissertation enables "*structured navigation*" between different levels of analysis (Holtz 2012, Köhler et al. 2019: 20) and the reconstruction of these processes within a specific time-space context. With reference to the conceptual approach, different types of new organizational forms are used in the transition topology to make the institutional dynamics underpinning regional transitions paths to sustainability visible (see Chapter 4).

(3) An additional aim of the dissertation was to apply the conceptual and methodological approaches "*to generate empirical insights into regional sustainability transitions and the underlying micro-dynamics on the basis of (comparative) regional case studies*" (see Chapter 1.2). Four papers made an original empirical contribution to the research question outlined above. The RTPS framework and the transition topology allowed for focusing on agency and processes that were, due to their regime-overarching character, neglected in the existing literature.

However, these three aims were not implemented one by one. Using an abductive research design (see Chapter 1.3), the conceptual and empirical work conducted in this thesis have been closely interwoven. Figure 21 displays the research design for this thesis.

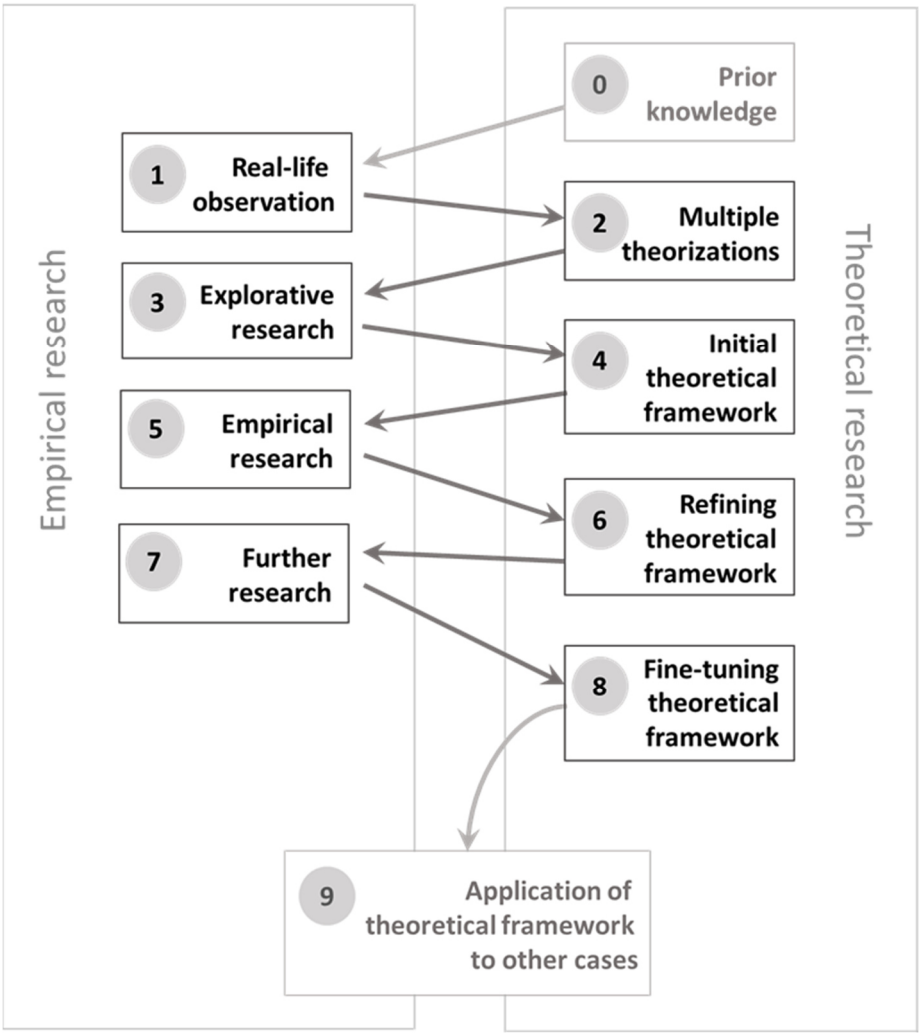

Figure 21: Abductive research design of the dissertation project (refinement and extension of Figure 2).

Figure 21 shows that the development of the conceptual and methodological approaches in this thesis started out with an empirical observation in the Augsburg region (see box 1 in Figure 21). Subsequently, a broad literature study was conducted, enabling multiple theorizations of the phenomenon (see Chapter 2.2). This procedure led to the assumption that the empirical observation did not fully match the existing theoretical frameworks (box 2). Explorative research in the Augsburg region (box 3) strengthened this initial assumption. It showed that the regional transition process to

sustainability in the Augsburg region did not involve any disruptive processes as suggested by the MLP. It rather evolved in a gradual way. While no single sector seemed to have changed radically, the process in Augsburg involved an astonishingly broad range of sectors. Therefore, the aim of developing a new theoretical and methodological approach for the analysis of regional sustainability transitions was formulated. The literature on the geography of sustainability transitions, which had already generated valuable insights on sustainability transitions at the regional level, as well as approaches from Neo-institutional Theory and EEG, provided a rich repertoire from which insights and inspiration for the new approaches have been drawn (see Chapter 2.3) (box 4). This theoretical framework was then tested in an empirical study in the Augsburg region (box 5). Yet, this empirical investigation led to new observations that did not fit the initial theoretical framework. This required to refine the framework (box 6) and revisit the empirical phenomenon (box 7). In this vein, the empirical results were also discussed with interviewees and other actors in order to assess how well the approaches were able to depict the empirical phenomenon. After some fine-tuning, the process ended with a suggestion of a theoretical and methodological approach (see Chapter 4) (box 8) that needs to be tested by applying it to other cases (box 9).

9.2 Central empirical findings

In the following, the most important empirical findings, that have been generated in the course of the abductive research process outlined above, are presented. These findings mainly concern the role of individual actors, new organizational forms, event sequences and incoherencies in institutional dynamics in RTPS.

On the role of individual actors

A first empirical finding was that individual value-driven actors played an important role in regional sustainability transitions. While there has been a focus in the geography of sustainability transition literature on influential actors from the public field (e.g., Block and Paredis 2013, Bulkeley et al. 2014, Gibbs and O'Neill 2014), in Augsburg the role of civil society actors is particularly worth mentioning. Several value-driven actors from civil society fostered and coordinated institutional work activities in the region over a substantial amount of time (see Chapters 5 & 6). These individuals were often involved in several fields at the same time and thus able to realize synergies between different institutional work activities (see also Frantzeskaki et al. 2017b).[23] With its long-term perspective, this dissertation showed how these actors were able to achieve substantial changes in values and cognitions across different societal sectors over time. These findings are in line with recent publications that emphasize the importance of more distributed institutional work processes in regional sustainability transitions (e.g., Brown et al. 2013, Binz et al. 2016, Jolly et al. 2016), and studies that point out the capability of civil society actors and social movements to foster change in social practices in regional sustainability transitions (e.g., Frantzeskaki et al. 2017c, Ehnert et al. 2018a&b).[24]

[23] Analyzing transition initiatives in three city-regions, Frantzeskaki et al. (2017b) emphasize the potential of individual urban change agents as intermediaries in urban transitions. These actors do not only mediate and network between different sectors, but also between different thematic domains.

[24] Binz et al. (2016) showed e.g., how early actors in the emerging innovation system of potable water reuse in California had to engage in different kinds of institutional work to legitimize new technological innovations in their broader local environment. Frantzeskaki et al. (2017b) and Ehnert et al. (2018a&b) have e.g., shown how

Value-driven individuals also played a key role in the university-internal transformation processes in Augsburg and Linz (see Chapter 6 & 7). It became apparent that HEIs do not become involved in regional sustainability transitions in a holistic organizational sense, but primarily through selected sub-units and individuals (see Chapter 6). Sustainability-related outreach as well as teaching and research activities were found to be highly dependent on the intrinsic motivation, private engagement and personal networks of individual actors (see Chapters 6 & 7). These actors did not necessarily have a particular influential or leading position in the HEI. They were rather characterized by their networking and mediation competencies as well as their strong dedication to the sustainability topic, which made them a "role model" for other actors (see Chapters 4 & 7). The bottom-up engagement of these actors can furthermore be explained by the relatively high amount of freedom individuals have in the academic sector and the openness towards innovation on part of the higher education regime (see also Hume 2015).
These findings show that the engagement of such value-driven individual actors builds an important basis for regional sustainability transitions. However, it also became apparent that processes should not be linked too strongly to specific persons (see Chapter 7). When these persons retire or leave the region, there is a risk that the activities will not be continued.

On the role of new organizational forms

Second, actors need other actors to enact change in order to transform a regional path. In this regard, new organizational forms (comprising new temporary institutionalized events, networks and more permanent forms of organization) turned out to be important. They brought together heterogeneous actors with different institutional logics and enabled the development of new perspectives on complex sustainability challenges and the generation of innovative social practices (see Chapter 5).
These institutional work processes were in some cases directed towards specific socio-technical regimes (e.g., the LA forums on mobility and energy). However, more often these institutional work processes were initiated due to a specific (local) sustainability problem (e.g., LA 21 forum for the redevelopment of an inner-city shopping mall or a sustainable shopping guide for Augsburg). Sometimes, they were also directed at broader thematic fields that were part of different socio-technical regimes at the same time (e.g., LA forum on culture or education). The latter shows that regional transitions are important starting points for broader socio-political transitions that are primarily institutionally driven. The latter has recently also been argued by Gibbs and O'Neil (2017).[25]
The results from this thesis also show how changes in such broader socio-political systems can also initialize changes or at least tensions in multiple socio-technical regimes and can thus lead to regime-overarching dynamics.
In particular new institutionalized temporary organizations that bring together actors with different institutional logics (e.g., round tables, conferences or forums) have been found to be a facilitator for these broader institutional work processes within the regional path. Alongside these temporary forms

local transition initiatives in different city-regions in different European countries fostered and diffused change in societal practices. In doing so, they played an important role in the regional sustainability transitions.

[25] Gibbs and O'Neill (2017) highlight the importance of institutional changes for sustainability transitions. The authors refer to existing empirical studies that describe the development of local "*alternative milieus*" at the example of several kinds of initiatives (e.g., local transition town initiatives, slow city movements, permaculture projects) that promote ideas of an alternative economy. The authors argue that regions can also be important starting points for such broader socio-political change processes, which do not primarily rely on technological changes, but require changes in ideologies, societal values and belief systems.

of organizations, new more permanent organizations (e.g., new departments in the city administration, a new energy agency) turned out to be essential (see Chapter 5 & 6). These organizations were equipped with the necessary resources in order to stabilize the newly established practices. Without these stabilizing mechanisms, the effect of temporary events can "fizzle out" and do not have an impact at the system level of the regional path.

In particular, the facilitating role of intermediary organizations became apparent. Different kinds of intermediaries have also received ample attention in the geography of sustainability transitions literature (see also Kivimaa et al. 2019; e.g., Hodson and Marvin 2010 & 2012, Brown et al. 2013). In the Augsburg case, it was in particular hybrid organizational forms (e.g., Kumas, LA 21, WZU), which were active in several institutional fields at the same time, which enabled coordination activities between different actor groups. Compared to previous studies, the transition topology explicitly showed how these organizations have come into a position, which enabled them to mediate between different actor groups in the first place (see Chapter 5). The LA 21 in Augsburg for example established permanent organizational proximity to actors from the public field to overcome institutional barriers between actors from the public field and civil society. At the same time, it kept its organizational anchoring in civil society to enable critical reflection and further input from civil society.

The empirical findings thus show that the establishment of new place-specific organizational forms plays an important role for the emergence *and* stabilization of transition dynamics over time.

On the role of event sequences

The empirical findings also show that transition processes are characterized by particular sequences of interlinked organizational and institutional changes. It was found that often an interlinked sequence of new institutionalized temporary events, networks and more permanent organizations was necessary in order to enact institutional change (e.g., in the case of the sustainable action program of the city of Augsburg). Multiple of these sequences in different thematic fields generated a self-reinforcing regime-overarching dynamic within the Augsburg region over time, which then also became visible for actors from outside the region (see Chapter 4 & 5). This development shows how several more gradual changes can add up to a more fundamental change in the regional path over time.

Seeing impacts from outside the region as part of an interlinked sequence of organizational and institutional changes, it becomes apparent that these events only had such influence because of preceding events in the region. For example, in the case of the declaration of Augsburg as an environmental competence region by the Bavarian state government, actors in the region had, through a number of institutional and organizational changes, already created a basis for this measure. What was also important is that they took over the actual implementation of the measure, amongst others through the establishment of Kumas and its working groups as well as the WZU (see Chapter 5 & 6).

In particular, the comparative case study of the transition paths in Augsburg and Linz showed that these event sequences are place-specific (see Chapter 6). The drivers of such sequences have been different in these two regions. While in Augsburg initial organizational changes towards sustainability have been initiated in a bottom-up way by members of the university and regional actors, in Linz they have been generated in a top-down fashion by the federal state government. These different drivers had an impact on the further development of the process, which became visible in different event sequences. In particular, in the Augsburg region, much longer sequences of interlinked organizational changes developed, compared to Linz. In this way, in Augsburg a broad range of actors and topics were involved in the transition, while in Linz the process was thematically focused and shaped by the agenda

of the federal state government. These different kinds of processes significantly influenced the role of the universities in the regional transition process.
Hence, not only organizational forms are place-specific but also the *linkages* between them, i.e. the underlying generative mechanisms of an event sequence, which leads to place-specific patterns over time.

On the role of incoherencies

Third, the empirical findings also made apparent that transition processes are shaped by incoherencies that describe diverging institutional logics within a system (see also Fünfschilling and Truffer 2014). In the case of Augsburg, it can be seen how over time two different institutional trajectories evolved in the region that have their basis in different societal sectors and rely on a different understanding of sustainability. These trajectories have repeatedly influenced each other at least in an indirect way. At some points, tensions developed due to these different understandings of sustainability, which opened up scope for interpretation in existing institutional structures (e.g., in the case of the declaration of Augsburg as an environmental competence region). Actors used these "windows of opportunity" for conducting institutional work (see Chapter 5).
In this vein, it also became apparent that different sub-systems in a region can transform at a different pace and thus also create incoherencies in the regional system. In Augsburg, it was particularly actors from the economic field and from civil society, that initiated the first organizational changes towards sustainability within these fields in the 1990s. Public actors then also started to get involved in the process. The scientific field was, however, rather lagging behind. Only recently has this imbalance started to dissolve, when regional actors began to involve the university more strongly in the process (see Chapter 6).
Thus incoherencies on the system level can be important drivers of regional transition processes by providing starting points for institutional work on the micro-level.

9.3 Reflections on the conceptual and methodological approaches

The starting point of this dissertation was to develop a comprehensive regional approach to analyze sustainability transitions. Compared to existing approaches that are interested in the transformation of particular sectoral systems, such an approach focuses on the transformation of the region as a whole.
Chapter 2.3 of this dissertation outlined the contours of such a regional approach. It was argued that such an approach needs to be particularly sensitive for certain processes (see conditions outlined in Chapter 2.1). These processes comprise more gradual forms of change, dynamics within paths, different perceptions of sustainability, regional specificities, micro-dynamics and institutional change. In order to validate the conceptual and methodological approaches, in the following the empirical findings will be reflected upon these conditions.
The *first* condition was that the approach should be able to visualize more gradual forms of change. The empirical findings have depicted more gradual forms of change by making sequences of interlinked organizational and institutional changes visible. It became apparent that sequences of organizational changes often culminated in a tangible institutional change. This indicates that organizational changes are indeed an indicator for more informal institutional changes (see Chapter 4). These sequences also made core areas of institutional change in regional transitions visible. In this way, it also became apparent that gradual institutional change evolves in different paces in different parts of the regional

system. The *second* condition was that the approach should acknowledge different perceptions and interpretations of sustainability in a region. The approach not only depicted such different perceptions and interpretations, it also showed how they can lead to the development of different institutional trajectories. It was also able to make apparent how the two different development trajectories towards sustainability in the Augsburg region influenced each other over time, also in a more indirect way. The *third* condition was that the approach needed to be place-sensitive in that it acknowledged particular processes at the regional scale. The empirical findings indeed made place-specific dynamics between the institutional settings of different sectors and at different spatial scales visible. Moreover, the impact of events on other spatial scales, on the transition process in the region, became apparent. The *fourth* condition was that the approach should consider endogenous dynamics within path dependent trajectories. It did so by showing how incoherencies at the system level of a path developed, e.g., through the above mentioned trajectories relying on different perceptions of sustainability. Regarding the *fifth* and *sixth* conditions, the empirical findings also help to better understand the role of different individual and collective actors in regional sustainability transitions by showing how exactly the activities of these actors have contributed to institutional changes at the system-level of the path and also by showing how these actors got into a position to conduct these activities in the first place. The approach also was able to capture institutional dynamics at the regional system-level. It made interdependencies between different institutional elements in a regional system visible and showed how these led to incoherencies that built important starting points for institutional work processes. Moreover, it became apparent that institutional work activities often induced institutional dynamics in multiple institutional settings.

The RTPS framework is thus more sensitive to gradual changes on the micro-level and therefore also to transition processes that do not yet become visible on the system-level (as it was initially the case in Augsburg). It is also more sensitive to dynamics between sectors and thus thematically broader transition processes (like the one in Augsburg). Indeed, the Augsburg case might not be classified as a transition from an MLP perspective at all, because the MLP would expect a more fundamental change in the architecture of at least one local socio-technical system. In the Augsburg region, however, more gradual changes in multiple socio-technical systems have taken place. Furthermore, most of these changes were not driven by technologies, but changes in social practices and institutions. Hence, the transition in Augsburg is based on gradual changes in multiple regimes, which are, however, connected to each other and therefore have the potential to add up to a more fundamental transition of the regional system.[26] These rather "hidden", diffuse and "messy" processes that often take place between sectors differ in quality from the strong functional and structural couplings of regimes that have been described in the sustainability transition literature (Raven 2006, Raven and Verbong 2007, Konrad et al. 2008).

The transition topology has been crucial for the operationalization of the RTPS framework, as it makes the connection between processes on the micro- and the system-level of the path visible. It also enabled investigation of changes across regime boundaries. At the same time, the topology helped to develop the conceptual approach further through its application in empirical studies. By making more abstract and reproducible mechanisms visible, it also facilitates systematic comparisons between cases and between different phases over time (Langley et al. 2013). It therefore, went beyond the

[26] However, recently Geels (2018) also pointed out that it needs to be acknowledged that gradual changes can also add up to more fundamental changes over time and that this is particularly the case when multi-regime dynamics are in place (see also Chapter 4).

description of "*idiosyncratic stories*" (Langley et al. 2013: 8) and enabled the development of more general theoretical insights.

It can thus be concluded that the RTPS framework provides a perspective that results in findings that are different from those that can be generated with existing approaches. Yet, this aim could only be achieved by developing a distinct method that was able to focus on the processes that the theoretical framework assumed to be relevant for regional sustainability transitions (see Chapter 4). At this point, some limitations of the conceptual and methodological approaches and their application in this dissertation also deserve mention, however.

The conceptual approach has been developed in close alignment with the in-depth case study in the city-region of Augsburg and the comparative case study in the city-regions of Augsburg and Linz. A broader application of the RTPS framework, also outside the Western European context, would be necessary in order to determine the generalizability of the approach. For example, transition scholars have recently started to apply transition frameworks and governance approaches in developing countries. In this vein, it has been found that participatory processes in developing countries differ substantially from those in Western Europe. They are strongly affected by, for example, gender norms, strong hierarchies and unequal relations among actors. External influences from outside the region through collective actors from developed countries (e.g., NGOs, donors, companies or international organizations) are also much more pronounced in these transition processes (Van Welie et al. 2018, Van Weilie and Romijn 2018, Wieczorek 2018). These particularities could necessitate some shifts in focus in the conceptual approach.

A closely related issue is that the RTPS framework does not explicitly refer to issues of power and justice that have received increasing attention in the transition literature in recent years (e.g., Avelino and Wittmayer 2016, Jenkins et al. 2018). Although the RTPS framework considers different perspectives on sustainability and addresses conflicts, it does not examine these conflicts and their dynamics as closely.[27] For example, it does not analyze who is able or allowed to participate in certain processes and who gets excluded. Analyzing such questions could reveal additional mechanisms that result in particular patterns of institutional changes in the transition topology.

Further drawbacks of the dissertation relate to the methodological approach of the transition topology. First of all, the data collection process is relatively time-consuming, making comparative case studies a cumbersome procedure. For example interview partners that have been involved in the early stages of a transition are often hard to track, because they have already retired, have changed their job or moved away. Also the analysis of the material is time-consuming, as data from different sources must be integrated and contradictions, for example about the importance of an event or its relations to other events, may arise and need to be resolved. For this purpose, it is often necessary to conduct further empirical research.

Secondly, it is likely that one identifies more events in the recent past than in early phases of the transition. This bias is particularly pronounced when using interviews in combination with document analyses for identifying events, as was the case in the Augsburg study. Interviewees are likely to remember more recent events better. One can reduce this bias by tracing back sequences of events that led to these more recent events. However, then a new bias emerges, as one cannot find events that have not induced any further events.

Thirdly, the topology is based on relatively broad actor categories (science, business, civil society, public field), which in the case of Augsburg have also been used to select the interview partners. These

[27] Neo-institutional Theory, in particular Historical Institutionalism, also deals with issues of power, which have, however, so far not been explicitly included in the RTPS approach.

categories, however, consist of relatively heterogeneous actors groups. Therefore, it must be ensured that the perspectives of all relevant sub-groups in these categories are represented in the empirical data. In the Augsburg case, there is a certain bias, because the public field is mainly represented by administrative actors. Political actors are largely missing. Also when it comes to civil society, more alternative groups, which cooperate less with actors from other fields (e.g., attac, Greenpeace) and therefore have not been detected through snowball sampling, are underrepresented.

Other limitations concern the practical relevance of the approach. The RTPS framework is very comprehensive and captures the interplay of different institutional trajectories in the region. This makes complex relationships visible. Based on such findings, however, it is difficult to give specific policy recommendations, as is possible in for example MLP-based studies.[28] The RTPS framework rather enables policy makers to see the broader picture, by making relationships and dynamics visible that are often neglected in such sector specific approaches. It also makes long-term path and place decencies visible, which policy makers need to consider (see also Chapter 9.5).

A further drawback of the approach is related to the difficulty to make statements about more recent developments in RTPS. Important actors or events can only be identified in retrospect, by determining their long term impact on the regional path. This is in contrast to transition governance approaches like transition management (Rotmans et al. 2001, Kern and Smith 2008, Loorbach 2010) or strategic niche-management (Kemp et al. 1998, Smith 2007), in which tools are developed to intervene in ongoing transition processes. The RTPS approach can, however, again provide important insights for these approaches, due to its broader perspective.

9.4 Perspectives for future research

Needs and suggestions for further research based on the conceptual and methodological approaches can be differentiated into issues related to 1) the analytical scope and depth of the approaches, 2) to the procedure underlying the transition topology and 3) suggestions for further research, that can complement the results gained with the topology.

(1) Based on insights from the previous sections, two suggestions arise for how to expand the analytical scope and depth of the conceptual and methodological approaches.

The first suggestion is to further conceptualize and capture incoherencies in RTPS. Incoherencies provide starting points for transition processes. It can be assumed that the form of incoherencies has an effect on the regional transition path. A suggestion is therefore to distinguish different forms of incoherencies: incoherencies within sectoral regimes, between sectoral regimes, between institutional settings on different spatial scales and between different societal sectors in a region, as well as how these forms of incoherencies differ in their impact on the regional transition path. Capturing these dynamics could substantially enrich current explanations of why regional transitions unfold so differently across regions.

The second suggestion refers to the connectivity of the approaches developed in this dissertation to existing approaches in the sustainability transition literature. From the perspective of the MLP, a major drawback of these approaches would probably be seen to be in the difficulty of evaluating the progress in the transformation of specific socio-technical regimes (see Chapter 9.2). Although the latter is, as elaborated above, not the main goal of the RTPS approach, these dynamics could receive more

[28] In their MLP-based study on the energy transition in the Netherlands, Verbong and Geels (2007: 1036) for example outline promising routes for CO^2-reduction, by recommending to make adjustments in existing systems, while keeping "*more radical options alive*".

attention in the future. It would for example be interesting to investigate if the broad institutional transition process in Augsburg indeed builds the basis for the transition of specific socio-technical regimes in the region. Transition scholars have recently also increasingly acknowledged the importance of those processes that are in the focus of the RTPS approach. An example is the publication by Hodson et al. (2017), in which the authors suggest expanding the MLP to consider explicitly the multiplicity of socio-technical solutions, governance arrangements and perceptions of sustainability that shape urban reconfiguration processes (see also Chapter 4).

(2) Regarding the procedure underlying the transition topology, some recommendations and suggestions for future research can be made as well.

One recommendation is related to the relatively cumbersome data collection and visualization process. In order to enable a more widespread use of the transition topology, it would be advisable to automatize the establishment of the visual graph (see e.g., Spekkink and Boons 2016). To facilitate and accelerate the process of data collection, it would also be possible to focus the topology on specific sectors or thematic domains. Although this would obviously contradict the aim of the approach to draw a comprehensive picture of the regional transition process.

Another suggestion is to expand the range of methodological procedures in the data collection process. In the dissertation, document analyses, interviews and unstructured participatory observations were triangulated to collect the data for the establishment and interpretation of the topology. Mixed-methods approaches, which combine qualitative and quantitative approaches, could be fruitful here as well. Chapter 8 has shown how mixed-method approaches (Creswell 2003) can be used to validate findings and also to develop a more nuanced and differentiated understanding of the subject. Quantitative approaches could for example be used up-front to identify interesting regional cases that are suitable for multi-case comparisons, but also to complement and cross-validate the insights generated with the topology.

Finally, it should be mentioned that the greatest potential of the transition topology lies in its capacity to enable systematic comparative case studies. This potential already became apparent in the comparative study on the universities of Augsburg and Linz (see Chapter 6). In this dissertation, the topology was, however, primarily used to conduct one in-depth case study in the Augsburg region in order to test the conceptual approach and develop it further. In the future, more comparative research could be conducted. In this vein, the topology could for example be used to establish a typology of different RTPS, for example based on variations in key actors, the nature of their interactions with each other, and the organizational dynamics that develop over time (see Chapters 4 & 6).

(3) Another avenue for future research is to conduct more fine-grained analyses of the micro-dynamics underpinning the RTPS and in this way complement the empirical results gained with the topology.

The transition topology showed that the impact of temporary institutionalized organizations is dependent on the participation of specific individual actors that act as boundary spanners between actors from different institutional fields. A question that has not been analyzed in depth in this thesis is, how – following a reverse logic – certain institutional work activities of individual actors are enabled by these organizational forms. Empirical observations in the Augsburg region indicate that temporary institutionalized organizations, in addition to their direct impacts that become visible in the topology, also have more indirect effects, which unfold via the individual actors involved in these organizations. Further research could investigate how individual-value driven actors make use of temporary institutionalized organizations to conduct institutional work activities outside of these organizations – for example, activities within their professional life or in a more private context. In this vein, one could, for example, analyze to what extent such temporary organizational forms provide particularly engaged

individuals from civil society with resources for their institutional work activities (Frantzeskaki et al. 2017b).

9.5 Policy implications

The following recommendations are directed equally at actors from the political field, business, science and civil society. They concern particularly those actors, however, that want to make a region more sustainable as a whole, as this aim distinguishes the approach developed in this dissertation from others that are primarily focused on specific socio-technical systems. The proposals outlined in this section primarily deal with two major challenges that actors are facing who want to initiate a regional sustainability transition. The first is that regional sustainability transitions require interactions between actors with different perspectives and interests from multiple societal and thematic fields. The second is that regional sustainability transitions cannot be purposefully managed. They are characterized by a multiplicity of intended and unintended actions and rely on very complex dynamics, which is why the impact of specific activities cannot be foreseen in advance.

The thesis at hand showed that one cannot manage regional sustainability transition processes, but that one can create conditions for such processes to unfold. The creation of new organizations is a means to cope with the challenges mentioned above. Despite the spatial proximity of actors from different institutional settings in a region, opportunities for exchanges and encounters between these actors need to be created. By initiating organizational changes in the region, an important basis for transitions can thus be generated. The establishment and institutionalization of new temporary organizations can be a means to lift the creative potential in a region and to allow new interpretations of existing institutions to emerge. These new organizational forms seem to be particularly fruitful, if they enable encounters between actors from different societal sectors and thematic fields. Important however, is also the provision of resources for the establishment and equipment of more permanent organizations to stabilize changes, and therefore the regional transition process over time.

The establishment of new organizations is particularly important in light of the high-level of person-boundedness of activities that has been found in the empirical studies. Although individual value-driven actors seem to be indispensable, in particular in an early phase of transitions, there is always the risk that activities will not continue when the relevant individual leaves the organization or region. The institutionalization of activities through organizational forms is a way to spread the process across different actors. By also supporting intermediary organizations and individual actors that are involved in different thematic fields, regime-overarching dynamics can be initiated that stabilize the process dynamic over time.

It is also important ideally, to involve all actor groups into these activities. This dissertation had a particular focus on the role of HEIs in regional transitions, as these actors are often seen as change agents for sustainability in the literature. It was, however, shown that they do not necessarily get involved into regional sustainability transitions (see Chapter 6). Sustainability-related research is often not conducted in the region, although there is usually a high motivation on part of HEI members to get engaged in regional projects (see Chapter 8). HEIs should therefore not only be seen as change agents, but as actors that have to be transformed themselves in order to be able to make a contribution to regional sustainability transitions. Such organization-internal transformation processes can, on the one hand, be spurred by supporting already existing bottom-up activities in the organization, and by creating spaces for encounters between actors from different status groups and disciplines within the HEI and actors from the region.

In addition to these specific recommendations, it should also be mentioned that the transition topology turned out to be a valuable tool for researchers to discuss empirical results with regional stakeholders. The topology can illustrate more abstract mechanisms that would otherwise be hard to grasp. It makes among others the place and path dependent character of transition processes apparent, which need to be considered when designing policy approaches. Through the topology it becomes apparent for example that events cannot simply be transferred from one context to another, as their impact also depends on other events in the region. The topology can also help regional stakeholders to reflect upon the region's overall progress in the transition to sustainability and look beyond short-term impacts of single projects or events. The topology makes long-term and more indirect impacts of events visible, which can easily be missed out in more directed policy evaluations. Finally, it also helps to identify important actors in the transition process, which should be supported or at least be encouraged to participate in the process.

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Appendix

Appendix 1

This information was removed due to privacy and confidentiality issues. It will be provided by the author upon reasonable request.

Contents

Appendix 2

Table 17: Legend of institutional and organizational changes in the transition topology of the Augsburg region.

	Institutional change
A	Implementation of stricter environmental regulations for industrial companies by the German federal government
B	Announcement of voluntary climate protection standards by the Climate Alliance of European cities (Alianza del Clima e.V.)
C	Implementation of an eco-management program (Eco-Profit) aimed at the build up of local networks for environmental protection by the city of Graz
D	Implementation of a new environmentally-compatible waste management act by the Bavarian state government following a public referendum
E	Recommendation of the United Nations (UN) to start Local Agenda 21 (LA 21) groups and implementation of a framework convention on climate change
F	Ordinance of voluntary eco-management and audit regulation (EMAS) by the European Union (EU)
G	Implementation of European voluntary eco-management and audit scheme (EMAS) by several companies and public organizations in Augsburg
H	Recommendation of the German Association of Cities and Towns to implement LA 21
I	Declaration of the Augsburg region as an 'environmental competence center' by the Bavarian state government
J	Accession of the city of Augsburg to the climate alliance of European cities (Alianza del Clima e.V.) and adoption of the alliance's voluntary standards
K	Implementation of an annual award for processes, products, services or concepts which demonstrate environmental competence by KUMAS (Kumas Leitprojekte)
L	Implementation of the Eco-Profit program in Augsburg by the city council
M	Implementation of the city administration's environmental principles by the city council of Augsburg
N	Declaration of the Global Marshal Plan key goals and foundation of a Global Marshal Plan Initiative
O	Resolution of the city council about the renaming of the environmental advisory board into agenda advisory board
P	Resolution of a CO2-reduction concept by the city council of Augsburg
Q	Implementation of the LA 21's sustainable action program by the city council of Augsburg including a regular monitoring and reporting of the progress
R	Implementation of an award for exemplary sustainability projects in Augsburg by the city council (Zukunftspreis)
S	Environmental agreement between the city of Augsburg and the local industry
T	Announcement of the millennium goals by the UN
U	Adoption of Global Marshall Plan and UN Millennium goals by the city council of Augsburg

V	Implementation of an action plan (9-Punkte-Plan) for climate protection by the city council of Augsburg (+several other resolutions to foster the local energy transition)
W	Implementation of the regional climate protection plan by the three districts in the Augsburg region
X	Resolution of the city council to apply for the label `fair trade town´
Y	Resolution of the city council to prepare an urban development concept
Z	Resolution of a nuclear exit plan until 2022 and a key issue paper for an accelerated energy system transformation by the German federal government
AA	Resolution to update the sustainability action program by the city council of Augsburg
BB	Resolution about the continuation of the agenda advisory board and its renaming into sustainability advisory board
CC	Implementation of a regional climate concept
DD	Declaration of Augsburg as the second most sustainable city in Germany (behind Freiburg) by the German Sustainability Award Foundation e.V.
EE	Declaration of Augsburg as the most sustainable city in Germany by the German Sustainability Award Foundation e.V.
FF	Resolution of the city council to prepare a sustainability check for the city administration of Augsburg
GG	Declaration of resource efficiency as a superior objective in the university of applied science's development plan
HH	Implementation of the sustainability goals by the city council of Augsburg (Zukunftsleitlinien)
Organizational change	
1	Establishment of the post of an environmental consultant in the local chamber of industry and commerce (IHK)
2	Establishment of a department for environmental protection and safety in the city administration of Augsburg
3	Establishment of an environmental laboratory in the city administration of Augsburg
4	Establishment of an environmental department in the city of Augsburg
5	Establishment of a recycling research center (bifa institute) by the Bavarian state government, the IHK and the city of Augsburg
6	Foundation of first Local Agenda 21 (LA 21) groups in Germany (Munich, Berlin etc.)
7	Establishment of a working group on environmental management systems within the IHK, which meets twice a year
8	Establishment of an environmental incubation center (UTG) by the IHK, the chamber of crafts (HWK) and the Bavarian state government
9	Foundation of a network between the ‘Werkstatt Solidarische Welt’, the ‘Bund Naturschutz’ as well as a group of solar engineers with the aim to build a LA 21 group in Augsburg
10	Foundation of the LA 21 group in Augsburg
11	Dedication of the One-World-Workshop series to the LA 21 topic
12	Dedication of a temporary position in the city administration of Augsburg to the LA 21 group
13	Establishment of the Bavarian state office of the environment (LfU) through the integration of several Bavarian state offices and relocation of the LfU to Augsburg by the Bavarian state government

14	Establishment of a steering committee by (IHK) to define an action plan for the 'environmental competence center'
15	Foundation of a LA 21 forum on energy issues (FF Energie)
16	Foundation of LA 21 forum on development policy issues (FF Eine Welt)
17	Foundation of LA 21 forum on mobility issues (FF Verkehr)
18	Establishment of an environmental advisory board in the city administration of Augsburg
19	Start of a two-parted education series for a future-oriented Augsburg (Zukunftsfähiges Augsburg) by the LA 21
20	Establishment of an environmental competence center (KUMAS)
21	Dedication of a permanent position to the LA 21 in the city administration
22	Foundation of LA 21 forum for a sustainable urban development (FF Nachhaltige Stadtentwicklung)
23	Start of a workshop series for the development of sustainability guidelines for the city of Augsburg (Leitlinien)
24	Foundation of the “Eco-Profit” network
25	Start of a workshop series for the development of sustainability indicators for the city of Augsburg
26	Integration forum on poverty and social discrimination issues into the LA21 (FF Armutskonferenz)
27	Foundation of LA 21 forum for a family friendly Augsburg (FF Familienfreundlichkeit)
28	Foundation of LA 21 forum to implement the Eco-Profit program in Augsburg (FF Ökoprofit)
29	Foundation of LA 21 forum for a partnership between generations (FF Partnerschaft der Generationen)
30	Establishment of annual Bavarian waste and disposal days by KUMAS
31	Establishment of applied environmental research center at the University of Augsburg (WZU)
32	Establishment of the center for material and environmental research at the University of Augsburg (AMU)
33	Foundation of LA 21 forum to foster civic commitment (FF Bürgerstiftung)
34	Foundation of an annual exhibition on renewable energies (Renexpo) in Augsburg
35	Establishment of an expert commission on CO2 reduction by the city of Augsburg
36	Establishment a working group on international issues within the KUMAS network, which meets twice a year
37	Establishment of a working group on project management within the KUMAS network, which meets twice a year
38	Establishment of a working group on environmental education within the KUMAS network, which meets twice a year
39	Establishment of a working group on environmental medicine within the KUMAS network, which meets twice a year
40	Start of a three-parted workshop series for the definition of concrete sustainability goals for the city of Augsburg
41	Establishment of a municipal climate protection office
42	Establishment of a working group on climate protection by the city of Augsburg and the local public utility company

43	Foundation of LA 21 forum on nature conservation and environmental education (FF Nanu! e.V.)
44	Establishment of annual Bavarian water protection days by KUMAS
45	Foundation of the Bavarian state environmental cluster in Augsburg
46	Foundation of LA 21 forum for sustainable education (FF Bildung und Nachhaltigkeit)
47	Foundation of a LA 21 forum for the implementation of an online guide for sustainable consumption (Lifeguide)
48	Establishment of a study program on global change ecology at the University of Augsburg
49	Foundation of a network for energy efficient modernization of buildings (e + haus) by the municipal climate protection department
50	Foundation of a consulting network of engineers and architects on the topic of energy efficiency by the municipal department for climate protection
51	Foundation of LA 21 forum on sustainability in the financial sector (FF Fließendes Geld)
52	Establishment of a study program on environment and process engineering at the University of Applied Science Augsburg
53	Establishment of annual regional development conferences (Regionale Chancenkonferenz)
54	Increase in personnel of the municipal LA 21 department
55	Foundation of a corporate network in the local chamber of crafts (HWK) and start of climate protection program
56	Establishment of several regional climate conferences for the preparation of a regional climate protection plan by the three regional districts in cooperation with various regional actors
57	Establishment of an energy consultant pool (EnergieManagerPool) by the IHK for the implementation of a national support program for energy efficiency in SMEs
58	Establishment of a study program on energy efficient building at the University of Applied Science Augsburg
59	Establishment of annual Bavarian emission protection days by KUMAS
60	Establishment of a regional (economic) development agency (Regio Augsburg Wirtschaft GmbH)
61	Establishment of a research center for material resource management at the University of Augsburg
62	Establishment of a new position for a cycling official for the city of Augsburg
63	Foundation of LA 21 forum to promote the usage of recycling paper (FF Papierwende)
64	Foundation of LA 21 forum on climate protection issues (FF Prima Klima)
65	Establishment of a new chair for resource strategies at the University of Augsburg
66	Foundation of a working group with the aim to foster sustainability at the University of Augsburg
67	Establishment of a steering committee for a skills initiative for the Augsburg region by the Regio Augsburg Wirtschaft GmbH
68	Foundation of LA 21 forum on fair trade issues (FF Fairtrade Stadt)
69	Foundation of LA 21 forum to strengthen regional economic activities (FF Unser Land)
70	Establishment of a study program on economic engineering focused on resource management at the University of Augsburg
71	Foundation of LA 21 forum for social and ecological sustainability (FF ThinkCamp)

72	Foundation of LA 21 forum on urban gardening (FF Urbane Gärten)
73	Foundation of a strategic alliance for demographic management, innovative capability and resource efficiency (ADMIRE) funded by the German federal government by the University of Bayreuth, the Faktor10 research institute and the Regio Augsburg Wirtschaft GmbH
74	Establishment of a study program on climate and environmental sciences at the University of Augsburg
75	Establishment of a regional energy agency by several regional organizations
76	Foundation of a network with the aim to foster corporate responsibility in the Augsburg region (Augsburger Schule)
77	Foundation of the LA 21 working group on corporate responsibility (FF Unternehmerische Verantwortung)
78	Establishment of event series about the local energy transition by the municipal climate protection department taking place at least every six months
79	Foundation of LA 21 forum to promote the consumption of organic, regional and seasonal food in Augsburg (FF Biostadt)
80	Foundation of LA 21 forum on refuge and asylum issues (FF Flucht und Asyl)
81	Foundation of LA 21 forum for a self-determined life for girls and women (FF Terrre des Femmes)
82	Establishment of an advisory board for the Augsburg innovation park on resource efficiency
83	Start of workshops for the development of a sustainable urban development concept by the LA 21 forum for a sustainable urban development (Stadtwerkstatt)
84	Establishment of a first sustainability day for the regional economy (Fokus N) by the LA 21 forum on corporate responsibility
85	Establishment of the Augsburg innovation park GmbH
86	Relocation of the annual Bavarian climate weeks to Augsburg
87	Establishment of a lecture series on climate protection in Bavaria by the state department for the environment (LfU) and the university of Augsburg
88	Foundation of LA 21 forum to implement the transition town model in Augsburg (FF Transition Town)
89	Foundation of a network to develop an IT based assistant for elderly people by several regional non-profit organizations, research facilities and private companies (ASYST)
90	Relocation of the municipal LA 21 department from the climate department to a new staff position for environment, sustainability and integration and increase in personnel
91	Start of workshops for the further development of the sustainability goals for the city of Augsburg
92	Foundation of LA 21 forum on education issues (FF Bildungsbündnis)
93	Organization of a discussion series to foster environmental competence in regional companies by KUMAS and the local unites of the Federation of German Industries (VDI and VDE)
94	Foundation of LA 21 forum for a sustainable redevelopment of a local shopping mall (FF Schwabencenter)
95	Foundation of LA 21 forum on animal rights (FF Tierrechte)
96	Increase in personnel of the municipal LA 21 office

Appendix 3

Table 18: Institutional and Organizational Changes in the Regional Development Paths to Sustainability of the Augsburg region.

	Change	Type	Year	Location
	Institutional change (supra-regional level)			
I	Recommendation of the United Nations (UN) to start Local Agenda 21 (LA 21) groups and implementation of a framework convention on climate change	Instit. change	1992	Internat.
II	Declaration of the Augsburg region as an environmental competence center ("Umweltkompetenzregion") by the Bavarian state government	Instit. change	1996	Federal
III	Establishment of the Bavarian State Office of the Environment (LfU) through the integration of several Bavarian state offices and relocation of the LfU to Augsburg by the Bavarian state government	New orga-nization	1996	Public
IV	Foundation of a cluster organization to manage the Bavarian environmental cluster in Augsburg	New orga-nization	2005	Economy
V	Implementation of the UN Decade for Education on Sustainability	Inst. Change	2005	Internat.
VI	Resolution to provide special funding for climate- and energy-related research by the Bavarian government	Inst. Change	2012	Federal
VII	Foundation of the regional network of Higher Education Institutions and Sustainability in Bavaria (as part of the national network)	New network	2012	Federal
VIII	Implementation of the Bavarian sustainability strategy	Inst. Change	2013	Federal
IX	Declaration of Augsburg as the most sustainable city in Germany by the German Sustainability Award Foundation e.V.	Inst. Change	2013	National
	Organizational and institutional change in the region			
1	Establishment of an environmental laboratory in the city's health department	New orga-nization	1989	Public
2	Establishment of an environmental department in the city of Augsburg	New orga-nization	1990	Public
3	Establishment of a recycling research center (Bifa Institute) by the Bavarian state government, the IHK and the city of Augsburg	New orga-nization	1991	Economy
4	Foundation of a network between the 'Werkstatt Solidarische Welt', the 'Bund Naturschutz' as well as a group of solar engineers with the aim to build an LA 21 group in Augsburg	New network	1995	Civil Society

5	Foundation of the LA 21 group in Augsburg	New organization	1996	Civil Society
6	Establishment of a steering committee by (IHK) to define an action plan for the environmental competence center	New network	1996	Public
7	Dedication of a permanent position in the city administration to the LA 21 group	New organization	1996	Public
8	Foundation of an LA 21 forum on energy issues (“FF Energie”)	New inst. temporary event	1996	Civil Society
9	Foundation of an LA 21 forum on development policy issues (“FF Eine Welt”)	New inst. temporary event	1996	Civil Society
10	Foundation of an LA 21 forum on mobility issues (“FF Verkehr”)	New inst. temporary event	1996	Civil Society
11	Establishment of an environmental advisory board in the city administration of Augsburg (later renamed into sustainability advisory board)	New network	1997	Public
12	Establishment of an environmental competence center (KUMAS)	New organization	1998	Economy
13	Start of a workshop series for the development of sustainability guidelines for the city of Augsburg	New inst. temporary event	1998	Civil Society
14	Accession of the city of Augsburg to the climate alliance of European cities (Alianza del Clima e.V.) and adoption of the alliance’s voluntary standards	Inst. Change	1998	Public
15	Start of a workshop series for the development of sustainability indicators for the city of Augsburg	New inst. temporary event	1999	Civil Society
16	Foundation of LA 21 forum to implement the Eco-Profit program in Augsburg (“FF Ökoprofit”)	New inst. temporary event	1999	Civil Society
17	Integration of a forum on poverty and social discrimination issues into the LA 21 (“FF Armutskonferenz”)	New inst. temporary event	1999	Civil Society
18	Foundation of a LA 21 forum for a familiy friendly Augsburg ("FF Familienfreundlichkeit")	New inst. temporary event	1999	Civil Society
19	Foundation of a forum for a partnership between generations (“FF Partnerschaft der Generationen”)	New inst. temporary event	1999	Civil Society
20	Establishment of annual Bavarian waste and disposal days by Kumas	New inst. temporary event	2000	Economy

21	Foundation of an annual exhibition on renewable energies ("Renexpo") in Augsburg	New inst. temporary event	2000	Economy
22	Foundation of LA 21 forum to foster civic commitment ("FF Bürgerstiftung")	New inst. temporary event	2000	Civil Society
23	Accession of the city of Augsburg to the Local Governments for Sustainability Initiative (ICLEI)	Inst. Change	2001	Public
24	Establishment of a working group on environmental education within the KUMAS network, which meets twice a year	New network	2001	Economy
25	Establishment of a working group on international issues within the KUMAS network, which meets twice a year	New network	2001	Economy
26	Establishment of a working group on project management within the KUMAS Network, which meets twice a year	New network	2001	Economy
27	Establishment of a working group on environmental medicine within the KUMAS network, which meets twice a year	New network	2001	Economy
28	Establishment of an endowment chair for environmental management	New orga-nization	2002	Science
29	Establishment of a three-part workshop series for the definition of concrete sustainability goals for the city of Augsburg	New inst. temporary event	2002	Civil Society
30	Awarding the Kumas award for frontrunner projects in the field of environmental technologies to the WZU	Inst. Change	2002	Science
31	Establishment of a municipal climate protection department	New orga-nization	2003	Public
32	Implementation of the LA 21's sustainable action program by the city council of Augsburg including a regular monitoring and reporting of the progress	Inst. change	2004	Public
33	Foundation of an LA 21 forum on nature conservation and environmental education ("FF Nanu! e.V.")	New inst. temporary event	2004	Civil Society
34	Establishment of the annual water protection days by KUMAS	New inst. temporary event	2004	Economy
35	Foundation of an LA 21 forum on sustainable education ("FF Bildung und Nachhatligkeit")	New inst. temporary event	2005	Civil Society
36	Foundation of an LA 21 forum for the implementation of an online guide for sustainable consumption ("FF Lifeguide")	New inst. temporary event	2006	Civil Society

37	Foundation of an La 21 forum on sustainability in the financial sector (FF Fließendes Geld)	New inst. temporary event	2007	Civil Society
38	Establishment of the annual Bavarian emission protection days by KUMAS	New inst. temporary event	2008	Economy
39	Establishment of a regional (economic) development agency ("Regio Augsburg Wirtschaft GmbH")	New orga-nization	2009	Public
40	Foundation of an LA 21 forum to promote the usage of recycling paper ("FF Papierwende")	New inst. temporary event	2009	Civil Society
41	Foundation of an LA 21 forum on climate protection issues ("FF Prima Klima")	New inst. temporary event	2009	Civil Society
42	Foundation of an LA 21 forum on fair trade issues ("FF Fairtrade Stadt")	New inst. temporary event	2010	Civil Society
43	Foundation of an LA 21 forum to strengthen regional economic activity ("FF Unser Land")	New inst. temporary event	2010	Civil Society
44	Foundation of an LA 21 forum for social and ecological sustainability ("FF ThinkCamp")	New inst. temporary event	2011	Civil Society
45	Foundation of an LA 21 forum on urban gardening ("FF Urbane Gärten")	New inst. temporary event	2011	Civil Society
46	Establishment of an organizational platform on resource efficiency in the regional (economic) development agency	New inst. temporary event	2011	Public
47	Resolution to update the sustainability action program by the city council of Augsburg	Inst. change	2011	Public
48	Foundation of an LA 21 forum to promote the consumption of organic, regional and seasonal food in Augsburg ("FF Biostadt")	New inst. temporary event	2012	Civil Society
49	Foundation of an LA 21 forum on refuge and asylum issues ("FF Flucht und Asyl")	New inst. temporary event	2012	Civil Society
50	Foundation of an LA 21 forum for a self-determined life for girls and women ("FF Terre des Femmes")	New inst. temporary event	2012	Civil Society
51	Establishment of an advisory board for the Augsburg innovation park on resource efficiency	New orga-nization	2012	Public
52	Foundation of an LA 21 forum to implement the transition town model in Augsburg ("FF Transition Town")	New inst. temporary event	2013	Civil Society

53	Foundation of an LA 21 forum on education ("FF Bildungsbündnis")	New inst. temporary event	2013	Civil Society
54	Relocation of the LA 21 office to from the climate department to a new staff position for environment, sustainability and integration and increase in personnel	New organization	2014	Public
55	Organization of a discussion series to foster environmental competence in regional companies by KUMAS and the local unites of the Federation of German Industries (VDI and VDE)	New inst. temporary event	2014	Economy
56	Start of workshops for the further development of the sustainability goals for the city of Augsburg	New inst. temporary event	2014	Public
57	Foundation of an LA 21 forum for a sustainable redevelopment of a local shopping mall ("FF Schwabencenter")	New inst. temporary event	2015	Civil Society
	Organizational and institutional change in the University			
a	Foundation of a network Society for Environmental Economics ("Gesellschaft für Umweltökonomie e.V.")	New network	1991	Science
b	Foundation of an institute for environmental law	New organization	1991	Science
c	Signing of the Copernicus Charta and adoption of its principles by the Science management	Inst. Change	1993	Science
d	Day of Environmental and Material Sciences at the Science of Augsburg in cooperation with the Bifa Institute	New inst. temporary event	1997	Science
e	Foundation of LA 21 forum for a sustainable urban development ("FF Nachhaltige Stadtentwicklung")	New inst. temporary event	1998	Civil Society
f	Establishment of an applied environmental research center ("Wissenschaftszentrum Umwelt (WZU)")	New organization	2000	Science
g	Establishment of a center for material and environmental research ("Anwendungszentrum Umwelt (AMU)")	New organization	2000	Science
h	Establishment of the European Headquarter of the World Environmental Center (WEC) at the WZU	New organization	2001	Science
i	Establishment of the Augsburg Materials Declaration	Inst. Change	2002	Science
j	Establishment of a study program on environmental ethics	New organization	2002	Science
k	Establishment of a study program on global change ecology	New organization	2006	Science
l	Establishment of the Center for Material Resource Management (MRM)	New organization	2009	Science

m	Establishment of a new study program on sustainability education	New organization	2009	Science
n	Establishment of a new chair for resource strategies	New organization	2010	Science
o	Foundation of a working group with the aim to foster sustainability in the University	New inst. temporary event	2010	Science
p	Establishment of a study program on economic engineering focused on resource management	New organization	2011	Science
q	Establishment of a study program on climate and environmental Sciences	New organization	2011	Science
r	Establishment of a lecture series on climate protection in Bavaria by the state department for the environment (LfU) and the Science of Augsburg	New inst. temporary event	2013	Public
s	Establishment of a graduate school on resource strategies and concepts for future energy systems	New organization	2012	Science
t	Foundation of a network with the aim to foster corporate responsibility in the Augsburg region (“Augsburger Schule”)	New network	2012	Economy
u	Foundation of LA 21 working group on corporate responsibility (“FF Unternehmerische Verantwortung”)	New inst. temporary event	2012	Civil Society
v	Establishment of a first sustainability day for the regional economy (“Fokus N”) by the LA 21 forum on corporate responsibility	New inst. temporary event	2013	Economy
w	Establishment of a new chair and institute for environmental medicine at the Science clinic in Augsburg (UNIKA-T) in cooperation with the TU and LMU Munich and the Clinic Augsburg	New organization	2013	Science
x	Foundation of LA 21 forum on animal rights (“FF Tierrechte”)	New inst. temporary event	2015	Civil Society
y	Establishment of a chair for resource strategies in human geography	New organization	2015	Science
z	Foundation of a student initiative (“Green Office e.V.”) with the aim to foster sustainability in the university	New network	2016	Science
aa	Foundation of LA 21 working group Green Office (“FF Green Office”)	New inst. temporary event	2017	Civil Society

Table 19: Institutional and Organizational Changes in the Regional Development Paths to Sustainability of the Linz region.

	Change	Type	Year	Location
	Organizational and institutional change (supra-regional)			
I	Recommendation of the United Nations (UN) to start Local Agenda 21 (LA 21) groups and implementation of a framework convention on climate change	Inst. Change	1992	Internat.
II	Resolution of a sustainability concept by the federal government of Upper Austria	Inst. Change	1994	Federal
III	Resolution of an energy concept formulating precise targets and measures till 2010 by the federal-state government of Upper Austria	Inst. Change	1994	Federal
IV	Establishment of the Austrian Academy for Environment and Nature, which was amongst others responsible for coordinating the implementation of the environmental program and the LA 21 program in Upper Austria	New orga-nization	1995	Federal
V	Resolution of the environmental program by the government of Upper Austria	Inst. Change	1995	Federal
VI	Resolution of the LA 21 program by the government of Upper Austria	Inst. Change	1998	Federal
VII	Resolution of the second phase of the energy concept "Energy 21" by the government of Upper Austria	Inst. Change	2000	Federal
VIII	The Upper Austrian Energiesparverband takes over the management of the Eco-Energy Cluster	New orga-nization	2000	Economy
IX	Foundation of the Energy Institute on initiative of the government of Upper Austria, the Energieverband Upper Austria, the Energy AG, Linz AG and the OÖ Ferngas AG	New orga-nization	2001	Science
X	Resolution of an energy efficiency program by the government of Upper Austria	Inst. Change	2004	Federal
XI	Implementation of the UN Decade for Education on Sustainability	Inst. Change	2005	Federal
XII	Foundation of a cluster organization to manage the Environmental Technology Cluster	New orga-nization	2006	Economy
XIII	Establishment of a working group to elaborate measures in the frame of the energy concept under the leadership of the energy officer of Upper Austria	New network	2007	Federal
XIV	Resolution of an energy strategy “Energy Future 2030” by the government of Upper Austria	Inst. Change	2007	Federal

XV	Awarding the Austrian Sustainablity Award to the Institute for environmental law at the JKU by the government of Upper Austria	Inst. Change	2010	Science
XVI	Foundation of the future academy (Zukunftsakademie), a think tank to support the political decision making of the government of Upper Austria—replacing the Upper Austria Academy for Environment and Nature	New Inst. Temporary Event	2011	Federal
XVII	Resolution of an environmental program till 2030 by the government of Upper Austria	Inst. Change	2014	Federal
XVIII	Establishment of a working group for the elaboration of the environmental program	New network	2014	Federal
	Organizational and institutional change in the region			
1	Accession of the city of Linz to the Local Governments for Sustainability Initiative (ICLEI)	Inst. Change	1995	Public
2	Resolution of eight basic principles for sustainable development and to start an LA 21 process by the municipal council	Inst. Change	1995	Public
3	Foundation of the LA 21 working group on air/climate/energy	New. Inst. temporary event	2001	Public
4	Foundation of the LA 21 working group on nature/soil	New. Inst. temporary event	2001	Public
5	Foundation of the LA 21 working group on water	New. Inst. temporary event	2001	Public
6	Foundation of the LA 21 working group on mobility	New. Inst. temporary event	2001	Public
7	Foundation of the LA 21 working group on waste	New. Inst. temporary event	2001	Public
8	Foundation of the LA 21 working group on economy	New. Inst. temporary event	2001	Public
9	Foundation of the LA 21 working group on social issues	New. Inst. temporary event	2001	Public
10	Foundation of the LA 21 working group on as well as administration/service level	New. Inst. temporary event	2001	Public
11	Implementation of the Open Commons Linz Initiative	Inst. Change	2010	Public
12	Establishment of an advisory board for the Open Commons Linz Initiative	New network	2010	Public

13	Resolution of the Linzer social program	Inst. Change	2011	Public
14	Integration of the environmental department into the department of planning, technology and environment ("Planung, Technik und Umwelt")	New organization	2012	Public
15	Re-elaboration and adoption of the cultural development plan	Inst. Change	2013	Public
16	Establishment of an advisory board to accompany the implementation of the cultural development plan	New network	2013	Public
17	Resolution of a smart city project by the city of Linz	Inst. Change	2015	Public
	Organizational and institutional change in the University			
a	Signing of the Copernicus Charta and adoption of its principles by the JKU management	Inst. Change	1993	Science
b	Foundation of the Institute for Environmental Law	New organization	1994	Science
c	Establishment of the event series "Austrian Days of Environmental Law"	New. Inst. temporary event	1994	Science
d	Foundation of the Association of the Institute for Environmental Law	New network	1996	Science
e	Foundation of the Institute for Environmental Management in Companies and Regions (UWI)	New organization	1996	Science
f	Establishment of a new study program on "Environmental-, resource and quality management"	New organization	1996	Science
g	Establishment of the specialization environmental law in the study prorgram law (as first Austrian wide)	New organization	1999	Science
h	Signing of the Graz Declaration and adoption of its principles by the JKU management	Inst. Change	2005	Science
I	Establishment of the event series "Education for Sustainable Development"	New Inst. Temporary Event	2008	Science
j	Establishment of the graduate Master program "Energy Management"	New organization	2008	Science
k	Establishment of an international conference on European environmental law	New Inst. Temporary Event	2012	Science
l	Establishment of a symposium on European environmental law	New Inst. Temporary Event	2015	Science
m	Organization of the Future Lecture Series at the JKU by the Institute of Environmental Law	New Inst. Temporary Event	2015	Science

Appendix 4

Table 20: Institutional change in the located HEIs.

No	Year	Description
1	1993 – JKU	Copernicus Charter is signed
2	1996 – KTU	Commitment of the university management to an environmentally friendly operation of the HEI
3	2003 UAL	Upper Austrian Timber Award is initiated on the initiative of a professor from the University of Arts Linz
4	2005 – JKU	Graz declaration is signed
5	2007 – UoAS	Transition from Public Management to Public Governance in teaching
6	2009	EMAS process is initiated
7	2010 – KTU	The environmental guidelines of the KTU are decided by the faculty council
8	2010 – JKU	The Institute for Environmental Law, JKU is awarded the Austrian Sustainability Awards multiple times
9	2010 – PH	Austrian Sustainability Award of the ÖKOLOG initiative
10	2011 – KTU	The diocese is powered to 100% by green electricity due to the engagement of the environmental spokesperson of the diocese, who is professor and former rector of the KTU
11	2014 - oAS	The mission statement of the HEI states a commitment to ecological sustainability
12	2016 – PH	Austrian Sustainability Award for BINE – Education for Sustainable Development
13	2016 – UoAS	Audit as family-friendly HEI

(*JKU* Johannes Kepler University Linz, *KTU* Catholic Theological Private University, *PH* College of Education, *UoAS* University of Applied Sciences Upper Austria, *UAL* University of Arts Linz.)

Table 21: Organizational change in the located HEIs.

No	Year	Description
1	1994 – JKU	Institute for Environmental Law is founded
2	1994 – JKU	The event "Austrian Days of Environmental Law" takes place for the first time
3	1996 – JKU	Foundation of the Association of the Institute for Environmental Law
4	1998 – JKU	Institute for Environmental Management in Companies and Regions is founded
5	1999 – JKU	Specialization Environmental Law as part of the study program Law at the JKU is offered (as first Austrian-wide)
6	2000 – 2002 – UAL	Courses "Solar Architecture" and "Ecology" are introduced as courses in the study program Architecture
7	2007 – FH	The course Good Governance is introduced in the study program Public Management
8	2008 – JKU	The event series „Education for Sustainable Development" is initiated
9	2008 – JKU	Graduate Master Program Energy Management is initiated
10	2010 – UAL	Endowment professorship for "Sustainability and Spatial Tactics"
11	2010 – FH	Event Series "Public Management Impulse"
12	2010 – JKU	Event Series "Austrian Days of Environmental Law" at the Institute for Environmental Law is awarded the Sustainability Award 2010
13	2012 – JKU	International conference on "European Environmental Law"
14	2014 – PH	Start of the Public Lecture series, targeting on socio-political topics
15	2015 – JKU	First international symposium on European Environmental Law
16	2015 – JKU	Participation of the Institute of Environmental Law in the Future Lecture series

(*JKU* Johannes Kepler University Linz, *KTU* Catholic Theological Private University, *PH* College of Education, *UoAS* University of Applied Sciences Upper Austria, *UAL* University of Arts Linz.)

Appendix 5

The universities (official university code in brackets) that are considered in the analyses are:

U Kassel (1), U Duisburg-Essen (8), U Paderborn (12), U Siegen (13), U Wuppertal (14), Fernuniversität Hagen (15), Charité-Universitätsmedizin Berlin (18), Europa-U Viadrina Frankfurt (Oder) (19), Humboldt-Universität Berlin (20), U Rostock (26), U Greifswald (27), U Halle (30), U Magdeburg (31), U Leipzig (36), TU Dresden (37), TU Chemnitz (38), TU Bergakademie Freiberg (39), U Jena (49), U Bamberg (50), U Bayreuth (51), U Oldenburg (52), U Osnabrück (53), U Passau (54), Kath. U Eichstätt-Ingolstadt (55), Bauhaus-U Weimar (58), TU Ilmenau (59), U Erfurt (62), Jacobs University Bremen (Priv. H) (66), Helmut-Schmidt-Universität Hamburg (80), U der Bundeswehr München (81), Deutsche Hochschule der Polizei, Münster (91), Universität Vechta (96), U Lüneburg (99), U Kiel (100), U Lübeck (101), U Hamburg (102), U Göttingen (103), TU Hamburg-Harburg (104), U Bremen (105), U Bochum (108), U Bonn (109), U Düsseldorf (110), U Köln (111), U Münster (112), U Dortmund (113), U Bielefeld (114), Deutsche Sporthochschule Köln (115), U Frankfurt a.M. (116), U Gießen (117), U Marburg (118), U Trier (120), TU Kaiserslautern (121), U Mainz (122), Deutsche Universität für Verwaltungswissenschaften Speyer (123), U Freiburg i.Br. (124), U Heidelberg (125), U Konstanz (126), U Tübingen (127), U Koblenz-Landau (129), U Erlangen-Nürnberg (131), U München (132), U Würzburg (133), U Regensburg (134), U Augsburg (135), U des Saarlandes Saarbrücken (136), FU Berlin (138), TU Braunschweig (143), TU Clausthal (144), U Hannover (145), Zeppelin Universität Friedrichshafen (Priv. H) (146), TH Aachen (148), Priv. wiss. H Witten-Herdecke (149), TU Darmstadt (153), Karlsruher Institut für Technologie (KIT)—Bereich Hochschule (158), U Stuttgart (159), TU München (163), TU Berlin (169), ESCP Europe Wirtschaftshochschule Berlin (Priv. H) (170), Medizinische H Hannover (173), Tierärztliche H Hannover (174), U Hohenheim (180), U Mannheim (181), U Ulm (182), U Potsdam (350), and Steinbeis-H Berlin (Priv. H) (796).

The complete results of the VAR analyses are given in Tables 22, 23, 24 and 25.

Table 22: Results of the VAR analysis for law, economics and social sciences (*p*-values in brackets).

Variable	Period	Sustainable Publications	Y Patents	Green votes	Rel. publ.: Agricultural & social systems	Rel. publ.: Agricultural production	Rel. publ.: Natural resources
Sustainable Publications	Same	-	-	-	-	0.1972 (0.1231)	0.4169 (6e-04)
	Before	0.0405 (0.4359)	0.0000 (0.9488)	0.0000 (0.9461)	-0.0203 (0.2297)	-0.2504 (0.0653)	-0.1423 (0.013)
Y Patents	Same	-0.8363 (0.4669)	-	0.0785 (0.1558)	-0.4227 (0.4448)	-0.4546 (0.8657)	0.3126 (0.6727)
	Before	-5e-04 (0.9998)	0.4665 (0)	-0.0531 (0.3812)	0.5437 (0.5478)	1.1014 (0.6898)	-0.6423 (0.5762)
Green votes	Same	0.494 (0.4816)	-	-	0.0945 (0.7301)	-0.4097 (0.7856)	0.3118 (0.5125)
	Before	0.6577 (0.4122)	-0.0698 (0.0682)	0.9593 (0)	0.2739 (0.5089)	2.0324 (0.3736)	0.8974 (0.1868)
Related publications: Agricultural & social systems	Same	0.4581 (0.0165)	-	-	-	0.7853 (0.1692)	0.2512 (0.3382)
	Before	-0.0326 (0.8997)	5e-04 (0.7993)	0.0013 (0.2061)	0.4092 (0.033)	-0.113 (0.8472)	0.0441 (0.8879)
Related publications: Agricultural production	Same	-	-	-	-	-	-
	Before	0.0000 (0.9963)	0.0000 (0.9992)	0.0000 (0.9912)	0.0000 (0.9974)	1.0275 (0)	0.0000 (0.9997)
Related publications: Natural resources	Same	-	-	-	-	0.0216 (0.875)	-
	Before	-0.0785 (0.1926)	-6e-04 (0.4689)	0.001 (0.0569)	0.0594 (0.1128)	0.1035 (0.5225)	0.328 (0.0015)

Table 23: Results of the VAR analysis for natural sciences (*p*-values in brackets).

Variable	Period	Sustainable Publications	Y Patents	Green votes	Rel. publ.: Agricultural & social systems	Rel. publ.: Agricultural production	Rel. publ.: Renewable	Rel. publ.: Natural resources
Sustainable Publications	Same	-	-	-	-	0.0517 (0.5436)	0.4733 (0)	0.1474 (0.0203)
	Before	0.2497 (0.002)	0.0000 (0.9534)	0.0012 (0.0059)	0.051 (0.0493)	0.0143 (0.9046)	-0.2015 (0.3729)	-0.0076 (0.9445)
Y Patents	Same	1.9811 (0.1316)	-	0.0822 (0.1179)	-0.7005 (0.3594)	-0.3834 (0.9123)	-1.3362 (0.3766)	0.7877 (0.5813)
	Before	-0.3398 (0.8792)	0.462 (0)	-0.0617 (0.3033)	0.2324 (0.8513)	1.1561 (0.7168)	-0.4294 (0.7527)	0.5878 (0.8343)
Green votes	Same	0.8918 (0.335)	-	-	0.164 (0.5556)	-0.6144 (0.6613)	0.1945 (0.8448)	-0.1479 (0.8437)
	Before	2.7532 (0.0372)	-0.0726 (0.0552)	0.9539 (0)	0.2647 (0.4956)	1.9192 (0.3459)	0.0836 (0.9296)	-0.8021 (0.5322)
Related publications: Agricultural & social systems	Same	0.3088 (0.1636)	-	-	-	0.8852 (0.1851)	-0.0659 (0.8045)	1.1376 (0)
	Before	-0.0119 (0.9209)	0.0000 (0.999)	6e-04 (0.5701)	0.339 (0.1108)	-0.317 (0.6571)	0.0369 (0.9011)	-0.1713 (0.6779)
Related publications: Agricultural production	Same	-	-	-	-	-	-	-
	Before	0.0000 (0.9945)	0.0000 (0.9973)	0.0000 (0.9926)	0.0000 (0.9981)	1.0275 (0)	0.0000 (0.9995)	0.0000 (0.9934)
Related publications: Renewable	Same	-	-	-	-	0.058 (0.3471)	-	0.0589 (0.3437)
	Before	1e-04 (0.9956)	0.0000 (0.6544)	0.0000 (0.8363)	0.003 (0.769)	-0.0498 (0.5722)	0.2404 (0.0392)	-0.0014 (0.9789)
Related publications: Natural resources	Same	-	-	-	-	0.0105 (0.939)	-	-
	Before	0.0255 (0.5806)	-3e-04 (0.4896)	5e-04 (0.0767)	-8e-04 (0.9355)	0.0994 (0.4829)	-0.0091 (0.9158)	0.4251 (0.0536)

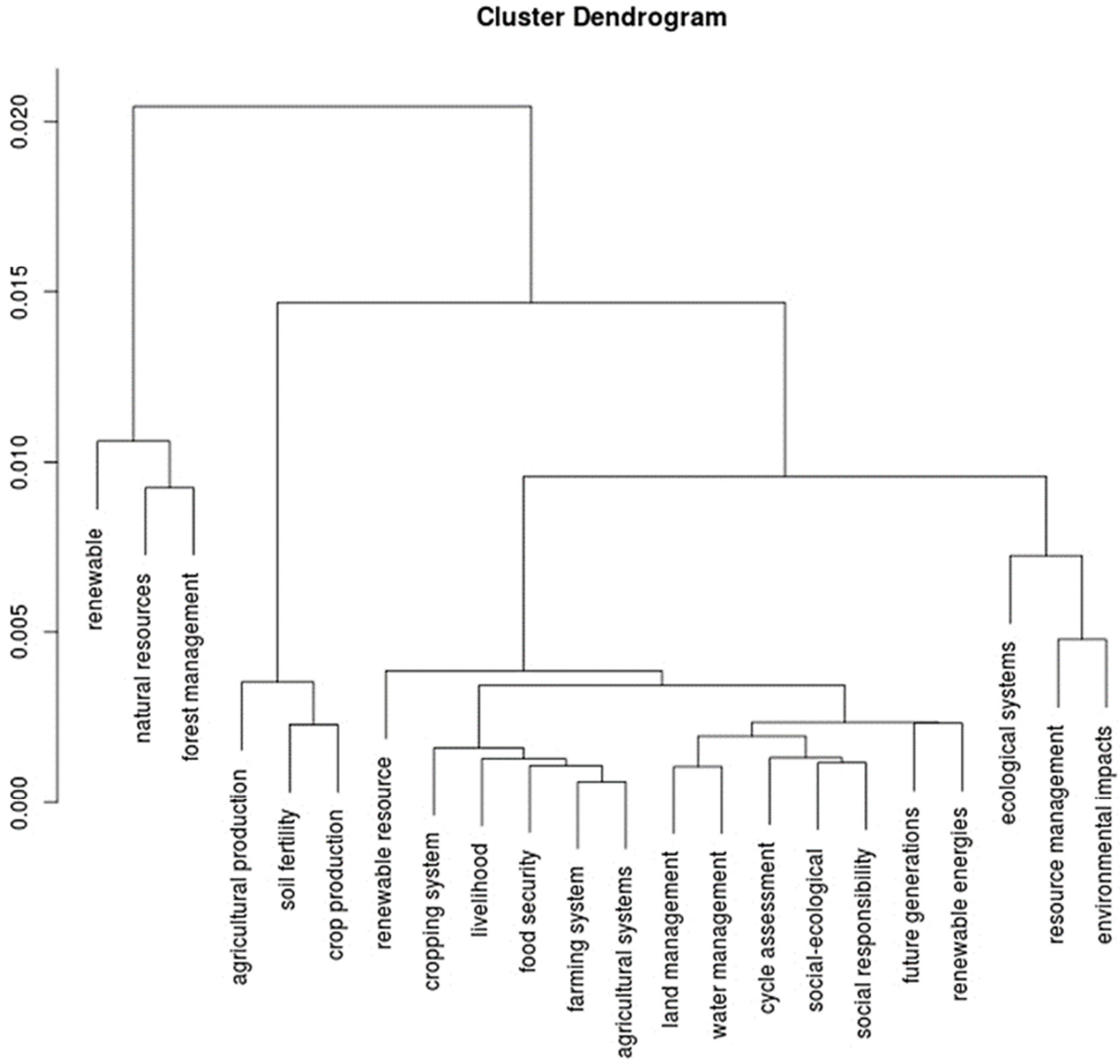
Table 24: Results of the VAR analysis for agriculture (*p*-values in brackets).

Variable	Period	Sustainable Publications	Y Patents	Green votes	Rel. publ.: Agricultural & social systems	Rel. publ.: Agricultural production	Rel. publ.: Renewable	Rel. publ.: Natural resources
Sustainable Publications	Same	-	-	-	-	-0.113 (0.8085)	-	0.0516 (0.6103)
	Before	0.7899 (0)	0.001 (0.2633)	7e-04 (0.0875)	0.0212 (0.5679)	0.2613 (0.6181)	0.5976 (0.0525)	-0.0675 (0.5578)
Y Patents	Same	0.8899 (0.4169)	-	0.0827 (0.1201)	-0.4549 (0.4602)	0.2112 (0.9474)	-0.4208 (0.1653)	1.3166 (0.3358)
	Before	-2.8107 (0.0341)	0.4628 (0)	-0.0547 (0.3256)	0.7014 (0.3709)	0.8559 (0.7481)	-0.8378 (0.5148)	-0.1073 (0.9703)
Green votes	Same	0.2572 (0.6557)	-	-	0.0648 (0.814)	-0.3227 (0.8027)	0.567 (0.005)	0.2209 (0.7662)
	Before	0.4137 (0.7233)	-0.0657 (0.0434)	0.9574 (0)	0.2653 (0.5291)	1.8642 (0.334)	1.0144 (0.2042)	-0.1631 (0.9088)
Related publications: Agricultural & social systems	Same	0.5269 (0.0163)	-	-	-	0.7972 (0.089)	-	0.9846 (0)
	Before	0.2266 (0.3754)	-0.0015 (0.5127)	0.0000 (0.9921)	0.1986 (0.3357)	-0.3848 (0.4698)	-0.2994 (0.2538)	-0.0156 (0.9666)
Related publications: Agricultural production	Same	-	-	-	-	-	-	-
	Before	0.0000 (0.9951)	0.0000 (0.9921)	0.0000 (0.9923)	0.0000 (0.995)	1.0275 (0)	0.0000 (0.999)	0.0000 (0.9917)
Related publications: Renewable	Same	0.2027 (0.0396)	-	-	-0.0185 (0.5611)	0.0924 (0.494)	-	0.063 (0.1849)
	Before	-0.1423 (0.1421)	-2e-04 (0.4398)	-1e-04 (0.3033)	0.0021 (0.8843)	-0.1074 (0.4079)	0.1198 (0.1253)	0.0116 (0.7831)
Related publications: Natural resources	Same	-	-	-	-	-0.0019 (0.9877)	-	-
	Before	0.0251 (0.8256)	-3e-04 (0.4614)	5e-04 (0.0664)	-0.0018 (0.9073)	0.1006 (0.4236)	0.0019 (0.9781)	0.4467 (0.0084)

Table 25: Results of the VAR analysis for engineering (*p*-values in brackets).

Variable	Period	Sustainable Publications	Y Patents	Green votes	Rel. publ.: Agricultural & social systems	Rel. publ.: Agricultural production	Rel. publ.: Natural resources
Sustainable Publications	Same	-	-	-	-	-	-
	Before	0.4775 (0.0177)	8e-04 (0.0229)	4e-04 (0.014)	0.0259 (0.3269)	0.0073 (0.8212)	0.1146 (0.0254)
Y Patents	Same	-0.1778 (0.9444)	-	0.0665 (0.2151)	-0.5815 (0.2909)	-0.3017 (0.9056)	-0.0246 (0.9778)
	Before	3.8234 (0.2441)	0.459 (0)	-0.0445 (0.3964)	0.4229 (0.6611)	1.2722 (0.6578)	-0.5776 (0.6155)
Green votes	Same	1.2601 (0.3416)	-	-	0.0151 (0.9521)	-0.3231 (0.8481)	0.3026 (0.5855)
	Before	4.259 (0.1058)	-0.0809 (0.0199)	0.953 (0)	0.0312 (0.9417)	2.0166 (0.3721)	0.857 (0.139)
Related publications: Agricultural & social systems	Same	0.9757 (0.0281)	-	-	-	0.8445 (0.11)	0.3267 (0.161)
	Before	0.508 (0.4239)	-0.0015 (0.4597)	7e-04 (0.3863)	0.2549 (0.1202)	-0.0252 (0.9649)	-0.1697 (0.5115)
Related publications: Agricultural production	Same	0.1291 (0.1051)	-	-	-	-	-
	Before	-0.0616 (0.2316)	-1e-04 (0.2017)	-1e-04 (0.4491)	-0.0033 (0.6714)	1.0265 (0)	-0.0148 (0.1775)
Related publications: Natural resources	Same	0.8971 (4e-04)	-	-	-	-0.1 (0.4994)	-
	Before	0.2992 (0.3383)	-0.0019 (0.0242)	2e-04 (0.6227)	0.0052 (0.8669)	0.2273 (0.2744)	0.1538 (0.1445)

Figure 23: Dendrogram for the 22 keywords.



Acknowledgements

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