# The spatial dimension of innovation and socio-technical change: insights from economic geography

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Dr. Sebastian Losacker

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# Abstract

This habilitation thesis explores the spatial dimension of innovation and socio-technical change. While innovation is a key driver of economic development and socio-technical transformation, its geographical embeddedness remains insufficiently understood. The thesis addresses this gap by examining the origins, situatedness, and implications of innovation processes, with particular attention to the bioeconomy and the twin transition – domains of high political and societal relevance. The thesis is a cumulative one, combining 21 published articles. The theoretical foundation of this thesis draws on (and contributes to) three main strands of scholarship: First, literature on the geography of innovation, including frameworks for analyzing national, regional, technological, and global innovation systems, alongside debates on mission- and challenge-oriented policy. Second, evolutionary economic geography, including theoretical approaches to understanding specialization, diversification, relatedness, and complexity, which help explain why regional development pathways are often path-dependent and uneven. Third, transition studies, including perspectives on socio-technical systems and imaginaries, highlighting how institutional and cultural elements stabilize or transform existing systems and how visions of the future influence their directionality. Together, these strands inform an integrative perspective on the spatiality of innovation and socio-technical change. Methodologically, the thesis employs a mixed-methods design. Quantitative analyses use patent data to trace the emergence, diffusion, and geography of innovation activities, complemented by novel datasets and indicators such as machine-learning-based classifications of patent texts, large-scale web-mining of firms and municipalities, and a geolocated corpus of German news articles. Sequence analysis is introduced as a methodological innovation, enabling the study of region-specific temporal trajectories. In addition, qualitative studies provide conceptual and inductive insights into socio-technical imaginaries, legitimacy struggles, and actor constellations. The cumulative work shows that innovation and socio-technical change are spatially uneven, shaped by regional preconditions, multi-scalar linkages, and technology-specific features. It demonstrates the value of combining quantitative and qualitative approaches to capture both systematic evidence and contested, imaginative dimensions. Overall, the thesis contributes to geographically informed understandings of sustainability transitions and to debates on policies fostering inclusive, place-sensitive pathways of change.

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As for personal acknowledgements beyond the academic context, I refer to those included in my published PhD thesis. Nothing has changed in that regard.

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# 1. Introduction

Planet Earth is facing a deep crisis. The current modes of production and consumption — that is, the ways in which the global economy is organized and how humans live on this planet — are highly unsustainable. We are on the verge of disrupting critical global processes that regulate the stability and resilience of the Earth system. As a result, in the near future, the safe and stable conditions of Earth system processes and the environment that characterize the Holocene may be fundamentally altered, with severe consequences for how humans (and other species) can live on this planet. To date, six of the nine Earth system processes considered essential for safeguarding planetary conditions have already been crossed, including climate change, biosphere integrity, and biogeochemical flows (Richardson et al., 2023; Rockström et al., 2009; Steffen et al., 2015).

At the same time, humanity faces multiple socio-economic challenges, including poverty, inequality (in its various dimensions), economic crises, pandemics, and wars. All of these are deeply interrelated and constitute what scholars have labeled wicked problems, i.e. complex issues that cannot be resolved through simple solutions. Such wicked problems manifest as grand societal challenges. While this habilitation thesis cannot directly contribute to solving these challenges, they form the broader context in which it is situated. Addressing societal challenges requires profound *socio-technical change*, which is both driven and enabled by *innovation* (Geels et al., 2017; Markard et al., 2012). Moreover, both socio-technical change and innovation have an explicit spatial dimension; something I will explore in this thesis and elaborate on further in this introduction.

Before turning back to these aspects, I first address two proposed solutions to the grand societal challenges of our time, particularly the environmental crises the world is facing. The first is the concept of a bioeconomy. The idea of a bioeconomy has emerged in response to pressing environmental problems, particularly climate change, resource overexploitation, and environmental degradation (Aguilar et al., 2018; Lang, 2022; Patermann & Aguilar, 2018). It refers to the sustainable utilization of biological resources, processes, and systems to produce goods, services, and energy, encompassing diverse sectors such as agriculture, forestry, fisheries, biotechnology, and renewable energy (Befort, 2020, 2023; Bugge et al., 2016). However, the application of bio-based products and technologies is intended to extend across all economic sectors. The overarching aim is to replace the linear economic model with a

circular and regenerative approach, in which biological resources are efficiently and responsibly managed (Allain et al., 2022; Heiden, 2020; Patermann & Aguilar, 2021). In other words, the basic idea of the bioeconomy is to transition from a linear economy based on non-renewable (often fossil) resources to one that relies on renewable resources used in a circular way. In recent years, more than 60 countries have adopted dedicated bioeconomy policies or strategies, underlining the global relevance of the idea of a bioeconomy and the political will to promote it at national and regional levels (Proestou et al., 2024). For economic geography, the bioeconomy holds particular interest because it is expected to transform traditional production systems, promote new regional growth and development models, and link local resources with global markets. Its impacts on regional development, industrial restructuring, and sustainability transitions are therefore key areas of investigation in economic geography and related fields (Giustolisi, 2025; Laasonen, 2024; Mittenzwei & Schiller, 2025; Prochaska & Schiller, 2024; Schlaile et al., 2024; Steinböck & Trippl, 2023; Stock & Schiller, 2024). Moreover, innovation plays a central role in the transition from a fossil-based to a bio-based economy. Defined as any novel economic activity, innovation in the bioeconomy ranges from incremental drop-in solutions and bio-based substitutes to transformative innovations that reshape socio-technical systems and redefine production networks (Befort, 2023; Bröring et al., 2020; Giurca & Befort, 2023; Golembiewski et al., 2015; Lhuillery et al., 2025; Pyka & Prettner, 2018; Wydra, 2020). This includes advanced biotechnological processes alongside traditional low-tech activities, leading to products such as biodegradable plastics, bio-based fuels, and environmentally friendly fertilizers. A strong emphasis is placed on circular economy principles, in which biological waste streams are recycled into new products, reducing environmental impacts while fostering new economic paths (Klein et al., 2022; Schlaile et al., 2024; Stegmann et al., 2020). In academic debates, the bioeconomy is usually viewed from multiple perspectives. In this regard, Bugge et al. (2016) distinguish between a biotechnology vision focusing on biotechnology research, commercialization, and its application across industries; a bio-resource vision emphasizing the processing and upgrading of biological raw materials to establish new value chains; and a bio-ecology vision centered on ecological processes, biodiversity protection, and sustainable resource use. While expectations about the sustainability impacts of the bioeconomy differ across these visions, there is broad agreement in academia (and beyond) that the bioeconomy encompasses a highly diverse range of industries and technologies and that it can eventually contribute to solving grand

societal challenges. Most of the research papers included in this thesis directly engage with the bioeconomy (Fischer et al., 2024; Fischer & Losacker, 2024, 2025; Jayaweera et al., 2025; Kriesch & Losacker, 2024b, 2024a; Losacker, Becker, et al., 2025; Losacker, Heiden, et al., 2023; Mazzoni et al., 2025; Mazzoni & Losacker, 2024), while others address it more implicitly.

In addition to the idea of a bioeconomy, a second proposed solution to current societal challenges, or rather attempt at a solution, is the idea of a twin transition. Two of the papers included in this thesis engage with this idea (Brueck et al., 2025; Kriesch et al., 2025).

The twin transition refers to the parallel transformation towards greener, more sustainable practices and the rapid digitalization of economies. It has gained growing attention in economic geography, regional science, and related fields due to its far-reaching implications for regional development (Cattani et al., 2023; Cicerone et al., 2023, 2024; Faggian et al., 2024; Fazio et al., 2024). The concept has been promoted primarily by governments and policymakers, most notably by the European Union, and is an example of a policy idea that has entered the agenda before being fully understood in academic research (Faggian et al., 2024). While the twin transition is often framed as a mutually reinforcing combination of the green and digital domains, several scholars have warned that potential synergies should not be taken for granted and that one domain might hinder the progress of the other (García Casañas & Kovacic, 2025; Kovacic et al., 2024). The green dimension focuses on environmental sustainability, including renewable energy, climate change mitigation, and sustainable manufacturing. The digital dimension involves the integration of advanced technologies such as artificial intelligence, big data, and automation across sectors. Together, these changes have the potential to reshape industrial structures, create new sectors, and transform existing ones (Brueck, 2024). For regions, the twin transition could be transformative, but it also risks widening spatial inequalities. Urban and economically advanced areas, with better access to technology and investment, are more likely to benefit, while rural or less developed regions may face difficulties adapting (Barbero et al., 2025; Bianchini et al., 2022; Santoalha et al., 2021).

The bioeconomy and the twin transition share two important features. First, both have a clear geographical dimension: they span multiple sectors and industries, affecting regions and places across the globe. Second, both emphasize innovation as a key driver of change — an idea that underlies many proposed responses to grand societal challenges. I argue that the bioeconomy and the twin transition, along with the many

policies through which they take shape, offer valuable insights into the spatial dimensions of innovation and socio-technical change. This makes them highly relevant and productive areas of study for this habilitation.

Innovation and socio-technical change have emerged as key areas of research in economic geography in recent years, shaping the discipline profoundly. Innovation, defined as a new (economic) activity that enters the market and diffuses, is considered a major driver of structural change and economic growth (Romer, 1986; Schumpeter, 1934; Solow, 1956). Socio-technical change, defined as the transformation of the modes of production and consumption in a sector, including institutional change, is considered necessary for addressing environmental crises and enabling more sustainable futures (Geels, 2004; Köhler et al., 2019; Markard et al., 2012). Both innovation and socio-technical change are inherently geographical phenomena, as they emerge unevenly across space and affect places in heterogeneous ways. Moreover, the two are deeply interconnected, with the former enabling the latter and the latter requiring and stimulating the former.

Although innovation and socio-technical change have attracted considerable attention in scholarly research, a plethora of research gaps remain, too many to be listed in this habilitation thesis. For the sake of simplicity, I therefore refrain from outlining these gaps in the introduction, as each research article included in the thesis builds on a dedicated gap that is outlined within the article itself. Instead, I would like to frame some overarching research aims to which the included articles contribute and which have guided my research over the past years.

(1) First, this habilitation thesis seeks to contribute to a better understanding of the spatial dimension of innovation and socio-technical change, unveiling their geographical origins, their situatedness, and their implications. (2) Second, it aims to do so by providing insights into societally relevant and timely domains that can inform current policymaking, in particular the bioeconomy and the twin transition, both of which span multiple sectors and industries. (3) Third, it seeks to shed light on innovation and socio-technical change in different geographical contexts, not only across multiple countries but also across multiple scales, ranging from the local to the global. (4) Fourth, the thesis bears an exploratory character in that it engages with new quantitative data, methods, and indicators to study innovation and socio-technical change.

This cumulative habilitation thesis is structured into two main parts. The first part, including this introduction, provides an overview of the individual research papers and

explains how they collectively form a coherent habilitation thesis. The second part contains the individual research articles, all of which have been published in peer-reviewed international journals.

As such, the remainder of the thesis is structured as follows. Section 2 elaborates on the theoretical background underpinning the research conducted for this habilitation. It discusses three major strands of literature: the geography of innovation, regional structural change, and the geography of sustainability transitions. Section 3 offers a brief overview of the empirical approaches used in the research, outlining data and methods for both more deductive and quantitative papers, as well as more inductive and qualitative ones. Section 4 summarizes the main findings of each individual article included in the thesis. Section 5 presents the overarching conclusions drawn from connecting the individual articles and considering them as a whole. Finally, Section 6 provides links to each published article along with their abstracts.

# 2. Theoretical background

The collection of articles in this cumulative habilitation, as well as my research more generally, builds on theoretical approaches at the intersection of multiple scholarly disciplines. It first draws on theoretical work in the spatial sciences, most prominently human and economic geography, but also regional studies and regional science. Second, it builds on innovation studies, in particular its strand of innovation economics. Third, it engages with the emerging scholarly field of transition studies.

Since it is difficult (if not impossible) to draw clear boundaries between these fields, I do not attempt to impose a distinct label here. In this sense, it would also be close to impossible to cover the entire theoretical background underpinning the different papers collected in this cumulative habilitation. It is simply too much. Therefore, I will limit this section to three main strands of literature that I consider to be the most important backbones of the paper collection, all of which stem from the intersection of the disciplines mentioned above.

First, I will elaborate in the next section on the geography of innovation, a research field that I consider central to my work. Here, I will touch on two interrelated topics: the conceptualization of (territorial) innovation systems and innovation policy. Second, I will discuss regional structural change, focusing on how regions develop and transform over time from an (evolutionary) economic geography perspective. Third and finally, I will engage with the literature on the geography of sustainability transitions, elaborating on the notion of socio-technical systems and how they change (or fail to change). I will also reflect on imaginaries of socio-technical systems that do not yet exist.

The first and third sections will carry an implicit geographical imprint, while the second section will bear a more explicit one. The aim of the following pages is to outline the theoretical background that informs my own approach to studying "*the spatial dimension of innovation and socio-technical change*".

## 2.1 The geography of innovation

### 2.1.1 Innovation systems and their geography

Innovations, particularly technological innovations, are widely regarded as a central driver of economic development and thus hold a prominent position in the social sciences and economics (Romer, 1986; Schumpeter, 1934; Solow, 1956). Because innovations are both shaped by spatial factors and exert spatial effects, human and economic geography has likewise devoted considerable attention to innovation, as reflected in the emergence of a growing research community within the geography of innovation (Asheim & Gertler, 2006; Feldman, 1994; Shearmur et al., 2016). Technological innovations are the outcome of complex interactions among heterogeneous actors with complementary capabilities (Weitzman, 1998). They therefore require not only expertise in research and development but also effective innovation management, supportive policy measures, and the constructive shaping of overarching institutional norms and rules.

It has long been recognized that innovation does not follow linear paths but instead evolves through feedback mechanisms and interactive processes (Dosi, 1988; Kline & Rosenberg, 1986; Nelson & Winter, 1977, 1982). This inherent complexity has led to the adoption of a systemic perspective in order to capture and understand the processes through which innovations emerge and diffuse. Within innovation studies, this perspective is formalized in the concept of innovation systems (Lundvall, 1992). Over the past three decades, a variety of theoretical frameworks have been developed to conceptualize the heuristics of innovation systems (Godin, 2009). Early studies, focusing particularly on state innovation policy and the role of national institutions, examined innovation systems primarily within national boundaries. The so-called National Innovation Systems (NIS) approach highlights how the composition of actors and system-level factors at the national scale contribute to successful innovation (Freeman, 1995; Lundvall, 1992).

Geographical research, however, has emphasized that many system-relevant factors, such as institutional contexts, cooperation in innovation processes, or policy measures for innovation support, operate most strongly at the regional level. This insight has given rise to the concept of Regional Innovation Systems (RIS), which seeks to account for interregional and intranational differences in innovation success (Asheim & Gertler, 2006; Cooke, 1992, 2001; Cooke et al., 1997). While NIS and RIS frameworks

have made important contributions to understanding territorially embedded innovation dynamics, they often overlook linkages between regional and extra-regional actors, such as research collaborations or value chains. Both perspectives have thus helped to identify geographically constituted system conditions for innovation, but they also neglect two important aspects. First, innovation is not confined to geographical spaces; it is also shaped by sectoral and technological dynamics. Territorial perspectives often remain blind to the heterogeneity of innovation processes across industries or technological fields. Second, much of the geographical literature on innovation systems has concentrated on knowledge creation, frequently operationalized through patent data, while paying comparatively little attention to market entry and diffusion (Castaldi, 2024, 2025; Losacker, 2022a). Yet for innovations with positive environmental impacts, the study of market uptake and diffusion processes is of particular societal relevance (Isaksen et al., 2022; Losacker, Hansmeier, et al., 2023; Rennings, 2000, 2014; Tödtling et al., 2022).

Beyond territorially oriented approaches, the sociology-influenced strand of innovation studies has established Technological Innovation Systems (TIS) as a prominent heuristic. Instead of defining system boundaries geographically, TIS frameworks delineate innovation systems along technological fields. Technological innovation systems vary across dimensions such as knowledge generation, market formation, financial capital provision, legitimation and social acceptance, and diffusion dynamics (Bergek et al., 2008, 2015; Hekkert et al., 2007; Jacobsson & Bergek, 2011; Markard et al., 2015; Markard & Truffer, 2008). Proponents of this approach argue that innovation systems are shaped more fundamentally by technological than by geographical factors, in contrast to NIS and RIS. TIS analysis allows for a more precise mapping of relevant actors, networks, and institutions and, due to the narrower scope of actors and resources, enables dynamic studies of system evolution. Accordingly, the TIS literature has focused extensively on the dynamics of emerging technological fields, often with reference to green technologies (Hekkert et al., 2007; Markard et al., 2015; Negro et al., 2012).

Taken together, two main strands of research can be distinguished in this regard: a geographical literature that defines innovation systems territorially and often examines innovation activity across a whole nation or region, and a sociologically informed literature that defines systems in terms of technological fields and investigates only the innovation processes within those fields. The coexistence of these perspectives has stimulated the development of the Global Innovation Systems (GIS)

framework, which explicitly integrates technological and geographical dimensions (Binz & Truffer, 2017).

The GIS framework distinguishes different system configurations based on two dimensions: the innovation mode and the valuation of innovation. The innovation mode contrasts "Doing, Using, Interacting" (DUI) processes, in which partnerships, users, and consumers play a central role, with "Science and Technology" (STI) processes, in which innovation primarily results from formal research and development (Alhusen et al., 2021; C. Friedrich & Kagel, 2025; Jensen et al., 2007; Losacker & Liefner, 2020a). The valuation process, by contrast, involves the creation of markets, financing, and societal legitimation and acceptance (Angstmann, 2025; Carvalho & van Winden, 2018; Jeannerat, 2024; Jeannerat & Kebir, 2016). Depending on whether valuation follows standardized or customized trajectories, and whether innovation arises from DUI or STI modes, four generic GIS configurations can be distinguished (Binz & Truffer, 2017): (1) Production-anchored GIS, characterized by DUI innovation modes and standardized valuation (e.g., electric vehicles), (2) Footloose GIS, with STI modes and standardized valuation (e.g., solar photovoltaics), (3) Spatially-sticky GIS, combining DUI modes with specific valuation (e.g., specialized machinery, luxury watchmaking, wind energy), and (4) Market-anchored GIS, characterized by STI modes and specific valuation (e.g., carbon storage technologies, biogas plants). These configurations illustrate the multiplicity and global reach of innovation systems across technological fields. While the GIS concept provides a useful heuristic to compare geographies of innovation across industries, it has been criticized for remaining largely static and insufficiently accounting for the evolutionary dynamics of innovation systems (Ayrapetyan et al., 2025; Heiberg & Truffer, 2022)

A further key notion in the GIS literature is that of structural coupling. Structural coupling refers to the multi-scalar interlinkages between different subsystems of innovation, serving to bridge gaps in system resources (Tsouri et al., 2021). For instance, production-anchored GIS are characterized by localized DUI innovation processes coupled with global subsystems of valuation such as capital, legitimacy, and markets. The success of an innovation in such systems depends on how effectively these subsystems can be structurally connected. These vertical, multi-scalar couplings are typically more complex than horizontal linkages within a single region or country (Rohe, 2020; van Welie et al., 2020). The capacity to establish such couplings depends heavily on the agency of particular actors and intermediaries (Grillitsch et al., 2023; Grillitsch & Sotarauta, 2020).

Overall, research on innovation systems has undergone a significant shift in perspective in recent years. This is driven not only by the globalization and simultaneous regionalization of economic and innovation activities but also by the growing orientation of innovation processes toward addressing societal challenges, particularly environmental crises. Recent contributions have sought to integrate this mission-oriented dimension into the innovation systems framework (Hekkert et al., 2020; Janssen et al., 2021). The GIS approach thus represents an important step in acknowledging the interplay of geographical and technological dimensions, the role of global linkages, and the relevance of societal missions in contemporary innovation processes.

### 2.1.2 (Regional) innovation policy

As explained above, innovation has increasingly come to be seen as a central driver of economic performance and societal change. Over the last three (or even more) decades, policy-makers have developed a growing concern for innovation not only as a source of competitiveness and growth but also as a necessary tool for tackling major societal challenges such as climate change, demographic shifts, and social inequality (Edler & Fagerberg, 2017). The idea that policy can and should play a role in supporting innovation has become widespread, with "innovation policy" emerging as a key domain of public policy. While the term itself only gained prominence from the mid-1990s onwards, policies influencing innovation have existed for much longer. States have historically supported scientific knowledge and technological development in areas of strategic importance, ranging from agriculture to military technology. Many transformative innovations, such as the internet, were the result of such mission-oriented policies (Mazzucato, 2016, 2018). In this sense, innovation policy as a practice predates the theoretical frameworks that now justify it.

The early rationale for innovation policy was primarily framed through a market failure approach, which draws on neoclassical economics and the assumption that markets alone would underprovide socially desirable levels of innovation. Early research on innovation economics emphasized that knowledge is a public good that cannot be fully appropriated by its producers, thereby reducing private incentives to invest in R&D (Arrow, 1962a; Nelson, 1959). Policy interventions were justified to correct this underinvestment by financing public research, subsidizing private R&D, or strengthening intellectual property rights. While influential and still widely used, this

perspective has been criticized for its narrow focus on the early stages of the innovation process and for ignoring the importance of diffusion, incremental improvement, and user feedback in shaping the economic and social value of innovations (Kline & Rosenberg, 1986; von Hippel, 1976)

From the late 1980s onwards, the innovation systems perspective emerged as a more comprehensive framework, as described in the previous section. The (national) innovation system approach emphasized that innovation depends on systemic interactions among firms, universities, intermediaries, and public organizations, and that institutional contexts shape these processes in distinct ways (Freeman, 1987, 1995; Lundvall, 1992). Rather than focusing solely on market failures, this perspective identified systemic failures such as weak linkages, lack of demand, missing competencies, or inadequate coordination as barriers to innovation (Metcalfe, 1994). It also underscored that innovation is interactive, cumulative, and path-dependent, with historical choices and institutional arrangements shaping current trajectories. The concept of path dependency highlighted how early selections, reinforced by network externalities and infrastructural investments, could lock societies into particular technological pathways even when better alternatives emerge (Arthur, 1989; David, 1985; Kemp, 1994). This problem is particularly salient in sustainability transitions, where entrenched socio-technical systems such as fossil-fuel-based energy or car-based mobility resist change despite their negative externalities (Geels, 2002), an aspect on which I will elaborate in more detail in Section 2.3.

As a response, a renewed emphasis was placed on mission-oriented innovation policies, which seek to deliberately direct innovation towards solving concrete societal problems. Rather than leaving the trajectory of technological change entirely to market forces, these policies define missions — such as developing renewable energy, combating climate change, or eradicating diseases — and mobilize public and private actors to achieve them (Edquist & Zabala-Iturriagagoitia, 2012; Janssen et al., 2021; Mazzucato, 2016, 2018). The normative turn in innovation policy thus places directionality at the center, recognizing that innovation is not only about increasing economic efficiency but also about shaping the future in line with collective goals (Boon & Edler, 2018; Lundvall, 2023; Uyarra et al., 2019). In practice, this requires a broad policy mix that integrates supply-side measures like R&D support with demand-side instruments such as public procurement and regulation, while also ensuring inclusiveness and accountability (Edler & Georghiou, 2007; Kivimaa & Kern, 2016; Rogge & Reichardt, 2016). Innovation policy, in other words, has evolved from narrow

science-push interventions to systemic and mission-oriented approaches that seek to govern the direction as well as the pace of socio-technical change (Edler & Fagerberg, 2017; Schot & Steinmueller, 2018).

While much of the early debate on innovation systems (and innovation policy) focused on the national level, it has become increasingly clear that the regional scale plays a crucial role. Regions differ in their innovative capacity, institutional set-up, and integration into global knowledge networks, which explains why patterns of innovation are highly uneven across space (Feldman, 1994). The concept of regional innovation systems (see above) emerged in the 1990s as a way to capture these dynamics and provide a framework for place-based policies (Tödtling & Trippl, 2005). RIS scholarship emphasizes that regional innovation performance depends on systemic interdependencies among firms, research and educational institutions, intermediaries, and policy-makers embedded in territorial institutions (Asheim et al., 2011). By highlighting the specificities of regions, the RIS approach has provided a powerful counterpoint to one-size-fits-all policy models and inspired strategies such as smart specialization in the European Union (Landabaso & Foray, 2014; McCann & Ortega-Argilés, 2013a, 2013b).

Traditionally, RIS research and policy emphasized technological and business innovation with the aim of strengthening regional competitiveness and growth, following a Schumpeterian logic of creative destruction. However, in light of persistent and escalating societal challenges such as climate change, social inequalities, and demographic pressures, this focus appears too narrow (Coenen & Morgan, 2020). A critical reassessment of RIS is therefore needed to align regional innovation policies with transformative change. Recent work has introduced the notion of challenge-oriented regional innovation systems (CoRIS), which builds on the RIS concept but adapts it to the context of grand societal challenges (Tödtling et al., 2022; Trippl et al., 2024).

The CoRIS perspective implies several important shifts. First, it calls for a broader understanding of innovation that includes social, institutional, and user-driven innovations alongside technological ones. Second, it emphasizes the directionality of innovation, arguing that policies should actively steer innovation toward addressing societal needs rather than assuming competitiveness as the sole objective. Third, it highlights the importance of inclusiveness, stressing that civil society actors, users, and communities should be actively involved in shaping innovation processes. Fourth, it argues for greater attention to the application and diffusion of innovations within

regions, focusing on how new solutions are adopted, anchored, and scaled up to address concrete regional problems (Losacker & Liefner, 2020b; Tödtling et al., 2021). Fifth, it acknowledges the ambivalence of innovation, noting that innovation can also produce negative outcomes (Coad et al., 2021; Schot & Steinmueller, 2018). Finally, it calls for new governance roles for policy-makers, who must act not only as funders but also as coordinators of complex actor constellations and as mediators of conflicting interests (Tödtling et al., 2022).

As such, a challenge-oriented RIS recognizes that grand societal challenges have both global and regional dimensions. While climate change is global, its manifestations and potential solutions vary across territories, requiring place-specific strategies. CoRIS provides a framework for understanding how regions can mobilize their assets, institutions, and networks while also drawing on extra-regional knowledge flows to address these challenges. It stresses that transformative change is inherently multi-scalar, shaped by interactions between regional, national, and supranational levels of governance (Binz & Truffer, 2017; Miörner & Binz, 2021).

In conclusion, the theory and practice of innovation policy have undergone a profound transformation. From early market failure rationales and R&D-focused interventions, the field has expanded into systemic and mission-oriented frameworks that emphasize interaction, inclusiveness, and directionality (Edler & Fagerberg, 2017; Schot & Steinmueller, 2018). At the same time, the regional scale has emerged as a crucial arena where societal challenges are manifested and addressed. The RIS framework, reinterpreted through the lens of challenge orientation, highlights the need for policies that not only enhance competitiveness but also mobilize innovation for sustainability and social well-being (Tödtling et al., 2022). These evolving perspectives underscore the role of innovation policy today; it is both an economic imperative and a societal necessity.

## 2.2 Regional structural change

### 2.2.1 Regional economies and specialization

The research on the geography of innovation, as outlined above, points to an uneven spatial pattern of innovation. This pattern does not only hold for the overall innovation capacity of regions or nations, but even more so for their specialization in different industries or technological fields. These patterns of regional specialization have been evident for several decades and appear to persist over time. Silicon Valley was and remains specialized in IT and software, and more recently in firms engaged with the platform economy. Frankfurt is specialized in service sectors, particularly in finance. This does not seem likely to change in the near future.

All this, of course, is not new to the field of economic geography; it dates back to early work on comparative advantages, industrial districts, and clusters (Arrow, 1962b; Marshall, 1890; Porter, 1998; Romer, 1986). Yet, I believe that keeping in mind why regional specializations (still) matter in today's complex economy is of great importance. Regions tend to specialize in particular industries or technology fields due to a combination of economic, institutional, and knowledge-related mechanisms. Concentrating on specific industries allows regions to benefit from economies of scale and learning effects, which in turn increase productivity and competitiveness. By focusing on activities in which they hold a comparative advantage, regions can position themselves more effectively within global markets. This specialization is further reinforced by the ability of leading regions to attract capital, skilled labor, and complementary firms, such as suppliers and specialized service providers, which create a self-reinforcing dynamic of growth. Specialization also contributes to the formation of dense networks of firms, research institutions, and workers in related fields. Such networks facilitate the exchange of knowledge and innovation, especially the transfer of tacit, non-codified knowledge that thrives on spatial proximity. The clustering of activities fosters cumulative learning processes and accelerates technological development. In parallel, specialized industries demand specific skill sets, which promotes the adaptation of local education and training systems to these needs. This creates a thick labor market, where workers can move between firms while retaining the value of their skills, thereby enhancing both firm-level adaptability and regional resilience.

From a policy perspective, specialization also provides strategic clarity. In particular, within the European Union, regional specialization is viewed as a means to avoid spreading resources too thinly across unrelated domains. Instead, concentrating on selected strengths enables targeted support for regional innovation and industrial development. The European Union's Smart Specialisation Strategy (S3) framework builds explicitly on these insights (Foray et al., 2012; Landabaso & Foray, 2014; McCann & Ortega-Argilés, 2013b, 2014, 2015). It acknowledges that regional development is most effective when rooted in existing industrial and technological strengths, where economies of scale, knowledge spillovers, and specialized labor markets are already present. By encouraging regions to identify and invest in their distinctive areas of competitive advantage, S3 operationalizes the notion that innovation is embedded in territorial contexts. This approach is closely linked to the concept of regional innovation systems (see above). In this way, S3 provides a policy instrument that translates long-standing theoretical insights from economic geography and innovation studies into practical strategies for regional development.
Now that it is quite evident that regions tend to specialize in particular economic activities, I want to shift the focus to why these specializations might potentially change (or not). Here, I draw on the rich literature in evolutionary economic geography, which has investigated in particular how regions transform their economic activities over time, why such change may fail to occur, and how this relates to regional economic development. In the next subsection, I therefore elaborate more explicitly on the dynamics of regional structural change.

### 2.2.2 Regional branching, relatedness and complexity

Research in evolutionary economic geography (EEG) has significantly advanced our understanding of how regions develop over time through processes of diversification and structural change (Boschma, 2017; Boschma & Frenken, 2006, 2011; Boschma & Lambooy, 1999; Boschma & Martin, 2007; Dopfer et al., 2023; Frenken & Boschma, 2007; Henning, 2019; Kogler et al., 2023). At its core, EEG conceptualizes regional development as an evolutionary trajectory, where past knowledge, institutions, and industrial structures shape future opportunities in a path-dependent manner (Martin & Sunley, 2006, 2022). The branching process by which regions diversify into new activities is seen as contingent upon their existing knowledge base and technological

capabilities. Accordingly, the literature has highlighted two key determinants of diversification: relatedness and complexity, both of which I will discuss in this section. The concept of path dependency implies that regions are not free to choose any new development trajectory but are constrained by their inherited structures of capabilities, institutions, and knowledge (Boschma, 2017; Martin & Sunley, 2006; Neffke et al., 2011). Regions thus evolve along trajectories shaped by their existing industrial and technological assets, as new activities typically build on related knowledge domains (Heimeriks & Boschma, 2014; Neffke et al., 2011; Tanner, 2016). Such continuity explains why regions often diversify into industries and technologies that are close to their existing competencies rather than into entirely unrelated domains. Empirical evidence substantiates that regional diversification is rooted in territorial capabilities rather than random events (Boschma & Frenken, 2011; Rigby, 2015). Regional structural change can therefore be conceptualized as a branching process, in which new activities evolve from pre-existing related ones through shared resources such as knowledge, skills, technologies, and infrastructures. This process is facilitated by cognitive proximity between activities, i.e. workers and firms can more easily move across industries and occupations that share similar knowledge requirements and skill sets (Boschma & Frenken, 2012; Breschi et al., 2003; Frenken et al., 2023; Frenken & Boschma, 2007; Neffke et al., 2017). Through such mechanisms, regional economies generate new combinations of existing knowledge and competencies, giving rise to new industrial specializations.

The central concept of relatedness emphasizes that diversification is more likely when potential new activities share cognitive, technological, or institutional similarities with existing ones (Balland, 2016; Boschma, 2017; Hidalgo et al., 2018). Activities are considered related when they rely on similar resources, inputs, or knowledge bases. Consequently, diversification tends to align with pre-existing specializations, reinforcing the cumulative and path-dependent nature of regional development. A region's current portfolio of capabilities strongly influences which new activities are most likely to emerge. This evolutionary process of related diversification contributes to the growth of industrial clusters, technological upgrading, and regional competitiveness (Balland et al., 2019; Buyukyazici et al., 2023; Moreno & Ocampo-Corrales, 2022; Santoalha et al., 2021).

Although related diversification is generally associated with higher success rates, it is not without risks. Deegan et al. (2021) highlight that regions face a higher probability of failure when diversifying into activities unrelated to their existing portfolio.

Conversely, Mewes and Broekel (2020) note that related diversification can also generate market failures when local capabilities are insufficient to support the new activity. These tensions illustrate the complexity of branching strategies. While relatedness reduces risks by leveraging existing capabilities, it does not guarantee success, especially in the absence of critical complementary assets. In other words, relatedness can also create limitations. Regions with a narrow range of activities or insufficient capabilities face significant challenges in branching into new areas. In such cases, diversification trajectories may lead to lock-ins, where regions remain trapped in low-growth or technologically lagging activities (Cecere et al., 2014; Martin & Sunley, 2006). Over time, lock-ins can hinder adaptability, reducing the ability of regions to seize windows of opportunities in emerging technological domains. To overcome these constraints, some scholars have argued for the importance of unrelated diversification, particularly for long-term growth and resilience (Boschma et al., 2023; Castaldi et al., 2015; Frenken et al., 2007). Although more risky, unrelated diversification may provide the structural break needed for regions to escape low-development equilibria and open new growth paths.

A further dimension crucial to understanding regional branching is economic complexity. Complexity refers to the extent to which economic activities require sophisticated knowledge combinations and capabilities (Balland et al., 2022; Hidalgo & Hausmann, 2009). Highly complex activities often depend on rare and specialized knowledge inputs, and regions able to host such activities typically enjoy higher competitiveness and prosperity. Research has demonstrated that economic complexity is a strong predictor of long-term economic growth, income, and development, often outperforming institutional or governance-related predictors (Balland et al., 2020, 2022; Hausmann et al., 2014; Hidalgo et al., 2007). At the regional level, complexity plays a twofold role. On one hand, branching into complex activities can substantially upgrade a region's industrial base, fostering competitiveness and higher value creation (Mewes & Broekel, 2022; Pintar & Scherngell, 2022). On the other hand, entering complex domains is inherently difficult, as it requires a wide variety of complementary capabilities that may be absent locally (Balland et al., 2019). Hence, diversification into complex fields represents both an opportunity and a challenge. While it offers the potential for upgrading, it also carries higher risks of failure if the necessary capabilities are not present. An important feature of complexity is its uneven spatial distribution. Complex economic activities are often highly concentrated in a limited number of regions, thereby reinforcing patterns of territorial inequality (Balland et al.,

2020; Balland & Rigby, 2017; Broekel et al., 2023). Regions lacking sufficient knowledge variety and connectivity may therefore find it difficult to establish a foothold in complex technological domains, perpetuating existing disparities.

Outcomes of regional branching are also uneven across regions. Empirical studies reveal that prosperous regions are more likely to diversify into related and complex activities, thereby reinforcing their competitive advantages (Pinheiro et al., 2022). Peripheral or structurally weaker regions, by contrast, often struggle to branch into high-complexity domains, reinforcing divergence across territories (Balland et al., 2019; Balland & Boschma, 2021). This unevenness underscores the importance of considering both structural preconditions and dynamic capabilities when analyzing regional branching processes.

In sum, regional structural change is increasingly understood through the lens of evolutionary economic geography, emphasizing path dependence, relatedness, and complexity as key determinants of diversification. Regions evolve through branching processes in which new activities emerge from existing ones, facilitated by shared knowledge, skills, and institutional frameworks. While related diversification is the dominant mechanism, unrelated diversification remains important for escaping lock-ins and opening new trajectories. Complexity adds another dimension, offering opportunities for upgrading but also posing challenges due to capability requirements and spatial concentrations. Ultimately, regional branching is a dynamic interplay between structure and agency, past dependencies and future opportunities. It explains why some regions manage to establish new technological pathways and maintain competitiveness, while others remain trapped in stagnation. As empirical research continues to refine these concepts, the understanding of regional diversification provides valuable insights into the long-run processes of structural change and the uneven geography of economic development.

When it comes to sustainability transition processes, which will be the focus of the next section, several lessons can be drawn from the discussion thus far (Boschma et al., 2017). I have explained that there is an uneven geography of innovation, with some regions being highly innovative while others lag behind, and that regional specialization also differs significantly. Moreover, regional specializations are path-dependent and relatively rigid; they do not change naturally over time. Now given that regional economies will have to transform in response to the manifold sustainability crises the world is facing, it is evident that some regions will adapt more successfully than others. This is already apparent in many cases: regions specialized in polluting

industries and technologies now face high transition costs (Becker & Losacker, 2024), while pioneering regions are thriving in the wake of the green technology surge, specializing in environmentally benign economic activities (Barbieri et al., 2020, 2022; Montresor & Quatraro, 2020; Perruchas et al., 2020). Yet, there is more to learn about the geography of sustainability transitions, as I will demonstrate in the next section.

## 2.3 The geography of sustainability transitions

### 2.3.1 Socio-technical systems and their geography

The literature discussed so far has implicitly viewed technological change and innovation through a rather simplified economic lens, neglecting their societal and institutional embedding. For the final theoretical approach presented in this background section, I aim to broaden this view by applying an explicit socio-technical perspective, which understands innovation as embedded in socio-technical systems. I argue that such a broadened perspective is necessary to fully grasp sustainability transition processes and their geography.

Socio-technical systems are complex, dynamic configurations that integrate technologies, infrastructures, institutions, actors, and cultural meanings in the provision of essential societal functions such as energy, transport, housing, or health (Geels, 2002, 2004; Kemp, 1994). Central to the concept is the recognition that technologies do not exist independently of their societal embedding but are part of larger systems that reproduce stability through the interaction of material and immaterial elements. These elements include networks of firms, users, and policymakers; technological standards and regulatory frameworks; infrastructures and industrial structures; as well as shared routines, cultural meanings, and collective practices. Their interdependence explains why socio-technical systems are remarkably stable and resistant to change, but also why once change occurs, it is systemic, far-reaching, and deeply transformative (Geels, 2011; Geels et al., 2017).

A socio-technical transition refers to the long-term, multidimensional reconfiguration of such systems, in which new technologies emerge, infrastructures are redesigned, institutions adapt, and practices evolve (Köhler et al., 2019; Markard et al., 2012). Unlike incremental technological change, transitions imply more fundamental transformations that cut across economic, social, and cultural dimensions. The multi-level perspective (MLP) has become the dominant heuristic to study such processes, conceptualizing transitions as resulting from interactions between stabilized socio-technical regimes, radical innovations developed in niches, and exogenous pressures arising at the level of landscapes (Geels, 2002, 2004, 2011; Geels & Schot, 2007; Markard & Truffer, 2008; Smith et al., 2010). While this framework has advanced understanding of the systemic nature of transitions, it has been criticized for its

tendency to simplify spatial variation and to privilege a nationally bounded view of regimes (Coenen et al., 2012; Coenen & Truffer, 2012; Truffer & Coenen, 2012).

In response, an expanding body of scholarship has brought geography to the center of sustainability transitions research. The literature on the geography of sustainability transitions (GeoST) underscores that socio-technical change is always situated, contingent on regional conditions, and shaped by multi-scalar interdependencies (Binz et al., 2020, 2025). This perspective builds on traditions in economic and innovation geography while extending them to account for the normative and systemic orientation of transition studies. Three main insights have emerged from this literature: the importance of regional preconditions, the multi-scalar nature of transition processes, and the conditioning role of technology characteristics.

First, regional preconditions strongly influence the trajectories of sustainability transitions. Early contributions highlighted that transitions unfold unevenly across space and that places differ in their ability to nurture niche innovations and enable regime change (Hansen & Coenen, 2015; Hansmeier & Kroll, 2024; Losacker & Liefner, 2020b). This uneven geography is not only a function of regional innovation capabilities but also shaped by broader sets of factors, including industrial specialization, natural resource endowments, market formation processes, local demand structures, cultural practices, and informal institutions. For example, regions with strong technological clusters and favorable industrial structures may serve as breeding grounds for renewable energy or electric mobility innovations, while others lag due to structural weaknesses or institutional inertia. At the same time, localized social practices, norms, and consumer behaviors shape the acceptance and diffusion of new technologies, highlighting that transition pathways are socio-culturally embedded as much as they are technologically driven. Furthermore, formal policy frameworks, such as urban sustainability strategies or regional green industrial policies, play an important role in enabling or constraining change (Hansen & Coenen, 2015). Taken together, these factors create place-specific transition dynamics that can reinforce virtuous cycles of innovation and adoption in frontrunner regions or trap others in unsustainable trajectories.

Second, transitions are inherently multi-scalar processes. While regional preconditions matter, local change rarely occurs in isolation. Instead, regional sustainability transitions are deeply interwoven with extra-regional developments through flows of knowledge, capital, technologies, and legitimacy (Heiberg et al., 2020; Miorner et al., 2025; Miörner & Binz, 2021). Innovations developed in one region may

diffuse globally, but their adoption in other regions often depends on institutional adaptations and alignment with local conditions. Conversely, local niches may rely on global networks to access resources, expertise, and markets, creating structural couplings across scales (Binz et al., 2014; Binz & Truffer, 2017; Truffer et al., 2015). The same is true for legitimacy. In some cases, new technologies gain credibility and acceptance through international institutions, scientific bodies, or global advocacy networks, which then facilitate their adoption at the local or national level (Rohe & Chlebna, 2021). The multi-scalar nature of transitions also applies to regimes. While some sectors are structured by global regimes, others remain nationally or regionally bounded. Consequently, regime change may occur in a small set of pioneering places before diffusing more widely, or through the formation of global niches that eventually challenge incumbent regimes (Fuenfschilling & Binz, 2018; Miorner et al., 2025; Späth & Rohracher, 2012). This underscores that sustainability transitions cannot be understood without considering how local and global processes co-constitute one another.

Third, the characteristics of technologies themselves shape the geography of transitions. Technologies differ in their complexity, degree of modularity, requirements for customization, and compatibility with existing infrastructures (Agutu et al., 2024; Huenteler et al., 2016; Malhotra et al., 2019; Walz, 2007; Wilson et al., 2020). These inherent specificities condition how innovations emerge, diffuse, and become embedded in socio-technical systems. Standardized and modular technologies such as solar photovoltaics can be scaled globally with relative ease, leading to more uniform diffusion patterns. By contrast, infrastructure-intensive or highly customized technologies, such as hydrogen systems or bio-based construction materials, require tailored institutional support, region-specific resources, and local acceptance. As a result, their transition pathways are more heterogeneous and spatially uneven. The implication is that regional preconditions and multi-scalar linkages do not affect all technologies equally; the importance of place and scale depends on the specific socio-technical characteristics of the innovation under study.

Bringing these insights together, the GeoST perspective emphasizes that socio-technical transitions are simultaneously place-specific, multi-scalar, and technology-contingent. They are shaped by the interplay between local and global dynamics, and the characteristics of the technologies themselves. This adds nuance to conventional innovation frameworks, highlighting that there is no single pathway towards socio-technical change but rather a multiplicity of geographically differentiated trajectories.

Moreover, it underlines the political and normative stakes of transitions. While some regions may become frontrunners and reap the economic and environmental benefits of early action, others risk marginalization, deepening inequalities across places (Coenen & Morgan, 2020).

Conceptualizing sustainability transitions through a geographical lens on socio-technical systems thus enriches our understanding in several ways. It reveals why some regions succeed in fostering transformative change while others struggle; it highlights the importance of analyzing how global and local processes interact; and it shows that technologies are not spatially neutral but embedded in socio-technical and geographical contexts. Ultimately, this perspective advances the study of innovation and socio-technical change as dynamic, contested, and uneven processes that unfold across multiple scales and spaces.

### 2.3.2 Socio-technical imaginaries and (regional) futures

Sustainability transitions are, by definition, long-term processes of systemic change. As such, transition research typically adopts an ex-post perspective, aiming to understand how and why change has occurred in the past (or not), or how it is currently unfolding (or not). However, in recent years, there has been growing interest within the field of sustainability transitions to also explore how the future might unfold and how socio-technical systems could become more sustainable. The main conceptual framework used to study the future in this context is the notion of imaginaries (Benner, 2025).

Socio-technical imaginaries (STI) have become a central concept in transition studies, offering a lens to analyze how societies imagine and shape desirable futures. They are defined as collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of social life and social order attainable through advances in science and technology (Jasanoff & Kim, 2009, 2013). Crucially, imaginaries are not neutral representations of the future; they are performative. They shape expectations, legitimize policy choices, direct investments, and thereby influence which pathways of socio-technical change gain traction and which are sidelined (Berkhout, 2006; Borup et al., 2006; Jasanoff & Kim, 2015).

In contrast to narrow forecasts or technological roadmaps, imaginaries capture the interplay of material and social dimensions. They are simultaneously technological and normative, embedding specific innovations within broader visions of how societies

should be organized. This makes them powerful instruments of directionality in sustainability transitions, revealing not only what futures are imagined as technologically possible but also what is envisioned as socially desirable. By connecting technological expectations with normative orders, imaginaries disclose the political struggles underpinning transition pathways (J. Friedrich & Hendriks, 2024).

The formation of imaginaries is rarely linear. Emerging transitions are typically characterized by fragmented and contested visions that can be described as imaginaries in the making (Braun & Kropp, 2023). These proto-imaginaries circulate among expert communities, industry actors, and civil society, but they are not yet widely shared or institutionalized. Over time, such visions can either coalesce into dominant imaginaries or remain alternative and counter-hegemonic (Rudek, 2022). Importantly, imaginaries may not simply compete; they can also complement one another, overlap in hybrid forms, or coexist in parallel (Hawxwell et al., 2024; Mast, 2022; Trencher & van der Heijden, 2019). Imaginaries are rarely monolithic. They evolve through processes of negotiation, coalition building, and alignment, where initially divergent visions adapt to one another and may eventually converge (Kuchler & Stigson, 2024). This relational quality underscores that imaginaries are best understood as dynamic, continuously reworked, and performative. They are not the outcome of transitions but an integral part of their constitution, shaping trajectories as much as they are shaped by material and institutional developments.

A central mechanism for imaginaries to emerge and institutionalize is legitimation. For visions to move from the individual or organizational level to collectively shared imaginaries, they must resonate with wider social values and institutional norms. Legitimacy operates along three dimensions: pragmatic, when visions offer tangible benefits to stakeholders; moral, when they align with prevailing values and norms; and cognitive, when they appear comprehensible and even inevitable within established cultural frames (Suchman, 1995). Only when visions are legitimized across these dimensions, they attract broader support and gain the stability required to become dominant imaginaries. Conversely, visions that fail to achieve legitimacy risk remaining marginal, regardless of their technical feasibility. This highlights how imaginaries are filtered through socially constructed systems of meaning, trust, and authority (Benner, 2025; Braun & Kropp, 2023).

Imaginaries are also profoundly shaped by situatedness. They emerge from specific socio-material contexts and reflect the positionality of the actors producing them (Jasanoff & Kim, 2015). Industrial associations, policymakers, scientists, and activist

groups articulate different imaginaries depending on their interests, resources, and institutional embedding. Consequently, imaginaries vary across geographical settings, reflecting differences in infrastructures, cultural values, and political economies. What is considered a desirable transition pathway in one place may not resonate in another, underscoring the importance of spatially grounded analysis This geographical specificity means that imaginaries are never spatially neutral; they are co-produced with the places and contexts in which they are articulated (Benner, 2024, 2025). At the same time, socio-technical imaginaries also encompass visions of how the future of specific places should look, making geography a core component of these imaginaries. Consequently, there has been growing research interest in studying regional futures within economic geography and related disciplines, adding important geographical nuances to the analysis of socio-technical imaginaries (Gong, 2024).

In sum, socio-technical imaginaries provide a conceptual framework to understand the ideational underpinnings of sustainability transitions. They highlight that transitions are not only about replacing technologies but also about redefining social orders, norms, and practices. Imaginaries reveal the multiplicity of contested futures, the mechanisms through which some visions gain legitimacy and dominance, and the power relations that underpin these dynamics. By examining imaginaries, researchers and policymakers can better anticipate the diversity of possible pathways, critically interrogate which futures are being privileged, and explore how more inclusive and democratic imaginaries of sustainable societies might be cultivated. And, last but not least, imaginaries are inherently connected to different geographies, both in how they are produced and in how they ought to materialize.

# 3. Data and methodology

The empirical research that I have conducted, together with the many co-authors of the papers included in this cumulative habilitation, is quite diverse and draws from both the qualitative and the quantitative research spectrum. While I do not intend to provide a comprehensive overview of the data and methods used in each individual paper, I aim to briefly describe the core methodological approaches underlying the research.

The cumulative habilitation is to be understood as a mixed-methods body of research, where the overall findings are more than the sum of the individual papers. For the sake of clarity, however, I distinguish below between qualitative and quantitative approaches. The combination of both has enabled me to address multiple research gaps in the literatures discussed in the previous section: the quantitative papers provide systematic evidence, whereas the qualitative papers seek to make sense of single (or multiple) phenomena and derive conceptual insights from them. Accordingly, I follow a rather standard deductive approach in the quantitative papers, while the qualitative papers are guided by an inductive approach, contributing to theory-led conceptual debates. In some of the quantitative papers, however, hypotheses are not tested in a strictly deductive manner; instead, these studies serve to explore new data sources or methods (Kriesch & Losacker, 2024a, 2025a; Losacker & Kuebart, 2024). In addition, some of the papers included in the habilitation do not engage with data and methods at all but should be understood as conceptual contributions aimed at stimulating scholarly debate (Liefner et al., 2025; Losacker, Heiden, et al., 2023).

With this in mind, I now turn to the quantitative research approaches employed in many of the empirical papers.

## 3.1 Quantitative approaches

As discussed above, the quantitative papers included in this habilitation thesis are primarily deductive, aimed at testing hypotheses or addressing quantifiable research questions. In this sense, they mainly contribute to the fields of the geography of innovation and economic geography, as outlined in the theory section. By contrast, much of the research in transition studies requires qualitative approaches.

The quantitative approaches applied in my work can, broadly speaking, be divided into three thematic sets. The first set concerns quantitative analyses using patent data. The second set revolves around new forms of data collection, such as web scraping, combined with natural language processing techniques. The third set focuses on sequence analysis techniques, a methodological approach that I have sought to establish as a novel tool for geographical research and that I have applied in several papers.

As for the first set, the use of patent data to study innovation is widely recognized as a standard research approach. Patent data has become a widely used and well-established indicator for studying innovation, as it provides systematic and internationally comparable information on inventive activities. Patents capture new technical knowledge at an early stage of the innovation process and thus allow researchers to trace technological change over time and across regions, sectors, and organizations. Compared to many other data sources, patent statistics offer a high level of detail, including information on inventors, applicants, technological classifications, and geographical origins, which enables the analysis of both the direction and geography of innovation. While not all innovations are patented, and patenting behavior varies across industries, the richness and accessibility of patent data make it a particularly valuable source for empirical research (Archibugi, 1992; Griliches, 1990; Kleinknecht et al., 2002; Nagaoka et al., 2010). As such, patent data not only allows for the quantitative assessment of innovation dynamics but also provides a solid foundation for studying broader patterns of knowledge production and diffusion.

In the papers included here, I have used patent data to study inventive activities in bio-based technologies at the national level (Fischer et al., 2024), and I have employed it at the regional level to track the development of green technologies (Hansmeier et al., 2025; Hansmeier & Losacker, 2024). In addition, I have drawn on matched patent–licensing data, as outlined in my earlier PhD work (Losacker, 2020, 2022a, 2022b; Losacker, Horbach, et al., 2023), to analyze the diffusion of innovations in China

(Losacker, Horbach, et al., 2025). Building on this, I have developed a new dataset on bioeconomy-related patents by applying natural language processing techniques (Kriesch & Losacker, 2024a). In this approach, patent abstracts are used as input to determine whether a patent is related to the bioeconomy, thereby overcoming the limitations of predefined technology classes, which are inadequate to capture the full scope of relevant patents in this field. This work directly connects to the second theme of quantitative papers, as discussed above.

In this second set, I have worked on empirical papers that use text as data. This involves the collection of suitable textual material, either from existing databases or through large-scale web scraping. The resulting datasets can then be analyzed using natural language processing techniques, which include, for example, supervised and unsupervised classification methods or semantic comparison approaches such as topic modeling. For this habilitation thesis, I have worked on two papers that build on a dataset of German firm websites developed by Lukas Kriesch in his PhD research (Kriesch, 2023). We used this data to identify firms that engage with the bioeconomy, based on the information provided on their websites. To this end, we trained a model capable of identifying bioeconomy-related text content, distinguishing between high-tech and low-tech activities, and subsequently mapped the spatial distribution of these activities to reveal the (uneven) geography of bioeconomy activities in Germany (Kriesch & Losacker, 2024b). In a similar vein, in another paper, we applied a comparable approach to firm website texts, identifying whether firms engage in green economic activities, AI-related activities, or both (Kriesch et al., 2025). As already mentioned above, we conducted a similar identification exercise with patent data, classifying patent abstracts according to whether they relate to the bioeconomy or not (Kriesch & Losacker, 2024a). We made this dataset available to fellow researchers and continue to use it in other papers as well (Losacker et al., 2024). Another natural language processing paper revolves around the idea of geolocating news articles. Since news articles provide valuable information for various research questions, particularly in the social sciences, we argued for systematically exploring their geographic content. Accordingly, we developed a dataset that links geographic places to news articles, deriving geographic coordinates directly from the article texts (Kriesch & Losacker, 2025a). Again, we made this dataset available and continue to use it in subsequent research (Kriesch & Losacker, 2025b). Finally, in another text-as-data paper, we scraped texts from the websites of municipalities and counties in Germany. Regional governments provide interesting information that can be fruitfully applied in regional

research as well as in related fields. In this paper, we analyzed the text data and mapped local government priorities using a topic modeling approach (Schütz et al., 2025). In sum, this collection of research papers demonstrates the manifold possibilities of using novel (big) text data for geographical research and illustrates how natural language processing techniques can be employed to exploit it — an approach that will certainly continue to play an important role in the future (Wolf et al., 2021).

The last set of quantitative papers included in this habilitation thesis revolves around a methodological approach called sequence analysis. Sequence analysis is a rich set of methods originating in bioinformatics that was introduced to the social sciences several decades ago (Abbott, 1995; Abbott & Tsay, 2000; Liao et al., 2022). However, it has not yet been widely applied in geographical research, particularly not in economic geography, geographical innovation studies, or transition research. Sequence analysis is not so much a single method as it is a way of handling categorical panel data. It treats individual sequences as ordered lists of states. In my case, I propose to study regional sequences, examining how regions change over time, with the states capturing particular phenomena in each region. Sequence analysis enables rich visualizations that facilitate comparisons across regional sequences, allowing researchers to identify overarching patterns or, depending on the use case, particularly interesting individual trajectories. Without going into too much detail here, I have explored how sequence analysis can inform research in economic geography and related fields (Losacker & Kuebart, 2024). As part of this, I also developed a reproducible script that serves as a manual and guide, enabling other researchers to apply sequence analysis in their own projects. Building on this conceptual contribution, I applied the approach in two research papers included here. One paper uses sequence analysis to study how German regions engage with eco-innovation activities and how these change over time (Hansmeier & Losacker, 2024). The other, also focusing on Germany, applies sequence analysis to explore how regional relatedness densities and regional economic complexity evolve, thereby making the case for a history-informed approach to smart specialization policies (Otto et al., 2025). Sequence analysis is already being adopted by other geographers (Kuebart, 2022; Walther et al., 2025), and it may eventually become part of the broader methodological toolkit of the discipline.

## 3.2 Qualitative approaches

As for the qualitative research approaches, I primarily draw on two types of data sources, which I then analyze using qualitative techniques. The first source is policy documents, which I have used in three research papers. One paper focuses on the content of policy documents from three Chinese regions as well as the national level, with a particular emphasis on green- and digital-related policies. In this paper, we examine how regions engage with the twin transition, and more specifically, how policies in those regions strategically address (or fail to address) the twin transition (Brueck et al., 2025). The second paper based on policy documents uses a less structured analytical approach and instead draws on insights into the Chinese policy logic, linking it to the notion of mission-oriented innovation policies (Liefner et al., 2025). In a completely different context, I worked on a paper about socio-technical imaginaries in aviation, as reflected in policy documents and reports, examining how the future of aviation is portrayed in these texts (Muehlberger et al., 2024).

In several other papers, I draw on data collected through expert interviews, in all cases with experts working in the construction sector. The data were collected in different countries, using different interview guidelines, and conducted either online or in person. In most cases, the interviews were analyzed using a qualitative content analysis approach. For example, in one paper I worked with data collected in three regions in Vietnam, where we assessed how region-technology specificities and multi-scalar linkages shape regional sustainability transition pathways (Jayaweera et al., 2025). Other papers based on expert interviews draw on data from stakeholders in the construction sectors of China, India, Germany, and Italy, with different subsets of the material used for different analyses. For instance, I used the Chinese interview data to study how guanxi, i.e. the strong, mutually trusted personal relationships characteristic of Chinese society, affects innovation in bio-based construction (Losacker, Becker, et al., 2025). In other work, I relied on interview data from all four countries, for example when examining the socio-technical imaginaries that stakeholders co-produce and legitimize (Fischer & Losacker, 2024, 2025). Also drawing on all interview data, I analyzed how the global innovation system in the bio-based construction sector changes its configuration along the value chain (Mazzoni & Losacker, 2024). Building on this, and zooming in on more narrowly defined system boundaries, I combined interview data from China and India with additional

interviews conducted at trade fairs to better understand how bamboo technologies can mobilize innovation system resources from the timber industry (Mazzoni et al., 2025). Taken together, the qualitative research papers primarily address the field of transition studies, where conceptual approaches cannot easily be operationalized using quantitative indicators or methods (Hansmeier et al., 2021). Instead, expert interviews and policy documents provide crucial information that cannot be obtained in other ways. Analyzing these sources qualitatively enables an in-depth understanding of various processes and relationships, as reflected in the published papers.

# 4. Summary of main findings

In this section, I provide a concise summary of the main findings of each research article included in this habilitation thesis. The aim is to offer an overview of the individual articles I have worked on, without yet attempting to draw overarching conclusions. This broader perspective will be developed in Section 5. The articles are listed in Table 1 and are not presented in any particular order, as I will briefly explain in Section 6.

*Tab 1. Articles included in the cumulative habilitation thesis*

| # | Title and author(s) | Published in |
|---|---|---|
| 1 | *Rethinking bioeconomy innovation in sustainability transitions*<br><br>Losacker, Heiden, Liefner, Lucas | Technology in Society (2023) |
| 2 | *Regional eco-innovation trajectories*<br><br>Hansmeier, Losacker | European Planning Studies (2024) |
| 3 | *National specialization and diversification in the bioeconomy: Insights from biobased technologies in chemical and pharmaceutical sectors*<br><br>Fischer, Losacker, Wydra | Technology in Society (2024) |
| 4 | *Bioeconomy firms and where to find them*<br><br>Kriesch, Losacker | REGION (2024) |
| 5 | *Introducing sequence analysis to economic geography*<br><br>Losacker, Kuebart | Progress in Economic Geography (2024) |
| 6 | *Socio-technical imaginaries of climate-neutral aviation*<br><br>Muehlberger, Gruen, Liefner, Losacker | Energy Research & Social Science (2024) |
| 7 | *A global patent dataset of bioeconomy-related inventions*<br><br>Kriesch, Losacker | Scientific Data (2024) |
| 8 | *What hinders the transition towards a bio-based construction sector? A global innovation system perspective on its value chain*<br><br>Mazzoni, Losacker | Progress in Economic Geography (2024) |
| 9 | *Competing or complementary? Socio-technical imaginaries of a bio-based construction sector*<br><br>Fischer, Losacker | TATuP–Journal for Technology Assessment in Theory and Practice (2024) |
| 10 | *A spatial perspective on green technology adoption in China: insights from patent licensing data*<br><br>Losacker, Horbach, Liefner | Innovation and Development (2025) |
| 11 | *What can mission-oriented innovation policy learn from China?*<br><br>Liefner, Brueck, Losacker, Zeng | Science and Public Policy (2025) |
| 12 | *China's digital and green (twin) transition: insights from national and regional innovation policies*<br><br>Brueck, Losacker, Liefner | Regional Studies (2025) |

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|---|---|---|
| 13 | *A geolocated dataset of German news articles*<br><br>Kriesch, Losacker | Scientific Data (2025) |
| 14 | *Regional specializations in green incumbents and green start-ups in the German transport sector*<br><br>Hansmeier, Losacker, Bersch, Kroll | Growth and Change (2025) |
| 15 | *Relatedness, complexity, and regional development paths in Germany: a sequencing approach*<br><br>Otto, Losacker, Hansmeier | The Annals of Regional Science (2025) |
| 16 | *Guanxi and innovation in China: insights from the (bio-based) construction sector*<br><br>Losacker, Becker, Shang | Innovation and Development (2025) |
| 17 | *Regional preconditions and sustainability transition pathways: Insights from circular, bio-based and resource-efficient building material innovations in Vietnam*<br><br>Jayaweera, Losacker, Song, Schwede | Energy Research & Social Science (2025) |
| 18 | *How to build (in) the future? Legitimacy of socio-technical visions in a bio-based construction sector*<br><br>Fischer, Losacker | Environmental Innovation and Societal Transitions (2025) |
| 19 | *The geography of digital and green (twin) firms in Germany*<br><br>Kriesch, Abbasiharofteh, Losacker | Regional Studies, Regional Science (2025) |
| 20 | *What can the bamboo industry learn from timber? Resource mobilization across global innovation systems in the construction sector*<br><br>Mazzoni, Binz, Losacker | Geoforum (2025) |
| 21 | *Mapping local government priorities: a web-mining approach for regional research*<br><br>Schuetz, Kriesch, Losacker | Regional Science Policy & Practice (2025) |

**Article #1**

Losacker, S., Heiden, S., Liefner, I., & Lucas, H. (2023). Rethinking bioeconomy innovation in sustainability transitions. Technology in Society, 74, 102291.

The article examines how research on the bioeconomy has conceptualized innovation and its role in sustainability transitions. We argue that much of the existing literature predominantly views the bioeconomy through a substitution lens, focusing on the replacement of fossil-based products with bio-based alternatives such as bioplastics or biofuels. While substitution is important, this framing risks narrowing the scope of analysis by overlooking the transformative potential of advanced biotechnologies. The article contends that technologies such as synthetic biology, gene editing, metabolic engineering, and precision fermentation extend beyond mere substitution. They have the capacity to reshape socio-technical systems, reconfigure global value chains, and

enable entirely new industries. Examples include microbial production of novel molecules, cell-cultured materials that circumvent resource-intensive agriculture, and waste-to-resource bioprocesses that create value in previously overlooked streams. These innovations point to system-disruptive trajectories that cannot be captured adequately by substitution-oriented frameworks. By primarily framing the bioeconomy as a matter of substituting inputs, transition studies risk underestimating both the opportunities and challenges posed by these disruptive biotechnologies. In this article, we stress that sustainability transitions research needs to broaden its conceptual approach, shifting from substitution to a transformative innovation perspective. Such a shift would allow a better assessment of how frontier biotechnologies can contribute to sustainability pathways, while also critically interrogating the risks, ethical considerations, and governance needs associated with them. In conclusion, this article highlights the necessity of rethinking how bioeconomy innovation is positioned in transition studies. Instead of restricting the bioeconomy to incremental change, it should be recognized as a potential driver of systemic transformation, requiring frameworks that capture both its disruptive capacity and its sustainability implications.

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**Article #2**

Hansmeier, H., & Losacker, S. (2024). Regional eco-innovation trajectories. European Planning Studies, 32(6), 1401-1422.

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The article studies the spatio-temporal dynamics of eco-innovation across German regions and investigates how green development pathways unfold beyond single case studies of industries or technologies. It focuses on 401 German NUTS-3 regions between 1997 and 2018 and asks how green incumbents and green start-ups contribute to regional eco-innovation trajectories. The article uses sequence analyses to trace long-term developments in regional eco-innovation specialization. By combining green patent data from the OECD REGPAT database with green start-up data from the Mannheim Enterprise Panel, it develops measures of relative patent advantage (RPA) and relative start-up advantage (RSA). These indicators capture the comparative importance of incumbents and newcomers in shaping green trajectories. Applying sequence analysis and clustering techniques, the study identifies similarities and divergences in regional pathways and derives a typology of eco-innovation trajectories. The article finds that regional eco-innovation trajectories are highly persistent and

path-dependent. Most regions follow stable trajectories dominated by either incumbents, start-ups, or non-specialization, with only a minority showing transitions toward more comprehensive green specialization. In total, six types of trajectories are identified: green incumbent regions, green start-up regions, non-specialized regions, fully green regions, and two transition types where greening is induced either by incumbents or by start-ups. Notably, start-up induced greening appears more common than incumbent-induced change. The article shows that spatial clustering matters. Green and greening trajectories are more frequent in eastern and northern Germany, while non-specialized regions dominate in the west and south. Moreover, neighboring regions tend to share similar trajectories, underlining spatial spillovers and systemic interdependencies. Importantly, metropolitan regions do not emerge as green-specialized, which suggests that density and diversity of actors do not automatically translate into green specialization. Overall, the article contributes by demonstrating that green regional development is gradual rather than radical, shaped by strong path- and place-dependencies. It highlights the need to consider both incumbents and start-ups in long-term analyses and positions sequence analysis as a valuable method in economic geography for uncovering persistent patterns of eco-innovation.

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**Article #3**

Fischer, L., Losacker, S., & Wydra, S. (2024). National specialization and diversification in the bioeconomy: Insights from biobased technologies in chemical and pharmaceutical sectors. Technology in Society, 76, 102462.

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The article studies national specialization and diversification patterns in the bioeconomy, focusing on biobased technologies in the chemical and pharmaceutical sectors. It investigates how countries develop comparative advantages in these technologies, which are central to sustainability transitions, and examines whether policy, technological complexity, and existing specialization shape these dynamics. The article uses patent and publication data for 15 industrialized countries between 1997 and 2019, covering four technology groups: bioplastics, biopharmaceuticals, biotechnology, and biobased detergents. It applies econometric panel models with revealed technological advantage (RTA) as the main indicator, accounting for path dependencies, technological complexity, environmental policy stringency, and regulatory quality. In doing so, it combines insights from innovation system theory and economic geography to analyze processes of specialization and diversification. The

article finds strong path dependencies. Countries that were already specialized in biobased technologies are much more likely to maintain or expand their advantage, while diversification into new fields without prior specialization is rare. Bioplastics constitute a notable exception, as several countries successfully diversified into this field due to lower entry barriers and broader application potential. By contrast, biotechnology, biopharmaceuticals, and detergents present higher technological complexity and stronger entry barriers, limiting diversification. The article shows that basic research (publications) and applied research (patents) follow divergent patterns, with countries often specializing in one but not the other. This indicates that innovation systems are globally interconnected and that analytical knowledge from one country can be used for applied innovation elsewhere. Moreover, the analysis reveals that stringent environmental policy does not significantly increase specialization in biobased technologies, suggesting that current policies may not effectively target the specific challenges of the bioeconomy. Overall, the article contributes to understanding the uneven and path-dependent nature of bioeconomy transitions. It highlights the crucial role of existing specialization, technological complexity, and sector-specific dynamics in shaping national trajectories, while stressing the need for more tailored policies and indicators to foster biobased innovation.

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**Article #4**

Kriesch, L., & Losacker, S. (2024). Bioeconomy firms and where to find them. Region, 11(1), 55-78.

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This paper investigates how bioeconomy firms can be identified, measured, and mapped, addressing a critical challenge in tracking emerging sustainability-oriented industries. It argues that existing statistical classifications fall short in capturing the cross-sectoral and dynamic character of the bioeconomy and proposes an alternative methodological approach. The study develops a novel dataset of bioeconomy firms in Germany using web-mining and natural language processing. Drawing on the CommonCrawl repository of German company websites, the authors apply semantic search with transformer-based models and machine learning classification to detect firms engaged in bio-based activities. Topic modeling with BERTopic further uncovers the range of economic activities, while geocoding allows a spatial analysis of firms across NUTS-3 regions. This framework makes it possible to classify firms by technological capability, distinguishing between general bioeconomy firms and high-

tech bioeconomy firms in areas such as biotechnology and biopharmaceuticals. The analysis identifies around 143,000 bioeconomy firms in Germany, of which approximately 9.5% are high-tech. Results reveal distinct geographical patterns. The majority of bioeconomy firms are located in rural areas, often close to biomass feedstocks such as forests and agricultural land, confirming long-standing assumptions about resource-based clustering. By contrast, high-tech bioeconomy activities concentrate in large cities such as Munich, Heidelberg, Darmstadt, and Jena, where agglomeration economies and research infrastructures foster biotechnology and advanced knowledge-intensive domains. Statistical tests confirm these spatial patterns, with bioeconomy firms scaling sublinearly with regional firm populations, while high-tech bioeconomy firms scale superlinearly with urban density. The study contributes by introducing a comprehensive dataset that overcomes the limitations of conventional sectoral classifications. It demonstrates the usefulness of web-based text mining for regional economic research and offers openly accessible aggregated data. The findings underscore the urban–rural divide within the bioeconomy, with resource-based firms concentrated in rural regions and knowledge-intensive firms clustering in urban hubs.

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**Article #5**

Losacker, S., & Kuebart, A. (2024). Introducing sequence analysis to economic geography. Progress in Economic Geography, 2(1), 100012.

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This paper introduces sequence analysis to the field of economic geography, emphasizing its potential to better capture the temporal dynamics of regional and firm-level processes. While time and history are widely recognized as crucial in evolutionary economic geography, empirical studies often lack methods that adequately account for long-term trajectories. The authors argue that sequence analysis provides a suitable toolbox to fill this methodological gap. The study explains sequence analysis as a collection of techniques designed to analyze categorical longitudinal data, uncover typical trajectories, and cluster similar patterns of change. Originating from bioinformatics and widely used in sociology and demography, sequence analysis allows for the exploration of ordered states and transitions over time. The paper outlines two main applications for geography: territory-based approaches, which examine how regions evolve in terms of structural or sectoral composition, and entity-based approaches, which trace the spatiotemporal trajectories of actors such as firms,

products, or individuals. To demonstrate its applicability, the paper presents a use case analyzing structural change in European regions between 2001 and 2020 using employment data from agriculture, manufacturing, and services. The analysis reveals both persistent trajectories and significant shifts toward service-based economies. Clustering techniques identify six distinct regional development paths, one of which closely mirrors Fourastié's classical model of economic transformation, progressing from agriculture to industry and then to services. The article highlights several advantages of geographical sequence analysis: its ability to combine visualization and statistical analysis, its accessibility for researchers without advanced statistical training, and its suitability for integration with both quantitative methods (e.g., regression) and qualitative approaches (e.g., path tracing). In conclusion, the paper calls for wider adoption of sequence analysis in economic geography. It stresses that this approach can enrich the study of path-dependence, regional branching, resilience, and other temporal processes, offering a valuable methodological addition to the discipline.

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**Article #6**

Muehlberger, C. M., Gruen, L., Liefner, I., & Losacker, S. (2024). Socio-technical imaginaries of climate-neutral aviation. Energy Research & Social Science, 114, 103595.

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The article analyzes how different stakeholders envision pathways toward climate-neutral aviation, applying the lens of socio-technical imaginaries. We identify three distinct but overlapping imaginaries that structure debates on decarbonizing this hard-to-abate sector. The first, travel innovation, emphasizes demand management and behavioral change. It argues that up to 40% of necessary reductions could come from reducing air traffic through carbon pricing, jet fuel taxation, and an end to aviation subsidies and airport expansion. This imaginary, largely advocated by environmental associations, challenges the growth paradigm of aviation by calling for smaller sectoral scales and behavioral shifts in business and leisure travel. The second imaginary, fleet innovation, stresses radical modernization through new technologies such as hydrogen-powered and battery-electric aircraft. Rooted in ecological modernization and green growth logic, this framing sees the transition as a technological opportunity that preserves the socio-economic benefits of aviation. Industry and research actors emphasize large-scale investments in R&D, infrastructure, and policy frameworks to

enable disruptive propulsion technologies, while viewing sustainable aviation fuels (SAF) mainly as a bridging measure. The third imaginary, fuel innovation, foregrounds the aggressive scaling-up of alternative fuels and renewable energy. Advocated by cross-sector coalitions, this perspective stresses SAF as a long-term solution compatible with existing infrastructure and fleets, thereby minimizing systemic disruption. It envisions decarbonization primarily through energy transitions, though it faces challenges of sustainable feedstock supply, investment risks, and policy support needs. Our analysis shows that these imaginaries reflect the situatedness, power, and interests of their creators. Environmental groups stress sufficiency, industry promotes techno-economic fixes, and cross-sector partnerships emphasize incremental fuel-based solutions. While imaginaries can co-exist, fleet innovation currently dominates, reflecting the influence of powerful industry and research actors. However, fuel innovation may prove most implementable given its compatibility with existing systems. Ultimately, we highlight how power, geography, and competing visions shape the politics of aviation's sustainability transition, stressing the need for inclusive recognition of alternative imaginaries beyond techno-economic framings.

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**Article #7**

Kriesch, L., & Losacker, S. (2024). A global patent dataset of bioeconomy-related inventions. Scientific Data, 11(1), 1308.

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The article introduces a global dataset of bioeconomy-related patents, addressing the challenge of monitoring innovation in this rapidly expanding field. We argue that existing approaches, relying on technology classifications or keyword searches, are insufficient to capture the breadth and complexity of bio-based innovation. Such rule-based methods risk overlooking relevant patents due to language variability, cross-sectoral overlaps, or misclassifications. To overcome these limitations, we leverage the semantic capabilities of pre-trained transformer models and apply active learning to classify patents based on abstracts. Using a manually annotated training set enriched through iterative uncertainty sampling, we trained a text classification model that identified over 5.6 million bioeconomy patents — 8.3% of the global patent corpus. Our findings highlight the diversity of bioeconomy innovation, with relevant patents spread across 660 of 672 CPC classes. While pharmaceuticals, biotechnology, and agriculture dominate, we also observe substantial contributions from water treatment, food processing, and environmental technologies. To further explore the thematic structure

of the dataset, we applied BERTopic, which revealed 98 coherent topics ranging from organic plant cultivation and animal husbandry to gene expression and aquaculture. These topics underscore that the bioeconomy extends far beyond conventional boundaries, encompassing a wide spectrum of technological domains. We validated our approach against traditional IPC-based methods and show that while overlaps exist, our NLP-based classification captures large numbers of patents that rule-based searches miss, particularly in emerging or cross-disciplinary areas. At the same time, we recognize that reliance on abstracts can omit certain patents, and therefore encourage users to combine our dataset with rule-based filters for specific applications. In conclusion, we provide a comprehensive, open dataset and reproducible workflow that allows policymakers and researchers to analyze the technological knowledge base of the bioeconomy at unprecedented scale. By integrating frontier NLP methods with patent landscaping, we offer a foundation for studying how bio-based innovation unfolds globally, supporting both empirical research and informed governance of sustainability transitions

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**Article #8**

Mazzoni, F., & Losacker, S. (2024). What hinders the transition towards a bio-based construction sector? A global innovation system perspective on its value chain. Progress in Economic Geography, 2(2), 100023.

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The article investigates the barriers to a sustainability transition in the construction sector by examining how innovation unfolds along the value chain of bio-based construction. Drawing on the global innovation system (GIS) framework, we analyze how different modes of innovation and valuation are spatially configured and how they shape the emergence and diffusion of bio-based materials and building practices. Based on 55 expert interviews across Germany, Italy, China, and India, we find that the sector exhibits a pronounced innovation gap 2.0. In more detail, upstream scientific knowledge about novel bio-based materials often fails to translate into downstream implementation. This gap stems from a shift in GIS configuration along the value chain. The upstream segment is characterized by a science-driven (STI) innovation mode and a customized valuation mode, forming a market-anchored GIS. In contrast, the core segment, where buildings are designed and engineered, operates under a project-specific, interaction-based (DUI) innovation mode and similarly customized valuation, resulting in a spatially sticky GIS. This misalignment creates structural

bottlenecks for the transition. Scientific advancements in bio-based materials struggle to reach architects and builders due to fragmented actor constellations, limited training, and insufficient institutional support. However, we also observe the rise of integrated firms that span multiple value chain segments, bridging knowledge gaps through vertical integration and education efforts. These firms play a key role in advancing the transition by actively reshaping the sector's regime logic and institutional configurations. We conclude that transitioning to a bio-based construction sector is not only a matter of substituting materials like cement and steel. It requires a reorganization of value chains and innovation systems to overcome structural frictions. Recognizing the localized and multi-scalar nature of innovation and valuation processes is crucial for designing effective policy support and unlocking the transformative potential of bio-based construction.

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**Article #9**

Fischer, L., & Losacker, S. (2024). Competing or complementary?: Socio-technical imaginaries of a bio-based construction sector. TATuP–Journal for Technology Assessment in Theory and Practice, 33(3), 15-21.

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The article explores how different stakeholders envision a bio-based future for the construction sector, focusing on whether their visions are competing or complementary. We argue that the lack of momentum in material transitions cannot be explained solely by technological or economic barriers. Instead, diverging socio-technical imaginaries, i.e. publicly shared visions of desirable futures, play a decisive role in shaping and constraining the sector's transition. Drawing on 84 expert interviews across China, India, Italy, and Germany, we identify six imaginaries of bio-based construction that differ in their socio-technical logics, including preferred materials, targeted market segments, economic characteristics, and stages of development. These imaginaries span from engineered bamboo and frugal bamboo in China and India, to serial timber and eco-balanced timber in Germany and Italy, alongside cross-cutting visions of selective mixes with conventional materials and circular bioeconomy innovations. While many of these visions appear complementary in principle, for example, serving distinct market segments, they also reveal profound conflicts. Bamboo is simultaneously imagined as a premium material for luxury tourism and as a low-cost solution for affordable housing, producing social contradictions that undermine wider acceptance. Similarly, in Italy, timber

imaginaries split between mass-produced serial construction and ecologically balanced, low-adhesive timber use, competing over which values should dominate. Our analysis shows that imaginaries are not merely descriptive but actively shape legitimacy and delegitimation processes. By framing materials as suitable for "the poor" or "the rich," or by privileging certain logics of prefabrication and scale, actors can constrain alternative uses and slow down the overall transition. We conclude that socio-technical imaginaries in the making are crucial to understanding why the construction sector struggles to decarbonize. Transitions will only gain traction if complementarities are recognized and competing visions are bridged, enabling collective imaginaries that accommodate diversity while fostering a shared direction for systemic change.

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**Article #10**

Losacker, S., Horbach, J., & Liefner, I. (2025). A spatial perspective on green technology adoption in China: insights from patent licensing data. Innovation and Development, 15(1), 41-61.

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The article examines the geography of green technology adoption in China by analyzing patent licensing as an indicator of innovation diffusion. We argue that while much is known about the conditions under which green technologies emerge, less is understood about whether adopters use technologies developed locally or sourced from other regions. To address this gap, we analyze 8,825 licensing agreements for Chinese green technology patents from 2008 to 2019, geocoded at the prefectural level. Our findings show that regional context plays a crucial role in shaping adoption patterns. In some regions, such as Chongqing, most adopters rely heavily on locally developed technologies, whereas in others, like Suzhou, adoption depends largely on technologies from elsewhere. We use two-level mixed effects probit models to disentangle technology-specific and region-specific factors. At the licensing level, we find that patents filed by individuals are more likely to be adopted locally, while high-quality invention patents with more forward citations are more often licensed to other regions. Exclusive licensing agreements also show a strong local bias, reflecting the importance of proximity and trust in such transactions. At the regional level, we identify significant effects of green specialization and innovation capacity. Regions with high relative patent activity in green technologies and strong innovation capacity are more likely to adopt locally developed technologies, consistent with concepts of

regional innovation systems and lead markets. In contrast, less innovative regions without strong green industries tend to depend on technology transfer from other areas. We also find positive effects of educational infrastructure and, to some extent, manufacturing intensity, while regulatory designation as environmental model cities shows no influence. Overall, our study demonstrates that green technology adoption is shaped both by characteristics of patents and by regional innovation structures. Locally innovative and specialized regions are better positioned to match supply and demand, while others rely on external sources of green technology.

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**Article #11**

Liefner, I., Brueck, C., Losacker, S., & Zeng, G. (2025). What can mission-oriented innovation policy learn from China?. Science and Public Policy, scaf023.

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The article examines what mission-oriented innovation policy (MOIP) can learn from China by analyzing key features of its innovation system. While MOIP has recently gained prominence in Western policy debates as a response to grand societal challenges, we argue that China has long pursued policies with mission-oriented characteristics. Based on a review of publications and an analysis of 60 Chinese policy documents in the fields of artificial intelligence (AI) and environmental innovation, we identify four core features of Chinese policy that resonate with MOIP: durability, scope, coordination and reflexivity, and directionality. First, policy durability in China extends far beyond legislative cycles. Initiatives such as carbon neutrality by 2060 or the AI Development Plan until 2030 illustrate how long-term horizons are paired with intermediate milestones and detailed measures. Second, policy scope is broad, with coordination across ministries, levels of government, and the Communist Party. National missions are embedded in overarching narratives but also translated into provincial and municipal plans, ensuring vertical coherence. Third, policy coordination, tinkering, and reflexivity are achieved through designated zones — such as Special Economic Zones, eco-industrial parks, and AI hubs — that serve as experimental spaces. These zones allow for trial and error, localized adaptation, and comparative evaluation, with successful approaches scaled up nationally. Fourth, policy directionality and demand articulation are strongly state-led. The government deliberately creates and terminates markets, for example by banning certain products or mandating substitutes, thereby reducing uncertainty for firms and accelerating adoption of new technologies. We conclude that China's experience demonstrates how

missions can be operationalized through long-term planning, multi-level governance, and experimental policy spaces. While systemic differences limit direct transferability, the Chinese case highlights opportunities for Western policymakers to reflect on the importance of durable frameworks, designated zones for experimentation, and stronger directionality in market creation when designing MOIP.

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**Article #12**

Brueck, C., Losacker, S., & Liefner, I. (2025). China's digital and green (twin) transition: insights from national and regional innovation policies. Regional Studies, 59(1), 2384411.

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The article examines how policy shapes China's digital and green (twin) transition, drawing on a qualitative content analysis of 60 national and regional policy documents. We focus on three case study regions, Shanghai, Wuhan, and Hangzhou, to investigate how national strategies are adopted, adjusted, or reinterpreted at the regional level. While China pursues rapid digitization and green transformation simultaneously, we find that a comprehensive twin transition is not explicitly addressed at the national level but is partially implemented in the regions. Our findings reveal important differences in multi-level governance and regional pathways. In digital transformation, national policies emphasize AI development, digital infrastructure, data governance, and industry digitalization, typically articulated at a high level of abstraction. Regions translate these objectives into more concrete measures. Shanghai follows national strategies most closely, aiming to be a global AI hub with strong state involvement. Wuhan emphasizes infrastructure, security, and provincial integration, relying on state-owned enterprises and research institutes. Hangzhou pursues a distinct path, prioritizing smart city applications such as the "city brain" and supporting private enterprise-led ecosystems, notably through Alibaba. For green transformation, national policy focuses on eco-innovation, environmental governance, and green industries, supported through R&D, demonstration zones, and demand-side measures. Regional implementation again differs. Shanghai emphasizes state-led projects and large enterprises; Wuhan focuses on transforming production systems and supporting state-owned institutes; and Hangzhou highlights pilot projects, industrial platforms, and private-sector-driven initiatives. Regarding the twin transition, we find that national policy documents make reference to both "green digital" (e.g., energy-efficient data centers) and "digital green" technologies (e.g., AI for

pollution monitoring), but these synergies are only partially translated into regional strategies. Shanghai shows little evidence of integration, Wuhan embeds digital in specific green applications, and Hangzhou advances smart city solutions with environmental elements. We conclude that China's twin transition remains fragmented. National strategies set overarching directions, but regional governments selectively implement and adapt them. The result is heterogeneous regional pathways that highlight the importance of place-based dynamics in shaping the intersection of digital and green transitions.

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**Article #13**

Kriesch, L., & Losacker, S. (2025). A geolocated dataset of German news articles. Scientific Data, 12(1), 1128.

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The article introduces a large-scale dataset of geolocated German news articles, providing a new resource for studying regional discourse and societal trends. We argue that while digital news corpora are widely available, their potential for spatial analysis has remained underutilized due to the lack of systematic geolocation. To address this, we develop an end-to-end pipeline that processes raw CommonCrawl News data into a structured dataset with geographic and semantic annotations. Our workflow consists of five main stages. First, we acquire the global CommonCrawl News dataset and filter it for German-language content. Second, we extract article texts using Trafilatura and apply rigorous quality heuristics to ensure reliable content. Third, we create training data using a large language model to annotate location entities and train a custom spaCy model for named-entity recognition (NER). Fourth, we geoparse identified entities using Nominatim, assigning them to German NUTS-3 regions. Finally, we embed the full-text articles with the deepset-mxbai-embed-de-large-v1 sentence transformer, enabling semantic search through an integrated Usearch vector database. The resulting dataset comprises nearly 50 million German news articles published between 2016 and 2023, of which about 70% contain at least one valid city mention. Each article is linked to structured metadata in an SQLite database and to semantic vectors in the accompanying Usearch database. Our validation demonstrates that article volumes strongly correlate with population size ($R^2 = 0.507$), confirming the robustness of the geocoding approach. The NER model achieves an F1 score of 93.9%, ensuring reliable entity extraction. We also show through a use case on "heat pumps" that semantic search results align closely with external benchmarks such as Google

Trends (correlation 0.84). We conclude that the dataset provides a scalable and replicable foundation for spatial analysis of news data. By linking textual content, geographic information, and semantic embeddings, it enables researchers to study regional discourse, public opinion, and societal change at unprecedented scale.

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**Article #14**

Hansmeier, H., Losacker, S., Bersch, J., & Kroll, H. (2025). Regional Specializations in Green Incumbents and Green Start-ups in the German Transport Sector. Growth and Change, 56(1), e70025.

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The article analyzes regional differences in eco-innovation within the German transport sector, focusing on the relative specialization of green incumbents and green start-ups. We argue that while both types of actors are central to sustainability transitions, little is known about how their regional prevalence compares and how their coexistence shapes green development. Using data from 46,228 transport patents (15,000 green) and 900 green transport start-ups between 2009 and 2018 across 96 German labor market regions, we construct a typology of regional specializations. Our results reveal four categories: hotspots (above-average specialization in both incumbents and start-ups), start-up-driven regions, incumbent-driven regions, and laggards. We find that 37% of regions fall into the laggard category, 29 regions are start-up-driven, 18 are incumbent-driven, and only 14 (around 15%) can be classified as hotspots. This distribution shows that it is rather exceptional for regions to simultaneously specialize in both types of eco-innovation actors. Instead, green start-ups and incumbents tend to emerge in different regional contexts, challenging assumptions about co-location or simple substitution between new and established actors. Spatially, hotspots and start-up-driven regions are concentrated in southern and eastern Germany, while laggards cluster in central and northwestern areas. Interestingly, some major automotive hubs such as Munich, Ingolstadt, and Stuttgart appear as start-up-driven or hotspot regions, indicating that strong regime structures do not necessarily prevent eco-innovation. Regression models further highlight the importance of regional human capital and technological capabilities. Regions with higher shares of highly skilled individuals and R&D-intensive industries are significantly more likely to specialize in green incumbents, start-ups, or both. Conversely, regions dominated by large enterprises show lower likelihoods of being

hotspots, suggesting that excessive incumbent dominance can hinder diversification. We conclude that regional pathways to sustainable transport are heterogeneous. Eco-innovation is not exclusively an urban phenomenon, nor is it confined to either incumbents or start-ups. Instead, both actor types contribute to regional greening in different ways, depending on local capacities and institutional contexts.

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**Article #15**

Otto, A., Losacker, S., & Hansmeier, H. (2025). Relatedness, complexity, and regional development paths in Germany: a sequencing approach. The Annals of Regional Science, 74(2), 50.

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The article examines the long-term evolution of regional development paths in Germany, focusing on how relatedness and complexity shape industrial portfolios. We argue that while the EU's Smart Specialization Strategy (S3) emphasizes building on current regional capabilities, it overlooks the importance of historical trajectories. To address this gap, we apply sequence analysis and optimal matching techniques to employment data for 401 German NUTS-3 regions from 1993 to 2018, measuring inter-industry skill relatedness and task complexity. This approach enables us to trace the co-evolution of branching potential and complexity in regional economies over time. Our findings reveal five distinct trajectory types. Successful regions maintain both high complexity and high relatedness, largely encompassing Germany's major urban agglomerations, which combine diversified portfolios with strong growth and innovation outcomes. Complex regions also exhibit high complexity but low coherence, reflecting a disembedded structure with limited branching potential, often in East German and mid-sized cities. Fragile regions follow unstable trajectories, frequently shifting between states of relatedness and complexity; they illustrate heterogeneous paths, with some catching up and others declining. Less complex specialized regions show stable but low complexity with relatively high relatedness, typically in rural areas, where opportunities to branch into higher-value activities remain constrained. Finally, lagging regions maintain both low complexity and low coherence throughout, concentrated in structurally weak peripheries such as coastal, border, and rural areas. Comparisons of socio-economic indicators show that successful and complex regions achieve the strongest GDP per capita growth and reductions in unemployment, while lagging and less complex regions remain dependent on subsidies. Fragile regions

occupy a middle ground with diverse outcomes. Two case studies, Worms and Cloppenburg, illustrate how trajectories differ: Worms shifted from a complex to a less complex portfolio with weaker growth, while Cloppenburg increased coherence in agriculture-related industries, achieving above-average performance. We conclude that incorporating long-term trajectories into S3 design is crucial. Regional development paths are highly path-dependent, and strategies must account for historical contexts to effectively leverage diversification opportunities.

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**Article #16**

Losacker, S., Becker, T., & Shang, Y. (2025). Guanxi and innovation in China: insights from the (bio-based) construction sector. Innovation and Development, 1-24.

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The article examines the role of guanxi in shaping innovation in China's construction sector, with a particular focus on bio-based building materials. We argue that while the construction industry is traditionally resistant to change and innovation, guanxi, i.e. trust-based interpersonal relationships deeply rooted in Chinese culture, can play a decisive role in enabling innovation activities. Drawing on 20 expert interviews with actors across the construction value chain, we investigate how guanxi influences collaboration and knowledge exchange in different organizational and material contexts. Our findings show that guanxi is especially pronounced in smaller firms and academic institutions, where personal ties facilitate access to resources and knowledge, thereby enabling innovation projects that might otherwise not materialize. In contrast, larger organizations and international collaborations rely more on formal networks, technical expertise, and professionalized procedures, reducing the relative importance of guanxi. We also find differences along the value chain. In upstream material innovation, guanxi matters most for bio-based construction actors, particularly in bamboo innovation, where collaborations often stem from long-standing personal or academic relationships. Downstream, in design and engineering, guanxi is vital for acquiring clients and navigating bureaucratic processes, especially through connections with government officials. Comparisons between conventional and bio-based construction highlight that guanxi is more critical in the latter, given its niche status, high uncertainty, and fragmented actor base. For bamboo construction in particular, guanxi networks serve as crucial channels for trust, legitimacy, and resource mobilization. However, reliance on guanxi also entails risks. Small, closed networks may reinforce insider advantages, limit openness, and inhibit broader diffusion once

innovation scales beyond niche contexts. We conclude that guanxi plays an important yet ambivalent role in China's construction innovation system. It can mitigate key sectoral challenges (complexity, local boundedness, loose coupling, and strong institutionalization) but its benefits are most pronounced in the early stages of bio-based construction. As the sector matures, guanxi's influence may diminish, requiring complementary mechanisms for sustaining innovation and broader diffusion.

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**Article #17**

Jayaweera, R., Losacker, S., Song, L.T., & Schwede, D. (2025). Regional preconditions and sustainability transition pathways: Insights from circular, bio-based and resource-efficient building material innovations in Vietnam. Energy Research & Social Science, 125, 104133.

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The article investigates how regional preconditions shape the innovation, diffusion, and transition dynamics of sustainable building material technologies in Vietnam. We argue that while the Global South experiences rapid urbanization and construction, transition studies have often treated "green innovations" and "the Global South" as homogeneous categories. Instead, we examine how place- and technology-specific configurations influence potential transition pathways for bio-based, circular, and resource-efficient building materials in Hanoi, Da Nang, and Ho Chi Minh City. Our analytical framework distinguishes three key dimensions of regional preconditions: institutional factors, technical specialization and material flows, and market networks and demand. Based on 25 expert interviews, we find that these factors vary across technologies and regions, producing highly differentiated opportunity spaces. For bio-based materials, high availability of agricultural by-products (rice straw, bamboo, timber) exists nationwide, but economic viability is constrained by transport costs, land prices, and limited certification. Da Nang shows stronger experimentation due to tourism demand and cheaper land, while Hanoi and Ho Chi Minh City are more risk-averse. For circular innovations, industrial by-products such as fly ash and slag are widely used in cement production, yet construction waste recycling remains marginal due to regulatory barriers and weak markets. For resource-efficient materials, particularly unburnt bricks, state regulations mandate adoption in public projects, though enforcement is uneven; strong in Hanoi, weak in Da Nang and Ho Chi Minh City. Beyond regional conditions, multi-scalar dynamics play a decisive role.

Transnational corporations create demand for certified green buildings, especially in Ho Chi Minh City, while global technology imports and international certifications shape legitimacy and market access. At the same time, weak local knowledge about material flows and high perceived risks hinder adoption. We conclude that Vietnam's sustainability transition in the building sector is characterized by heterogeneous, place- and technology-specific pathways. Regional preconditions interact with national policies and global market dynamics, generating opportunities and constraints that differ across innovations and regions.

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**Article #18**

Fischer, L., & Losacker, S. (2025). How to build (in) the future? Legitimacy of socio-technical visions in a bio-based construction sector. Environmental Innovation and Societal Transitions, 56, 100996.

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The article investigates the legitimacy of socio-technical visions for a bio-based construction sector, focusing on how private visions become collectively adopted and shape potential transition pathways. We argue that while the use of bio-based materials such as timber and bamboo is increasingly seen as a strategy to decarbonize construction, there is little consensus on what a bio-based future should look like. Drawing on 87 expert interviews with key actors in Germany, Italy, India, and China, we identify six locally validated socio-technical visions and analyze their legitimacy as a necessary condition for collectivization. Two visions center on bamboo in Asia: engineered bamboo, emphasizing prefabrication and global markets, and frugal bamboo, stressing locally available, traditional use in affordable housing. In Europe, we find visions of serial timber construction, focusing on prefabricated mass timber, and eco-balanced timber, highlighting sustainable, low-adhesive use. Across countries, actors envision a selective mix with conventional materials, integrating bio-based with mineral-based components, and a circular bioeconomy vision, centered on cradle-to-cradle innovations and modularity. Our analysis shows that the legitimacy of these visions varies across pragmatic, moral, and cognitive dimensions. The selective mix vision is the most legitimized across countries, since it allows actors to retain familiar practices while symbolically incorporating bio-based elements, making it the dominant socio-technical vision. By contrast, engineered bamboo in China and serial timber in Germany achieve partial legitimacy through pilot projects and policy support

but remain alternative. Frugal bamboo and eco-balanced timber face difficulties in gaining broader acceptance, as they lack cognitive legitimacy beyond niche contexts. The circular bioeconomy vision is promising but still marginal, with limited materialization. We conclude that legitimacy is central to understanding which socio-technical visions become dominant in the bio-based construction sector. The dominance of the selective mix demonstrates how incremental change can capture legitimacy from more radical visions, shaping the trajectory of sustainability transitions.

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**Article #19**

Kriesch, L., Abbasiharofteh, M., & Losacker, S. (2025). The geography of digital and green (twin) firms in Germany. Regional Studies, Regional Science, 12(1), 513-516.

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The article analyzes the geography of Germany's digital and green "twin transition," focusing on firms engaged in both domains. We argue that while the twin transition has become a central policy priority, there is limited knowledge about how digital, green, and combined (twin) activities are distributed across space. Existing administrative classifications provide only a rough picture and often miss firms whose activities cut across categories. To overcome this, we apply a web-mining and natural language processing (NLP) approach to identify firms engaged in green, digital, and twin activities. Our dataset covers 678,381 firms, from which we extracted over 44 million website text paragraphs. Using a cosine similarity filter with green and AI-related keywords, we pre-selected relevant texts. We then manually annotated 1,437 paragraphs to fine-tune two transformer models in a SetFit framework, which accurately classified firms as digital, green, or both. Validation against 500 manually annotated samples yielded an F1-score of 90%, ensuring robust performance. Aggregating the firm-level results into hexagonal grid cells allows us to map the spatial distribution of the twin transition. We identify 249,483 firms involved in green activities, which are relatively evenly spread across Germany, including rural areas. By contrast, 57,669 firms are active in AI and other digital technologies, concentrated in major urban centers. Crucially, 23,819 firms combine both digital and green activities, forming the core of the twin transition. These twin firms cluster in metropolitan hubs such as Berlin, Munich, Hamburg, and Frankfurt, as well as in specialized mid-sized cities like Aachen, Stuttgart, and Karlsruhe. We conclude that Germany's twin transition is highly uneven. While green firms are broadly distributed, digital and twin

firms remain concentrated in urban innovation hubs. This spatial imbalance highlights the risk that peripheral regions may be left behind, underscoring the need for policies that account for place-based dynamics in fostering the twin transition.

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**Article #20**

Mazzoni, F., Binz, C., & Losacker, S. (2025). What can the bamboo industry learn from timber? Resource mobilization across global innovation systems in the construction sector. Geoforum, 165, 104378.

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The paper examines how the emerging GIS for bamboo construction can mobilize resources from the more mature timber construction GIS to accelerate its development. We use and expand the GIS framework to conceptualize cross-system resource mobilization, focusing on knowledge, legitimacy, market access, and financial investment. Drawing on 46 expert interviews from China, India, and the global bamboo industry, complemented by desk research on timber construction, we find that bamboo's GIS is spatially sticky, centered mainly in China, with localized, customized valuation and a stronger reliance on DUI innovation modes. In contrast, timber's GIS is market-anchored, more globalized, and mature, with standardized elements and stronger STI characteristics. We find a commensal relationship; bamboo benefits from timber without affecting it. Cross-system mobilization is strongest in knowledge. Bamboo actors adopt timber's research insights, engineering methods, and machinery, adapt them to bamboo's properties, and develop hybrid products (e.g., cross-laminated bamboo timber). Knowledge transfer occurs via codified resources, trade fairs, joint projects, and returnee entrepreneurs who adapt timber know-how from abroad. Legitimacy is mobilized through cognitive assimilation, presenting bamboo as similar to timber, and performance benchmarking, often via demonstration projects that compare or combine the two materials. Market access is supported by emulating timber's building codes and standards, providing a basis for future bamboo-specific regulations. Financial investment mobilization is minimal, as bamboo finance remains place-bound and heavily reliant on government subsidies, while timber's investment structures are spatially sticky and tied to mature markets. Our findings show that resource mobilization from market-anchored GISs is easier for footloose STI-related knowledge than for spatially sticky valuation resources. Geographic separation between bamboo (Asia) and timber (Europe/North America) further limits transfers of tacit knowledge and valuation dynamics.

**Article #21**

Schütz, M., Kriesch, L., & Losacker, S. (2025). Mapping Local Government Priorities: A Web-Mining Approach for Regional Research. Regional Science Policy & Practice, 17(12), 100240.

The article presents a novel method for systematically mapping local government priorities using web-mined textual data from German county websites. Recognizing that local and regional governments play a central role in shaping place-based development strategies, we address the lack of scalable data on their strategic orientations. We compile a large dataset by exhaustively web scraping over 74,000 county subpages, extracting and cleaning 360,000 text paragraphs. Applying BERTopic, a transformer-based topic modeling approach, we identify 205 coherent topics, with the 30 most common covering a wide spectrum of governance functions — ranging from regulatory duties (e.g., water rights, environmental protection) to participatory and community-building initiatives (e.g., volunteering, partnerships). Three exemplary topics, Urban Development and Planning, Climate Protection Initiatives, and Business Development and Support, are analyzed in depth. Spatial patterns reveal that urban development correlates with population density, while climate and business topics show distinct regional clustering, particularly an East–West divide. Western states display higher engagement and internal diversity, whereas eastern states show lower, more uniform emphasis. State-level variation is statistically significant for climate and business priorities, but less so for urban development. Qualitative examination of selected counties' texts highlights differences in strategic framing even within the same topic. Some adopt formalized, long-term planning approaches, while others emphasize community participation or operational service delivery. These differences underscore the performative and legitimizing nature of government website content, which reflects curated narratives rather than complete records of governance activity. Methodologically, the paper demonstrates the feasibility and value of combining web mining, NLP, and topic modeling for regional research. We make aggregated topic data publicly available and suggest future research avenues, including longitudinal analyses, sentiment studies, and integration with other web-based or structured datasets to deepen understanding of regional governance dynamics.

# 5. Conclusions

This habilitation thesis set out to explore the spatial dimensions of innovation and socio-technical change in the context of the bioeconomy and the twin transition. At the outset, I framed these processes against the backdrop of planetary crises and grand societal challenges, which demand profound transformations in the ways economies are organized and societies function. While the individual research papers that make up this thesis have examined specific cases and contexts, the following conclusion brings these findings together and reflects on what they collectively tell us about innovation, socio-technical change, and their geographical character.

In the introduction, I outlined four overarching aims that have guided this work. In the following, I revisit each of them in turn, drawing together insights from the individual articles to highlight broader contributions and implications.

(1) The first aim of this thesis was to contribute to a better understanding of the spatial dimension of innovation and socio-technical change, paying attention to their geographical origins, situatedness, and implications. Across the empirical studies, a central message emerges: innovation and socio-technical change are profoundly uneven in space. They are not processes that unfold uniformly across countries and regions, but ones that are deeply shaped by local capacities, institutions, and histories. Taken together, the findings underline that geography is not just a backdrop against which innovation happens. It actively shapes the processes of innovation and socio-technical change, influencing who drives them, where they occur, and how they unfold. This becomes evident in both the qualitative and the quantitative contributions. While the quantitative analyses primarily illuminate the spatial heterogeneity of innovation (e.g. Hansmeier & Losacker, 2024; Kriesch et al., 2025; Kriesch & Losacker, 2024b), the qualitative contributions reveal how these spatial patterns emerge and how they solidify over time (e.g. Jayaweera et al., 2025; Mazzoni & Losacker, 2024). Beyond highlighting the geographical heterogeneity of innovation and socio-technical change, the thesis also demonstrates the strong influence of geographical contingencies, both between regions or nations and across different scales (e.g. Brueck et al., 2025; Mazzoni et al., 2025). This underscores the global and multi-scalar character of innovation and socio-technical change, which goes beyond a mere description of spatial patterns. Instead, it emphasizes the significance of geography in a way that exceeds the simplistic “mapping of regional differences” often suggested in geographical research. The findings indicate that the role of geography is far more

complex than it is frequently portrayed (Binz et al., 2020). They make clear that a systemic perspective is required to grasp the (geographical) complexity of innovation and transition processes. As such, innovation and technology are embedded within systems whose geographies often extend beyond regional and national boundaries.

(2) The second aim was to examine how innovation and socio-technical change come about in selected societally relevant domains that have gained prominence in policy and academic debates, particularly the bioeconomy and the twin transition. The bioeconomy is often presented as a promising solution to environmental crises (Befort, 2023; Bugge et al., 2016). Yet, as the research shows, it is far from straightforward. In conceptual terms, the literature has often treated the bioeconomy as a matter of substitution, focusing on replacing fossil inputs with bio-based ones (Losacker, Heiden, et al., 2023). While substitution is important, such a framing risks overlooking the transformative potential of new biotechnologies that can reconfigure value chains and industries altogether. From a spatial perspective, however, the mapping of bioeconomy firms in Germany reveals a strong urban–rural divide in this regard. Resource-based activities are often concentrated in rural regions, while knowledge-intensive and high-tech bioeconomy activities cluster in large cities (Kriesch & Losacker, 2024b). These patterns reflect long-standing assumptions about resource access and agglomeration economies, but the new data presented in this thesis make it possible to see them in much greater detail. Complementing this, the (global) patent dataset shows just how diverse bio-based innovation is (Kriesch & Losacker, 2024a; Wydra, 2020), spanning hundreds of technological fields and challenging narrow bioeconomy definitions (Befort, 2020; Lhuillery et al., 2025). The construction sector illustrates how the bioeconomy is contested in practice (e.g. Fischer & Losacker, 2025). The study on the construction sector's value chains highlights a misalignment between upstream scientific advancements and downstream adoption, which creates structural bottlenecks for innovation and socio-technical change (Mazzoni & Losacker, 2024). At the same time, the analyses of socio-technical imaginaries and visions reveal how divergent expectations about timber, bamboo, and other materials create competing or complementary pathways (Fischer & Losacker, 2024, 2025). Altogether, legitimacy has emerged as a crucial factor. While radical innovations struggle to gain acceptance, incremental approaches such as selective mixes of materials often dominate because they are more easily legitimized across actor groups. Turning to the twin transition, the studies on China and Germany show that it, too, is uneven and contested. In China, national policies emphasize both digitalization and greening, but integration is

fragmented and left to regional governments, which interpret strategies differently depending on their contexts (Brueck et al., 2025; Liefner et al., 2025). In Germany, the mapping of digital, green, and twin firms shows that while green firms are broadly distributed, digital and especially twin firms remain concentrated in a few urban hubs (Kriesch et al., 2025). This creates a spatial imbalance and raises concerns about who benefits from the twin transition (Cicerone et al., 2024; Faggian et al., 2024). Across both empirical contexts, bioeconomy and the twin transition, a clear message is that transformative potential exists, but it is shaped and often constrained by structural conditions, institutional misalignments, and divergent visions. These findings caution against overly optimistic framings of the bioeconomy and the twin transition as straightforward solutions. They are instead highly uneven, contested, and place-dependent.

(3) The third aim of the thesis was to shed light on how innovation and socio-technical change unfold across different geographical contexts and scales. The research presented in this thesis spans a wide spectrum of countries and regions, while a multi-scalar approach has been crucial in showing how transitions are shaped by interactions across spatial scales. The articles highlight country- and region-specific innovation conditions and demonstrate their relevance. This includes, for example, the importance of guanxi in the Chinese innovation system or the more frugal innovation approach in India (Fischer & Losacker, 2024, 2025; Losacker, Becker, et al., 2025). These differences manifest not only in context-dependent innovation cultures but also in the role of innovation-promoting policies and their specific measures (Liefner et al., 2025). Moreover, the contributions show how local (and localized) conditions shape the success of different innovations, as demonstrated in the study of building material innovations in regions of Vietnam (Jayaweera et al., 2025). At the same time, beyond these contextual specificities, the relevance of multi-scalar and cross-regional interdependencies in innovation and transition processes becomes evident, as in the case of the bamboo GIS (Losacker, Becker, et al., 2025; Mazzoni et al., 2025; Mazzoni & Losacker, 2024). Taken together, the thesis demonstrates that scale matters. Transitions are not only multi-scalar, they are also shaped by how different scales interact. Global knowledge can feed into local innovation systems, national strategies can be reinterpreted regionally, and local preconditions can either enable or constrain broader transitions. Recognizing this interplay is crucial for both academic analysis and policy design.

(4) The fourth aim was to advance data, methods, and indicators for studying innovation and socio-technical change. Several of the papers explicitly engage in methodological development. The introduction of sequence analysis to economic geography demonstrates how long-term trajectories can be captured and compared in new ways, highlighting temporal dynamics that are often overlooked (Hansmeier & Losacker, 2024; Losacker & Kuebart, 2024; Otto et al., 2025). The creation of large-scale datasets, whether on bioeconomy patents, geolocated news articles, or local government priorities, opens new opportunities for spatial analysis and for connecting text data, innovation data, and geographical contexts (Kriesch & Losacker, 2024a, 2025a; Schütz et al., 2025). The use of web-mining and natural language processing demonstrates the value of computational methods for studying emerging and cross-sectoral phenomena such as the bioeconomy and the twin transition (Kriesch et al., 2025; Kriesch & Losacker, 2024b). These contributions underline that methodological novelty is not a technical side-note but central to how we can understand innovation and socio-technical change. New tools allow us to see patterns and dynamics that would remain invisible with conventional data and methods. Based on the experiences gained through the research presented in this thesis, I encourage fellow scholars to broaden their methodological repertoire and to incorporate novel methods and data into their research practice.

Looking across the research aims discussed thus far, several cross-cutting themes stand out. First, transitions are strongly path-dependent, yet disruptive potential exists. The tension between gradual, incremental change and more transformative possibilities runs through many of the articles (e.g. Fischer & Losacker, 2024). Second, imaginaries, visions, and legitimacy play a decisive role. Transitions are not just about technologies and markets, but also about how futures are imagined and accepted in society (e.g. Muehlberger et al., 2024). Third, spatial divides are persistent, whether between rural and urban regions, between more and less innovative regions, or between different parts of the world (e.g. Otto et al., 2025). This is an obvious but important stylized fact about the geography of innovation. Fourth, policy directionality and governance matter greatly (e.g. Brueck et al., 2025; Liefner et al., 2025). The examples presented in the thesis show how policies and institutions can either enable or constrain transitions, depending on how they align with local capacities and contexts.

In sum, this habilitation thesis contributes to economic geography by deepening our understanding of the geography of innovation and socio-technical change, by bringing

societally relevant domains such as the bioeconomy and the twin transition into focus, by analyzing transitions across multiple geographical contexts and scales, and by expanding the methodological toolkit available to researchers. The findings underline the importance of place-based and multi-scalar approaches to understanding innovation and socio-technical change. They also highlight that transitions are not inevitable or uniform, but contested, uneven, and shaped by complex interactions of technologies, institutions, and visions, among other (socio-technical) factors. For policymakers, this means that promoting innovation and socio-technical change requires more than generic strategies. It requires attentiveness to place-based dynamics while simultaneously accounting for global and multi-scalar contingencies.

What this habilitation thesis ultimately shows is that socio-technical change is profoundly geographical. It emerges unevenly, it is shaped by local and global interactions, and it carries implications for regional development. Understanding these dynamics is not only a matter of academic interest, but also of societal urgency, as humanity searches for pathways toward more sustainable futures.

# 6. Individual articles

In the final section of this cumulative habilitation thesis, I list all articles that are part of the thesis. For each article, I provide the full bibliographic information as well as the DOI link to the full text as available through the respective publishers. I also include the abstract for the sake of completeness. All articles have been published in peer-reviewed international journals, including leading journals in the academic fields addressed by this thesis.

The articles are not presented in a specific thematic order. I believe the preceding chapters sufficiently demonstrate how they collectively form a coherent habilitation thesis, offering insights into *the spatial dimension of innovation and socio-technical change* from an economic geography perspective. Accordingly, I have refrained from imposing an artificial structure on their presentation. Instead, the articles are listed in roughly chronological order, similar to how they would appear when sorting my Google Scholar profile by year of publication.

# ARTICLE #1

## Rethinking bioeconomy innovation in sustainability transitions

Authors: Sebastian Losacker, Stefanie Heiden, Ingo Liefner, Henning Lucas

Published 2023 in *Technology in Society*, 74, 102291
DOI: https://doi.org/10.1016/j.techsoc.2023.102291

**Abstract**

Over the past two decades, a new research field dealing with "sustainability transitions" has emerged, analyzing the transformation of socio-technical systems towards more sustainable futures. While there is consensus on the crucial role of the bioeconomy in sustainability transitions research, we argue that the true potential of many bioeconomy innovations is not yet sufficiently recognized and assessed. Much of the literature on the bioeconomy focuses on the bio-based substitution of environmentally harmful goods, neglecting the disruptive potential of innovative biotechnologies. In this commentary, we present some examples on advanced biotechnology and we invite sustainability transitions scholars to rethink their notion of bioeconomy innovations.

# ARTICLE #2

## Regional eco-innovation trajectories

Authors: Hendrik Hansmeier, Sebastian Losacker

Published 2024 in *European Planning Studies*, 32 (6), 1401-1422
DOI: https://doi.org/10.1080/09654313.2024.2308027

**Abstract**

Given that eco-innovations and the associated renewal of regional economic structures are pivotal in addressing environmental challenges, regional research is increasingly focusing on their spatio-temporal dynamics. While green technological and industrial path developments in specific regions have received considerable attention, little effort has been made to derive general patterns of environmental inventive activities across regions. Drawing on unique data capturing both green incumbent and green start-up activities in the 401 German NUTS-3 regions over the period 1997–2018, this paper sheds light on how eco-innovation activities unfold in different regional contexts. For this purpose, we introduce sequence analysis methods into the research toolkit of research on regional development. These novel methods allow us to understand to what extent regions engage in eco-innovation activities, how these activities change over time and to what extent similar or unique eco-innovation trajectories (co)evolve. Based on this empirical approach, we distinguish different types of regional eco-innovation trajectories and find a strong persistence and path dependency in green regional development.

# ARTICLE #3

## National specialization and diversification in the bioeconomy: insights from biobased technologies in chemical and pharmaceutical sectors

Authors: Lennart Fischer, Sebastian Losacker, Sven Wydra

Published 2024 in *Technology in Society*, 76, 102462
DOI: https://doi.org/10.1016/j.techsoc.2024.102462

**Abstract**

Facilitating the transformation of innovation systems is a vital endeavor within the global quest to diminish the detrimental environmental consequences of economic activities. Against this background, scholars and policymakers emphasize the potentials of a societal transition towards a 'bioeconomy'. In this paper, we study the technological specialization of countries in biobased technologies relating to chemicals and pharmaceuticals, which are key constituents for a future bioeconomy. By identifying these technologies in patent and publication data, we analyse specialization and diversification processes for 15 countries from 1997 to 2019. We find that countries that already had a relative advantage in biobased technologies are more likely to develop new specializations in technologies that relate to the bioeconomy. Beyond that, countries' specialization in biobased technologies varies between basic research (scientific publications) and applied research (patents). Our study also shows that greater technological complexity tends to limit specialization in biobased publications, highlighting the need for targeted policy interventions supporting the bioeconomy.

# ARTICLE #4

## Bioeconomy firms and where to find them

Authors: Lukas Kriesch, Sebastian Losacker

Published 2024 in *REGION*, 11 (1), 55-78
DOI: https://doi.org/10.18335/region.v11i1.523

**Abstract**

The bioeconomy represents a transformative approach to economic development and sustainability by harnessing biological resources and knowledge to produce goods, services, and energy while reducing dependence on non-renewable resources. In order to understand and support the bioeconomy, scholars and policymakers rely on an accurate measurement and monitoring of biobased economic activities. However, existing statistical frameworks and industry classifications often fall short in capturing the unique characteristics and complexities of the bioeconomy. This article addresses this challenge by developing a methodological approach for comprehensive measurement and mapping of biobased economic activities. We build a novel data set of bioeconomy firms in Germany using web-mining and machine learning techniques. This data set enables detailed analysis of biobased economic activities, providing valuable insights into the spatial organization of the bioeconomy. The paper demonstrates the applicability of the data set by testing several stylized facts about the bioeconomy. Our research contributes to a better understanding of the bioeconomy's regional impacts and offers a valuable resource for policymakers and researchers interested in understanding the geography of biobased economic activities. We make an aggregated version of the data set freely available online.

# ARTICLE #5

## Introducing sequence analysis to economic geography

Authors: Sebastian Losacker, Andreas Kuebart

Published 2024 in *Progress in Economic Geography*, 2 (1), 100012
DOI: https://doi.org/10.1016/j.peg.2024.100012

**Abstract**

In this short paper, we introduce sequence analysis methods to economic geography. Sequence analysis is a rich set of research methods that is widely used to analyze temporal variance in several disciplines in the social sciences, including sociology, demography and employment research. However, the toolbox of sequence methods has yet to gain significant attention among economic geographers. Sequence analysis methods can be used to analyze and understand patterns and structures of various phenomena over time. It employs mathematical and statistical techniques to study the sequential order, duration, and transitions between temporal conditions. We argue that sequence analysis holds great potential for advancing research in (evolutionary) economic geography. In the paper, we explain how to use sequence analysis, we ponder on empirical applications for research in economic geography, and we demonstrate its applicability in a use case. We also provide a reproducible R script and manual for the use case in the online appendix.

# ARTICLE #6

## Socio-technical imaginaries of climate-neutral aviation

Authors: Clara-Marie Muehlberger, Lennart Gruen, Ingo Liefner, Sebastian Losacker

Published 2024 in *Energy Research & Social Science*, 114, 103595
DOI: https://doi.org/10.1016/j.erss.2024.103595

**Abstract**

Limiting global warming to 1.5 °C is crucial to prevent the worst effects of climate change. This entails also the decarbonization of the aviation sector, which is considered to be a "hard-to-abate" sector and thus requires special attention regarding its sustainability transition. However, transition pathways to a potentially climate-neutral aviation sector are unclear, with different stakeholders having diverse imaginations of the sector's future. This paper aims to analyze socio-technical imaginaries of climate-neutral aviation, as different perceptions of various stakeholders on this issue have not been sufficiently explored so far. In that sense, this work contributes to the current scientific debate on socio-technical imaginaries of energy transitions, for the first time studying the case of the aviation sector. Drawing on six decarbonization reports composed by different interest groups (e.g. industry, academia, and environmental associations), three imaginaries were explored, following the process of a thematic analysis: rethinking travel and behavioral change (travel innovation), radical modernization and technological progress (fleet innovation), and transition to alternative fuels and renewable energy sources (fuel innovation). The results reveal how different and partly conflicting socio-technical imaginaries are co-produced and how the emergence and enforceability of these imaginaries is influenced by the situatedness of their creators, indicating that the sustainability transition of aviation also raises political issues. Essentially, as socio-technical imaginaries act as a driver for change, policymakers should acknowledge the existence of alternative and counter-hegemonic visions, created by actors from civil society settings to take an inclusive and equitable approach to implementing pathways towards climate-neutral aviation.

# ARTICLE #7

## A global patent dataset of bioeconomy-related inventions

Authors: Lukas Kriesch, Sebastian Losacker

Published 2024 in *Scientific Data*, 11 (1), 1308
DOI: https://doi.org/10.1038/s41597-024-04163-6

**Abstract**

Many governments worldwide have proposed transitioning from a fossil-based economy to a bioeconomy to address climate change, resource depletion, and other environmental concerns. The bioeconomy utilizes renewable biological resources across all sectors and is strongly founded on scientific advances and technological progress. Given that the bioeconomy spans multiple sectors, industries, and technological fields, tracking it is challenging, and both policymakers and researchers lack a comprehensive understanding of the bioeconomy transition's progress. We aim to solve this problem by providing a dataset on patents, a commonly used indicator to study the development of novel knowledge and technological change, that identifies bioeconomy-related inventions. We leverage the advanced semantic understanding embedded in pre-trained transformer models to identify bioeconomy-related patents based on patent abstracts, and we use a topic modelling approach to identify several coherent technological fields within the corpus of bioeconomy patents. The dataset can be linked to other patent databases and therefore provides rich opportunities to study the technological knowledge base of the bioeconomy.

# ARTICLE #8

## What hinders the transition towards a bio-based construction sector? A global innovation system perspective on its value chain

Authors: Francesca Mazzoni, Sebastian Losacker

Published 2024 in *Progress in Economic Geography*, 2 (2), 100023
DOI: https://doi.org/10.1016/j.peg.2024.100023

**Abstract**

The construction sector is heavily polluting and an actual threat to the natural environment, therefore its transition towards becoming bio-based is imperative. This transition is currently unfolding and it is driven in particular by innovation activities taking place along the sector's value chain. In the upstream segment, bio-based materials are being improved, while novel building techniques in the core segment enable the use of these materials. In this paper, we utilize the global innovation systems (GIS) framework to examine these innovation activities and their valuation dynamics. In particular, we investigate how the GIS of the bio-based construction sector is organized along its value chain, providing insights into the barriers to the sector's sustainability transition. Our empirical analysis, based on a rich set of expert interviews, demonstrates that the GIS configuration changes along the value chain, driven by profound differences in the innovation mode. This situation creates a bottleneck that hinders the sector's transition, where knowledge about bio-based materials developed upstream fails to translate down the value chain. However, we also find that several niche firms cover and integrate multiple value chain segments and overcome this knowledge gap, suggesting that the transition towards a bio-based construction sector could accelerate with further innovation system reconfigurations.

# ARTICLE #9

## Competing or complementary? Socio-technical imaginaries of a bio-based construction sector

Authors: Lennart Fischer, Sebastian Losacker

Published 2024 in *TATuP–Journal for Technology Assessment in Theory and Practice*, 33 (3), 15-21
DOI: https://doi.org/10.14512/tatup.7145

**Abstract**

The construction sector needs to transition toward using bio-based building materials in order to reduce its negative environmental impact. However, it is unclear how exactly such a bio-based future will look like, with different stakeholders in different geographical contexts having different visions of the sector's future. Based on an extensive collection of expert interviews with stakeholders from the construction industry in China, India, Italy, and Germany, we have identified six primary visions. These are characterized by variations in their socio-technical logics, including preferred materials, targeted market segments, economic characteristics, and stage of development. While many visions appear to be complementary in principle, our findings also reveal conflicts, which are often socially constructed. These conflicts may impede the transition toward a bio-based construction sector, as certain visions may delegitimize alternative uses of bio-based materials.

# ARTICLE #10

## A spatial perspective on green technology adoption in China: insights from patent licensing data

Authors: Sebastian Losacker, Jens Horbach, Ingo Liefner

Published 2025 in *Innovation and Development*, 15 (1), 41-61
DOI: https://doi.org/10.1080/2157930X.2023.2233199

**Abstract**

In the transition to more sustainable regional economies, the widespread adoption of green technologies is crucial. However, little is known about the geography of green technology adoption and the relationship between regional demand and supply of green technologies. In this paper, we shed light on the (regional) factors explaining whether innovation adopters use green technologies that have been developed locally or green technologies that have been developed in other places. We analyze a unique data set of 8825 licensing agreements for Chinese patents in green technologies, which we use as an indicator to measure innovation diffusion. Our results suggest that the regional context plays a key role in predicting whether innovation adopters use local or non-local green technologies. We show, among other things, that the use of locally developed green technologies is more likely in regions characterized by green technology specializations and high innovation capacity than in less innovative regions.

# ARTICLE #11

## What can mission-oriented innovation policy learn from China?

Authors: Ingo Liefner, Chris Brueck, Sebastian Losacker, Gang Zeng

Published 2025 in *Science and Public Policy*, scaf023
DOI: https://doi.org/10.1093/scipol/scaf023

**Abstract**

The concept of a mission-oriented innovation policy has been discussed for several years now, with definitions and conceptual understanding gradually emerging. Although focused on grand societal challenges, i.e. on a particular type of problem that has been receiving attention only in the last couple of years, the discussion and the design of mission-oriented innovation policy can still draw on past experiences. This paper reviews selected elements of China's innovation policy that can help to inform the debate about mission-oriented innovation policy. In particular, this paper analyses policy durability, policy scope, policy coordination, tinkering, and reflexivity as well as policy directionality and demand articulation as key features of China's innovation policy with a clear link to mission-oriented policy. An important result in this context is the preeminent role of designated zones for policy implementation and experimentation in China. Based thereon, the paper discusses to what degree Chinese instruments might become part of policy mixes in the West.

# ARTICLE #12

## China's digital and green (twin) transition: insights from national and regional innovation policies

Authors: Chris Brueck, Sebastian Losacker, Ingo Liefner

Published 2025 in *Regional Studies*, 59 (1), 2384411
DOI: https://doi.org/10.1080/00343404.2024.2384411

**Abstract**

This paper examines the role of policy in China's digital and green (twin) transition, building on a qualitative study of a large corpus of policy documents in green and digital domains. We analyse the multi-level governance of these transitions for three regional case studies: Shanghai, Wuhan and Hangzhou. We find that regions both adopt and adjust green and digital aims and means differently from national policy. A twin transition is not comprehensively addressed at the national level, but is partially implemented in the three regions. Based on our findings, we develop a regional typology sketching top-down policy implementation strategies.

# ARTICLE #13

## A geolocated dataset of German news articles

Authors: Lukas Kriesch, Sebastian Losacker

Published 2025 in *Scientific Data*, 1128
DOI: https://doi.org/10.1038/s41597-025-05422-w

**Abstract**

The emergence of large language models and the exponential growth of digitized text data have revolutionized research methodologies across a broad range of social sciences. News data is crucial for the social sciences as it provides real-time insights into public discourse and societal trends. In this paper, we provide insights into how news articles can be geolocated and how the texts can then be further analyzed. We collect data from the CommonCrawl News dataset and clean the text data. We then use a named-entity recognition model for geocoding. Finally, we transform the news articles into text embeddings using SBERT, enabling semantic searches within the news data corpus. In the paper, we apply this process to all German news articles and make the German location data, as well as the embeddings, available for download. We compile a dataset containing text embeddings for about 50 million German news articles, of which about 70% include geographic locations. The process can be replicated for news data from other countries.

# ARTICLE #14

## Regional specializations in green incumbents and green start-ups in the German transport sector

Authors: Hendrik Hansmeier, Sebastian Losacker, Johannes Bersch, Henning Kroll

Published 2025 in *Growth and Change*, 56 (1), e70025
DOI: https://doi.org/10.1111/grow.70025

**Abstract**

The regional variety of actors is considered a key determinant in the last decade's rich literature on the geography of eco-innovation and green regional development. However, little is known about the extent to which regions differ in their specialization in new and established eco-innovation actors. In this article, we propose a regional typology based on green specializations concerning both incumbents and start-ups in the German transport sector. While many regions show green specializations in either start-ups or incumbents, only some regions manage to specialize in both. We find that the above-average regional specialization in eco-innovation does not seem to be primarily a phenomenon of urban areas, but rather depends on regions' human capital endowments and technological capabilities. The observed heterogeneity in eco-innovation specializations, both in innovation centers and lagging regions, calls for regional policies that are more sensitive to these differences.

# ARTICLE #15

## Relatedness, complexity, and regional development paths in Germany: a sequencing approach

Authors: Anne Otto, Sebastian Losacker, Hendrik Hansmeier

Published 2025 in *The Annals of Regional Science,* 74 (2), 50
DOI: https://doi.org/10.1007/s00168-025-01375-5

**Abstract**

This paper critiques the implementation of the EU's Smart Specialization Strategies (S3), advocating for a deeper analysis of the long-term evolution of regional industrial portfolios. We investigate the changing coherence of these portfolios across 401 German NUTS-3 regions from 1993 to 2018, utilizing skill- and task-based metrics for relatedness and complexity, alongside sequence analysis and optimal matching techniques. We identify various regional trajectory types, enriching the understanding of regional economic development. We find that the majority of regions exhibit a stable coherence of their economic portfolio over time while only a few regions have undergone either more dynamic or fragile development paths. While the selection of priorities in S3 policies is based on the evaluation of the current knowledge base, our findings underscore the importance of historical contexts in regional economic structures, offering insights for enhancing regional diversification strategies and prioritizing capabilities in S3 policy frameworks.

# ARTICLE #16

## Guanxi and innovation in China: insights from the (bio-based) construction sector

Authors: Sebastian Losacker, Tim Becker, Yongmin Shang

Published 2025 in *Innovation and Development*, 1-24
DOI: https://doi.org/10.1080/2157930X.2025.2518825

**Abstract**

This paper explores the role of *guanxi* in facilitating innovation within the Chinese construction sector. Guanxi, denoting the network of trust-based relationships, is deeply rooted in Chinese culture and orchestrates innovation activities. As the construction sector shifts toward bio-based building materials, understanding how guanxi influences innovation activities becomes crucial for the sector's sustainability transition. Through qualitative research involving expert interviews, we examine how guanxi varies along the construction value chain, between bio-based and conventional materials, and among Chinese and foreign stakeholders. Our findings reveal that guanxi is particularly important in smaller firms and academic institutions, where personal relationships drive innovation collaborations. In contrast, larger organizations and international partnerships rely more on formal networks and expertise. In bio-based construction, guanxi plays a critical role in accessing resources and knowledge, fostering innovation through established personal networks.

# ARTICLE #17

## Regional preconditions and sustainability transition pathways: insights from circular, bio-based and resource-efficient building material innovations in Vietnam

Authors: Ravi Jayaweera, Sebastian Losacker, Le Thi Song, Dirk Schwede

Published 2025 in *Energy Research & Social Science,* 125, 104133
DOI: https://doi.org/10.1016/j.erss.2025.104133

**Abstract**

High urbanization dynamics and major construction activities in its cities have highlighted the need for more sustainable building practices in the Global South. While local innovation processes take place at the grassroots level, they often struggle to break through. The study follows the main research question of how regional preconditions characterize the innovation, diffusion and transition dynamics of different "green" building material technologies in different spatial settings of Vietnam. We seek to understand the relations between local socio-technical configurations and the diversity of innovations and potential transition pathways. This is particularly relevant for southern contexts where scholars have noted a greater regime heterogeneity. Instead of black boxing "green innovations" and "the Global South", we study place- and technology-specific effects of regional configurations as preconditions for the development and diffusion of circular, bio-based and more resource-efficient building material innovations in three regions of Vietnam (Hanoi, Da Nang and Ho Chi Minh City). To understand the region- and technology-specific characteristics, we build a framework that differentiates three main dimensions of regional preconditions, institutional factors, the technical specialisation and material flows, and thirdly, market networks and demand. The results show that some preconditions vary for different material innovations and regions while others take effect across technologies, regions or scales. This creates highly differentiated opportunity-spaces for different innovations that can be addressed with targeted and diversified transition strategies that address (trans) regional preconditions on different scales and for different emergent technologies and regions.

# ARTICLE #18

## How to build (in) the future? Legitimacy of socio-technical visions in a bio-based construction sector

Authors: Lennart Fischer, Sebastian Losacker

Published 2025 in *Environmental Innovation and Societal Transitions*, 56, 100996
DOI: https://doi.org/10.1016/j.eist.2025.100996

**Abstract**

The use of bio-based materials offers opportunities to mitigate the climate impacts of construction, with buildings potentially acting as carbon sinks. However, it remains unclear what a future bio-based construction sector will look like. One reason for this are diverse socio-technical visions for the use of bio-based construction materials. In this paper, we use discourse analysis across a comprehensive set of expert interviews to pinpoint (competing) socio-technical visions of a bio-based construction sector in China, India, Germany and Italy. Drawing on the sociological literature on legitimacy, we examine the legitimacy of socio-technical visions as a necessary condition for their collective adoption by stakeholders in the sector. It enables us to conceptualize the development and validation of visions, providing a framework for transition studies to track one part of the collective adoption of visions. This, in turn, adds to the understanding of the formation of ideations that potentially influence transition processes.

# ARTICLE #19

## The geography of digital and green (twin) firms in Germany

Authors: Lukas Kriesch, Milad Abbasiharofteh, Sebastian Losacker

Published 2025 in *Regional Studies, Regional Science*, 12 (1), 513-516
DOI: https://doi.org/10.1080/21681376.2025.2510679

**Abstract**

The twin transition, which combines green and digital innovation in economic activities, is increasingly central to policy agendas and is also receiving growing attention in regional research. However, accurately mapping green, digital and twin (both green and digital) economic activities across regions remains challenging, particularly due to data constraints. In this study, we advance this research frontier and present a geographic analysis of digital, green and twin economic activities in Germany, using a web-mined dataset of website texts from 678,381 firms, collected through web scraping in 2023. By processing over 44 million text paragraphs from these websites and applying a cosine similarity filter with green and AI-related terms, we filtered firms that are likely engaged in green, digital and twin activities. Based on this subset, 1437 text paragraphs were manually annotated to fine-tune two transformer models within a SetFit framework, accurately classifying firms as green, digital or both. We aggregate this firm-level data into hexagonal cells to reveal the geographic concentration of the twin transition in Germany. The final map shows a higher number of firms involved in green activities, widely spread across Germany, while AI activities are concentrated in urban centres. We identify 23,819 firms engaged in both green and digital activities, with major hubs like Berlin and Munich leading, and peripheral regions potentially being left behind. Our findings offer critical insights into the geography of the twin transition and highlight the need for policies that address potentially induced spatial inequalities.

# ARTICLE #20

## What can the bamboo industry learn from timber? Resource mobilization across global innovation systems in the construction sector

Authors: Francesca Mazzoni, Christian Binz, Sebastian Losacker

Published 2025 in *Geoforum*, 165, 104378
DOI: https://doi.org/10.1016/j.geoforum.2025.104378

**Abstract**

In the scholarly literature on the geography of transitions, the global innovation systems framework has been used to understand how system resources—such as knowledge, legitimacy, markets, and financial investments—are linked across various geographical scales, contributing to the emergence and performance of an innovation system within a distinct technological field. In this paper, we further develop and adapt the conceptualization of global innovation systems to the case in which system resources of a focal innovation system are mobilized from adjacent innovation systems, building on the literature on technology interactions. Empirically, we demonstrate how multi-scalar resource mobilizations between two innovation systems emerge in the case of the evolving spatially sticky innovation system of bamboo building technologies, which draws system resources from the more mature market-anchored innovation system of timber building technologies. We find that the bamboo system mobilizes legitimacy, knowledge, and market resources from the timber system in a commensal relationship, meaning that the bamboo system benefits while the timber system is not affected by the interaction. Given the footloose nature of knowledge resources in the timber system, compared to the system's spatially sticky valuation-related resources, the former are more easily mobilized across systems than the latter. Moreover, we posit that the distinct spatial anchoring of both systems hinders further cross-system resource mobilization. Our paper contributes to geographical innovation and transition research by providing a conceptual lens for understanding resource mobilization across innovation system boundaries.

# ARTICLE #21

## Mapping local government priorities: a web-mining approach for regional research

Authors: Moritz Schuetz, Lukas Kriesch, Sebastian Losacker

Published 2025 in *Regional Science Policy & Practice*, 17 (12), 100240
DOI: https://doi.org/10.1016/j.rspp.2025.100240

**Abstract**

The relevance of institutions for regional development has been well established in economic geography. In this context, local and regional governments play a central role, particularly through place-based and place-sensitive strategies. However, systematic and scalable insights into their priorities and strategies remain limited due to data availability. This paper develops a methodological approach for the comprehensive measurement and analysis of local governance activities using web mining, natural language processing (NLP), and machine learning techniques. We construct a novel dataset by web scraping and extracting cleaned text data from German county and municipality websites, which provides detailed information on local government functions, services, and regulations. Our county-level topic modelling approach identifies 205 topics, from which we select 30 prominent topics to demonstrate the variety of topics found on county websites. An in-depth analysis of the three exemplary topics, Urban Development and Planning, Climate Protection Initiatives, and Business Development and Support, reveals how strategic priorities vary across space and how counties differ in their framing of similar topics. This study offers an explanatory framework for analysing the discursive dimensions of local governance and mapping regional differences in policy focus. In doing so, it expands the methodological toolkit of regional research and opens new avenues in understanding local governance through web data. We make an aggregated version of the data set freely available online.

# References


Abbott, A. (1995). Sequence Analysis: New Methods for Old Ideas. *Annual Review of Sociology*, *21*(1), 93–113. https://doi.org/10.1146/annurev.so.21.080195.000521

Abbott, A., & Tsay, A. (2000). Sequence Analysis and Optimal Matching Methods in Sociology. *Sociological Methods & Research*, *29*(1), 3–33. https://doi.org/10.1177/0049124100029001001

Aguilar, A., Wohlgemuth, R., & Twardowski, T. (2018). Perspectives on bioeconomy. *New Biotechnology*, *40*, 181–184. https://doi.org/10.1016/j.nbt.2017.06.012

Agutu, C., Steffen, B., & Schmidt, T. S. (2024). How do technology-inherent characteristics affect valuation processes in innovation systems? *Environmental Innovation and Societal Transitions*, *51*, 100824. https://doi.org/10.1016/J.EIST.2024.100824

Alhusen, H., Bennat, T., Bizer, K., Cantner, U., Horstmann, E., Kalthaus, M., Proeger, T., Sternberg, R., & Töpfer, S. (2021). A New Measurement Conception for the 'Doing-Using-Interacting' Mode of Innovation. *Research Policy*, *50*(4), 104214. https://doi.org/10.1016/j.respol.2021.104214

Allain, S., Ruault, J.-F., Moraine, M., & Madelrieux, S. (2022). The 'bioeconomics vs bioeconomy' debate: Beyond criticism, advancing research fronts. *Environmental Innovation and Societal Transitions*, *42*, 58–73. https://doi.org/10.1016/j.eist.2021.11.004

Angstmann, M. (2025). From waste to value? Valuation and materiality in geographies of industrial by-product use. *Progress in Economic Geography*, *3*(1), 100034. https://doi.org/10.1016/J.PEG.2024.100034

Archibugi, D. (1992). Patenting as an indicator of technological innovation: a review. *Science and Public Policy*, *19*(6), 357–368. https://doi.org/10.1093/spp/19.6.357

Arrow, K. (1962a). Economic Welfare and the Allocation of Resources for Invention. In *The Rate and Direction of Inventive Activity: Economic and Social Factors* (pp. 609–626). National Bureau of Economic Research.

Arrow, K. (1962b). The Economic Implications of Learning by Doing. *The Review of Economic Studies*, *29*(3), 155–173. https://doi.org/10.2307/2295952

Arthur, W. B. (1989). Competing technologies, increasing returns, and lock-In by historical events. *Economic Journal*, *99*(394), 1161–1181.

Asheim, B., & Gertler, M. S. (2006). The Geography of Innovation: Regional Innovation Systems. In J. Fagerberg & D. C. Mowery (Eds.), *The Oxford*

*Handbook of Innovation* (pp. 291–317). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199286805.003.0011

Asheim, B., Smith, H. L., & Oughton, C. (2011). Regional Innovation Systems: Theory, Empirics and Policy. *Regional Studies*, *45*(7), 875–891. https://doi.org/10.1080/00343404.2011.596701

Ayrapetyan, D., Befort, N., & Hermans, F. (2025). From local markets to global legitimacy: A materialization perspective on technological innovation system's dynamics. *Research Policy*, *54*(1), 105130. https://doi.org/10.1016/j.respol.2024.105130

Balland, P. A. (2016). Relatedness and the geography of innovation. *Handbook on the Geographies of Innovation*, 127–141. https://doi.org/10.4337/9781784710774.00016

Balland, P. A., & Boschma, R. (2021). Complementary interregional linkages and Smart Specialisation: an empirical study on European regions. *Regional Studies*, *55*(6), 1059–1070. https://doi.org/10.1080/00343404.2020.1861240

Balland, P. A., Boschma, R., Crespo, J., & Rigby, D. L. (2019). Smart specialization policy in the European Union: relatedness, knowledge complexity and regional diversification. *Regional Studies*, *53*(9), 1252–1268. https://doi.org/10.1080/00343404.2018.1437900

Balland, P. A., Broekel, T., Diodato, D., Giuliani, E., Hausmann, R., O'Clery, N., & Rigby, D. (2022). The new paradigm of economic complexity. *Research Policy*, *51*(3), 104450. https://doi.org/10.1016/J.RESPOL.2021.104450

Balland, P. A., Jara-Figueroa, C., Petralia, S. G., Steijn, M. P. A., Rigby, D. L., & Hidalgo, C. A. (2020). Complex economic activities concentrate in large cities. *Nature Human Behaviour 2020 4:3*, *4*(3), 248–254. https://doi.org/10.1038/s41562-019-0803-3

Balland, P. A., & Rigby, D. (2017). The Geography of Complex Knowledge. *Economic Geography*, *93*(1), 1–23. https://doi.org/10.1080/00130095.2016.1205947

Barbero, J., A. Collado, L., Rodríguez-Crespo, E., & Santos, A. M. (2025). The twin transition in the European Union: assessing regional patterns of EU-funded investments. *European Planning Studies*, 1–21. https://doi.org/10.1080/09654313.2025.2528882

Barbieri, N., Consoli, D., Napolitano, L., Perruchas, F., Pugliese, E., & Sbardella, A. (2022). Regional technological capabilities and green opportunities in Europe.

*The Journal of Technology Transfer*. https://doi.org/10.1007/s10961-022-09952-y

Barbieri, N., Perruchas, F., & Consoli, D. (2020). Specialization, Diversification, and Environmental Technology Life Cycle. *Economic Geography*, *96*(2), 161–186. https://doi.org/10.1080/00130095.2020.1721279

Becker, T., & Losacker, S. (2024). Die räumliche Dimension des EU-Emissionshandels (EU ETS): Messung des regionalen Transformationsdrucks in Deutschland. *Standort 2024*, 1–9. https://doi.org/10.1007/S00548-024-00951-9

Befort, N. (2020). Going beyond definitions to understand tensions within the bioeconomy: The contribution of sociotechnical regimes to contested fields. *Technological Forecasting and Social Change*, *153*, 119923. https://doi.org/10.1016/J.TECHFORE.2020.119923

Befort, N. (2023). *The Bioeconomy: Institutions, Innovation and Sustainability*. Routledge. https://doi.org/10.4324/9781003103011

Benner, M. (2024). An ideational turn in economic geography? *Progress in Economic Geography*, *2*(1), 100014. https://doi.org/10.1016/j.peg.2024.100014

Benner, M. (2025). Imaginaries: The Ideational Foundation of Sustainability Transitions. *Tijdschrift Voor Economische En Sociale Geografie*, *70003*(0), 1–15. https://doi.org/10.1111/TESG.70003

Bergek, A., Hekkert, M., Jacobsson, S., Markard, J., Sandén, B., & Truffer, B. (2015). Technological innovation systems in contexts: Conceptualizing contextual structures and interaction dynamics. *Environmental Innovation and Societal Transitions*, *16*, 51–64. https://doi.org/10.1016/J.EIST.2015.07.003

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy*, *37*(3), 407–429. https://doi.org/10.1016/J.RESPOL.2007.12.003

Berkhout, F. (2006). Normative expectations in systems innovation. *Technology Analysis & Strategic Management*, *18*(3–4), 299–311. https://doi.org/10.1080/09537320600777010

Bianchini, S., Damioli, G., & Ghisetti, C. (2022). The environmental effects of the "twin" green and digital transition in European regions. *Environmental and Resource Economics 2022*, 1–42. https://doi.org/10.1007/S10640-022-00741-7

Binz, C., Coenen, L., Frenken, K., Murphy, J. T., Strambach, S., Trippl, M., & Truffer, B. (2025). Exploring the Economic Geographies of Sustainability Transitions:

Commentary and Agenda. *Economic Geography*, *101*(1), 1–27. https://doi.org/10.1080/00130095.2024.2445530

Binz, C., Coenen, L., Murphy, J. T., & Truffer, B. (2020). Geographies of transition—From topical concerns to theoretical engagement: A commentary on the transitions research agenda. *Environmental Innovation and Societal Transitions*, *34*, 1–3. https://doi.org/10.1016/j.eist.2019.11.002

Binz, C., & Truffer, B. (2017). Global Innovation Systems—A conceptual framework for innovation dynamics in transnational contexts. *Research Policy*, *46*(7), 1284–1298. https://doi.org/10.1016/j.respol.2017.05.012

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*(1), 138–155. https://doi.org/10.1016/j.respol.2013.07.002

Boon, W. P. C., & Edler, J. (2018). Demand, challenges, and innovation. Making sense of new trends in innovation policy. *Science and Public Policy*, *45*(4), 435–447. https://doi.org/10.1093/scipol/scy014

Borup, M., Brown, N., Konrad, K., & Van Lente, H. (2006). The sociology of expectations in science and technology. *Technology Analysis & Strategic Management*, *18*(3–4), 285–298. https://doi.org/10.1080/09537320600777002

Boschma, R. (2017). Relatedness as driver of regional diversification: a research agenda. *Regional Studies*, *51*(3), 351–364. https://doi.org/10.1080/00343404.2016.1254767

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*(1), 31–45. https://doi.org/10.1080/00343404.2016.1258460

Boschma, R., & Frenken, K. (2006). Why is economic geography not an evolutionary science? Towards an evolutionary economic geography. *Journal of Economic Geography*, *6*(3), 273–302. https://doi.org/10.1093/jeg/lbi022

Boschma, R., & Frenken, K. (2011). The emerging empirics of evolutionary economic geography. *Journal of Economic Geography*, *11*(2), 295–307. https://doi.org/10.1093/jeg/lbq053

Boschma, R., & Frenken, K. (2012). Technological relatedness and regional branching. In H. Bathelt, M. P. Feldman, & D. F. Kogler (Eds.), *Beyond Territory: Dynamic*

*Geographies of Knowledge Creation, Diffusion, and Innovation*. Routledge, Taylor & Francis. https://doi.org/10.4324/9780203814871

Boschma, R., & Lambooy, J. G. (1999). Evolutionary economics and economic geography. *Journal of Evolutionary Economics*, *9*(4), 411–429. https://doi.org/10.1007/s001910050089

Boschma, R., & Martin, R. (2007). Editorial: Constructing an evolutionary economic geography. *Journal of Economic Geography*, *7*(5), 537–548. https://doi.org/10.1093/jeg/lbm021

Boschma, R., Miguelez, E., Moreno, R., & Ocampo-Corrales, D. B. (2023). The Role of Relatedness and Unrelatedness for the Geography of Technological Breakthroughs in Europe. *Economic Geography*, *99*(2), 117–139. https://doi.org/10.1080/00130095.2022.2134005

Braun, K., & Kropp, C. (2023). Building a better world? Competing promises, visions, and imaginaries-in-the-making of the digitalization of architecture and construction. *Futures*, *154*, 103262. https://doi.org/10.1016/J.FUTURES.2023.103262

Breschi, S., Lissoni, F., & Malerba, F. (2003). Knowledge-relatedness in firm technological diversification. *Research Policy*, *32*(1), 69–87. https://doi.org/10.1016/S0048-7333(02)00004-5

Broekel, T., Knuepling, L., & Mewes, L. (2023). Boosting, sorting and complexity—urban scaling of innovation around the world. *Journal of Economic Geography*. https://doi.org/10.1093/JEG/LBAD006

Bröring, S., Laibach, N., & Wustmans, M. (2020). Innovation types in the bioeconomy. *Journal of Cleaner Production*, *266*, 121939. https://doi.org/10.1016/J.JCLEPRO.2020.121939

Brueck, C. (2024). The role of foreign MNEs in China's twin transition: a study on the organization of green and digital innovation processes. *Competitiveness Review: An International Business Journal*, *34*(5), 879–895. https://doi.org/10.1108/CR-08-2023-0207

Brueck, C., Losacker, S., & Liefner, I. (2025). China's digital and green (twin) transition: insights from national and regional innovation policies. *Regional Studies*, *59*(1), 1–17. https://doi.org/10.1080/00343404.2024.2384411

Bugge, M., Hansen, T., & Klitkou, A. (2016). What Is the Bioeconomy? A Review of the Literature. *Sustainability*, *8*(7), 691. https://doi.org/10.3390/su8070691

Buyukyazici, D., Mazzoni, L., Riccaboni, M., & Serti, F. (2023). Workplace skills as regional capabilities: relatedness, complexity and industrial diversification of regions. *Regional Studies*. https://doi.org/10.1080/00343404.2023.2206868

Carvalho, L., & van Winden, W. (2018). Making waves: the valuation of innovations in San Sebastian's surf economy. *European Planning Studies*, *26*(1), 75–93. https://doi.org/10.1080/09654313.2017.1372369

Castaldi, C. (2024). The geography of urban innovation beyond patents only: New evidence on large and secondary cities in the United States. *Urban Studies*, *61*(7), 1248–1272. https://doi.org/10.1177/00420980231204718

Castaldi, C. (2025). Mapping innovation in space. *Spatial Economic Analysis*. https://doi.org/10.1080/17421772.2025.2481276

Castaldi, C., Frenken, K., & Los, B. (2015). Related Variety, Unrelated Variety and Technological Breakthroughs: An analysis of US State-Level Patenting. *Regional Studies*, *49*(5), 767–781. https://doi.org/10.1080/00343404.2014.940305

Cattani, L., Montresor, S., & Vezzani, A. (2023). Firms' eco-innovation and Industry 4.0 technologies in urban and rural areas. *Regional Studies*, 1–13. https://doi.org/10.1080/00343404.2023.2243984

Cecere, G., Corrocher, N., Gossart, C., & Ozman, M. (2014). Lock-in and path dependence: an evolutionary approach to eco-innovations. *Journal of Evolutionary Economics*, *24*(5), 1037–1065. https://doi.org/10.1007/s00191-014-0381-5

Cicerone, G., Faggian, A., Montresor, S., & Rentocchini, F. (2023). Regional artificial intelligence and the geography of environmental technologies: does local AI knowledge help regional green-tech specialization? *Regional Studies*, *57*(2), 330–343. https://doi.org/10.1080/00343404.2022.2092610

Cicerone, G., Losacker, S., & Ortega-Argilés, R. (2024). *Regional diversification into green and digital economic activities-The case of UK Local Authorities* (2024–07; ESCoE Discussion Paper).

Coad, A., Nightingale, P., Stilgoe, J., & Vezzani, A. (2021). Editorial: the dark side of innovation. *Industry and Innovation*, *28*(1), 102–112. https://doi.org/10.1080/13662716.2020.1818555

Coenen, L., Benneworth, P., & Truffer, B. (2012). Toward a spatial perspective on sustainability transitions. *Research Policy*, *41*(6), 968–979. https://doi.org/10.1016/J.RESPOL.2012.02.014

Coenen, L., & Morgan, K. (2020). Evolving geographies of innovation: existing paradigms, critiques and possible alternatives. *Norsk Geografisk Tidsskrift*, *74*(1), 13–24. https://doi.org/10.1080/00291951.2019.1692065

Coenen, L., & Truffer, B. (2012). Places and Spaces of Sustainability Transitions: Geographical Contributions to an Emerging Research and Policy Field. In *European Planning Studies* (Vol. 20, Issue 3, pp. 367–374). Routledge. https://doi.org/10.1080/09654313.2012.651802

Cooke, P. (1992). Regional innovation systems: Competitive regulation in the new Europe. *Geoforum*, *23*(3), 365–382. https://doi.org/10.1016/0016-7185(92)90048-9

Cooke, P. (2001). Regional innovation systems, clusters, and the knowledge economy. *Industrial and Corporate Change*, *10*(4), 945–974. https://doi.org/10.1093/icc/10.4.945

Cooke, P., Gomez Uranga, M., & Etxebarria, G. (1997). Regional innovation systems: institutional and organisational dimensions. *Research Policy*, *26*(4–5), 475–491. https://doi.org/10.1016/S0048-7333(97)00025-5

David, P. A. (1985). Clio and the Economy of QWERTY. *The American Economic Review*, *75*(2), 332–337. https://doi.org/10.2104/ha080079

Deegan, J., Broekel, T., & Fitjar, R. D. (2021). Searching through the Haystack: The Relatedness and Complexity of Priorities in Smart Specialization Strategies. *Economic Geography*, *97*(5), 497–520. https://doi.org/10.1080/00130095.2021.1967739

Dopfer, K., Nelson, R. R., Potts, J., & Pyka, A. (2023). Routledge Handbook of Evolutionary Economics. In *Routledge Handbook of Evolutionary Economics*. Routledge. https://doi.org/10.4324/9780429398971

Dosi, G. (1988). The nature of the innovative process. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg, & L. Soete (Eds.), *Technical Change and Economic Theory* (Pinter, pp. 221–238).

Edler, J., & Fagerberg, J. (2017). Innovation policy: What, why, and how. *Oxford Review of Economic Policy*, *33*(1), 2–23. https://doi.org/10.1093/oxrep/grx001

Edler, J., & Georghiou, L. (2007). Public procurement and innovation—Resurrecting the demand side. *Research Policy*, *36*(7), 949–963. https://doi.org/10.1016/J.RESPOL.2007.03.003

Edquist, C., & Zabala-Iturriagagoitia, J. M. (2012). Public Procurement for Innovation as mission-oriented innovation policy. *Research Policy*, *41*(10), 1757–1769. https://doi.org/10.1016/J.RESPOL.2012.04.022

Faggian, A., Marzucchi, A., & Montresor, S. (2024). Regions facing the 'twin transition': combining regional green and digital innovations. *Regional Studies*, 1–7. https://doi.org/10.1080/00343404.2024.2398555

Fazio, G., Maioli, S., & Rujimora, N. (2024). The twin innovation transitions of European regions. *Regional Studies*, 1–19. https://doi.org/10.1080/00343404.2024.2309176

Feldman, M. P. (1994). *The Geography of Innovation*. Kluwer Academic Publishers.

Fischer, L., & Losacker, S. (2024). Competing or complementary?: Socio-technical imaginaries of a bio-based construction sector. *TATuP - Zeitschrift Für Technikfolgenabschätzung in Theorie Und Praxis*, *33*(3), 15–21. https://doi.org/10.14512/TATUP.7145

Fischer, L., & Losacker, S. (2025). How to build (in) the future? Legitimacy of socio-technical visions in a bio-based construction sector. *Environmental Innovation and Societal Transitions*, *56*, 100996. https://doi.org/10.1016/j.eist.2025.100996

Fischer, L., Losacker, S., & Wydra, S. (2024). National specialization and diversification in the bioeconomy: Insights from biobased technologies in chemical and pharmaceutical sectors. *Technology in Society*, *76*, 102462. https://doi.org/10.1016/J.TECHSOC.2024.102462

Foray, D., Goddard, J., Beldarrain, X. G., Landabaso, M., McCann, P., Morgan, K., Nauwelaers, C., & Ortega-Argilés, R. (2012). *Guide to research and innovation strategies for smart specialisations*.

Freeman, C. (1987). *Technology, policy, and economic performance: lessons from Japan*. Pinter Publishers.

Freeman, C. (1995). The national system of innovation in historical perspective. *Cambridge Journal of Economics*, *19*(1), 5–24.

Frenken, K., & Boschma, R. (2007). A theoretical framework for evolutionary economic geography: industrial dynamics and urban growth as a branching process. *Journal of Economic Geography*, *7*(5), 635–649. https://doi.org/10.1093/JEG/LBM018

Frenken, K., Neffke, F., & van Dam, A. (2023). Capabilities, institutions and regional economic development: a proposed synthesis. *Cambridge Journal of Regions, Economy and Society*. https://doi.org/10.1093/CJRES/RSAD021

Frenken, K., Van Oort, F., & Verburg, T. (2007). Related Variety, Unrelated Variety and Regional Economic Growth. *Regional Studies*, *41*(5), 685–697. https://doi.org/10.1080/00343400601120296

Friedrich, C., & Kagel, A. S. (2025). STI and DUI modes of innovation in poorly developed RIS. Systemic failures and challenges. *European Planning Studies*. https://doi.org/10.1080/09654313.2024.2430240

Friedrich, J., & Hendriks, A. (2024). Imagined futures in sustainability transitions: Towards diverse future-making. *Futures*, *164*, 103502. https://doi.org/10.1016/J.FUTURES.2024.103502

Fuenfschilling, L., & Binz, C. (2018). Global socio-technical regimes. *Research Policy*, *47*(4), 735–749. https://doi.org/10.1016/j.respol.2018.02.003

García Casañas, C., & Kovacic, Z. (2025). Implementing the twin transitions: A critical perspective from the Spanish energy sector. *Environmental Science & Policy*, *164*, 104012. https://doi.org/10.1016/J.ENVSCI.2025.104012

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems. *Research Policy*, *33*(6–7), 897–920. https://doi.org/10.1016/j.respol.2004.01.015

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, *1*(1), 24–40. https://doi.org/10.1016/J.EIST.2011.02.002

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy*, *36*(3), 399–417. https://doi.org/10.1016/j.respol.2007.01.003

Geels, F. W., Sovacool, B. K., Schwanen, T., & Sorrell, S. (2017). Sociotechnical transitions for deep decarbonization. *Science*, *357*(6357), 1242–1244. https://doi.org/10.1126/science.aao3760

Giurca, A., & Befort, N. (2023). Deconstructing substitution narratives: The case of bioeconomy innovations from the forest-based sector. *Ecological Economics*, *207*, 107753. https://doi.org/10.1016/j.ecolecon.2023.107753

Giustolisi, A. (2025). The role of scientists in regional innovation system transformation: shaping the direction to a biomass-bioeconomy. *Industry and Innovation*, *32*(6), 631–654. https://doi.org/10.1080/13662716.2024.2400978

Godin, B. (2009). National Innovation System: The System Approach in Historical Perspective. *Science, Technology, & Human Values*, *34*(4), 476–501. https://doi.org/10.1177/0162243908329187

Golembiewski, B., Sick, N., & Bröring, S. (2015). The emerging research landscape on bioeconomy: What has been done so far and what is essential from a technology and innovation management perspective? *Innovative Food Science & Emerging Technologies*, *29*, 308–317. https://doi.org/10.1016/J.IFSET.2015.03.006

Gong, H. (2024). Futures should matter (more): Toward a forward-looking perspective in economic geography. *Progress in Human Geography*. https://doi.org/10.1177/03091325231224434

Griliches, Z. (1990). Patent Statistics as Economic Indicators: A Survey. *Journal of Economic Literature*, *28*(4), 1661–1707.

Grillitsch, M., & Sotarauta, M. (2020). Trinity of change agency, regional development paths and opportunity spaces. *Progress in Human Geography*, *44*(4), 704–723. https://doi.org/10.1177/0309132519853870

Grillitsch, M., Sotarauta, M., Asheim, B., Fitjar, R. D., Haus-Reve, S., Kolehmainen, J., Kurikka, H., Lundquist, K.-J., Martynovich, M., Monteilhet, S., Nielsen, H., Nilsson, M., Rekers, J., Sopanen, S., & Stihl, L. (2023). Agency and economic change in regions: identifying routes to new path development using qualitative comparative analysis. *Regional Studies*, *57*(8), 1453–1468. https://doi.org/10.1080/00343404.2022.2053095

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. https://doi.org/10.1016/J.EIST.2014.11.001

Hansmeier, H., & Kroll, H. (2024). The geography of eco-innovations and sustainability transitions: A systematic comparison. *ZFW – Advances in Economic Geography*, *68*(2), 125–143. https://doi.org/10.1515/zfw-2022-0010

Hansmeier, H., & Losacker, S. (2024). Regional eco-innovation trajectories. *European Planning Studies*, *32*(6), 1401–1422. https://doi.org/10.1080/09654313.2024.2308027

Hansmeier, H., Losacker, S., Bersch, J., & Kroll, H. (2025). Regional Specializations in Green Incumbents and Green Start-ups in the German Transport Sector. *Growth and Change*, *56*(1), e70025. https://doi.org/10.1111/grow.70025

Hansmeier, H., Schiller, K., & Rogge, K. S. (2021). Towards methodological diversity in sustainability transitions research? Comparing recent developments (2016-2019) with the past (before 2016). *Environmental Innovation and Societal Transitions*, *38*, 169–174. https://doi.org/10.1016/J.EIST.2021.01.001

Hausmann, R., Hidalgo, C. A., Bustos, S., Coscia, M., Simoes, A., & Yildirim, M. A. (2014). *The Atlas of economic complexity: mapping paths to prosperity*. MIT Press.

Hawxwell, T., Hendriks, A., & Späth, P. (2024). Transformative or incumbent futures? How the future of mobility is imagined in sustainability transitions research. *Futures*, *159*, 103325. https://doi.org/10.1016/J.FUTURES.2024.103325

Heiberg, J., Binz, C., & Truffer, B. (2020). The Geography of Technology Legitimation: How Multiscalar Institutional Dynamics Matter for Path Creation in Emerging Industries. *Economic Geography*, *96*(5), 470–498. https://doi.org/10.1080/00130095.2020.1842189

Heiberg, J., & Truffer, B. (2022). The emergence of a global innovation system – A case study from the urban water sector. *Environmental Innovation and Societal Transitions*, *43*, 270–288. https://doi.org/10.1016/J.EIST.2022.04.007

Heiden, S. (2020). Innovation und Bioökonomie. In *Das System Bioökonomie* (pp. 277–296). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-60730-5_18

Heimeriks, G., & Boschma, R. (2014). The path- and place-dependent nature of scientific knowledge production in biotech 1986-2008. *Journal of Economic Geography*, *14*(2), 339–364. https://doi.org/10.1093/jeg/lbs052

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. https://doi.org/10.1016/J.EIST.2019.11.011

Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S., & Smits, R. E. H. M. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change*, *74*(4), 413–432. https://doi.org/10.1016/j.techfore.2006.03.002

Henning, M. (2019). Time should tell (more): evolutionary economic geography and the challenge of history. *Regional Studies*, *53*(4), 602–613. https://doi.org/10.1080/00343404.2018.1515481

Hidalgo, C. A., Balland, P.-A., Boschma, R., Delgado, M., Feldman, M., Frenken, K., Glaeser, E., He, C., Kogler, D. F., Morrison, A., Neffke, F., Rigby, D., Stern, S.,

Zheng, S., & Zhu, S. (2018). The Principle of Relatedness. In M. A., G. C., B. D., M. A., & B.-Y. Y. (Eds.), *Unifying Themes in Complex Systems IX. ICCS 2018. Springer Proceedings in Complexity* (pp. 451–457). Springer, Cham. https://doi.org/10.1007/978-3-319-96661-8_46

Hidalgo, C. A., & Hausmann, R. (2009). The building blocks of economic complexity. *Proceedings of the National Academy of Sciences*, *106*(26), 10570–10575. https://doi.org/10.1073/pnas.0900943106

Hidalgo, C. A., Klinger, B., Barabási, A.-L., & Hausmann, R. (2007). The Product Space Conditions the Development of Nations. *Science*, *317*(5837), 482–487. https://doi.org/10.1126/science.1144581

Huenteler, J., Schmidt, T. S., Ossenbrink, J., & Hoffmann, V. H. (2016). Technology life-cycles in the energy sector — Technological characteristics and the role of deployment for innovation. *Technological Forecasting and Social Change*, *104*, 102–121. https://doi.org/10.1016/J.TECHFORE.2015.09.022

Isaksen, A., Trippl, M., & Mayer, H. (2022). Regional innovation systems in an era of grand societal challenges: reorientation versus transformation. *European Planning Studies*, *30*(11), 2125–2138. https://doi.org/10.1080/09654313.2022.2084226

Jacobsson, S., & Bergek, A. (2011). Innovation system analyses and sustainability transitions: Contributions and suggestions for research. *Environmental Innovation and Societal Transitions*, *1*(1), 41–57. https://doi.org/10.1016/J.EIST.2011.04.006

Janssen, M. J., Torrens, J., Wesseling, J. H., & Wanzenböck, I. (2021). The promises and premises of mission-oriented innovation policy—A reflection and ways forward. *Science and Public Policy*, *48*(3), 438–444. https://doi.org/10.1093/scipol/scaa072

Jasanoff, S., & Kim, S.-H. (2009). Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea. *Minerva*, *47*(2), 119–146. https://doi.org/10.1007/s11024-009-9124-4

Jasanoff, S., & Kim, S.-H. (2013). Sociotechnical Imaginaries and National Energy Policies. *Science as Culture*, *22*(2), 189–196. https://doi.org/10.1080/09505431.2013.786990

Jasanoff, S., & Kim, S.-H. (2015). *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*. University of Chicago Press.

Jayaweera, R., Losacker, S., Song, L. T., & Schwede, D. (2025). Regional preconditions and sustainability transition pathways: Insights from circular, bio-based and resource-efficient building material innovations in Vietnam. *Energy Research & Social Science*, *125*, 104133. https://doi.org/10.1016/J.ERSS.2025.104133

Jeannerat, H. (2024). Let's innovate! but for what value(s)? Towards an economic geography of valuation in markets and society. *Progress in Economic Geography*, *2*(2), 100022. https://doi.org/10.1016/J.PEG.2024.100022

Jeannerat, H., & Kebir, L. (2016). Knowledge, Resources and Markets: What Economic System of Valuation? *Regional Studies*, *50*(2), 274–288. https://doi.org/10.1080/00343404.2014.986718

Jensen, M. B., Johnson, B., Lorenz, E., & Lundvall, B. A. (2007). Forms of knowledge and modes of innovation. *Research Policy*, *36*(5), 680–693. https://doi.org/10.1016/J.RESPOL.2007.01.006

Kemp, R. (1994). Technology and the transition to environmental sustainability: The problem of technological regime shifts. *Futures*, *26*(10), 1023–1046. https://doi.org/10.1016/0016-3287(94)90071-X

Kivimaa, P., & Kern, F. (2016). Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Research Policy*, *45*(1), 205–217. https://doi.org/10.1016/J.RESPOL.2015.09.008

Klein, O., Nier, S., & Tamásy, C. (2022). Towards a Circular Bioeconomy? Pathways and Spatialities of Agri-Food Waste Valorisation. *Tijdschrift Voor Economische En Sociale Geografie*, *113*(2), 194–210. https://doi.org/10.1111/TESG.12500

Kleinknecht, A., Van Montfort, K., & Brouwer, E. (2002). The Non-Trivial Choice between Innovation Indicators. *Economics of Innovation and New Technology*, *11*(2), 109–121. https://doi.org/10.1080/10438590210899

Kline, S. J., & Rosenberg, N. (1986). An overview of innovation. In R. Landau & N. Rosenberg (Eds.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth* (pp. 275–305). National Academy Press.

Kogler, D. F., Evenhuis, E., Giuliani, E., Martin, R., Uyarra, E., & Boschma, R. (2023). Re-imagining evolutionary economic geography. *Cambridge Journal of Regions, Economy and Society*, *16*(3), 373–390. https://doi.org/10.1093/CJRES/RSAD029

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.,

… Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions*, *31*, 1–32. https://doi.org/10.1016/j.eist.2019.01.004

Kovacic, Z., García Casañas, C., Argüelles, L., Yáñez Serrano, P., Ribera-Fumaz, R., Prause, L., & March, H. (2024). The twin green and digital transition: High-level policy or science fiction? *Environment and Planning E: Nature and Space*, *7*(6), 2251–2278. https://doi.org/10.1177/25148486241258046

Kriesch, L. (2023). *Web Mining und Natural Language Processing als methodisches Komplement in der Wirtschaftsgeographie*. https://doi.org/10.22029/JLUPUB-15686

Kriesch, L., Abbasiharofteh, M., & Losacker, S. (2025). The geography of digital and green (twin) firms in Germany. *Regional Studies, Regional Science*, *12*(1), 513–516. https://doi.org/10.1080/21681376.2025.2510679

Kriesch, L., & Losacker, S. (2024a). A global patent dataset of bioeconomy-related inventions. *Scientific Data*, *11*(1), 1308. https://doi.org/10.1038/s41597-024-04163-6

Kriesch, L., & Losacker, S. (2024b). Bioeconomy firms and where to find them. *REGION*, *11*(1), 55–78. https://doi.org/10.18335/region.v11i1.523

Kriesch, L., & Losacker, S. (2025a). A geolocated dataset of German news articles. *Scientific Data*, *12*(1), 1–13. https://doi.org/10.1038/s41597-025-05422-w

Kriesch, L., & Losacker, S. (2025b). Tracking the public perception of heat pumps: A sentiment analysis of German news articles. *Papers in Innovation Studies* , *2025*(08). https://doi.org/10.13140/RG.2.2.24796.71046

Kuchler, M., & Stigson, G. M. (2024). Unravelling the 'collective' in sociotechnical imaginaries: A literature review. *Energy Research & Social Science*, *110*, 103422. https://doi.org/10.1016/J.ERSS.2024.103422

Kuebart, A. (2022). Open creative labs as functional infrastructure for entrepreneurial ecosystems: Using sequence analysis to explore tempo-spatial trajectories of startups in Berlin. *Research Policy*, *51*(9), 104444. https://doi.org/10.1016/J.RESPOL.2021.104444

Laasonen, V. (2024). Building dynamic capabilities in the transition toward a knowledge-based bioeconomy: a case study of three Finnish regions. *Regional Studies*, *58*(6), 1308–1319. https://doi.org/10.1080/00343404.2023.2249499

Landabaso, M., & Foray, D. (2014). From smart specialisation to smart specialisation policy. *European Journal of Innovation Management*, *17*(4), 492–507. https://doi.org/10.1108/EJIM-09-2014-0096

Lang, C. (2022). Bioeconomy - from the Cologne paper to concepts for a global strategy. *EFB Bioeconomy Journal*, *2*, 100038. https://doi.org/10.1016/J.BIOECO.2022.100038

Lhuillery, S., Befort, N., & Atmane, S. (2025). Biotechnology or bioeconomy: Six of one and half a dozen of the other? *Ecological Economics*, *229*, 108470. https://doi.org/10.1016/J.ECOLECON.2024.108470

Liao, T. F., Bolano, D., Brzinsky-Fay, C., Cornwell, B., Fasang, A. E., Helske, S., Piccarreta, R., Raab, M., Ritschard, G., Struffolino, E., & Studer, M. (2022). Sequence analysis: Its past, present, and future. *Social Science Research*, *107*, 102772. https://doi.org/10.1016/J.SSRESEARCH.2022.102772

Liefner, I., Brueck, C., Losacker, S., & Zeng, G. (2025). What can mission-oriented innovation policy learn from China? *Science and Public Policy*, *00*, 1–13. https://doi.org/10.1093/scipol/scaf023

Losacker, S. (2020). The geography of green technology licensing in China. *Regional Studies, Regional Science*, *7*(1), 387–389. https://doi.org/10.1080/21681376.2020.1809507

Losacker, S. (2022a). 'License to green': Regional patent licensing networks and green technology diffusion in China. *Technological Forecasting and Social Change*, *175*, 121336. https://doi.org/10.1016/j.techfore.2021.121336

Losacker, S. (2022b). *The Diffusion of Environmental Innovations: A Geographical Perspective on Lead Markets and Technology Licensing in China* [Leibniz University Hannover]. https://doi.org/10.15488/11898

Losacker, S., Becker, T., & Shang, Y. (2025). Guanxi and innovation in China: insights from the (bio-based) construction sector. *Innovation and Development*, 1–24. https://doi.org/10.1080/2157930X.2025.2518825

Losacker, S., Befort, N., Kriesch, L., & Lhuillery, S. (2024). Tracking pathways towards a bioeconomy: a sequence analysis of regional patent portfolios. *Papers in Innovation Studies*, *2024*(21). https://doi.org/10.13140/RG.2.2.25466.61123

Losacker, S., Hansmeier, H., Horbach, J., & Liefner, I. (2023). The geography of environmental innovation: a critical review and agenda for future research. *Review of Regional Research*, *43*(2), 291–316. https://doi.org/10.1007/s10037-023-00193-6

Losacker, S., Heiden, S., Liefner, I., & Lucas, H. (2023). Rethinking bioeconomy innovation in sustainability transitions. *Technology in Society*, *74*, 102291. https://doi.org/10.1016/J.TECHSOC.2023.102291

Losacker, S., Horbach, J., & Liefner, I. (2023). Geography and the speed of green technology diffusion. *Industry and Innovation*, *30*(5), 531–555. https://doi.org/10.1080/13662716.2022.2071237

Losacker, S., Horbach, J., & Liefner, I. (2025). A spatial perspective on green technology adoption in China: insights from patent licensing data. *Innovation and Development*, *15*(1), 41–61. https://doi.org/10.1080/2157930X.2023.2233199

Losacker, S., & Kuebart, A. (2024). Introducing sequence analysis to economic geography. *Progress in Economic Geography*, *2*(1), 100012. https://doi.org/10.1016/J.PEG.2024.100012

Losacker, S., & Liefner, I. (2020a). Implications of China's innovation policy shift: Does "indigenous" mean closed? *Growth and Change*, *51*(3), 1124–1141. https://doi.org/10.1111/grow.12400

Losacker, S., & Liefner, I. (2020b). Regional lead markets for environmental innovation. *Environmental Innovation and Societal Transitions*, *37*, 120–139. https://doi.org/10.1016/j.eist.2020.08.003

Lundvall, B.-A. (1992). *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning*. Pinter.

Lundvall, B.-A. (2023). Transformative innovation policy – lessons from the innovation system literature. *Innovation and Development*, 1–18. https://doi.org/10.1080/2157930X.2022.2158996

Malhotra, A., Schmidt, T. S., & Huenteler, J. (2019). The role of inter-sectoral learning in knowledge development and diffusion: Case studies on three clean energy technologies. *Technological Forecasting and Social Change*, *146*, 464–487. https://doi.org/10.1016/J.TECHFORE.2019.04.018

Markard, J., Hekkert, M., & Jacobsson, S. (2015). The technological innovation systems framework: Response to six criticisms. *Environmental Innovation and Societal Transitions*, *16*, 76–86. https://doi.org/10.1016/J.EIST.2015.07.006

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy*, *41*(6), 955–967. https://doi.org/10.1016/J.RESPOL.2012.02.013

Markard, J., & Truffer, B. (2008). Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research Policy*, *37*(4), 596–615. https://doi.org/10.1016/J.RESPOL.2008.01.004

Marshall, A. (1890). *Principles of Economics*. Macmillan.

Martin, R., & Sunley, P. (2006). Path dependence and regional economic evolution. *Journal of Economic Geography*, *6*(4), 395–437. https://doi.org/10.1093/jeg/lbl012

Martin, R., & Sunley, P. (2022). Making history matter more in evolutionary economic geography. *ZFW – Advances in Economic Geography*, *66*(2), 65–80. https://doi.org/10.1515/ZFW-2022-0014

Mast, H. S. (2022). Conflicting sociotechnical imaginaries of the future built environment: An analysis of current discourses on timber construction in France and Germany. *GAIA - Ecological Perspectives for Science and Society*, *31*(3), 151–157. https://doi.org/10.14512/GAIA.31.3.5

Mazzoni, F., Binz, C., & Losacker, S. (2025). What can the bamboo industry learn from timber? Resource mobilization across global innovation systems in the construction sector. *Geoforum*, *165*, 104378. https://doi.org/10.1016/j.geoforum.2025.104378

Mazzoni, F., & Losacker, S. (2024). What hinders the transition towards a bio-based construction sector? A global innovation system perspective on its value chain. *Progress in Economic Geography*, *2*(2), 100023. https://doi.org/10.1016/j.peg.2024.100023

Mazzucato, M. (2016). From market fixing to market-creating: a new framework for innovation policy. *Industry and Innovation*, *23*(2), 140–156. https://doi.org/10.1080/13662716.2016.1146124

Mazzucato, M. (2018). Mission-oriented innovation policies: challenges and opportunities. *Industrial and Corporate Change*, *27*(5), 803–815. https://doi.org/10.1093/icc/dty034

McCann, P., & Ortega-Argilés, R. (2013a). Modern regional innovation policy. *Cambridge Journal of Regions, Economy and Society*, *6*(2), 187–216. https://doi.org/10.1093/CJRES/RST007

McCann, P., & Ortega-Argilés, R. (2013b). Transforming European regional policy: a results-driven agenda and smart specialization. *Oxford Review of Economic Policy*, *29*(2), 405–431. https://doi.org/10.1093/OXREP/GRT021

McCann, P., & Ortega-Argilés, R. (2014). Smart specialisation in European regions: issues of strategy, institutions and implementation. *European Journal of Innovation Management*, *17*(4), 409–427. https://doi.org/10.1108/EJIM-05-2014-0052

McCann, P., & Ortega-Argilés, R. (2015). Smart Specialization, Regional Growth and Applications to European Union Cohesion Policy. *Regional Studies*, *49*(8), 1291–1302. https://doi.org/10.1080/00343404.2013.799769

Metcalfe, J. S. (1994). Evolutionary Economics and Technology Policy. *The Economic Journal*, *104*(425), 931–944. https://doi.org/10.2307/2234988

Mewes, L., & Broekel, T. (2020). Subsidized to change? The impact of R&D policy on regional technological diversification. *Annals of Regional Science*, *65*(1), 221–252. https://doi.org/10.1007/S00168-020-00981-9

Mewes, L., & Broekel, T. (2022). Technological complexity and economic growth of regions. *Research Policy*, *51*(8), 104156. https://doi.org/10.1016/j.respol.2020.104156

Miörner, J., & Binz, C. (2021). Towards a multi-scalar perspective on transition trajectories. *Environmental Innovation and Societal Transitions*, *40*, 172–188. https://doi.org/10.1016/J.EIST.2021.06.004

Miorner, J., Schelbert, V., & Binz, C. (2025). How Transformative Innovations Travel: Tracing the Diffusion of Circular District-Scale Sanitation Systems in Europe. *Economic Geography*, *101*(2–3), 93–121. https://doi.org/10.1080/00130095.2025.2489965

Mittenzwei, M., & Schiller, D. (2025). Bioeconomy innovation within traditional value chains: The example of the sugar industry in three European regions. *Progress in Economic Geography*, *3*(1), 100035. https://doi.org/10.1016/j.peg.2024.100035

Montresor, S., & Quatraro, F. (2020). Green technologies and Smart Specialisation Strategies: a European patent-based analysis of the intertwining of technological relatedness and key enabling technologies. *Regional Studies*, *54*(10), 1354–1365. https://doi.org/10.1080/00343404.2019.1648784

Moreno, R., & Ocampo-Corrales, D. (2022). The ability of European regions to diversify in renewable energies: The role of technological relatedness. *Research Policy*, *51*(5), 104508. https://doi.org/10.1016/J.RESPOL.2022.104508

Muehlberger, C.-M., Gruen, L., Liefner, I., & Losacker, S. (2024). Socio-technical imaginaries of climate-neutral aviation. *Energy Research & Social Science*, *114*, 103595. https://doi.org/10.1016/j.erss.2024.103595

Nagaoka, S., Motohashi, K., & Goto, A. (2010). Patent Statistics as an Innovation Indicator. *Handbook of the Economics of Innovation*, *2*(1), 1083–1127. https://doi.org/10.1016/S0169-7218(10)02009-5

Neffke, F., Henning, M., & Boschma, R. (2011). How Do Regions Diversify over Time? Industry Relatedness and the Development of New Growth Paths in Regions. *Economic Geography*, *87*(3), 237–265. https://doi.org/10.1111/j.1944-8287.2011.01121.x

Neffke, F., Otto, A., & Weyh, A. (2017). Inter-industry labor flows. *Journal of Economic Behavior & Organization*, *142*, 275–292. https://doi.org/10.1016/J.JEBO.2017.07.003

Negro, S. O., Alkemade, F., & Hekkert, M. P. (2012). Why does renewable energy diffuse so slowly? A review of innovation system problems. *Renewable and Sustainable Energy Reviews*, *16*(6), 3836–3846. https://doi.org/10.1016/j.rser.2012.03.043

Nelson, R. R. (1959). The Simple Economics of Basic Scientific Research. *Journal of Political Economy*, *67*(3), 297–306. https://doi.org/10.1086/258177

Nelson, R. R., & Winter, S. G. (1977). In search of useful theory of innovation. *Research Policy*, *6*(1), 36–76. https://doi.org/10.1016/0048-7333(77)90029-4

Nelson, R. R., & Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*. Bellknap Press.

Otto, A., Losacker, S., & Hansmeier, H. (2025). Relatedness, complexity, and regional development paths in Germany: a sequencing approach. *The Annals of Regional Science*, *74*(2), 50. https://doi.org/10.1007/s00168-025-01375-5

Patermann, C., & Aguilar, A. (2018). The origins of the bioeconomy in the European Union. *New Biotechnology*, *40*, 20–24. https://doi.org/10.1016/J.NBT.2017.04.002

Patermann, C., & Aguilar, A. (2021). A bioeconomy for the next decade. *EFB Bioeconomy Journal*, *1*(1), 100005. https://doi.org/10.1016/J.BIOECO.2021.100005

Perruchas, F., Consoli, D., & Barbieri, N. (2020). Specialisation, diversification and the ladder of green technology development. *Research Policy*, *49*(3), Art. 2019–07. https://doi.org/10.1016/j.respol.2020.103922

Pinheiro, F. L., Balland, P. A., Boschma, R., & Hartmann, D. (2022). The dark side of the geography of innovation: relatedness, complexity and regional inequality in Europe. *Regional Studies*. https://doi.org/10.1080/00343404.2022.2106362

Pintar, N., & Scherngell, T. (2022). The complex nature of regional knowledge production: Evidence on European regions. *Research Policy*, *51*(8), 104170. https://doi.org/10.1016/J.RESPOL.2020.104170

Porter, M. E. (1998). Clusters and the new economics of competition. *Harvard Business Review*, *76*(6), 77–90.

Prochaska, L., & Schiller, D. (2024). Spatial distribution of bioeconomy R&D funding: opportunities for rural and lagging regions? *European Planning Studies*, *32*(7), 1552–1572. https://doi.org/10.1080/09654313.2024.2316193

Proestou, M., Schulz, N., & Feindt, P. H. (2024). A global analysis of bioeconomy visions in governmental bioeconomy strategies. *Ambio*, *53*(3), 376–388. https://doi.org/10.1007/s13280-023-01958-6

Pyka, A., & Prettner, K. (2018). Economic Growth, Development, and Innovation: The Transformation Towards a Knowledge-Based Bioeconomy. In I. Lewandowski (Ed.), *Bioeconomy* (pp. 331–342). Springer International Publishing. https://doi.org/10.1007/978-3-319-68152-8_11

Rennings, K. (2000). Redefining innovation — eco-innovation research and the contribution from ecological economics. *Ecological Economics*, *32*(2), 319–332. https://doi.org/10.1016/S0921-8009(99)00112-3

Rennings, K. (2014). Introduction: Global diffusion of environmental innovations. *Environmental Innovation and Societal Transitions*, *10*, 1–3. https://doi.org/10.1016/J.EIST.2013.12.005

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., … Rockström, J. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, *9*(37). https://doi.org/10.1126/sciadv.adh2458

Rigby, D. L. (2015). Technological Relatedness and Knowledge Space: Entry and Exit of US Cities from Patent Classes. *Regional Studies*, *49*(11), 1922–1937. https://doi.org/10.1080/00343404.2013.854878

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., De Wit, C. A., Hughes, T., Van Der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., … Foley, J. A. (2009). A safe operating space for humanity. *Nature*, *461*(7263), 472–475. https://doi.org/10.1038/461472a

Rogge, K. S., & Reichardt, K. (2016). Policy mixes for sustainability transitions: An extended concept and framework for analysis. *Research Policy*, *45*(8), 1620–1635. https://doi.org/10.1016/j.respol.2016.04.004

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. https://doi.org/10.1016/j.eist.2020.02.002

Rohe, S., & Chlebna, C. (2021). A spatial perspective on the legitimacy of a technological innovation system: Regional differences in onshore wind energy. *Energy Policy*, *151*, 112193. https://doi.org/10.1016/j.enpol.2021.112193

Romer, P. M. (1986). Increasing Returns and Long-Run Growth. *Journal of Political Economy*, *94*(5), 1002–1037. https://doi.org/10.1086/261420

Rudek, T. J. (2022). Capturing the invisible. Sociotechnical imaginaries of energy. The critical overview. *Science and Public Policy*, *49*(2), 219–245. https://doi.org/10.1093/SCIPOL/SCAB076

Santoalha, A., Consoli, D., & Castellacci, F. (2021). Digital skills, relatedness and green diversification: A study of European regions. *Research Policy*, *50*(9), 104340. https://doi.org/10.1016/j.respol.2021.104340

Schlaile, M. P., Friedrich, J., & Zscheischler, J. (2024). Rethinking Regional Embeddedness and Innovation Systems for Transitions Towards Just, Responsible, and Circular Bioeconomies. *Circular Economy*, *2*(1). https://doi.org/10.55845/DTFI9420

Schot, J., & Steinmueller, W. E. (2018). Three frames for innovation policy: R&D, systems of innovation and transformative change. *Research Policy*, *47*(9), 1554–1567. https://doi.org/10.1016/J.RESPOL.2018.08.011

Schumpeter, J. (1934). *The theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle*. Harvard University Press.

Schütz, M., Kriesch, L., & Losacker, S. (2025). Mapping local government priorities: a web-mining approach for regional research. *Regional Science Policy & Practice*, *17*(12), 100240. https://doi.org/10.1016/j.rspp.2025.100240

Shearmur, R., Carrincazeaux, C., & Doloreux, D. (2016). *Handbook on the Geographies of Innovation* (R. Shearmur, C. Carrincazeaux, & D. Doloreux, Eds.). Edward Elgar.

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*(4), 435–448. https://doi.org/10.1016/J.RESPOL.2010.01.023

Solow, R. M. (1956). A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics*, *70*(1), 65. https://doi.org/10.2307/1884513

Späth, P., & Rohracher, H. (2012). Local Demonstrations for Global Transitions-Dynamics across Governance Levels Fostering Socio-Technical Regime Change Towards Sustainability. *European Planning Studies*, *20*(3), 461–479. https://doi.org/10.1080/09654313.2012.651800

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223). https://doi.org/10.1126/science.1259855

Stegmann, P., Londo, M., & Junginger, M. (2020). The circular bioeconomy: Its elements and role in European bioeconomy clusters. *Resources, Conservation & Recycling: X*, *6*, 100029. https://doi.org/10.1016/J.RCRX.2019.100029

Steinböck, N., & Trippl, M. (2023). The thorny road towards green path development: the case of bioplastics in Lower Austria. *Regional Studies, Regional Science*, *10*(1), 735–749. https://doi.org/10.1080/21681376.2023.2244572

Stock, L., & Schiller, D. (2024). Regionale Bioökonomiepfade. In A. Hassel, D. Schiller, S. Seiberling, C. Theel, & S. Fleßa (Eds.), *Bioökonomie und regionaler Strukturwandel* (pp. 203–219). Springer Gabler. https://doi.org/10.1007/978-3-658-42358-2_9

Suchman, M. C. (1995). Managing Legitimacy: Strategic and Institutional Approaches. *Academy of Management Review*, *20*(3), 571–610. https://doi.org/10.5465/amr.1995.9508080331

Tanner, A. N. (2016). The emergence of new technology-based industries: the case of fuel cells and its technological relatedness to regional knowledge bases. *Journal of Economic Geography*, *16*(3), 611–635. https://doi.org/10.1093/JEG/LBV011

Tödtling, F., & Trippl, M. (2005). One size fits all?: Towards a differentiated regional innovation policy approach. *Research Policy*, *34*(8), 1203–1219. https://doi.org/10.1016/J.RESPOL.2005.01.018

Tödtling, F., Trippl, M., & Desch, V. (2022). New directions for RIS studies and policies in the face of grand societal challenges. *European Planning Studies*, *30*(11), 2139–2156. https://doi.org/10.1080/09654313.2021.1951177

Tödtling, F., Trippl, M., & Frangenheim, A. (2021). Policy options for green regional development: Adopting a production and application perspective. *Science and Public Policy*, *47*(6), 865–875. https://doi.org/10.1093/scipol/scaa051

Trencher, G., & van der Heijden, J. (2019). Contradictory but also complementary: National and local imaginaries in Japan and Fukushima around transitions to hydrogen and renewables. *Energy Research & Social Science*, *49*, 209–218. https://doi.org/10.1016/J.ERSS.2018.10.019

Trippl, M., Baumgartinger-Seiringer, S., & Kastrup, J. (2024). Challenge-oriented regional innovation systems. *Investigaciones Regionales - Journal of Regional Research*, *60*, 105–116. https://doi.org/10.38191/iirr-jorr.24.026

Truffer, B., & Coenen, L. (2012). Environmental Innovation and Sustainability Transitions in Regional Studies. *Regional Studies*, *46*(1), 1–21. https://doi.org/10.1080/00343404.2012.646164

Truffer, B., Murphy, J. T., & Raven, R. (2015). The geography of sustainability transitions: Contours of an emerging theme. *Environmental Innovation and Societal Transitions*, *17*, 63–72. https://doi.org/10.1016/J.EIST.2015.07.004

Tsouri, M., Hanson, J., & Normann, H. E. (2021). Does participation in knowledge networks facilitate market access in global innovation systems? The case of offshore wind. *Research Policy*, *50*(5), 104227. https://doi.org/10.1016/j.respol.2021.104227

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*(12), 2359–2375. https://doi.org/10.1080/09654313.2019.1609425

van Welie, M. J., Boon, W. P. C., & Truffer, B. (2020). Innovation system formation in international development cooperation: The role of intermediaries in urban sanitation. *Science and Public Policy*, *47*(3), 333–347. https://doi.org/10.1093/scipol/scaa015

von Hippel, E. (1976). The dominant role of users in the scientific instrument innovation process. *Research Policy*, *5*(3), 212–239. https://doi.org/10.1016/0048-7333(76)90028-7

Walther, O. J., Radil, S. M., & Russell, D. G. (2025). The Spatial Conflict Life Cycle in Africa. *Annals of the American Association of Geographers*, *115*(2), 456–477. https://doi.org/10.1080/24694452.2024.2428812

Walz, R. (2007). The role of regulation for sustainable infrastructure innovations: The case of wind energy. *International Journal of Public Policy*, *2*(1–2), 57–88. https://doi.org/10.1504/IJPP.2007.012276

Weitzman, M. L. (1998). Recombinant Growth. *The Quarterly Journal of Economics*, *113*(2), 331–360. https://doi.org/10.1162/003355398555595

Wilson, C., Grubler, A., Bento, N., Healey, S., De Stercke, S., & Zimm, C. (2020). Granular technologies to accelerate decarbonization. *Science*, *368*(6486), 36–39. https://doi.org/10.1126/science.aaz8060

Wolf, L. J., Fox, S., Harris, R., Johnston, R., Jones, K., Manley, D., Tranos, E., & Wang, W. W. (2021). Quantitative geography III: Future challenges and challenging futures. *Progress in Human Geography*, *45*(3), 596–608. https://doi.org/10.1177/0309132520924722

Wydra, S. (2020). Measuring innovation in the bioeconomy – Conceptual discussion and empirical experiences. *Technology in Society*, *61*, 101242. https://doi.org/10.1016/j.techsoc.2020.101242