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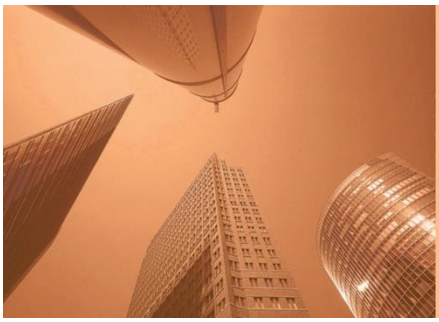

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Regional Perspectives on Socio-technical Transitions. Combining Research Insights from Geography of Innovation and Transition Studies

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Regional Perspectives on Socio-technical Transitions. Combining Research Insights from Geography of Innovation and Transition Studies

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Contents

Abstract

While societal challenges are global in nature, solving and addressing them usually tends to take place at smaller spatial scales. As place-specific technological, institutional and actor settings have a decisive influence on the direction, scope and speed of transformative dynamics, regions vary greatly in the generation and application of innovations required for socio-technical transitions. With a broader understanding of regional innovation systems (RIS), on the one hand, and spatial considerations in transition studies, on the other, geographic research has recently contributed to a better understanding of innovation-based structural and systemic change. At the same time, the research findings are still insufficiently linked with one another. We argue that recent theorizing on expanded regional innovation systems provides additional explanatory power in the context of systemic transitions by considering similar aspects, e.g. the role of experimentation and different modes of innovation, yet incorporating a more spatial perspective. Against this background, we show that innovation policies at the regional level seem to be particularly effective when they support innovation dynamics aimed at sustainability through the inclusion of various actor groups and the attention to both the production and application side. Given the increasing spatial disparities in innovation dynamics, however, further research is needed on the opportunities and barriers of different regional settings for sustainability transitions.

1 Introduction

In times of pressing global challenges such as climate change or the consumption of natural resources, the question arises as to how socio-technical systems can be realigned to improve human wellbeing without being ecologically destructive (Smith et al., 2010; Markard et al., 2012). Against this backdrop, scientific and political discourses have recently focused on sustainability-oriented innovations (Truffer and Coenen, 2012; Mazzucato, 2018; Köhler et al., 2019). However, since the generation and diffusion of innovations is spatially constituted, countries and regions differ considerably in terms of their innovation potentials and thus capabilities to solve sustainability challenges (Moulaert and Sekia, 2003; Hansen and Coenen, 2015).

Accordingly, this paper addresses the question of what role regions, defined as functional or political spatial units between the level of the nation-state and the local level, (might) play in socio-technical transitions.[1] This question fits into the current political discussion on regional structural change, for example "Smart Specialization Strategies" (for sustainability) by the European Commission and political funding measures such as "Innovation and Structural Change" in Germany (Koschatzky and Stahlecker, 2019). In order to be able to develop new scientific and political perspectives here, reference will not only be made to the common concepts of evolutionary economic geography (Boschma, 2014), but insights from research on sustainability transitions will also be taken into account (Köhler et al., 2019).

While economic geography is largely concerned with evolutionary and linear path developments (Martin and Sunley, 2006), transformation research looks at sustainable, but also radical and non-linear path developments in sectors and industries that result in a fundamental and desired system change of more sustainable modes of production and consumption (Markard et al., 2012); changes that hence go far beyond incremental innovation steps. In the face of profound systemic changes and multi-dimensional interdependencies, transition research also focuses on forces of stability, resulting from disagreement and uncertainty about the scope and desired direction of sustainability dynamics (Köhler et al., 2019).

At the same time, insights from transition research and spatial innovation research focus on similar topics, such as path dependency and lock-in (Strambach and Pflitsch, 2020; Trippl et al., 2020) or systems of innovation (Uyarra and Flanagan, 2010; Wieczorek et al., 2015). The essential difference is, however, that transition research focuses on sectoral changes towards sustainability across territorial boundaries (e.g. Köhler et al., 2019), while studies in economic geography focus on the specific actor constellations, knowledge, creative and technology profiles of specific regions or countries and the measures to further develop and sharpen them (Boschma et al., 2017).

Therefore, both from a scientific and a political perspective, there is an increasing need to bring together the scientific discourses on the geography of innovation (Isaksen and Trippl, 2017) and the geography of transitions (Coenen et al., 2012; Hansen and Coenen, 2015). An attempt has been made in recent years to include geographic theories in the field of transitions research (Binz et al., 2020). Yet, corresponding links regarding concepts, ideas and heuristics between both research disciplines are still rare. In particular, the role of regional innovation systems (RIS) in systemic transitions has only been sporadically studied (Cooke, 2011; Tödtling et al., 2021).

[1] The two terms "transformation" and "transition" are used synonymously. They describe a comprehensive approach to identify and implement (radical) non-linear paths and solutions for a substantial (desirable) system change of the environment and society. The term "transitions" is rather used in sustainability research while "transformation" is used broader in different literature strands.

Against this background, we argue that a stronger reference to the extended RIS heuristics (Warnke et al., 2016) can be seen as a valuable analytical tool and starting point to intensively integrate both research traditions. Hence, the aim of this paper is to shed light on the role of the regional level in transition processes. Our analyses focus on the following questions:

1) What region-specific characteristics does the literature highlight to explain heterogeneity in innovation and sustainability transitions?
2) What are the implications for a modified heuristic of a regional innovation system that includes elements crucial for systemic transitions?
3) Which governance structures and instruments at the sub-national level are particularly conducive to socio-technical transitions and system-changing innovations?

To analyse these questions, we first discuss the conceptualization of regions being apparent in the respective research field, before focusing on the heterogeneity of regions and regional capabilities. Building on this, both research on the geography of innovation and research on the geography of sustainability transitions are characterized in more detail. This is followed by a reference to place-specific conditions that essentially influence innovation and transition processes. Finally, section 4 provides implications for regional governance and a conclusion.

2 Linking the geography of innovation and the geography of sustainability transitions

The following sections contrast key concepts, research logics and frameworks of the research on the geography of innovation with the research on the geography of system transitions.

2.1 Conceptualization of regions

In a very broad and general way, a "region" can be described as a territory with homogeneous features. However, a fixed and exclusive definition of "region" does not exist, so in different contexts the term is used in different ways. Innovation studies and regional sciences mainly use the term to describe territorial entities at the subnational level, while analyses at global scale often refer to world regions such as Asian countries or the Americas. Usually, however, "region" is a functional term that describes a spatial unit located between the local and nation level. Thus, a region can be considered as the environment or context of innovating actors, i.e. the specific (territorial) context in which innovation takes place and which provides the context of relations and structures as determinants of economic and hence social activities (Bathelt and Glückler, 2003; Cooke et al., 2011).

Studies on the geography of innovation mainly draw on definable territorial entities that have a certain degree of political capacity and policy making - i.e. administrative regions - such as districts or federal states (Cooke et al., 1997), or regions with specific interrelations and functional relationships, for example labour market regions. The ability to govern does not necessarily have to correspond to the ability of a state governance unit (as is the case, for example, in a political-administrative spatial unit), but can be defined by bottom-up strategy processes (Heidenreich and Koschatzky, 2011). This conceptual-theoretical spatial construct must then be transferred to existing real spatial units in empirical analyses (e.g. spatial planning regions, but also landscape-defined regions).

Accordingly, empirical and specifically regional comparative analyses in the European context often draw on the *Nomenclature des unités territoriales statistiques* (NUTS) of the European Union. This system has a hierarchical structure and divides the territory of the European Union in different levels. These categories form the base for regional statistics and empirical analyses, but are also the territorial frame for regional policies. Here, they often reflect the governance level for regional and innovation policies in the Member States. In addition, NUTS regions are reference units for regional data and are defined according to pre-defined ranges in the population size (Eurostat, 2015).[2]

Research on the geography of transitions, on the other hand, has a rather constructivist and relational understanding of regions (Hansen and Coenen, 2015). Since various actors usually contribute to the development and diffusion of innovations, innovation can be considered as constructed by social processes that occur in a specific setting of actors, activities, institutions, mentalities, socio-cultural conditions etc. at a specific place or in a given territory - the region. Social relations, economic action and their environment are thus interlinked.[3] According to this relational conceptualisation, space is not a physical territorial unit, but is constituted as a multi-scalar environment of distributed actors and networks (Levin-Keitel et al., 2018).

Following Binz et al., 2020, the spatiality of complex and multi-dimensional transition processes can ideally be structured along the categories of scales, places and spaces. While *"scale"* reflects the

[2] Cf. also https://ec.europa.eu/eurostat/web/nuts/background

[3] This view brings together economic action, social relationships and the spatial environment. See for instance Bathelt and Glückler (2003).

multi-scalar nature of social, economic and political relations beyond the local and regional level, *"space"* resonates with spatially bound conditions that influence trajectories towards sustainability. Place-making processes and shared understanding (values, meanings, etc.) are ultimately subsumed under the term *"place"*. Since places are relationally constituted, regions are rather holistic categories in which different socio-technical systems influence one another. As we believe that this structuration has additional explanatory power, subsequent chapters repeatedly refer to this distinction.

2.2 Characterization of geographical work on innovation and transitions

Both transition studies and literature on the geography of innovation are based on key concepts that are important for assessing the relevance of the regional context in the emergence of radical innovation and the transformation of regional innovation systems.

Geography of innovation

Research on the geography of innovation has an explicit focus on the spatial level of economic activities, analysing the determinants of economic characteristics that can be observed empirically (Moulaert and Sekia, 2003; Feldman, 2016) . Though different strands of the literature develop different approaches and implement different models, they share the view that economic activity does not occur evenly in all places. When analysing creative and innovative activities, the co-location and clustering becomes obvious: some regions seem to be related stronger to innovation than others (Feldman, 2016). Evidence is provided by various types of indicator-based comparative analyses such as for instance the "Regional Innovation Scoreboard" which analyses a set of innovation data for European NUTS 2 regions. Various determinants are discussed as crucial factors for the generation and diffusion of innovations, and in addition to individual elements, their interrelations seem to be of pivotal importance (Carrincazeaux and Coris, 2011; Cooke et al., 2011).

This systemic understanding of innovation being the result of an interplay between different actors and activities rooted in very specific territorial contexts is referring to the process of generating innovations (Cooke et al., 1997; Doloreux and Parto, 2005). Creating an innovative solution requires various inputs and can be considered as a social activity that brings together different pieces of knowledge, technology, science and research, support structures (infrastructure, finance), and many further factors. This leads to the consideration that every territory has a very specific setting in terms of actors and institutions, industrial development paths, social norms, rules and regulations, ways of acting and interacting, and confronting new trends, developments and grand societal challenges (Feldman, 2016; Isaksen and Trippl, 2017). In evolutionary thinking, innovating actors and the economic structure that provides the context of economic action are interrelated and mutually influence each other (Boschma et al., 2017; MacKinnon et al., 2019). The environment in which innovation takes place provides different options for action through its endowment and arrangements; it is therefore considered as a "selection environment" and a "structural composition of a society within a framework of time and space" (Lambooy and Boschma, 2001)

This leads to the question under which conditions regions pursue existing paths, thus generating innovations based on existing core competencies, or develop more radical innovations that are not, or only to a small extent, related to existing (technological and institutional) arrangements (Boschma et al., 2017). In the latter case, existing trajectories constrain the development of new variety due to uncertainties, high costs or risks of turning to new development paths (Lambooy and Boschma, 2001; Cooke et al., 2011). In contrast, diversification without relation to previous paths and developments has its origins in breakthroughs based on new socio-technical configurations, without major relations to the existing technological and institutional setting (Boschma et al., 2017).

Following Scott (1999) and Storper and Walker (1989) and the "windows of locational opportunities" approach, economic actors not only "react" to territorial settings, but also influence and shape these arrangements (Bathelt and Glückler, 2003; Boschma et al., 2017).

More recent work emphasizes a broader view on innovation and a more comprehensive perspective on innovation systems at the regional level (Warnke et al., 2016; Isaksen and Trippl, 2017). A broader RIS understanding includes, first, different types of innovation (social, technological, user, etc.). Related to this is, secondly, an inclusion of actors beyond the triple helix of science, business and politics, as intermediaries and societal actors play a decisive role in both the emergence and diffusion of innovation. Third, collaborative platforms and infrastructures for experimentation among different groups of actors are increasingly important. And fourth, it has been recognized that demand-side aspects and institutional framework conditions are also enablers of innovation activities. Yet, research on the geography of innovation sees the emergence of innovation systems rather as path- and place-dependent (Feldman, 2016; Boschma et al., 2017).

Geography of transitions

The geography of transitions research field corroborates that sustainability transitions, defined as "long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard et al., 2012), have a distinct spatial dimension (Coenen and Truffer, 2012; Hansen and Coenen, 2015; Boschma et al., 2017). This builds on the recognition that the central elements of socio-technical systems, i.e. (networks) of actors, institutions and material artefacts / knowledge (Geels, 2004; Markard et al., 2012), are spatially constituted (Bridge et al., 2013). In the course of a sustainability transition, new products, services, business models and organizations emerge, partly complementing and partly substituting the existing ones. Technological and institutional structures change fundamentally, as well as the perceptions of consumers regarding what constitutes a particular service (or technology).

Against this backdrop, the geography of transitions research explicitly addresses questions regarding the spatial unevenness and geographical particularities of transition processes (Coenen et al., 2012). These processes are understood to unfold in scales, places and spaces, representing the underlying geographical conceptualisation of the field (Binz et al., 2020). The transformation of production and consumption systems is thus seen as influenced by changing spatial conditions, where places and territories are relationally constructed through social interactions positioned in multi-scalar relations (Dewald and Fromhold-Eisebith, 2015; Hansen and Coenen, 2015).

Along the three dimensions of place, space and scale, both conceptual and empirical work has emerged in recent years. On the one hand, studies have added spatial dimensions to the foundational transition-focused frameworks, especially the Multi-Level Perspective (MLP) and the Technological Innovation System approach (TIS), which were previously considered as "a-spatial" or "spatially naïve" (Coenen et al., 2012; Coenen and Truffer, 2012; Sengers and Raven, 2015). On the other hand, empirical work stresses specificities of distinct places and multi-scalar interdepencies of socio-technical change mostly using qualitative research methods. Coherently, generalizable knowledge about how and to what extent territorial factors influence transitions is still rare (Hansen and Coenen, 2015; Boschma et al., 2017; Binz et al., 2020). While research on transitions initially foregrounded the national level, the subnational level, i.e. regions, and local dynamics have recently received growing attention (Losacker and Liefner, 2020; Strambach and Pflitsch, 2020).

According to the MLP, which distinguishes between niche, regime and landscape, new system innovations with the potential for disruptive change usually emerge in niches (Markard and Truffer, 2008b). This strengthens network and learning activities and allows the involved actors to try and create new alignments of institutions, technologies and actor constellations (Boschma et al., 2017).

The regime is the domain in which knowledge, practices, and process technologies are socially embedded and seamlessly connected to user expectations and competencies, institutional structures, and higher-level infrastructure. The regime is path-dependent, network-based, and ultimately changeable only through radical disruption, while the landscape level refers to the exogenous environment that actors cannot directly influence (Geels, 2004). To achieve globally institutionalized regime-shifts, i.e. transitions of socio-technical systems, the upscaling or leveraging of niches innovation and practices beyond the places of origin is therefore of major importance (Coenen and Truffer, 2012; Strambach and Pflitsch, 2020). However, the MLP levels are not spatial categories and regime structures are assumed to be spatially homogenous although the factors supporting and hindering transitions have geographic, i.e. complex multi-scalar, dimensions (Coenen et al., 2012; Meelen et al., 2019). Because of this inconsistency of the three levels with geographic categories, the MLP is relatively little used in geographical transition studies.

In contrast, the TIS and its further development for global contexts (Binz and Truffer, 2017) has received much more attention (Wieczorek et al., 2015; Rohe, 2020). While national boundaries initially served as the "natural" delimitation of TIS (Coenen et al., 2012), recent studies propose a relational and network perspective to cover spatial processes in the way that networks may be confined to specific regions, but they can also be global (Binz et al., 2014; Dewald and Fromhold-Eisebith, 2015). As the TIS framework sees transitions to emerge through new, more sustainable technologies that displace established technologies, systemic elements of actors, networks, institutions that contribute to socio-technical change are analysed along sectoral structures beyond spatial borders (Coenen et al., 2012; Wieczorek et al., 2015). The role of regions is therefore mostly discussed, if at all, in relation to global technology innovations and diffusions, where the spatial manifestation seems to depend strongly on the form of their innovation and valuation mode (Binz and Truffer, 2017; Rohe, 2020).

2.3 Place-specificities that influence innovation and transition dynamics

Building on the recognition that innovation and transformation processes have a spatial dimension and, in particular, show variance on a small-scale/regional basis, scholarly work in both lines of research focus on the following place-specific determinants: the embeddedness in formal and informal institutions (e.g. rules, norms and values), actors, technological and industrial specialisation, consumers and market structures as well as regional policies (Horbach, 2008; Hansen and Coenen, 2015; Losacker and Liefner, 2020).[4]

Socio-institutional embeddedness

A general conclusion from transformation research, but as well from evolutionary economic geography, is that knowledge, practices and processes are both socially and institutionally embedded (Markard et al., 2012; Truffer and Coenen, 2012). If this assumption is applied to the understanding that niches are incubators for system transformations, then it can be assumed that **socio-institutional embeddedness** in the niche is advantageous for the emergence of innovations, knowledge exchange and creativity.

According to (Granovetter, 1985), a "father" of the embeddedness school alongside (Polanyi, 1957), individual actions are embedded in the social life of the actors. Social relationships between actors

[4] Hansen and Coenen (2015) additionally highlight the importance of local natural resource endowments, which are, however, far less relevant in the respective geographical discourses.

have a decisive influence on their decisions (Fougy and Amisse, 2016). The concept of embeddedness was also taken up in evolutionary economic geography and interpreted in terms of the advantage of a spatial embeddedness for economic activities (Hess, 2004; Jones, 2008). In the relevant literature, it is usually assumed with reference to Granovetter that organizational agreements and place-specific institutional environments comprising regulative, normative and cultural-cognitive elements (Strambach, 2017) facilitate coordination and reduce the risks of opportunistic behaviour in economic life (e.g. in the cluster approach). However, this assumption is in contrast with the embeddedness concept. According to (Granovetter, 1985), the relationship between organizational and institutional arrangements and the reduction of opportunism cannot be planned. The embeddedness of an organizational member enables an unpredictable and possibly less efficient functioning. The author claims that coordination can prove chaotic, since the high degree of trust potentially leads to a higher risk of opportunism and embeddedness can cause negative effects in interactions.

Therefore, we can draw the conclusion that the embeddedness of actors and processes in socio-institutional structures in specific spatial arrangements is not automatically advantageous, just as the conditions in a niche do not automatically have to be advantageous for all involved actors. Accordingly, institutions can be either a hindrance or facilitator of innovation-based and transformative change (Coenen et al., 2012). This latter assumption is in line with previous studies, which found that the embeddedness of actors in socio-institutional structures on the regional level has positive effects on the innovation and transformation activities (Cainelli et al., 2012; Truffer and Coenen, 2012; Corradini, 2019; Rohe, 2020). However, according to (Binz et al., 2016) and (Tödtling et al., 2020), the degree of spatial embeddedness highly depends on the form and availability of knowledge, the constitution of actor networks and institutional arrangements. At the same time, studies also indicate that strong place-based embeddedness leads to path dependencies and lock-ins ("over-embeddedness"), which tend to hinder disruptive developments (Boschma et al., 2017).

The misinterpretation in many studies consists in assuming a cause-and-effect relationship between embeddedness and economic performance, while the forms of embeddedness remain excluded with regard to coordination modalities, governance, risks of opportunism and thus the implementation of cooperation (Fougy and Amisse, 2016). As a matter of fact, strategic niche management and reflexive governance as two approaches of the promotion and governance of transformations have to take intra- and interregional interactions and different forms of embeddedness into account.

Actor constellations

Although individual actors might also play a pivotal role in innovation and transition processes, research usually conceptualise organisations as actors (Warnke et al., 2016). As network of actors mostly have a clear local or regional dimension, induced by geographical and other types of proximity, innovation and transition studies see them as being place-specific determinants (Hansen and Coenen, 2015; Grillitsch and Sotarauta, 2020).

In general, the literature distinguishes between different types of actors who play different roles, also over time. In the original innovation literature, the focus is usually on scientific, economic and political actors. This constellation is summarized under the term "triple helix" (Gibbs and O'Neill, 2017). Both research on the geography of transitions and the geography of innovation find that science actors such as research organisations, universities and higher education institutions are crucial to generate (transformative) knowledge, creating human capital and performing R&D activities (Markard and Truffer, 2008a; Cooke, 2011). Political decision-makers are important in the implementation of regulatory and policy frameworks and as a provider of funding. While they mostly have a steering effect at the national or international level, regional policy makers can be important

in strengthening knowledge exchange and cooperation processes (Wieczorek et al., 2015; Rohe, 2020). Economic actors such as companies or start-ups are the central force in innovation systems when it comes to the generation and diffusion of novel products and processes. In this regard, multi-national companies and transnational entrepreneurs have a leveraging potential on innovation activities beyond regional boarders. At the same time, new companies often emerge in close proximity to existing companies in the same sector, strengthening spatial path dependencies (Binz and Truffer, 2017; Corradini, 2019).

In recent years, actors beyond science, academia and the business sector moved into the centre of attention, especially in the research on the geography of transitions. These include intermediaries (cluster, networks, transfer agencies, trade unions) and civil society actors such as consumers, social entrepreneurs, citizens etc. (Wieczorek et al., 2015; Warnke et al., 2016). The broader understanding of innovation and socio-technical systems goes back to the findings that these actors are instrumental in various ways. Although societal actors' direct influence on innovation activities is rather incremental, they nevertheless exert an impact by creating (hindering) an innovation friendly environment, raising awareness, creating ideas or mobilising engagement (Loorbach et al., 2017; Levin-Keitel et al., 2018; Strambach and Pflitsch, 2020). The roles of intermediaries are primarily to network, transfer knowledge and mediate between, for example, research and industry. As such, they acting across sectoral boundaries that often transcend geographical boundaries (Sengers and Raven, 2015).

Interestingly, the role of actor groups might change and is highly place-specific. That is, in some regions specific actors are likely to foster (sustainable) change, while in others they create barriers. Moreover, interests of actors might change during the course of transition or innovation processes. As the direction and scope of pathways towards sustainability are far from being uncontested, innovation and transitions processes are rather long-term and open-ended. Negotiation and contestation are the rule rather than the exception (Markard et al., 2012; Köhler et al., 2019).

Technological and industrial specialisation

Influenced by evolutionary economic thinking (Boschma et al., 2017), the spatial heterogeneity of innovation and transition dynamics, explaining why certain places develop inertia to transformations while others tend to change, is mainly seen in path dependencies of socio-technical regime structures and its stabilizing forces (Strambach and Pflitsch, 2020; Trippl et al., 2020). Since new technologies and innovation activities are influenced by pre-existing system structures, regions follow specific (technology-oriented) paths towards sustainability. (Radinger-Peer and Pflitsch, 2017; Strambach and Pflitsch, 2018). Different technological specialisations thus partly explain the spatially uneven patterns of innovation activities and vice versa.

Due to complex interdependencies at the systems level, however, the acceleration of transitions towards sustainability requires broader organisational and institutional change. Against this backdrop, a strong technological regime structure at the regional level is seen as a hindrance to the development of novel and challenging solutions (Truffer and Coenen, 2012). Yet, some empirical studies find that a pre-existing specialisation in unsustainable technologies may even provide necessary capabilities for the sustainable development of regions and does not automatically constitute an aggravating factor (van den Berge et al., 2020; Santoalha and Boschma, 2021). This contradicts assumptions made in the MLP approach, where change is only seen to emerge in niches.

Overall, the scholarly debate on technological and industrial development draws on concepts of regional branching, which stresses the influence of technology relatedness on the diversification and specialisation of regions (Boschma et al., 2017; Santoalha and Boschma, 2021). Knowledge spillovers, induced by spatial proximity, play a crucial role in this process. Previous studies confirm

that innovation and industries develop mainly in those territories where related skills and capabilities, i.e. related variety, are available. (Trippl et al., 2020) show, however, that this does not happen automatically, but rather that opportunities need to be transformed, while (Corradini, 2019)) analogous to the embeddedness assumptions, points to the danger of regional lock-ins if the technology relatedness is too high.

Unrelated variety, on the other hand, stems from combining unconnected technologies and is regarded as a vital source of the transformation of unsustainable systems of production and consumption (Boschma et al., 2017). Spatial developments induced by unrelated variety are, however, the exception rather than the rule (Santoalha and Boschma, 2021) and usually of major importance in the early stages of technology emergence (Barbieri et al., 2020). Thus, both related and unrelated variety prove useful in describing industrial and technological development along pathways. What remains unclear, however, is how new, potentially disruptive pathways emerge that can contribute to sustainable development (Binz et al., 2016).

Consumers and market structures

While scientific studies on technological and industrial specialisation mainly focus on the supply side of innovation (technology push), the structure of (regional) markets, that is the environmental consciousness of actors, market conditions and the expected demand (demand pull), is another crucial determinant for innovation-based and transition processes (Horbach, 2008; Dewald and Truffer, 2012). Surprisingly, the demand and thus the diffusion side of innovation is, compared to other place-specific influences and spatial conditions, less the focus in both research traditions.

The geography of sustainability transitions field explicitly stresses the importance of end-users engaged in local market creation, where geographical proximity facilitates interactions between users and producers (Hansen and Coenen, 2015). The process of market formation is central for the development of technological innovation systems and the upscaling of transition processes. (Dewald and Truffer, 2012) show that local market formation are shaped by specific processes on the local level such as conducting experiments, building market segments, forming user groups or creating and providing legitimacy.

Since the early phases of market formation processes benefit from spatial proximity, the regional level is of crucial importance (Hansen and Coenen, 2015). Lead markets that drive global innovation diffusion accordingly emerge through the early adoption of later successful innovations. While the lead market concept originally referred to the national level, (Losacker and Liefner, 2020) have extended this to the regional level. The authors show for environmental innovation that regional lead markets gain competitive advantages in certain technologies or industries, constituted by regulatory, demand and technological advantages.

Environmental innovations that are key for the transformation of socio-technical systems are less market-driven than conventional types of innovation (Horbach, 2008). They not only suffer from market failures on the supply side such as under-investment in R&D but also face externalities in the diffusion phase, as they produce positive environmental outcomes to society, while the innovator bears the cost (Rennings, 2000; Losacker and Liefner, 2020). Regulatory frameworks and policy measures therefore play a particularly important role, as sustainable change requires addressing both market and transformational failures (Schot and Steinmueller, 2018).

Policies on innovation-based and transformative change

On the policy perspective, the recent years witnessed major changes regarding regional innovation approaches and support. Triggered by the need to define new modes of fostering regional development, aspects like endogenous regional development and innovation, proximity, institutions and globalisation / regionalisation were discussed since the 1980s, and a new focus on context-specific, "place-based" approaches appeared in the 2000s. This approach to regional development and cohesion targets context-specific (place-based) policy approaches, which take into consideration the local and regional strengths and weaknesses (instead of similar approaches implemented in all types of regions). Regional development policies consider that space and the spatial (cultural, social, institutional) context "matter" for inducing endogenous development. They explicitly build upon existing knowledge, values and social capital at a specific place (Barca, 2009; Barca et al., 2012). Innovation processes in a regions' core specialisations in this approach is a core priority, and it is one crucial policy intervention fields of European Cohesion policy and its implementation in Operational Programmes (see for instance Stahlecker and Koschatzky, 2010).

Regional Innovation Strategies for Smart Specialisation in European regions - which were introduced as conditionality of the 2014-2020 regional policy period of the European Union - require the implementation of context-specific innovation strategies across European regions. Smart specialisation refers to identifying strategic priorities based on region-specific characteristics through a process of broad stakeholder involvement. This process aims at including the wide knowledge base available in the region among political decision-makers, scientists, business actors, intermediaries and the broader public (Foray et al., 2009, 2011). Smart specialisation is thus place and context specific, rooted in the rationale to strengthen innovation as means to foster the development and competitiveness of a territory. It assumes an integrative role between policies and has connections with policies towards tackling grand challenges, R&D support and innovation policy, cohesion policy, industrial policy and value chains and networking (Foray et al., 2018).

Supporting innovation as driver for regional economies and as solution seeker for large societal problems needs reflections about how to address large-scale challenges that affect our societies. This requires new and even broader conceptual approaches and concepts - conceptions that go beyond a focus on (individual) technologies, on fixing market failures, on economic goals and technological solutions, etc. It is a vision that refers to finding ways of solving complex societal challenges, thus involving multiple stakeholders, societal interactions and behaviours, different policy fields, and regulations, in addition to science, technology and innovation. It involves a new way of thinking for addressing complex challenges (Foray et al., 2018; Mazzucato, 2018; Hekkert et al., 2020). In this context, Hekkert et al., 2020: 76) speak of "'transformative innovation policy" and propose Mission-oriented Innovation Systems (MIS) as new systems framework. This framework defines societal missions as goal of the development and diffusion of innovation - replacing the former objectives of economic development, growth and competitiveness. MIS develop around missions that are "translating" societal challenges, are thus less spatially bounded than regional innovation systems. The overall aim to address challenges and to solve problems inherently leads to a directional and normative approach (Hekkert et al., 2020).

3 Relevance of an extended RIS understanding for sustainability transitions

The last decade has not only seen a formation of new research streams, such as the geography of sustainability transitions, but also the expansion of existing concepts and theories in innovation studies. This expansion is reflected not least in a broadening understanding of RIS that provides direct links to transition studies. However, these reflections have so far been insufficiently taken up and linked to sectoral understandings as proclaimed in transitions research. We believe that an integrated view of the different ideas, helps to identify complementarities and policy implications and allows for a more holistic view on subnational innovation and transition processes.

With regard to an extended heuristic of the regional innovation system (Warnke et al., 2016), several aspects have to be considered:

- socio-cultural dimension and proximity
- broader view on regional innovation activities and actor constellations
- experimentation and related infrastructures
- innovation supply and demand

Socio-cultural dimension and proximity

As already mentioned in section 2.3, actor constellations are an important place-specific determinant influencing innovation and sustainability transitions in regions. With regard to actors and their socio-cultural impact on innovation, two forms of capital shape and influence actor constellations: social and relational capital. Social capital comprises a collective (Bourdieu, 1979) and an individualistic perspective (Coleman, 1988), which are both relevant in innovation systems. An actor, be it a single person, a group of persons or organisations (firms, intermediaries etc.), is usually part of the systemic and interactive character of innovation systems. Thus social capital "…consists of the stock of active connections among people: the trust, mutual understanding, and shared values and behaviours that bind members of human networks and communities and make cooperative action possible" (Cohen and Prusak, 2001). Besides connections, also their content is relevant. The content is composed of obligations and expectations, social norms and also channels of information (Coleman, 1988). In contrast to social capital, which exists as unintended by-product of activities in a spatial entity, relational capital emphasizes the importance of interactions, i.e. all relationships between different actors that result in particular from cooperation activities and a sense of belonging (Capello and Faggian, 2005). Relational capital implies a capability for interaction and collective learning and is therefore an important input and outcome of innovative activities (Maskell, 2000; Capello and Faggian, 2005).

A link exists between social and relational capital on the one hand and social proximity and embeddedness on the other. Proximity is an important factor in innovation processes, especially regarding the exchange of tacit, locally-bound knowledge and expertise (Carrincazeaux and Coris, 2011). Among the five different forms of proximity (cognitive, organizational, social, institutional, geographical), social proximity reflects "…economic relations (that) are … embedded in a social context" (Boschma, 2005). At the same time, embeddedness encompasses multiple manifestations, from embeddedness in markets and political systems, the social and technological embeddedness and ultimately framed by temporal and spatial embeddedness (Halinen and Törnross, 1998).

These embeddedness dimensions together with the notion of social and relational capital define the context of innovation activities and the transition of socio-technical systems at the regional

level. Territorial, cultural and social contextuality result from the endowment of regions with institutions, organisations and networks which all influence the generation and diffusion of innovations in specific ways (Doloreux and Parto, 2005). The localized character of tacit, non-codified knowledge (Polanyi, 1997) makes it necessary for actors, that need to get access to this knowledge, to closely locate to relevant knowledge sources (for example people, peer groups, research labs or creative enterprises).

To date, the aforementioned topics are addressed to varying degrees in transition research. A large number of studies emphasize the importance of actor networks, relational capital and the socio-institutional embeddedness, both within and beyond specific territories (Truffer and Coenen, 2012; Dewald and Fromhold-Eisebith, 2015; Binz et al., 2020). However, the consequences thereof have not yet been considered in more detail. Given the sectoral perspective on transformation dynamics, transition research has been rather silent on the importance of proximity, especially geographical proximity. Interestingly, the conceptualization of niches as protected spaces often presupposes a somewhat local context (Sengers and Raven, 2015), as does the market formation function inherent in the TIS framework, where proximity to end users is essential (Dewald and Truffer, 2012). The reference to findings from research on the geography of innovations is, however, still limited. Hence, the RIS perspective seems helpful in understanding the importance of knowledge spillovers and the regional dimension -despite trends such as digitalization- for the emergence and diffusion of system changing innovation (Gibbs and O'Neill, 2017; Corradini, 2019; Losacker and Liefner, 2020). This explicitly does not exclude the possibility of also considering connections to the national or supranational level. Yet, the relationship of regional determinants on the one hand and sectoral dependencies on the other requires further research.

Broader view on regional innovation activities and actor constellations

A broader view on innovation, e.g. social, service, user and business model innovation, involves a broad range of actors and activities that develop creative and innovative ideas as well as inputs for innovation and their implementation. Furthermore, the facets of innovation development and diffusion becoming much more diverse, with crowd funding, non-R&D intensive actors and venture philanthropy gaining increasing importance (Som, 2012; Warnke et al., 2016).

Although transitions research explicitly emphasizes the diversity of actors and different types of innovation, it tends to do so from a more sectoral and multi-scalar perspective (Binz et al., 2020). However, since regions witness different and place-specific innovation processes and performances, territorial challenges and strategic goal setting, for example by regional governments, is essential. Public actions may include the design of relevant regulatory framework conditions, the introduction of administrative process innovation or favouring innovative public procurement (Jakobsen et al., 2021). From this follows that regions are important places to create innovations, to find innovative solutions for responding to societal challenges and to become lead markets for environmental innovation (Losacker and Liefner, 2020). At the same time, regions are also places for implementing innovation developed outside the region as a response to overarching problems (Tödtling et al., 2020).

Understanding a regional innovation system as an interplay between the various innovation creating, supporting and mediating actors and activities helps to trace some of the aforementioned arguments. Indeed, also transition studies acknowledge the importance of governance and actors beyond the triple helix of business, politics and science (Boschma et al., 2017; Kern et al., 2019; Köhler et al., 2019), but the research focus is, however, less on its regional imprints. While system-changing technologies and innovation are typically multi-scalar by nature, regions can still have the responsibility and ability to bring innovation-related targets into practice and favour innovative

approaches in their territories. This holds for regions in different political systems, albeit to varying degrees (Cooke, 2011).

In addition to defining rules, to direct support and incentivising innovative actors, subnational entities can use their power and responsibility to include the broad range of innovating and innovation-supporting actors into strategy-building and roadmapping, through implementing and moderating participative approaches. Directly linked to the importance of vision-building for policy development stressed in transition studies (Weber and Rohracher, 2012; Grillitsch and Hansen, 2019), representatives of different interest groups not only help to better moderate, coordinate and anchor bottom-up and top-down views in the whole regional system, but it may be a vehicle to enhance acceptance and readiness to support the jointly taken decisions.

Considering local and regional mentalities and conditions can also help to define joint values for undertaking research and innovation. At the core of this reflection is the fact that innovation is expected to contribute to human welfare - a notion that increasingly goes beyond economic goals like competitiveness and jobs and includes desirable goals for the (regional) society (Fitjar et al., 2019). The basic idea is that research and innovation activities should be conducted in a responsible way in order to contribute to social welfare, based on a joint understanding of what this means for the society. This can cover addressing specific challenges such as the need for transforming to a resource-friendly production and consumption, to include people, actors and activities with diverse characteristics and talents into the socio-economic process, to build exchange and discussion processes within (and beyond) the community, etc. Although the approach of Responsible Research and Innovation was not primarily developed for the regional level, it may prove highly relevant on this sub-national scale, as here, the very specific conditions, endowments, values and challenges may be addressed in a tailored way (Uyarra et al., 2019).

Regions - better: the sum of regional actors - may therefore be attributed more active roles in innovation, including innovations that contribute to transformative change. This more active role results from responsibilities at regional level, a certain "regulatory leeway" and thus the power to include transformation and innovation needs, and also the social proximity to citizens on the one hand and to research, education and business actors on the other hand (Lambooy and Boschma, 2001; Dewald and Fromhold-Eisebith, 2015; Isaksen and Trippl, 2017). Research on regional innovation and the geography of innovation can provide valid starting points to address these issues.

Experimentation and related infrastructure

Developing innovation in an experimental mode can be a promising approach for supporting collaborative innovation. Generally, experimentation refers to real-life experiments which include a wide range of participants that jointly develop, test, pilot, and assess new approaches. Experiments must not necessarily include scientific organisations. As such, experimentation also refers to shaping processes that involve different societal actors and organisations and target joint learning processes as well as accepted and robust answers to real-world challenges (Schäpke et al., 2017; Partnerschaft Deutschland et al., 2020). Experimentation comprises several related concepts such as Living Labs, Urban and Campus Labs, real-world laboratories, sustainability experiments, real-life experiments, regulatory sandboxes or transition experiments (Schneidewind, 2014; Schäpke et al., 2017). However, given the diversity of definitions and semantic ambiguities, these concepts are often not clearly distinguished from one another and sometimes used synonymously.

The idea of (local) spaces for experimentation in the extended RIS heuristics is directly linked to transition research (Longhurst, 2015; Strambach, 2017). In line with the multi-scalar understanding of transitions, sustainability experiments can also connect capabilities and resources across territories (Wieczorek et al., 2015). For example, transition arenas, which are mentioned in the transition management framework, try to network all relevant groups of actors (science, business, civil society,

and politics) and develop cooperation. In the context of transitions towards environmental sustainability, experimental spaces provide the context for developing transformation processes and thus gather experience in the field of those large-scale changes through their specific approach and infrastructure and their orientation towards flexibility, societal learning, as well as their experimental-reflexive work mode (Nevens et al., 2013; Beecroft et al., 2018).

A specific characteristic of experimental approaches as an answer to new transformative (systemic) shifts is the complexity stemming from the necessity to consider new technological developments in connection with institutional developments in structures and arrangements (Boschma et al., 2017). The underlying context - often place-specific - conditions may support those evolutions and reduce uncertainties. Experimentation in this context may also refer to new supporting policies. Coenen et al. (2012) argue for a careful consideration of the very location-specific conditions which "... in general differ from one location to another and may be the result of each region or nation's history, economic structure, cultural preferences and so on". Experiments towards new innovative solutions may be considered as niches which work "... as 'incubation spaces' dominated by uncertainty and experimental disorder" (Coenen et al., 2012: 971) and provide the environment for learning both in a technological and an application-oriented sense. As such, experimentation in regional innovation systems might induce wider environmentally friendly pathways, when these solutions are successfully, shielded, nurtured and empowered (Boschma et al., 2017; Köhler et al., 2019).

At first sight, territories with high densities of research organisations, (innovative) firms, political decision makers, intermediaries and citizens may deliver a highly suitable frame for experimentation. However, as for example Lowe and Vinodrai (2020) and Partnerschaft Deutschland et al. (2020) show, experimentation-oriented approaches can deliver important options for different types of regions. The multi-faceted and reflexive character of experimental approaches can thus help to develop and deliver new policy approaches that target innovation in transformational contexts, based on a broad understanding of innovation and broad inclusion of related actors. In contrast, an exclusive focus on technological innovation may be too narrow and less well suited to address current overarching societal challenges. Experimental approaches can thus be considered as innovative transparent and interaction-based approaches (Schaffers and Santoro, 2010).

Innovation supply and demand

In the history of innovation research, two positions exist on how innovations can arise. One position has been formulated by (Schumpeter, 1933 [1911]), who analyses the innovation process from a behavioural point of view and places the daring pioneer entrepreneur at the centre of his investigations. The pioneer entrepreneur implements new combinations and products and thus creates new markets or new product characteristics from which he can achieve a monopoly return. Thus, the Schumpeterian approach is supply-oriented, as the supply determines demand and thus innovation activities. Schmookler (1966) takes a different position. Accordingly, innovation activities and demand behaviour are closely related. Rising incomes, capital accumulation and technological progress lead to changes in demand and thus to corresponding innovation activities that serve demand.

The innovation system concept, although it stresses the importance of intermediate and finale demand (Lundvall, 1992; Nelson, 1993), was initially focussing on the supply side of innovation. At the core of the concept are the various innovation actors (firms, research institutions, intermediary organizations), the innovation-relevant infrastructure, the political system, and the national and international framework conditions (e.g., markets, incentive systems) (Kuhlmann and Arnold, 2001). However, recent work on the extended RIS understanding decidedly also include the demand side of innovation, with Warnke et al. (2016, p. 33) stating: “Innovation supply and demand....can be fulfilled by a wide range of diverse actors form civil society, business and the public sector who are

immediately engaged into the innovation process through generating, requesting or embedding innovations."

Transitions research has traditionally had a stronger demand focus. It is less interested in how and under which (spatial) conditions potentially system-changing innovations come about (Strambach and Pflitsch, 2020; van den Berge et al., 2020), but rather how they can be accelerated and scaled-up in order to contribute to widespread socio-technical transitions (Coenen et al., 2012; Meelen et al., 2019). Accordingly, topics such as stability and change, as well as disagreement between the various actors involved, are central research topics (Köhler et al., 2019). In addition, there is the directionality of innovation policies, which increasingly support the generation and diffusion of innovations that target societal challenges such as climate change and biodiversity loss (Edler and Boon, 2018).

From a geographic perspective, the combination of supply and demand of innovations has several implications. First, research on the geography of innovations and transitions can cross-fertilize by looking at both the regional conditions fruitful for the emergence of (transformational) innovations and potentially relevant demand structures at the sector level (Boschma et al., 2017). Second, the demand articulation failure in transformative change results in limited market uptake due to deficits about the knowledge of user needs (Weber and Rohracher, 2012). A regional innovation perspective helps to overcome this failure, as it can be assumed that user needs can be better anticipated through the various forms of proximity and possibilities for experimentation (see above). In addition, regional administrations can implement certain demand incentives, i.e. public procurement, which explicitly address societal challenges. Third, regions follow specific development paths, mostly building on existing technological capabilities (see chapter 2.3), whereas unrelated path emergence tends to be the exception (Boschma et al., 2017). Accordingly, it makes less sense for all regions to follow the same paths in producing similar (environmental) innovation, especially since this would run counter to the idea of smart specialization. Rather, regions should support the adaption (diffusion) of environmentally friendly solutions, both developed within and outside the region to achieve sustainability targets. The dominant supply-side focus should thus be increasingly complemented by demand-side orientation at the regional level in order to achieve economic and environmental advantages (Tödtling et al., 2020; Hansmeier and Losacker, 2021).

4 Conclusion and reflections on policy

With the integration of geographical perspectives in transitions research and an expanded understanding of innovation systems being dealt with in the geography of innovation research field in recent years, topics such as normativity, new groups of actors, different modes and forms of innovation, and the demand side of innovation and transformation processes have become increasingly important. This is accompanied by changes in policy and governance approaches. At the same time, manifold studies show that the regional level is of particular relevance, regardless of whether regions are understood and conceptualized in a more relational (geography of transitions) or territorial (geography of innovations) sense. This is due to the fact that innovations and transitions are strongly influenced by place or region-specific factors such as institutional, technological and organizational conditions as well as actor constellations. In other words, innovations and transitions manifest themselves spatially, explaining the diversity and inequality in spatial development processes (Hansen and Coenen, 2015; Feldman, 2016). This is also the background to the discussion in innovation research about structurally weak regions in recent decades (Koschatzky and Stahlecker, 2019; Tödtling et al., 2020). Surprisingly, however, there is a lack of empirical evidence on the extent to which different types of regions face opportunities or challenges for transforming socio-technical systems. In essence, how structural and systemic change are interrelated requires more in-depth research, as mostly conceptual considerations have been made so far (e.g. Grillitsch and Hansen, 2019).

The differences between the two fields of research lie mainly in their different research objects and geographical understanding. On the one hand, there is the rather sectoral view in transitions research and the associated multi-scalar understanding of transition pathways. Although distant, cross-border forces play a decisive role, place-specific and spatial conditions are likewise important (Binz et al., 2020). On the other hand, the geography of innovation field usually has a spatial perspective, in the sense that innovation activities are studied within or between specific regions or countries. In addition to the systemic innovation understanding, this research strand follows a more evolutionary logic, where existing spatial characteristics, for example the technological and industrial specialization, determine future development paths of territories. However, the research focuses rather on the supply side and thus the generation of innovation (Boschma et al., 2017; Gibbs and O'Neill, 2017; Losacker and Liefner, 2020). Recently, the diffusion of innovation –i.e. demand side orientation- in space is increasingly being analysed and emphasised. This ties directly to transitions research, which traditionally tends to focus on the user or demand side. Accordingly, the diffusion of more sustainable processes, products and practices are of particular research interest. This is also reflected in the main transition-focused frameworks, such as MLP and TIS, with particular attention being paid to processes of destabilization and path breaking of potentially non-sustainable industrial and technological structures (Strambach and Pflitsch, 2020; Trippl et al., 2020).

Reflections on policy

The increasing focus on societal and environmental challenges leads to changes in (innovation) policies. The evident political paradigm shift is due to the fact that sustainability is a normative concept and thus object to contestation, limited consensus and target conflicts about necessary innovation processes and transition pathways. Accordingly, policies aimed at transformative change need to address these directionality failures through various policy instruments such as regulations, standards, taxes or subsidies (Schot and Steinmueller, 2018; Kern et al., 2019; Köhler et al., 2019). The need for regulatory measures is also rooted in the so-called double-externality problem. According to this, environmental innovation are not only affected by market failures in the develop-

ment phase, such as knowledge spillover, but also in the diffusion phase, in which market participants benefit from positive effects through decreasing environmental impacts without bearing costs. Hence, the incentive to invest in innovation for transformative change is rather low (Rennings, 2000). In addition, Weber and Rohracher (2012) see the rationale for transformative innovation policies in three other forms of failures: demand articulation failure (under-investment in market uptake of innovation), policy coordination failure (lack of coherence between spatial, sectoral and technological institutions) and reflexivity failure (insufficient ability of system monitoring).

Transformative innovation policies are challenging given the aforementioned failures, which result from the complexity of socio-technical change and unforeseeable future developments. Kern et al. (2019) therefore argue for extended policy-mixes including innovation strategies, characteristics of policy mixes such as coherence and comprehensiveness as well as implementation processes. However, new policies must be guided by existing policies and find ways forward, creating productive overlays of old and new policies (Schot and Steinmueller, 2018). Policies are also path dependent and only change slowly. More recently, mission-oriented approaches are increasingly being integrated into established funding programs, such as the German government's high-tech strategy or the EU's Horizon Europe innovation programme for the years 2021-2027. Given the heterogeneity of societal challenges, mission-oriented innovation policies (cf. chapter 2.3) need to be implemented and designed against the background of mission-specific properties (Hekkert et al., 2020; Bugge et al., 2021).

Transformative change has also implications for governance approaches. The transitions literature discusses three different governance approaches, which are seen as particularly relevant for the promotion of transitions. What all approaches have in common is that they take into account multi-actor structures and normative demands: The transition management framework is a descriptive lens to understand and explain the impact of governance processes on past transitions through retrospective case studies (Markard et al., 2012). Reflexive governance looks at how interaction patterns between different actors in the context of persistent problems and transitional dynamics do (not) lead to learning, behavioural change, and ultimately systemic change (Loorbach et al., 2017). Although it resonates with the reflexivity failure mentioned above, to our knowledge, no research has been done so far in combining reflexive governance with regional transitions. Since reflective governance is an important component of systemic transitions (Voß and Bornemann, 2011) a spatial perspective in this regard requires further research. Strategic niche management proposes the idea of niches as incubation spaces for disruptive innovations that are in practice often facilitated through government interventions. The core idea is that through learning, visioning and networking, processes of coevolution and novelties can be stimulated. In this way, governments manage regime-shifts by providing protected spaces, which are the basis for the development of new technologies (Longhurst, 2015).

Against the background of pressing grand societal challenges and the major paradigm shifts in innovation policies, the role and scope of regions in policy formation remains open to further debate. However, given the place-specific determinants, there is concensus in various research streams that complex policy-mixes are needed that are sensitive to the industrial and transformative pathways of specific regions (Schot and Steinmueller, 2018; Jakobsen et al., 2021). Consequently, regional innovation policies do not persue a one-size fits all approach (Tödtling and Trippl, 2005).

Ideally, policies are being implemented that consider the region-specific environmenal and industrial challenges. These policies can address both the generation side of innovation, usually technology-push instruments such as R&D spending, and the demand side. Examples of the latter include public procurement, support of user innovations and market regulations (Tödtling et al., 2020). Although policies adressing innovation diffusion are mainly considered at the national or supranational level (policies for regions) such as feed-in tariff, they have recently also been discussed for

the regional context (policies in regions). Especially in order to achieve overarching system transformations, regions might develop appropriate innovation diffusion policies These should be designed with regard to the region's technological and industrial specialisations in order to also create positive impacts on the supply side (Hansmeier and Losacker, 2021). The formulation and implementation of mission-oriented policies, on the other hand, is largely confined to higher spatial levels, as they address broader societal challenges (Mazzucato, 2018; Hekkert et al., 2020).

Clarifying the appropriate policy interventions and adequate spatial level for implementation is not always straightforward but relevant to the governance of innovation processes, i.e. for political responsibilities as well as for actor constellations and their location in space. In terms of innovation policy, these reflections could lead to define strategic goals around (region-specific) missions, hence to formulate mission-oriented innovation policies that take into account higher-level challenges, "translate" those to regional needs and conditions, and address them with regional resources and capacities. The prerequisite is that the RIS has openness, clarity about sustainability goals and the possibility to involve new groups of actors (Uyarra et al., 2019; Tödtling et al., 2021). So far, however, there is few empirical evidence on mission-oriented innovation policy at the regional level, so learning and best practice is rarely available. While the identification and formulation of relevant missions through the specific knowledge of regional actors could be promising, it is precisely the interplay between regional path developments on the one hand (as e.g. stressed in Smart Specialisation Strategies) and potentially disruptive developments through missions that has not yet been sufficiently clarified. Against this background, future research should ask how an adequate balancing of measures at the state level (such as the formulation of missions) and their implementation at the regional level (e.g. through experimentation) is possible.

In general, regions face different challenges on the production and application side, such as industrial inertia leading to lock-ins or poor absorptive capacity, in creating sustainable transition pathways. Embedded in multi-scalar, multi-actor and multi-sectoral dependencies, regions have to take different policy actions (Tödtling et al., 2020). With the extended RIS understanding and a broader problem understanding in transition studies, policy instruments might range from experimental spaces to R&D funding and a combination of instruments. Structural failures and transformative failures need to be likewise addressed, as regions not only competing with each other but also increasingly have to take non-market aspects into account (Coenen et al., 2015). Building on these conceptual considerations, more research is needed that considers structural and systemic change together, deriving policy implications to better address spatial inequalities.

5 References

Barbieri, N., Perruchas, F., Consoli, D., 2020. Specialization, Diversification, and Environmental Technology Life Cycle. Economic Geography 96, 161–181.

Barca, F., 2009. An agenda for a reformed cohesion Policy. A place-based approach to meeting European Union challenges and expectations: Independent Report prepard at the request of Danuta Hübner, Commissioner for Regional Policy. https://ec.europa.eu/regional_policy/archive/policy/future/pdf/report_barca_v0306.pdf. Accessed 7 July 2021.

Barca, F., McCann, P., Rodríguez-Pose, A., 2012. The case for regional development intervention: Place-based versus place-neutral approaches. Journal of Regional Science 52, 134–153.

Bathelt, H., Glückler, J., 2003. Toward a relational economic geography. Journal of Economic Geography, 117–144.

Beecroft, R., Trenks, H., Rhodius, R., Benighaus, C., Parodi, O., 2018. Reallabore als Rahmen transformativer und transdisziplinärer Forschung: Ziele und Designprinzipien. In: Defila, R., Di Giulio, A. (Eds.) Transdisziplinär und transformativ forschen. Eine Methodensammlung. Springer VS, Wiesbaden, Germany, pp. 75–100.

Binz, C., Coenen, L., Murphy, J.T., Truffer, B., 2020. Geographies of transition—From topical concerns to theoretical engagement: A comment on the transitions research agenda. Environmental Innovation and Societal Transitions 34, 1–3.

Binz, C., Truffer, B., 2017. Global Innovation Systems—A conceptual framework for innovation dynamics in transnational contexts. Research Policy 46, 1284–1298.

Binz, C., Truffer, B., Coenen, L., 2014. Why space matters in technological innovation systems—Mapping global knowledge dynamics of membrane bioreactor technology. Research Policy 43, 138–155.

Binz, C., Truffer, B., Coenen, L., 2016. Path Creation as a Process of Resource Alignment and Anchoring: Industry Formation for On-Site Water Recycling in Beijing. Economic Geography 92, 172–200.

Boschma, R., 2014. Towards an evolutionary perspetive on regional resilience. Working Paper, Lund, 30 pp.

Boschma, R., Coenen, L., Frenken, K., Truffer, B., 2017. Towards a theory of regional diversification: combining insights from Evolutionary Economic Geography and Transition Studies. Regional Studies 51, 31–45.

Boschma, R.A., 2005. Proximity and Innovation: A Critical Assessment. Regional Studies 39, 61–74.

Bourdieu, P., 1979. La distinction: critique sociale du jugement. Les Éd. de Minuit, Paris.

Bridge, G., Bouzarovski, S., Bradshaw, M., Eyre, N., 2013. Geographies of energy transition: Space, place and the low-carbon economy. Energy Policy 53, 331–340.

Bugge, M.M., Andersen, A.D., Steen, M., 2021. The role of regional innovation systems in mission-oriented innovation policy: exploring the problem-solution space in electrification of maritime transport. European Planning Studies, 1–22.

Cainelli, G., Mazzanti, M., Montresor, S., 2012. Environmental Innovations, Local Networks and Internationalization. Industry and Innovation 19, 697–734.

Capello, R., Faggian, A., 2005. Collective Learning and Relational Capital in Local Innovation Processes. Regional Studies 39, 75–87.

Carrincazeaux, C., Coris, M., 2011. Proximity and innovation. In: Cooke, P., Asheim, B., Boschma, R. Martin, R., Schwartz, D., Tödtling, F. (Eds.) Handbook of Regional Innovation and Growth. Edward Elgar Publishing, Cheltenham, Northampton, pp. 269–281.

Coenen, L., Benneworth, P., Truffer, B., 2012. Toward a spatial perspective on sustainability transitions. Research Policy 41, 968–979.

Coenen, L., Moodysson, J., Martin, H., 2015. Path Renewal in Old Industrial Regions: Possibilities and Limitations for Regional Innovation Policy. Regional Studies 49, 850–865.

Coenen, L., Truffer, B., 2012. Places and Spaces of Sustainability Transitions: Geographical Contributions to an Emerging Research and Policy Field. European Planning Studies 20, 367–374.

Cohen, D., Prusak, L., 2001. In Good Company. How Social Capital Makes Organizations Work. Harvard Business School Press, Boston.

Coleman, J.S., 1988. Social capital in the creation of human capital. American Journal of Sociology 94 (Supplement), 95–120.

Cooke, P., 2011. Transition regions: Regional–national eco-innovation systems and strategies. Progress in Planning 76, 105–146.

Cooke, P., Asheim, B., Boschma, R. Martin, R., Schwartz, D., Tödtling, F. (Eds.), 2011. Handbook of Regional Innovation and Growth. Edward Elgar Publishing, Cheltenham, Northampton.

Cooke, P., Gomez Uranga, M., Etxebarria, G., 1997. Regional innovation systems: Institutional and organisational dimensions. Research Policy 26, 475–491.

Corradini, C., 2019. Location determinants of green technological entry: evidence from European regions. Small Bus Econ 52, 845–858.

Dewald, U., Fromhold-Eisebith, M., 2015. Trajectories of sustainability transitions in scale-transcending innovation systems: The case of photovoltaics. Environmental Innovation and Societal Transitions 17, 110–125.

Dewald, U., Truffer, B., 2012. The Local Sources of Market Formation: Explaining Regional Growth Differentials in German Photovoltaic Markets. European Planning Studies 20, 397–420.

Doloreux, D., Parto, S., 2005. Regional innovation systems: Current discourse and unresolved issues. Technoloy in Society 27, 133–153.

Edler, J., Boon, W.P., 2018. 'The next generation of innovation policy: Directionality and the role of demand-oriented instruments'—Introduction to the special section. Science and Public Policy 45, 433–434.

Eurostat, 2015. Regions in the European Union. Nomenclature of territorial units for statistics NUTS 2013/EU-28: Eurostat Manuals and guidelines. Publications Office of the European Union, Luxembourg. https://ec.europa.eu/eurostat/documents/3859598/6948381/KS-GQ-14-006-EN-N.pdf/b9ba3339-b121-4775-9991-d88e807628e3?t=1444229719000. Accessed 6 July 2021.

Feldman, M.P., 2016. Geography of Innovation. In: Augier, M., Teece, D.J. (Eds.) The Palgrave Encyclopedia of Strategic Management. Palgrave Macmillan UK, London, pp. 1–6.

Fitjar, R.D., Benneworth, P., Asheim, B.T., 2019. Towards regional responsible research and innovation? Integrating RRI and RIS3 in European innovation policy. Science and Public Policy 46, 772–783.

Foray, D., David, P.A., Hall, B., 2009. Smart Specialisation - The Concept. Knowledge Economists Policy Brief.

Foray, D., David, P.A., Hall, B., 2011. Smart specialization. From academic idea to political instrument, the surprising career of a concept and the difficulties involved in its implementation. MTEI Working Paper, Lausanne.

Foray, D., Morgan, K., Radosevic, S., 2018. The Role of Smart Specialisation in the EU Research and Innovation Policy Landscape. https://ec.europa.eu/regional_policy/sources/docgener/brochure/smart/role_smartspecialisation_ri.pdf. Accessed 14 November 2020.

Fougy, F., Amisse, S., 2016. A matter of trust and time: back to the adoption of embeddedness in economic geography (1985-2015). Document de travail du GRANEM 2016-02-048. Université Angers, Angers.

Geels, F.W., 2004. From sectoral systems of innovation to socio-technical systems. Research Policy 33, 897–920.

Gibbs, D., O'Neill, K., 2017. Future green economies and regional development: a research agenda. Regional Studies 51, 161–173.

Granovetter, M., 1985. Economic action and social structure: the problem of embeddedness. American Journal of Sociology 91, 481–510.

Grillitsch, M., Hansen, T., 2019. Green industry development in different types of regions. European Planning Studies 27, 2163–2183.

Grillitsch, M., Sotarauta, M., 2020. Trinity of change agency, regional development paths and opportunity spaces. Progress in Human Geography 44, 704–723.

Halinen, A., Törnross, J.-A., 1998. The role of Embeddedness in the evolution of Business Networks. Scandinavian Journal of Management 14, 187–205.

Hansen, T., Coenen, L., 2015. The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field. Environmental Innovation and Societal Transitions 17, 92–109.

Hansmeier, H., Losacker, S., 2021. The combination of supply and demand-side eco-innovation policies for regional sustainability transitions. Regions eZine. https://doi.org/10.1080/13673882.2021.00001088.

Heidenreich, M., Koschatzky, K., 2011. Regional innovation governance. In: Cooke, P., Asheim, B., Boschma, R. Martin, R., Schwartz, D., Tödtling, F. (Eds.) Handbook of Regional Innovation and Growth. Edward Elgar Publishing, Cheltenham, Northampton, pp. 534–546.

Hekkert, M.P., Janssen, M.J., Wesseling, J.H., Negro, S.O., 2020. Mission-oriented innovation systems. Environmental Innovation and Societal Transitions 34, 76–79.

Hess, M., 2004. 'Spatial' relationships? Towards a reconceptualization of embeddedness. Progress in Human Geography 28, 165–186.

Horbach, J., 2008. Determinants of environmental innovation—New evidence from German panel data sources. Research Policy 37, 163–173.

Isaksen, A., Trippl, M., 2017. Innovation in space: the mosaic of regional innovation patterns. Oxford Review of Economic Policy 33, 122–140.

Jakobsen, S.-E., Uyarra, E., Njøs, R., Fløysand, A., 2021. Policy action for green restructuring in specialized industrial regions. European Urban and Regional Studies, 096977642110491.

Jones, A., 2008. Beyond embeddedness: economic practices and the invisible dimensions of transnational business activity. Progress in Human Geography 32, 71–88.

Kern, F., Rogge, K.S., Howlett, M., 2019. Policy mixes for sustainability transitions: New approaches and insights through bridging innovation and policy studies. Research Policy 48, 103832.

Köhler, J., Geels, F.W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M.S., Nykvist, B., Pel, B., Raven, R., Rohracher, H., Sandén, B., Schot, J., Sovacool, B., Turnheim, B., Welch, D., Wells, P., 2019. An agenda for sustainability transitions research: State of the art and future directions. Environmental Innovation and Societal Transitions 31, 1–32.

Koschatzky, K., Stahlecker, T., 2019. Innovation-based regional change - An introduction. In: Koschatzky, K., Stahlecker, T. (Ed.) Innovation-based Regional Change in Europe: Chances, Risks and Policy Implications introduction. Fraunhofer Verlag, Stuttgart, pp. 1–5.

Kuhlmann, S., Arnold, E., 2001. RCN in the Norwegian Research and Innovation Sysstem. Background Report No. 12 in the Evaluation of the Research Council of Norway. Fraunhofer ISI, Technopolis, Karlsruhe, Brighton.

Lambooy, J.G., Boschma, R., 2001. Evolutionary economics and regional policy. The Annals of Regional Science, 113–131.

Levin-Keitel, M., Mölders, T., Othengrafen, F., Ibendorf, J., 2018. Sustainability Transitions and the Spatial Interface: Developing Conceptual Perspectives. Sustainability 10, 1880.

Longhurst, N., 2015. Towards an "alternative" geography of innovation: Alternative milieu, socio-cognitive protection and sustainability experimentation. Environmental Innovation and Societal Transitions 17, 183–198.

Loorbach, D., Frantzeskaki, N., Avelino, F., 2017. Sustainability Transitions Research: Transforming Science and Practice for Societal Change. Annu. Rev. Environ. Resour. 42, 599–626.

Losacker, S., Liefner, I., 2020. Regional lead markets for environmental innovation. Environmental Innovation and Societal Transitions 37, 120–139.

Lowe, N., Vinodrai, T., 2020. The Maker-Manufacturing Nexus as a Place-Connecting Strategy: Implications for Regions 'Left Behind'. Economic Geography 14, 1–21.

Lundvall, B.-Å. (Ed.), 1992. National Systems of Innovation: Towards a Theory of Inno-vation and Interactive Learning. Pinter Publishers, London.

MacKinnon, D., Dawley, S., Pike, A., 2019. Rethinking Path Creation: A Geographical Political Economy Approach. Economic Geography 95, 113–135.

Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: An emerging field of research and its prospects. Research Policy 41, 955–967.

Markard, J., Truffer, B., 2008a. Actor-oriented analysis of innovation systems: exploring micro–meso level linkages in the case of stationary fuel cells. Technology Analysis & Strategic Management 20.

Markard, J., Truffer, B., 2008b. Technological innovation systems and the multi-level perspective: Towards an integrated framework. Research Policy 37, 596–615.

Martin, R., Sunley, P., 2006. Path dependence and regional economic evolution. Journal of Economic Geography 6, 395–437.

Maskell, P., 2000. Social capital and competitiveness. In: Baron, S., Field, J., Schuller, T. (Eds.) Social capital. Critical perspectives. Oxford University Press, Oxford, pp. 111–123.

Mazzucato, M., 2018. Mission-oriented innovation policies: Challenges and opportunities. Industrial and Corporate Change 27, 803–815.

Meelen, T., Frenken, K., Hobrink, S., 2019. Weak spots for car-sharing in The Netherlands? The geography of socio-technical regimes and the adoption of niche innovations. Energy Research & Social Science 52, 132–143.

Moulaert, F., Sekia, F., 2003. Territorial Innovation Models: A Critical Survey. Regional Studies 37, 289–302.

Nelson, R.R. (Ed.), 1993. National Innovation Systems. A Comparative Analysis. Oxford University Press, New York.

Nevens, F., Frantzeskaki, N., Gorissen, L., Loorbach, D., 2013. Urban Transition Labs: co-creating transformative action for sustainable cities. Journal of Cleaner Production 50, 111–122.

Partnerschaft Deutschland, Fraunhofer ISI, in Kooperation mit Lorenz-von-Stein-Institut für Verwaltungswissenschaften, 2020. Neue Ansätze der Innovationsförderung in Regionen des Wandels: Bericht.

Polanyi, K., 1957. The economy as instituted process. In: Polanyi, K., Arensberg, C.M, Pearson, H.W. (Ed.) Trade and market in the early empires. The Free Pres, Glencoe, pp. 243–270.

Polanyi, M., 1997. The Tacit Dimension. In: Prusak, L. (Ed.) Knowledge in Organizations. Resources for the knowledge-based economy. Butterworth-Heinemann, Boston, Oxford, Johannesburg, pp. 135–146.

Radinger-Peer, V., Pflitsch, G., 2017. The role of higher education institutions in regional transition paths towards sustainability. Rev Reg Res 37, 161–187.

Rennings, K., 2000. Redefining innovation — eco-innovation research and the contribution from ecological economics. Ecological Economics 32, 319–332.

Rohe, S., 2020. The regional facet of a global innovation system: Exploring the spatiality of resource formation in the value chain for onshore wind energy. Environmental Innovation and Societal Transitions 36, 331–344.

Santoalha, A., Boschma, R., 2021. Diversifying in green technologies in European regions: does political support matter? Regional Studies 55, 182–195.

Schaffers, H., Santoro, R., 2010. The living labs concept enhancing regional innovation policies and instruments. In: IEEE International Technology Management Conference 2010, pp. 1–8.

Schäpke, N., Stelzer, F., Bergmann, M., Singer-Brodowski, M., Wanner, M., Caniglia, G., Lang, D.J., 2017. Reallabore im Kontext transformativer Forschung: Ansatzpunkte zur Konzeption und Einbettung in den internationalen Forschungsstand.

Schmookler, J., 1966. Invention and Economic Growth. Harvard University Press, Cambridge, Mass.

Schneidewind, U., 2014. Urbane Reallabore - ein Blick in die aktuelle Forschungswerkstatt. Online, 1–7.

Schot, J., Steinmueller, W.E., 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. Research Policy 47, 1554–1567.

Schumpeter, J.A., 1933 [1911]. Theorie der wirtschaftlichen Entwicklung. Eine Untersuchung über Unternehmensgewinn, Kapital, Kredit, Zins und den Konjunkturzyklus. Duncker & Humblot, Berlin.

Scott, A.J., 1999. Regions and the world economy: The coming shape of global production, competition, and political order. Oxford University Press, Oxford, 200 pp.

Sengers, F., Raven, R., 2015. Toward a spatial perspective on niche development: The case of Bus Rapid Transit. Environmental Innovation and Societal Transitions 17, 166–182.

Smith, A., Voß, J.-P., Grin, J., 2010. Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. Research Policy 39, 435–448.

Som, O., 2012. Innovation without R&D - Heterogeneous Innovation Patterns of Non-R&D-Performing Firms in the German Manufacturing Industry. Springer Gabler, Wiesbaden, Germany.

Stahlecker, T., Koschatzky, K., 2010. Cohesion policy in the light of place-based innovation support: New approaches in multi-actors, decentralised regional settings with bottom-up strategies? Working Papers Firms and Region R1/2010. Fraunhofer ISI, Karlsruhe.

Storper, M., Walker, R., 1989. The capitalist imperative: Territory, technology, and industrial growth. Blackwell, New York, 279 pp.

Strambach, S., 2017. Combining Knowledge Bases in Transnational Sustainability Innovation: Microdynamics and Institutional Change. Economic Geography 93, 500–526.

Strambach, S., Pflitsch, G., 2018. Micro-dynamics in regional transition paths to sustainability - Insights from the Augsburg region. Applied Geography 90, 296–307.

Strambach, S., Pflitsch, G., 2020. Transition topology: Capturing institutional dynamics in regional development paths to sustainability. Research Policy 49, 104006.

Tödtling, F., Trippl, M., 2005. One size fits all? Research Policy 34, 1203–1219.

Tödtling, F., Trippl, M., Desch, V., 2021. New directions for RIS studies and policies in the face of grand societal challenges. European Planning Studies, 1–18.

Tödtling, F., Trippl, M., Frangenheim, A., 2020. Policy options for green regional development: Adopting a production and application perspective. Science and Public Policy 47, 865–875.

Trippl, M., Baumgartinger-Seiringer, S., Frangenheim, A., Isaksen, A., Rypestøl, J.O., 2020. Unravelling green regional industrial path development: Regional preconditions, asset modification and agency. Geoforum 111, 189–197.

Truffer, B., Coenen, L., 2012. Environmental Innovation and Sustainability Transitions in Regional Studies. Regional Studies 46, 1–21.

Uyarra, E., Ribeiro, B., Dale-Clough, L., 2019. Exploring the normative turn in regional innovation policy: responsibility and the quest for public value. European Planning Studies 27, 2359–2375.

van den Berge, M., Weterings, A., Alkemade, F., 2020. Do existing regional specialisations stimulate or hinder diversification into cleantech? Environmental Innovation and Societal Transitions 35, 185–201.

Warnke, P., Koschatzky, K., Dönitz, E., Zenker, A., Stahlecker, T., Som, O., Cuhls, K., Güth, S., 2016. Opening up the innovation system framework towards new actors and institutions. Fraunhofer ISI Discussion Papers "Innovation Systems and Policy Analysis", Karlsruhe, 50 pp.

Weber, K.M., Rohracher, H., 2012. Legitimizing research, technology and innovation policies for transformative change. Research Policy 41, 1037–1047.

Wieczorek, A.J., Hekkert, M.P., Coenen, L., Harmsen, R., 2015. Broadening the national focus in technological innovation system analysis: The case of offshore wind. Environmental Innovation and Societal Transitions 14, 128–148.