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“Innovation-based regional industrial change in the face
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Innovation-based regional industrial change in the face of societal challenges: green path development, interpath relations and barriers to change

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List of publications

1. Frangenheim, A., Trippl, M., and Chlebna, C. 2020. Beyond the Single Path View: Interpath Dynamics in Regional Contexts. *Economic Geography* 96 (1): 31–51. doi:10.1080/00130095.2019.1685378.
2. Trippl, M., Baumgartinger-Seiringer, S., Frangenheim, A., Isaksen, A., and Rypestøl, J. O. 2020. Unravelling green regional industrial path development: Regional preconditions, asset modification and agency. *Geoforum* 111: 189–97. doi:10.1016/j.geoforum.2020.02.016.
3. Tödtling, F., Trippl, M., and Frangenheim, A. 2020. Policy options for green regional development: Adopting a production and application perspective. *Science and Public Policy* 42 (7): 1030. doi:10.1093/scipol/scaa051.
4. Frangenheim, A. 2022. Regional preconditions to shape interpath relations across regions: two cases from the Austrian food sector. *European Planning Studies*, 1–20. doi:10.1080/09654313.2022.2053661.

Abstract

Societal challenges, such as climate and environmental change and recurrent economic and financial crises increase intra- and interregional inequalities in social and economic conditions. Despite the broad awareness of the resulting problems, we still search for common solutions and consensus about future development strategies.

This dissertation is based on recent contributions in evolutionary economic geography and innovation studies and contributes to emerging debates around economic change processes in the face of societal challenges. The overall aim is to contribute to a more nuanced conceptual and empirical understanding of innovation-based regional industrial change.

Six knowledge gaps have been identified as being particularly relevant in the face of rising societal challenges. The results have been compiled to be published in four internationally peer-reviewed scientific articles and a preceding framing text describing the overall dissertation project. The first research gap relates to the narrow (or limited) understanding of how different industrial activities, referred to as paths, interrelate in regional contexts. Earlier contributions either focus on reinforcing relations and left out impeding ones or they focus on single industries. While the second research gap concerns interpath relations *across* regions and countries, the third involves the regional preconditions affecting interpath relations at multiple scales. Both relate to the first one. The fourth gap concerns the missing framework of how green restructuring unfolds in regions. Although challenges for reaching sustainable economic development differ strongly across regions, potentials for *regional* policies to tackle societal challenges are not well explored. The fifth research gap refers to the excessively strong focus on the production side of green regional development as a basis for industrial and innovation policies. Since the ecological dimension of regional development is strongly related to the adoption and use of green innovations, the application side needs closer attention. The sixth research gap relates to the focus of evolutionary economic geography, innovation studies and

regional innovation policies on high-tech industries with intense research and development activities. Little attention is paid to foundational economies, one of which is exemplified as the food sector analyzed in this dissertation.

An important conceptual contribution lies in a more nuanced understanding of dynamics and interactions between regional industrial paths within and across regions and how they are affected by regional preconditions (*article I and IV*). Further contributions add to emerging discussions about how regional actors engage in the modification of regional and extra-regional assets with the aim to nurture green regional path development (*article II and IV*), discuss regional challenges to achieve green regional development (*article III*) and implications for policy (*article I, III and IV*). To prove and refine conceptualization, illustrative cases from the extant literature have been consulted and original evidence on path development activities in the Austrian food sector gathered and analyzed. As such, this dissertation contributes to understand the geography of innovation and informs spatially sensitive innovation policies, such as smart specialization.

Keywords: Economic geography, evolutionary economic geography, regional innovation system, new regional industrial path development, interpath relations, asset modification, green path development, green regional development, innovation policy

JEL Codes: O31; O33; R11; R58

Kurzfassung

Gesellschaftliche Herausforderungen wie Klima- und Umweltwandel sowie wiederkehrende Wirtschafts- und Finanzkrisen verstärken Ungleichheiten in den sozialen und ökonomischen Bedingungen innerhalb und zwischen Regionen. Obwohl daraus resultierende Probleme weitgehend anerkannt sind, sucht die Gesellschaft noch immer nach gemeinsamen Lösungen und einem Konsens über zukünftige Entwicklungsstrategien.

Diese Dissertation basiert auf rezenten Beiträgen der Evolutionären Wirtschaftsgeographie und Innovationsforschung und trägt zu aufstrebenden Debatten rund um den wirtschaftlichen Wandel angesichts gesellschaftlicher Herausforderungen bei. Das übergreifende Ziel ist es, zu einem konzeptionell und empirisch differenzierteren Verständnis von innovations-basiertem regionalem industriellem Wandel beizutragen.

Als besonders relevant im Kontext gesellschaftlicher Herausforderungen wurden sechs Wissenslücken identifiziert. Die Ergebnisse wurden für vier international begutachtete wissenschaftliche Artikel und einer vorangestellten Rahmenschrift, die das gesamte Dissertationsprojekt beschreibt, aufbereitet. Die erste Forschungslücke bezieht sich auf das enge (oder limitierte) Verständnis von Beziehungen zwischen verschiedenen industriellen Aktivitäten, genannt Pfade, in regionalen Kontexten. Frühere Beiträge fokussieren entweder auf stärkende Beziehungen und sparen hemmende Beziehungen aus oder sie fokussieren auf einzelne industrielle Pfade. Während sich die zweite Forschungslücke auf Inter-Pfad-Beziehungen über Regionen und Staaten hinweg bezieht, betrifft die dritte die regionalen Voraussetzungen, die Inter-Pfad-Beziehungen auf verschiedenen räumlichen Ebenen beeinflussen. Beide stehen in Verbindung zur ersten Forschungslücke. Die vierte Forschungslücke bezieht sich auf die nicht vorhandene Konzeptualisierung von Prozessen des ökologischen Strukturwandels in Regionen. Obwohl sich Herausforderungen auf dem Weg nachhaltiger wirtschaftlicher Entwicklungen stark zwischen Regionen unterscheiden, sind Potentiale für politische Handlungsoptionen auf regionaler Ebene nicht gut erforscht. Die fünfte Forschungslücke betrifft den übermäßig starken Fokus

auf die Produktionsseite von ökologisch-verträglicher Regionalentwicklung als Grundlage für Industrie- und Innovationspolitik. Da die ökologische Dimension von Regionalentwicklung stark mit der Annahme und Nutzung von grünen Innovationen verbunden ist, bedarf die Anwendungsseite mehr Aufmerksamkeit. Die sechste Forschungslücke bezieht sich auf den Fokus der Evolutionären Wirtschaftsgeographie und Innovationsforschung auf Hightech Industrien mit intensiven Forschungs- und Entwicklungsaktivitäten. Wirtschaftsbereiche der Alltagsökonomie, zu denen auch der im Rahmen dieser Dissertation analysierte Lebensmittelsektor gehört, finden kaum Beachtung.

Ein wichtiger konzeptioneller Beitrag liegt in dem Vorschlag eines wesentlich differenzierteren Verständnisses von Dynamiken und Interaktionen zwischen regionalen industriellen Pfaden innerhalb und zwischen Regionen und wie diese durch regionale Voraussetzungen beeinflusst werden (*Artikel I und IV*). Weitere Beiträge ergänzen rezente Untersuchungen, wie Akteure regionale und überregionale Ressourcen mit dem Ziel modifizieren, ökologische Pfadentwicklung zu unterstützen (*Artikel II und IV*), berücksichtigen regionale Herausforderungen bei der Erreichung ökologischer Regionalentwicklung (*Artikel III*) und stellen entsprechende Implikationen für die Politik bereit (*Artikel I, III und IV*). Zur Überprüfung und Präzisierung der Konzeptualisierung wurden illustrative Fallstudien aus der existierenden Literatur und originäre empirische Evidenz zu Pfadentwicklungsaktivitäten im österreichischen Lebensmittelsektor zusammengetragen. Mit der Dissertation wird damit ein Beitrag zum Verständnis der Geographie von Innovationen geleistet, der als Grundlage für raumsensible Innovationspolitiken wie "EU Smart Specialization" dient.

Keywords: Wirtschaftsgeographie, Evolutionäre Wirtschaftsgeographie, Regionale Innovationssysteme, Neue regionale industrielle Pfadentwicklung, Inter-Pfad-Beziehungen, Modifikation von Ressourcen, Ökologische Pfadentwicklung, Ökologische Regionalentwicklung, Innovationspolitik

JEL Codes: O31; O33; R11; R58



1 Introduction

This dissertation is motivated by some of the most striking challenges of our time. Climate and environmental change and recurrent economic and financial crises exacerbate regional inequalities in economic and societal conditions or generate new disparities. A growing interest of policy makers in understanding how innovation affects our responses to societal challenges and generates both, a contribution to productivity and growth on the one hand and well-being and public value on the other, alters our view about *how* to support *what* kind of regional restructuring processes *by and for whom* (OECD 2011, 2015; Schlaile et al. 2017). Concomitantly, scholarly interest shifted from regarding innovation as an engine of economic growth to the support of innovative activities that contribute to achieving wider ecological and societal goals (Markard, Raven, and Truffer 2012; Weber and Rohrer 2012; Mazzucato 2018; Schot and Steinmueller 2018; Tödtling and Trippel 2018; Sjøtun and Njøs 2019). Nevertheless, despite of its problem recognition since decades (Brundtland 1987), common solutions to solve societal challenges are not known and consensus about future development strategies is not yet given (Gibbs and O'Neill 2017).

Obviously, this dissertation provides no solution to these wicked scientific and societal problems. The thesis has been developed with the aim to personally enter this debate from an economic geography perspective where spatial inequalities of industrial change processes and the ways by which such dynamics contribute to regional development have a long tradition. My research contributes to the emerging field of new regional industrial path development and regional restructuring. It is ontologically guided by conceptualizations at the intersection of evolutionary economic geography (EEG) and regional innovation system (RIS) studies. While EEG provides knowledge on the *how, why and where* of industrial change, an important impact of RIS scholars is our understanding of regional inequalities in terms of economic development and the implementation of innovative activities through the conceptualization of ideal types of regions with different densities of economic activities and industrial structures (Tödtling and Trippel 2005;

Isaksen and Trippl 2016b; Isaksen and Trippl 2017b). Moreover, RIS are of high relevance in learning processes between policy and science and stimulate vivid discussions, various scientific contributions and practical applications (Isaksen, Martin, and Trippl 2018; Asheim, Isaksen, and Trippl 2019), which suits to contribute to current scientific and societal problems.

The combination of EEG and RIS studies provides valuable insights on regional preconditions beyond industrial structures, which recently opened the floor for broadened considerations of assets and actors also involved in structural change processes towards sustainability. Recent contributions at the intersection of EEG and RIS studies have revealed unresolved questions to which this dissertation contributes to respond (cf. [section 1.1](#)): Firstly, for new regional industrial path development to occur, the structure of RIS must undergo changes. To understand regional changes, RIS scholars contemplate the relation of existing (RIS) structures and its modification by regional and extra-regional actors. Current understandings of agency disentangle firm level agency, i.e. the initiation of new firms or innovation activities by industry actors and system level agency, i.e. operations in the regional support system undertaken by diverse actors (Isaksen and Jakobsen 2017; Isaksen et al. 2019). This distinction – between industry-related and system-related assets provided and altered also by non-firm actors – has prepared the conceptual grounds for analyzing the hitherto unknown relation between different path development activities and its uni- or bidirectional effects in regional contexts. Secondly, analyses of inflows and outflows of non-local knowledge and other assets, institutional structures, regulatory frameworks and policy actions set at higher spatial scales (Zukauskaitė, Trippl, and Plechero 2017; Trippl, Grillitsch, and Isaksen 2018; Asheim, Isaksen, and Trippl 2020) have revealed new perspectives to work on unresolved questions regarding interregional industrial relations. Thirdly, the deep knowledge about industries, supporting organizations, and institutions in the region, put forth by the RIS literature (Asheim, Isaksen, and Trippl 2019) has allowed conceptualizations of green restructuring processes. Fourthly, theoretical approaches ranging from the cluster theory (Porter 2008), work on regional diversification (Boschma and Frenken 2011b) and the RIS concept (Cooke, Heidenreich, and Braczyk 2010; Tödting and Trippl 2013) have helped to better understand where green industries emerge and evolve over time but leave out the application side of green innovations. Here, insights from the transition literature helps to

understand the adoption and use of green technologies and to conceptualize different challenges for green regional development in various contexts.

After presenting the aims, gaps, contributions and research questions that guided the dissertation, this chapter provides an overview of the articles representing this cumulative dissertation and the structure of the whole thesis.

1.1 Aims, gaps, contribution and research questions

The overall aim of this dissertation is to contribute to a more nuanced conceptual and empirical understanding of innovation-based regional industrial change in the face of societal challenges. It adds knowledge about the interplay of different path development processes within and across regions, the diversity of green regional restructuring processes and respective challenges in different regional contexts. In its conceptual discussion, I combine latest knowledge on new regional industrial path development and industry diversification in EEG and RIS studies with insights from related literatures, such as technological innovation system studies and global innovation system studies. Conceptualizations are inspired by recently integrated core arguments from other streams of economic geography than EEG, such as geographical political economy or the cluster approach, environmental innovation and technology studies, socio-technical transition studies, the social construction of technological systems (SCOT) literature and analyses of innovation policy. While I often make use of “boundary objects” to facilitate the interchange and integration of alternative knowledge across epistemic communities and beyond economic geography (Martin 2021), my contribution is directed to the literature intersecting EEG and RIS.

I identified six research gaps in the existing literature that are particularly relevant in the face of societal challenges. The first research gap relates to the narrow (or limited) understanding of how different (types of) industrial paths interrelate in regional contexts. Relations between existing regional industries (related versus unrelated variety) or old and new regional industries (related versus unrelated diversification) (Boschma and Frenken 2011c; Boschma 2017) have been intensely discussed by looking at trade data, sector classifications, patent data, labor flows, or co-occurrence (see Content and Frenken 2016 for a detailed overview on data sources in related variety studies). While measurable indicators and variables are useful to identify empirical regularities between objects, social analysis of causal mechanisms and contingent relations require the consideration of local institutional and

cultural contexts. Broader conceptualizations of path development, incorporating qualitative social analyses and considering the dynamics of path development at different development stages, however, intensely focus on single industries (exceptions see Martin and Sunley 2006; Simmie et al. 2008). Moreover, conceptualizations of related diversification only focus on reinforcing correlations between paths and left out impeding relationships (Boschma et al. 2017; Hassink, Isaksen, and Trippel 2019).

While the second research gap concerns interpath relations across regions and countries, the third involves the regional preconditions affecting interpath relations at multiple scales. Both aspects relate to the first one. As regards the second gap, assets needed for path development in different regions originate from or are modified at national or international sources and scales (Binz, Truffer, and Coenen 2016; Trippel, Grillitsch, and Isaksen 2018). Considerations of relations between existing and emerging industrial entities nevertheless focus on the same regional and national context (Sandén and Hillman 2011; Bergek et al. 2015; Boschma et al. 2017; Steen and Hansen 2018; Hassink, Isaksen, and Trippel 2019; Frangenheim, Trippel, and Chlebna 2020). Concerning the third gap, while recent contributions emphasize cumulative or combined effects of interpath dynamics to better account for their impact on whole regions (Breul, Hulke, and Kalvelage 2021; Chlebna, Martin, and Mattes 2021), regional preconditions enabling regional industrial paths to shape interpath relations are unexplored.

The fourth research gap reflects recurrent claims to regard needed changes in the RIS structure as going beyond innovation-based competitiveness and growth also targeting greater benefits for society (Weber and Rohrer 2012; Fagerberg, Martin Ben R., and Andersen 2013). Green restructuring processes have been analyzed in various spatial contexts by complementing EEG with the technological innovation system approach, transition approaches, global innovation and production networks literature (Simmie 2012a; Dawley et al. 2015; Binz, Truffer, and Coenen 2016; Binz and Truffer 2017; Steen and Hansen 2018; MacKinnon, Dawley, and Steen et al. 2019). For these approaches observations in socio-technical transition studies by Murphy (2015) apply: Geographical context is understood as relational rather than territorial, constituted through connections, flows, locations, and scales that often transcend administrative boundaries of regions and nation-states. Challenges for reaching sustainable economic development, however, differ strongly across regions and the complex potentials and challenges for *regional* policies

to tackle societal challenges are not well explored. In this dissertation, I therefore focus on the regional scale, where green development processes are by far not comprehensively examined. Furthermore, my co-authors and I provide a nuanced understanding about modification processes of regional structures as they are increasingly needed when structures of environmentally destructive industries are strengthened but rather have to be adapted or destabilized and green innovations require new support structures.

The fifth research gap refers to the excessively strong focus on the production side of green regional development informing industrial and innovation policies. Overall, conceptualizations of green regional development have still considerable ambiguities and are subject to contestation (Gibbs and O'Neill 2017). One aspect that has been overseen hitherto is that besides an economic dimension, the ecological dimension of regional development is strongly related to the application, i.e. the adoption and use of green technologies by firms and non-firm actors with the aim to reduce environmental problems. Since the emergence and adoption of green industries often takes place at the regional scale, challenges related to the regional preconditions to produce or apply non-regional innovations are considered important but not sufficiently conceptualized to inform policy makers.

The sixth research gap relates to the focus of EEG and RIS studies as well as regional innovation policies on industries with strong technological components, high R&D intensities, organizational and marketing innovations (Tödtling, Trippel, and Desch 2021). Foundational sectors supporting everyday life and everyone's consumption needs (Bentham et al. 2013), such as those that are not part of international trade systems, e.g. construction and social services or low-tech industries, such as textile and food production, receive much lesser attention (Hansen 2022). I approach this gap by providing original empirical material and conceptual analyses of two cases in the Austrian food sector, that are urban insect-based food and feed and rural aquaculture. Food sector innovation gains importance in meeting societal challenges as expressed in diverse international policy initiatives (Sustainable development goals, Food 2030, EU Green Deal, EU Farm to Fork Strategy, EU Biodiversity Strategy for 2030, IPES Food, Milan Urban Food Policy Pact). Moreover, progress in biotechnology and genetics have initiated experiments with new food process technologies (Berghofer, Schönlechner, and Schmidt 2015). Cities position themselves therewith as new centers of innovation in an otherwise peripherally characterized sector. Attention of EEG scholars on innovative

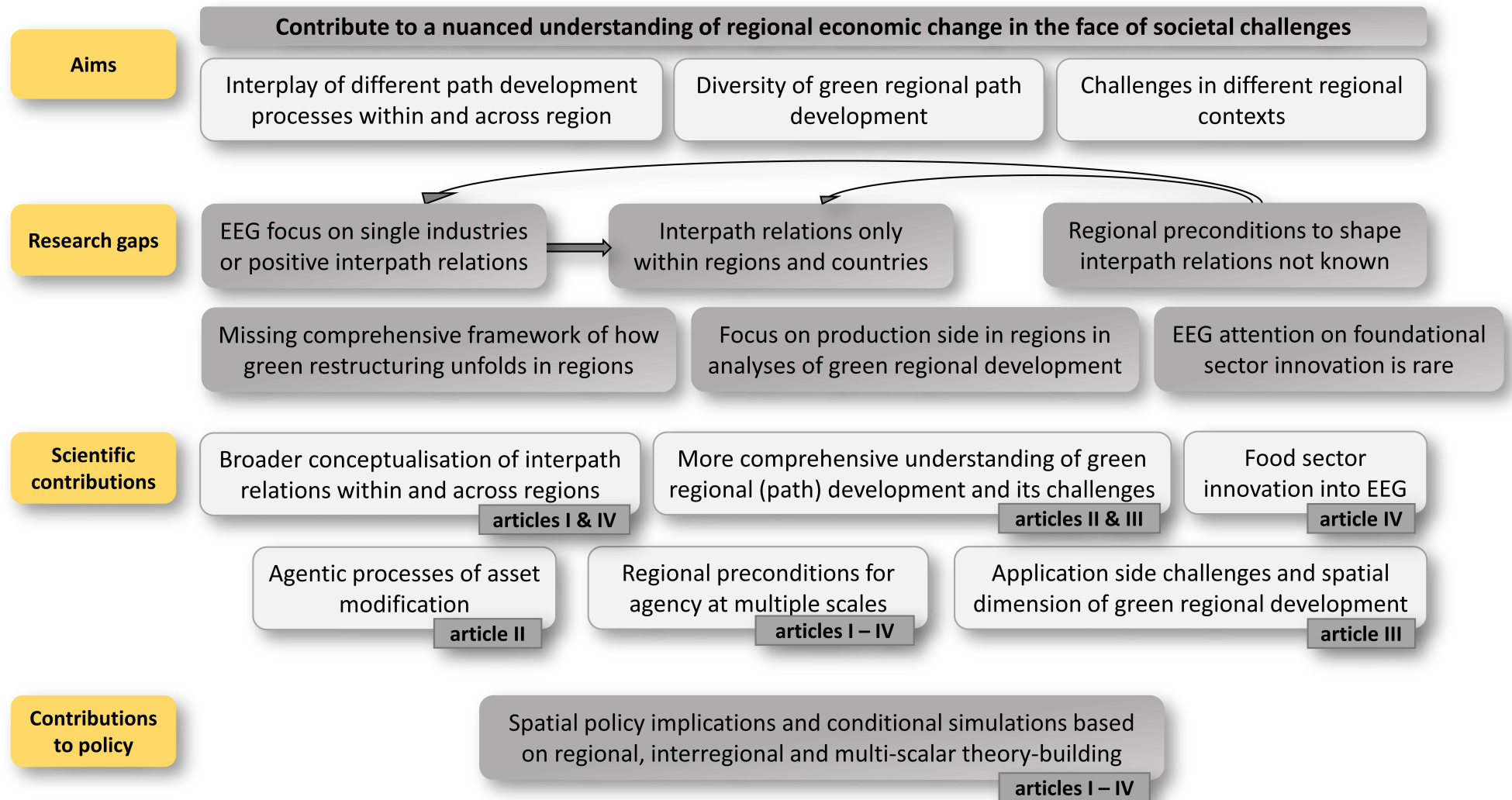
food products is nevertheless rare (Martin and Martin 2021) or analyses focus on traditional products in rural areas (Baumgartinger-Seiringer et al. 2022).

The dissertation is guided by the following research questions:

1. *What are the nature and effects of relationships between new regional industrial paths within and across regions? How do regional preconditions and agency shape them at multiple scales?*
2. *How do regional contexts support or impede green regional path development? How do agentic processes nurturing green restructuring look like and at which scales are they observed?*
3. *What challenges are to be met when aiming at reaching economic and/or ecological benefits in (different types of) regions and how?*

Conceptual arguments have been supported and grounded by means of empirical case studies either from the extant literature or through own empirical investigations. To explore the occurrence and nature of interpath linkages and the role of agency in creating or shaping relationships between linked paths, *article I* consults case-based existing empirical material including green and non-green paths. The examples are different renewable energy paths in Germany, the digital gaming industry and the new media industry in Southern Sweden, alternative transport fuel paths in Sweden, urban water provision paths in Australia, and creative industry paths in Berlin, Germany. The conceptual framework in *article II* aiming at developing a more comprehensive understanding of green regional path development is also supported by illustrative cases from the literature. These include the greening of the mature metallurgical and chemical industry in the Norwegian region Agder, the diversification from oil and gas to offshore wind in Norway, new on-site water recycling path creation in Beijing, China, as well as different renewable energy and fuel cell paths in Norway, Germany and Sweden. In *article III*, existing cases from e-mobility, green technologies and biomass heating in Austria were consulted to provide evidence for proposed routes and policies for green development in different regions. *Article IV* extends the framework of article I beyond single regions and tests the new conceptualization by means of fresh empirical material from Austria. Aiming at better understanding spatial complexities in interpath dynamics and respective regional preconditions to shape them, an empirical investigation of different early food path development activities in Vienna and Lower Austria, their mutual relations and relations to other food paths in other Austrian and non-Austrian regions has been undertaken.

Figure 1. Overview of aims, gaps, and contributions, own elaboration



1.2 Overview of the articles

This section briefly introduces the four articles included in this dissertation taking into account theoretical and empirical underpinnings and contributions to the research questions and gaps as introduced above. The articles have been drafted between 2017 and 2021 and published between 2020 and 2022. They are either co-authored (*article I, II and III*) or single-authored (*article IV*).

The *first article*, *Beyond the Single Path View: Interpath Dynamics in Regional Contexts*, published in Economic Geography (Frangenheim, Trippl, and Chlebna 2020), challenges the conceptual and empirical focus in EEG on the development of single paths and argues for a consideration of multiple related, interacting and interdepending industrial paths within regions. The article critically engages with conceptualization of relatedness (Boschma and Frenken 2011c; Neffke, Henning, and Boschma 2011; Boschma 2017; Carvalho and Vale 2018), new path development (Tödtling and Trippl 2013; Binz, Truffer, and Coenen 2016; Grillitsch, Asheim, and Trippl 2018; Steen and Hansen 2018), and agency (Sotarauta 2016; Isaksen and Jakobsen 2017; Isaksen et al. 2019). Taking a RIS perspective with a broad understanding of actors and assets, it supplements narrow understandings of path interdependencies considering existing regional industries (related versus unrelated variety) as well as old and new regional industries (related versus unrelated diversification) with broader conceptualizations of dynamics between early path development activities from different sectors. The framework provided by this article understands interpath linkages as being determined by the respective path's reliance on markets and broadly understood – scarce or abundant – regional assets. Such linkages are described in a continuum from very strong over weak to not existing. Agents may modify the regional support structure towards competitive, supportive or neutral relationships – with respective reinforcing or impeding effects for concerned paths. The significance of interpath dynamics is underlined by means of several illustrative empirical examples from the extant literature. The article discusses implications for policy and identifies avenues for future research. It relates to the research questions under 1 and 3.

The *second article*, *Unravelling green regional industrial path development: Regional preconditions, asset modification and agency*, published in Geoforum (Trippl et al. 2020), explores conceptually and based on empirical examples from the literature how green restructuring unfolds in regions. The framework

is informed by recent conceptualizations of new path development combining EEG with insights from regional and technological innovation system studies, socio-technical transitions, global production and innovation networks and sociological perspectives (Binz, Truffer, and Coenen 2016; Isaksen and Trippl 2016b; Boschma et al. 2017; Hassink, Isaksen, and Trippl 2019; MacKinnon, Dawley, Pike, and Cumbers 2019). Complementing EEG with the (open) RIS approach, the framework intends to overcome firm-centered views in favor of more systemic and multi-actor perspectives (Hassink, Isaksen, and Trippl 2019). It takes into account the role of exogenous actors and influences (Trippl, Grillitsch, and Isaksen 2018) and besides firm-level, also system-level agency (Isaksen and Jakobsen 2017) when shedding light on aspects illustrating how regional and extra-regional structures are used and altered for green path development. The article contributes to the understanding of regional industrial structures, organizational support configurations and institutional set-ups influencing the development of several types of green path development. Presenting different empirical examples of green industries, the article explicates the role of enabling and constraining environments and how different types of asset modification are combined to facilitate green path renewal, diversification and importation. It presents avenues for further research and refers to the second set of research questions.

The *third article*, *Policy options for green regional development: Adopting a production and application perspective*, published in Science and Public Policy (Tödtling, Trippl, and Frangenheim 2020), explores the role and importance of industrial and innovation policies for the emergence and development of green regional initiatives and activities. It takes into account particular regional settings and their capacity to nurture new industries in general (Isaksen and Trippl 2016b) and green industries in particular (Barbieri and Consoli 2019; Capasso et al. 2019; Corradini 2019; Santoalha and Boschma 2019). The article then distinguishes between the production side of green technologies (i.e. the industries that develop and produce such technologies) and the application side (i.e. the adoption of such technologies by firms and the wider society) and considers whether economic and ecological benefits rather accrue within the region or elsewhere. Three green regional development initiatives at the production and application side in an industrialized and diversified, a former old industrial and a peripheral Austrian region demonstrate the practical relevance of considering both sides

and the role of place-sensitive policies at various spatial scales to overcome respective challenges. The article relates to the third set of research questions.

The *fourth article*, *Regional preconditions to shape interpath relations across regions: two cases from the Austrian food sector*, published in European Planning Studies (Frangenheim 2022), provides a conceptual expansion and empirical testing of how interpath dynamics evolve in regional contexts (article I, Frangenheim, Trippl, and Chlebna 2020) towards inter-regional perspectives. The article is based on recent acknowledgements in EEG about the distribution of agency (Boschma et al. 2017; Isaksen et al. 2019) and adds considerations on the generation of reinforcing and impeding effects of interpath relations. A review of the availability and modification of broadly understood assets at different scales (Bergek et al. 2015; Fuenfschilling and Binz 2018; Pflitsch and Radinger-Peer 2018; Isaksen, Langemyr Eriksen, and Rypestøl 2020), core and peripheral RIS types influencing preconditions to access and modify them (Isaksen 2015; Isaksen and Trippl 2016b), and resulting capacities of regions to support industrial paths in modifying these assets builds the conceptual framework to be tested and enhanced with fresh empirical material. The article investigates two cases of emerging food path development activities evolving in a peripheral and in an urban region, both initiated to tackle societal challenges. The results provide knowledge about regional differences in supporting asset modification at multiple scales and demonstrate how reinforcing or impeding effects for path development result from interpath relations across regions. The article offers policy recommendations and presents avenues for further research. It relates to the research questions under 1, 2 and 3.

1.3 Structure of the thesis

This dissertation consists of the four scientific articles that have been published in internationally recognized peer-reviewed journals, preceded by a framing text that describes the overall dissertation project. The framing text consists of the following chapters: The theoretical underpinnings of EEG and RIS studies frame a discussion about the geography of regional industrial path development and present the approach to study green regional restructuring. Subsequently, the acknowledgement of existing contributions on agency and the recent broadening of understanding assets and change in path development perspectives as crucial background for the contributions of this dissertation are outlined.

The chapter on interpath relations follows including the main contribution to theory and empirics provided by this dissertation. Overall, these three chapters synthesize the state of research relevant to this dissertation and complements the narrower theoretical discussions in the four articles. Since much of the new conceptualizations has already been reflected in more recent publications, I also point out some of the work inspired by the first three articles. The fifth chapter outlines the research design with its ontological and epistemological groundings, methodology and methods, conceptual and empirical contributions, cases and their abstraction and the final chapter summarizes the main results, implications for policy and provides an outlook.

2 Theoretical background:

EEG and RIS

EEG derived ideas and concepts from evolutionary economics. In sharp contrast to neoclassical explanation of regional development, the natural state of the economy is considered as being in a disequilibrium (Nelson and Winter 1982). Economic transformation in evolutionary terms happens endogenously over time whereas the cause of endogenous change is the capacity to create novelty (Witt 2008). In contrast to neoclassical equilibrist models of economy, competition and economic development in EEG is driven by Schumpeterian innovation, which implies that knowledge is constantly being created and not seen as pre-given and separate from the economic process (Boschma and Frenken 2006; Boschma and Martin 2010). The “neo-Schumpeterian” view on innovation expands on Schumpeter’s theory (which takes entrepreneurial innovation center stage) by acknowledging that innovation is a complex process in which diverse components interact. This necessitates a systemic approach to study the influence of innovation on development (Eggink 2013).

EEG has its ontological roots in three main approaches to study evolution (Martin and Sunley 2007; Hodgson 2009; Boschma and Martin 2010). A large part of the work in EEG has been taken from generalized Darwinism. This includes ideas and metaphors such as variety, selection, novelty and retention. A second approach is based on complexity thinking, which centers non-linear interactions between systemic parts across multiple scales. To understand a system is, in this perspective, not possible through its reduction to its constituting elements. Exponents of this approach make use of notions coming from complexity science such as self-organization, co-evolution, emergence, far-from equilibrium dynamics, and criticality. Non-linearity and openness (the constant interaction and exchange with their environments), as inherent feature of complex systems, lead to the irreversibility of change (Martin and Sunley 2007). Both streams have strong overlaps with each other and with the third approach in EEG that is based on path dependence theory. Building on

the work of Paul David and Brian Arthur in the 1980s and early 1990s, a large body of conceptual and empirical work in EEG reflects the real historical dynamics of economic landscapes at a particular time. In their seminal article on “path dependence and regional economic evolution”, Martin and Sunley (2006) provide a conceptual overview of path dependence and lock-in as place-dependent processes. Path-dependence refers to the system’s “inability to shake free of their history” (Martin and Sunley 2006, 399). The “economy is an irreversible historical process in which future outcomes depend on past events and outcomes: *at any point in time the state of the economy depends on the historical adjustment path taken to it*” (Martin and Sunley 2006, 400, original emphasis). In geographic terms this means that path dependence does not only produce places, but place dependence is also responsible for path dependence (Martin and Sunley 2006).

In the following, recent achievements made in EEG and innovation studies explaining the geography of new regional industrial path development are presented ([section 2.1](#)) and the dissertation is positioned into the broader discourse on green regional development ([section 2.2](#)).

2.1 EEG and the geography of regional industrial path development

Interaction with and integration of conceptualizations from alternative interpretative frameworks from political science, have let economic geographers to overcome the canonical path dependence model. Instead of emphasizing equilibrating development with historical accidents as origin of new industrial paths and exogenous shocks as only source to de-lock paths, processes of structural change are described by evolutionary dynamics involving novelty, endogenous change and constant transformation (Martin 2010; Simmie 2012b). Yet, regional industrial development is considered to be path dependent, i.e. a certain state is irreversible since it is rooted in real historical time and place (Martin and Sunley 2006). Evolutionary economic geographers have supplemented the concept of path dependency and lock-in (Grabher 1993; Hassink 2005) by focusing on change processes rather than those of continuity (Martin 2010), industrial diversification through branching (Frenken and Boschma 2007; Boschma and Frenken 2011a) and the mindful creation of new industrial paths (Garud and Karnøe 2001; Simmie 2012b). In this context, the new path development literature has come into being with its

main objective to understand *how and under what conditions* (new) industrial paths develop in regions.

One approach describing the probability of regions to nurture new industrial paths as a function of the number of related activities in that location is the empirically generalized principle of relatedness (Hidalgo et al. 2018). Its reproducibility and robustness indeed demonstrate a solid foundation for current and future research, as well as policy, such as EU smart specialization. If industries, however, repetitively emerge out of existing territorial capabilities through mechanisms like regional branching and related diversification (Boschma and Frenken 2011a; Neffke, Henning, and Boschma 2011; Boschma 2017), over the long term it increases spatial inequalities and may, for instance reduce the development abilities of peripheral regions (Hidalgo et al. 2018).

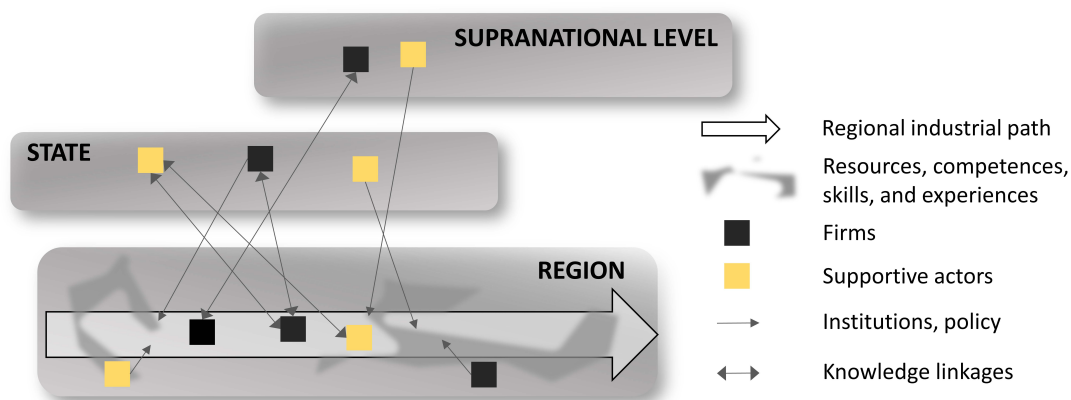
This interpretation not only appears to be more deterministic than evolutionary in their causal relations (Gong and Hassink 2020). Moreover, many cases have shown more multi-faceted pictures about the relation of regional preconditions and industry emergence that deviate from this single interpretation of outcome (the development of a new industry) as a result of one input dimension (related activities based on knowledge and skills). Isaksen (2015), for instance, points out the role of other sources, such as external investments, inflow of external knowledge and technology for peripheral regions to create new paths. Eder (2019) provides an overview about preconditions, processes and outcomes of innovation in the periphery to overcome the urban-rural dichotomy. Conceptual considerations and qualitative case studies add to this perspective insights on the diversity of mechanisms of regional industrial path development (Martin and Sunley 2006; Tödtling and Trippl 2013; Boschma 2017; Grillitsch, Asheim, and Trippl 2018), on assets beyond knowledge and skills (Binz, Truffer, and Coenen 2016; Carvalho and Vale 2018; MacKinnon, Dawley, and Steen et al. 2019; MacKinnon, Dawley, Pike, and Cumbers 2019), on actors and on agency beyond the firm level (Dawley 2014; Isaksen and Jakobsen 2017; Hassink, Isaksen, and Trippl 2019; Jolly, Grillitsch, and Hansen 2020). Others have emphasized phases of path decline resulting from competition with other regions and the availability of resources in other locations (Blažek et al. 2020) or the loss of legitimacy within the region (Jolly and Hansen 2021).

This does not mean that conversation between quantitative approaches and qualitatively developed conceptualizations and typologies is not useful as a

source of inspiration to understand overall regularities and patterns, specifically regarding cross-country perspectives or insights in countries beyond Europe. Important inspirations of relatedness studies include, for instance, considerations about the role of relatedness in more coordinated or more liberal forms of capitalism (Boschma, Balland, and Kogler 2015), the role of policy interventions when supporting regions to nurture new path creation (Zhu, He, and Zhou 2017), or the role of relatedness in developing and advanced economies (Petrulia, Balland, and Morrison 2017), among others. To link these two perspectives is yet not in focus of this dissertation.

The understanding of new regional industrial path development and the ways different paths are related to each other applied in this dissertation is, besides evolutionary approaches, associated with innovation system, relational and sociological approaches (Garud and Karnoe 2001; Martin and Sunley 2006; Simmie 2012b; Pike et al. 2015; Binz, Truffer, and Coenen 2016; Isaksen and Trippel 2016b; MacKinnon, Dawley, Pike, and Cumbers 2019). The definition of a regional industrial path applied in this dissertation is reasoned in contributions of these strands of literatures. During the perennial analyses of processes related to regional industrial path development, my own understanding of the topic evolved and has been finally published in the fourth article (figure 2): It represents related firms and supportive actors and is stimulated or enabled by place-specific resources, competences, skills, and experiences obtained from previous rounds of path development (Frenken, van Oort, and Verburg 2007; Martin 2010). Its development additionally depends on institutions and policy interventions of local and non-local organizations as well as knowledge linkages to actors across scales (Binz, Truffer, and Coenen 2016; Trippel, Grillitsch, and Isaksen 2018).

Figure 2. Regional industrial path, Frangenheim 2022



Differentiated views on regional industrial change have provided various typologies of path development including established and new paths (Martin and Sunley 2006; Tödtling and Trippl 2013; Grillitsch, Asheim, and Trippl 2018; Isaksen, Tödtling, and Trippl 2018). Established paths may be of interest for analyses about path decline or dissolution, path extension and also renewal or transformation. This dissertation focuses on new path development and therewith takes into account path renewal or transformation, diversification and new path creation or importation (Grillitsch, Asheim, and Trippl 2018; Isaksen, Tödtling, and Trippl 2018). Path renewal or transformation captures changes of an industrial path based on (radical) new technologies, organizational innovations or business models (Miörner and Trippl 2019; Baumgartinger-Seiringer, Miörner, and Trippl 2021). Path diversification means that an existing path diversifies into an industry that is new to the region but builds on related or unrelated competencies, knowledge and other assets of existing industries (Frenken, van Oort, and Verburg 2007). Finally, new path creation or importation describes the emergence and growth of entirely new-to-the-world or new-to-the-region industries based on radically new technologies and scientific discoveries or as outcome of search processes for and import of new business models, user-driven innovation and social innovation (Binz and Gong 2022).

To reproduce the regional dimension of industrial change and innovation (Martin 2010) and understand why innovation activities and economic development are unevenly distributed across space, linking EEG with RIS studies have a long tradition (Isaksen, Martin, and Trippl 2018; Asheim, Isaksen, and Trippl 2019). The RIS approach originates in neo-Schumpeterian and institutional theoretical positions and qualitative transformations of economies are said to result from dynamic processes. The architecture of a RIS includes regional knowledge infrastructure, networks of firms, a policy support system and an institutional framework comprising of laws, norms and routines (Asheim and Isaksen 2002; Asheim, Isaksen, and Trippl 2019). The established perspective of how different types of regions deal with specific innovation barriers stemming from Tödtling and Trippl (2005) has set the ground for moving beyond regional industrial preconditions and considering other enabling and constraining factors and conditions for path development. These include the role of diverse (system) assets and their modification, the presence and capabilities of diverse actors, the geography of knowledge sourcing, as well as considerations about growth and decline of green and

environmentally destructive sectors (Isaksen and Trippl 2016b; Isaksen and Trippl 2017b; Grillitsch and Hansen 2019; Blažek et al. 2020; Rypestøl et al. 2021).

The dissertation follows this tradition and links its contributions to the EEG literature to particularities of regional preconditions conceptualized in RIS studies. While a number of RIS typologies have been provided, in line with above mentioned scholars, I decided for one that orients at the thickness (cf. Zukauskaitė, Trippl, and Plechero 2017) of organizational and institutional structures and the degree of specialization in RIS (Isaksen and Trippl 2016b, table 1). Acknowledging a wide set of factors and elements that enable or constrain the regional capacity (or its deficiency) to nurture processes of new path development, this typology does support our understanding of regional inequalities and to tackle the identified research gaps. It helps conceptualizing new path development from a systemic as well as territorial perspective and thus allows to take into consideration the role of other regional industrial paths from within the region and beyond, regional preconditions to shape interpath relations, agentic processes of asset modification at the firm and system level as well as more comprehensive considerations of green regional development and respective challenges.

Table 1. Characteristics of RIS types, adapted from Trippl and Frangenheim 2018b

		Core RIS	Industrialized RIS	Peripheral RIS
Firms, sector structures, knowledge and support structures	Critical mass	High	High	Low
	Diversity	High	Low	Low
Institutional heterogeneity		High	Low	Low
Regional knowledge circulation		High	High	Low
Embeddedness in global knowledge networks		High	Low	Low
Exploration – exploitation		Balanced or too little exploitation	Too little exploration	Too little exploration and exploitation

Isaksen and Trippel (2016b) differentiate between three important types of regions, characterized through thick and diversified RIS, thick and specialized RIS and thin RIS. The former can be regularly found in urban or core regions with heterogeneous industrial structures, diverse innovative actors and economic, knowledge and support structures. They tend to have good preconditions to nurture new regional industrial paths. Thick and specialized RIS, as well as thin RIS are assumed to have lower innovation and path development capacities. Thick and specialized RIS are often found in old industrialized regions where assets tend to be locked in old, often traditional paths and its support structures (Grabher 1993; Hassink 2010a). Missing heterogeneity in industrial structures (Boschma and Frenken 2011a) and support structures that focus on specific industries (Asheim, Boschma, and Cooke 2011) limit the potential to combine and recombine diverse knowledge bases at the regional scale (Boschma 2015). Thin RIS tend to be found in peripheral regions where often a regional culture and strong bonding social capital (Westlund and Kobayashi 2013) limit the involvement and exploitation of benefits from interregional networks (Fitjar and Rodríguez-Pose 2011). They are generally characterized through a missing critical mass of innovative firms, weak networks and knowledge and support structures (Tödtling and Trippel 2005; Isaksen 2015).

Obviously, these general characteristics of core, industrialized and peripheral RIS are ideal types and research has brought about much more diverse pictures, for instance when regarding peripheries (e.g. Simmie 2012b; Isaksen 2015; Eder 2019). In the *third article* (Tödtling, Trippel, and Frangenheim 2020), we have shown how an old industrial region has overcome its challenges and developed a green-tech cluster with global reach and how a peripheral region created a new biomass heating path. In the *fourth article* (Frangenheim 2022), I presented a more nuanced perspective on why new path development initially failed in an urban region and has performed successfully in a peripheral region. While the arguments made in this dissertation put their analytical focus on the relations of different emerging industrial paths within and across regions, conceptualizations of green restructuring and challenges for green regional development, other contributions further develop conceptualizations about the regional preconditions supporting or hindering such processes and thus may eventually contribute to future refinements of this typology. Baumgartinger-Seiringer et al. (2022), for instance, go beyond simple considerations about constraining and enabling structural conditions

in regional industrial change by involving four different configurations, that are established, contested, aligned/emerging and fragmented configurations, which turn out to be different combinations of high and low elaboration, and high and low coherence. Miörner (2020) instead, examines factors that shape the reconfiguration capacity of RIS.

2.2 New path development and the green economy

Spurred by the increasing calls to react on recurring societal challenges, the emergence, growth, transformation or decline of (new) industrial paths has become a major concern in economic geography (Essletzbichler 2012; Fornahl et al. 2012; Simmie 2012a; Tödtling and Trippl 2013; Dawley 2014; Binz, Truffer, and Coenen 2016; Isaksen and Trippl 2016b; Grillitsch and Trippl 2018; MacKinnon, Dawley, Pike, and Cumbers 2019; Blažek et al. 2020; Jolly and Hansen 2021). How EEG scholars approach innovation and their related policy recommendations has been, however, criticized for stimulating any innovation and being neutral in the sense that it encourages industrial development per se, neglecting the need to rather stimulate green regional development (Tödtling and Trippl 2018; Grillitsch and Hansen 2019; Sjøtun and Njøs 2019). Moreover, established ways of measuring economic progress ignore the need to tackle societal challenges and therefore also the measurement of regional development through indicators of economic growth has consequently come under criticism (Pike, Rodríguez-Pose, and Tomaney 2017). Added to this, neither common solutions to solve societal challenges are known, nor a consensus about future development strategies, types of policies and instruments exist (Ferguson 2015; Gibbs and O'Neill 2017).

The hegemonic discourse focusing on more sustainable activities, solutions and practices in a business-as-usual manner, i.e. green growth is heavily challenged (Bina 2013). Degrowth solutions oriented at a downscaling of overall consumption and production and instead devoting more time to society, community and family (Kallis and March 2015; Brossmann and Islar 2020) show promise. These are, however, considered to remain niche developments with little potential to challenge the mainstream economy (Gibbs and O'Neill 2017) and thus hardly reflected in the international policy discourse (Ferguson 2015).

As in the broader social and environmental sciences also in economic geography a rethinking of *the economy* including a diversification of concerns and approaches that seek to embed considerations about our economic

systems into the broader social science framework happens (Martin 2021). Alternative and heterodox conceptions also influence the remit and orientation of EEG, which is explicitly reflected in the increasing emphasis on developing new green industries or greening mature ones (Steen and Hansen 2018; Grillitsch and Hansen 2019; Tripl et al. 2020; Sotarauta et al. 2021). More implicitly, it is addressed through extended perspectives on (radical) socio-technical innovation and regional development taking place in innovation systems where learning and knowledge diffusion happen in an unpredictable manner (Weber and Truffer 2017). The consideration of heterogeneous actors, their agency and involved assets (Dawley 2014; MacKinnon, Dawley, Pike, and Cumbers 2019; Jolly, Grillitsch, and Hansen 2020), the multi-scalarity of drivers and resources (Tripl, Grillitsch, and Isaksen 2018; Mörner and Binz 2021), and the acknowledgement of visions and interpath relations (Steen 2016; Steen and Hansen 2018; Hassink, Isaksen, and Tripl 2019) indicates an opening (away from one-dimensional, firm-oriented input-output considerations) of how economic change is theoretically conceptualized to direct its orientation towards recent societal challenges.

In this dissertation, I understand regional restructuring as the sum of new path development activities in regions and as such as being positioned in between green growth and degrowth approaches. The “selective growth perspective” sees correlation between growth and societal well-being in the medium term (Bär, Jacob, and Werland 2011). Ferguson (2015) describes this position as being agnostic about whether growth per se should be a policy objective (see also van den Bergh 2017). Rather, it calls for the expansion of green vis-à-vis environmentally destructive sectors of the economy, which either promote or impede environmental or social objectives. Moreover, before separating the green economy agenda from the commitment to growth (to progressively rearticulate a post-growth direction solely encompassing measures of welfare), he points to the need of technological innovation compensating for the ecological effects of current growth. Thus, the decline of economic activities that cause environmental damage requires growth in other fields, such as renewable energy production, sustainable forms of mobility, education, health-related products and services to ameliorate environmental and social problems. Though not explicitly mentioned in the new path development literature, I argue that conceptualizations of regional restructuring are compatible with this perspective. This is basically proven in the central concern of path development scholars to react at the regional level

to current societal challenges by focusing on the rise of new regional industrial paths, the renewal of existing ones, as well as the destabilization of non-sustainable regional industrial activities.

The matter of green growth is analyzed in fields studying industrial emergence and change, such as the literature on technological and global innovation systems and transition studies (see Capasso et al. 2019 who provide a synthesis on scientific findings for green growth). These studies increasingly consider various spatial contexts (Binz, Truffer, and Coenen 2016; Binz and Truffer 2017; MacKinnon, Dawley, and Steen et al. 2019; Heiberg, Binz, and Truffer 2020; Miörner and Binz 2021) and provide important contributions on the multi-scalar nature of institutional contexts. Geographical context is, however, understood as relational rather than territorial. Connections, flows, locations, and scales often transcend administrative boundaries of regions and countries but relational approaches do not, or only pretend to, consider the actual solution scope from a regional perspective. This implies that they focus on one industry and do not allow to consider the growth *and* decline of several regional industrial paths and are therefore also not compatible with a selective growth perspective. The complex processes of green *regional* restructuring are still an under-researched topic and contributions at the intersection of EEG and RIS are yet scarce. The RIS framework has arguably a huge potential to understand and shape the effects of growth and decline in regions since it is conceptualized to simultaneously stimulate or destabilize established paths to better meet broader sustainability concepts. Keeping in mind that the striking challenges of our time vary strongly across regions, green regional path development and dirty path decline have differing importance in particular regions.

A central recent contribution has been provided by Grillitsch and Hansen (2019) who point out the importance of whether regions are specialized in green or dirty industries. Overall, it makes a difference for green restructuring whether existing industries should be promoted, transformed or replaced and it determines what knowledge, innovation, and industrial dynamics should be supported by policy actors. Then again, Moreno and Ocampo-Corrales (2022) claim that the relevance of technological relatedness for the rise of renewable energies increases as the economic development in regions decreases. They argue that this would not be the case for other green technologies pointing to the low generality in impact and the narrow scope of knowledge in renewable

energy innovations. Overall, these are first insights to be supplemented by further research on the regional perspective of green restructuring.

In the *second article*, my co-authors and I focus on that under-researched topic and explore the mechanisms of new green regional path development. Applying the nuanced view of path development referring to typologies described above, we conceptualize and test by means of empirical examples the green renewal of existing paths, and the rise of green regional industrial paths through diversification, importation and new path creation (Trippel et al. 2020). Just as Grillitsch and Hansen (2019) and in line with recent conceptualizations of open RIS, we nevertheless explicitly consider the role of extra-regional linkages for green path development (cf. [section 3.2](#)).

For a long time, RIS studies have focused on the supply side of innovation, i.e. the generation and production of innovation in space and paid less attention to the role of the application side, i.e. how regions use and adopt or apply innovations produced or generated in the region or elsewhere. Transition studies focusing on sustainability innovation attract a great deal of attention to the role of green consumption and application patterns. To analyze and reach green regional development, it is therefore evident to include the application side and its challenges to adopt, apply and upscale green innovations. For the *third article*, my co-authors and I have therefore consulted various literature of economic geography and transitions studies to identify main challenges on the production and application side of green regional development (Tödtling, Trippel, and Frangenheim 2020). While the cluster approach, EEG and innovation studies, RIS and the conceptualization of interpath relations have helped to identify three main challenges on the production side, innovation diffusion research, sustainability transitions and transformative policy approaches supported the conceptualization of application side challenges. Applying the RIS perspective, we acknowledge regional differences in densities and structures that may differently affect these challenges.

Conceptualizing the application side of green regional development has inspired other analyses. Tödtling, Trippel, and Desch (2021) have, based on this and other arguments, developed the notion of “challenge-oriented RISs” to reassess the RIS approach in the face of grand societal challenges. Besides paying more attention to the application side of novel solutions, they argue for a more critical view on the directionality of innovation and change and a broader understanding of innovation (and its dark side). Similar, also Hassink

et al. (2021) view place-based, challenge-driven innovation policy as an important extension in regional innovation policies. Calignano and Trippel (2020) build their social network analysis, assessing whether innovativeness or energy demand and vulnerability are associated with node centrality or key positioning in the H2020-ENERGY network, on the distinction between the generation and application of green technologies. Finally and similar to our argument that place-based policies have to tackle varying challenges at the production and application side, Grandadam, Cohendet, and Suire (2021) argue for an opening of innovation policy perspectives who are ordinarily framed within a productivity context. To put emphasis no longer on the problem but rather on the solution they call for more open and inclusive mechanisms to include local actors' knowledge.

In the *fourth article* (Frangenheim 2022), I have picked up an argument brought forward in economics and transition studies, namely that structural change to meet societal challenges includes the development and interaction of several emerging green industrial activities (Stern 2007; Bergek, Jacobsson, and Sandén 2008). Industrial interdependencies become increasingly important (Mäkitie et al. 2020; Rosenbloom 2020). Emphasizing the interconnectedness of functionally related assets (Maskell and Malmberg 1999a), the article sheds light on the dynamic processes of acceleration and (re-)orientation of paths due to similar asset needs with related green paths. Further application of the framework could provide insights to better conceptualize cumulative or combined effects of dynamics between green paths and potential reinforcing or hindering effects on sustainable regional development (Breul, Hulke, and Kalvelage 2021; Chlebna, Martin, and Mattes 2021).

3 Broadening the resource-based view

The resource-based view explains competitiveness through the access to and the control over assets possibly also needed by other industrial activities (Maskell and Malmberg 1999b; Sydow, Schreyögg, and Koch 2020) and is inherent to the path development literature. As outcome of former industrial activities, localized capabilities are built on the sum of regional assets (Maskell and Malmberg 1999a) as input for (new) path development.

To understand regional restructuring in a broad and comprehensive manner, recent considerations about assets, needed for path development, expand conventional EEG perspectives in four aspects. Firstly, the narrow understanding of assets in the relatedness literature, such as (i) human resources (labor skills and knowledge) and (ii) industrial knowledge and skills (technology and skill competence) has been supplemented. In addition, the role of (iii) formal and informal institutional assets (rules, norms, values and routines), (iv) infrastructural (buildings, machines, knowledge and physical infrastructure) and material assets (financial resources), and (v) natural resources (land, climate, water reservoirs, raw materials) are taken into consideration (Maskell and Malmberg 1999a; MacKinnon, Dawley, Pike, and Cumbers 2019; MacKinnon, Dawley, and Steen et al. 2019, among others).

Moreover, analyses do not only focus on the deployment and conversion of existing local assets and capabilities (Martin 2010; Boschma 2017) favoring the extension of prevailing regional development paths (Rypestøl et al. 2021). Recent conceptualizations, secondly, also acknowledge the need to adapt the regional asset base and to create new local assets (Tödtling and Trippel 2013; Dawley et al. 2015) and thirdly, to import and anchor non-local industrial and knowledge assets, financial investment, and legitimacy (Binz, Truffer, and Coenen 2016; Trippel, Grillitsch, and Isaksen 2018) to nurture new path development.

Fourthly and finally, besides changing and building up new assets, also the destabilization of support structures for outdated or dirty technologies, such as subsidies for fossil fuel technologies or the financialization of education programs for engineers focused on particular technologies, has been acknowledged as important ingredient, especially for green economic restructuring processes to occur (Kivimaa and Kern 2016).

While the first extension refers to the regional endowment with assets and resulting capacities to make further breakthroughs, the second, third and fourth reflect time-wise historical and future processes of asset development, erosion, and substitution at multiple scales (Maskell and Malmberg 1999a) pointing to the role of agency in explaining new path development.

In this chapter, the theoretical groundings of agency as understood in recent conceptualizations of path development will be presented ([section 3.1](#)) to outline the theoretical considerations and contributions regarding the modification of assets at regional and higher scales, related challenges and the role of regional preconditions in supporting them ([section 3.2](#)).

3.1 Agency in the path development literature

Drawing on sociological theory, an emergent body of literature deals with the role of agency in new path development. Much of it refers to Emirbayer and Mische (1998) to emphasize intentionality, purposiveness and meaningfulness of actions and interventions to produce intended or unintended effects that are embedded in time and space (Sotarauta and Suvinen 2018; Isaksen et al. 2019; Grillitsch and Sotarauta 2020). Emirbayer and Mische (1998) assume for actors belonging to emerging paths being strongly oriented towards the future, though the strategies of agents to develop specific outcomes at the system level depend on initial asset constellations (Musiolik et al. 2020). Another much-cited research on the role of agency for the mindful development of new industrial paths is the work of Raghu Garud, Peter Karnøe and colleagues (Garud and Karnøe 2001; Garud and Karnøe 2003; Garud, Kumaraswamy, and Karnøe 2010; Karnøe and Garud 2012). They emphasize “mindful deviation” of entrepreneurs as a core mechanism of path development and assume their ability to intentionally deviate from existing structures with the goal of shaping future developments despite of potential short-term inefficiencies (Garud and Karnøe 2001). Agency is strategic in the sense that it has an influence on path development (Garud and Karnøe 2003; Simmie 2012b; Dawley 2014) but it is also inter-temporal and changeable

within the contexts that confront actors (Emirbayer and Mische 1998; Steen 2016).

A second argument made by Garud and Karnøe (2003) and first taken up by Simmie (2012b) is that processes of path development rely on collective action rather than individual efforts. Isaksen et al. (2019) focus on the key concepts of “distributed agency” and “embedded involvement” (Garud and Karnøe 2003) to maintain that multiple actors with different levels of involvement accumulate knowledge in micro-learning processes over time that become a platform for future path development. They link the concept of distributed agency to the ability of actors with long-term knowledge networks to collectively transform RIS structures with the aim to better support industries and call it system level agency in contrast to firm level agency. With system level agency actors exert influence outside of their institutional or organizational border, e.g. the development and implementation of new policy measures in the public support system to which actors can respond and institutions can adapt. When transforming the RIS, system level actors renew and create assets to be employed by several economic players (Rypestøl et al. 2021). With firm level agency, actors establish innovative firms or initiate innovative activities in existing firms with the potential to nurture regional industrial paths. Both types of agency need to be combined and aligned to develop different types of paths because any change of direction in path development requires changes in firm- as well as system-specific assets (Isaksen et al. 2019; Kyllingstad et al. 2021).

Isaksen et al. (2019) therewith focus on the outcome of agency at the system level, e.g. new or adapted institutions or system components or at the firm level, e.g. the development of new products or processes (see also Isaksen and Jakobsen 2017). Another emerging strand of literature focuses on the processes of how agency is intentionally undertaken. These occur in the form of different types of change agency (Sotarauta 2016; Holmen and Fosse 2017; Grillitsch and Sotarauta 2020) through different types of actors (Jolly, Grillitsch, and Hansen 2020), or by considering the similarities or differences of actors and roles in diverse regions (Sotarauta et al. 2021). Aiming to approach unresolved questions brought about by contributions at the intersection of EEG and RIS studies specifically resulting from the distinction between industry-related and system-related assets, this dissertation is much inspired by the first, resource-based conceptualization of agency. Yet, it does not ignore the value of analyzing the role and processes of agency for understanding new path

development in the face of societal challenges (cf., e.g., Sotarauta et al. 2021) nor to study the interplay between structure and agency over time in the context of regional economic development (Grillitsch et al. 2021).

To conceptualize interpath relations between emerging industrial paths in the same regional context (*article one*), the orientation of agents towards the future and the concept of distributed agency have been important. This helped to understand how heterogeneous actor groups and networks join forces to build, access, and deploy assets or shape markets with the aim of fashioning interpath relationships (Frangenheim, Trippel, and Chlebna 2020). We argue that agency may result in strengthening or weakening interpath linkages towards relationships that are supportive, competitive, or neutral.

3.2 Assets at multiple scales: regional preconditions, modification and challenges

Recently, it has been re-called what Maskell and Malmberg (1999a) have declared time-wise historical and future processes of “asset development, erosion, and substitution”. Local assets, seen as products of the RIS must be “identified, used and valorized” (MacKinnon, Dawley, Pike, and Cumbers 2019) through deliberate and purposeful action of one or several actors from within or outside the region (Maskell and Malmberg 1999b) to nurture new path development. In the *second article*, my co-authors and I have conceptualized this as *reuse of existing local assets* (entailing both the redevelopment and recombination of local assets), the *creation of new local assets* and the *destruction of old local assets* (Trippel et al. 2020).

Path dependency in EEG is strongly attributed to having favorable effects on regional industrial development. Likewise, in RIS studies the rules guiding agency are regarded as necessary for innovation rather than being barrier for desirable change. Therefore, the *reuse* and the *creation* of assets needed for path development are quite tangible modes of asset modification. To better understand challenges for path development and relating thereto the need to *deconstruct* existing assets, the engagement with epistemic approaches that focus on constraining effects is instructive. Key concepts of the multi-level perspective are technological niches and socio-technical regimes (Geels 2002, 2004). In the academic debate on sustainability transitions, a protective space enables path-breaking or system disrupting innovations. Constraints and resistance from actors unfold in established socio-technical regimes. This perspective provides insights for understanding the dynamics between

innovation as the basis for a new path and its competition with existing solutions in established industries. In contrast to EEG, where old industrial paths tend to be portrayed as having a reinforcing influence on new path development, the multi-level perspective underscores the impeding influence of established regime structures on radical innovations.

Thus, in transition studies the initial protection of niches within the selection environments dominated by prevailing sociotechnical regimes and incumbent interests is viewed as essential (Smith and Raven 2012; Boschma et al. 2017). For regional restructuring in the face of societal challenges this points to the need to *destabilize existing industrial, organizational and institutional structures*, to release bound assets. Exemplary destabilization strategies may be to internalize environmental costs of carbon emissions in order to compete on fair terms (van den Bergh et al. 2006) or to reconfigure institutional rules and economic frame conditions by altering policies or phasing out financial subsidies. Though often evident in the domain of institutions (Rypestøl 2020), other options refer to the replacement of incumbents by new actors in policy advisory councils or the formation of new organizations or networks to take on tasks linked to system change (Turnheim and Geels 2012; Kivimaa and Kern 2016). Destabilization activities are to be seen in contrast to institutional maintenance work focusing on the reproduction of existing norms and beliefs as a key form of institutional work going back to Lawrence and Suddaby (2006). The combination of change and maintenance has inspired recent conceptualizations of agency in industrial change processes (Jolly, Grillitsch, and Hansen 2020; Baumgartinger-Seiringer 2022; Löhr, Chlebna, and Mattes 2022).

In the *second article*, we moreover reflect on the re-location of assets by conceptualizing the *modification of non-local assets through accessing and transplanting them to the region* (Trippl et al. 2020). Despite that exogenous influence factors have been acknowledged as being relevant for new path development (Martin and Sunley 2006; Boschma and Iammarino 2009), multi-scalar and multi-locational perspectives only recently are placed on the agenda of research and policy (Binz, Truffer, and Coenen 2016; Trippl, Grillitsch, and Isaksen 2018; Asheim, Isaksen, and Trippl 2020; Gong et al. 2022). Binz, Truffer, and Coenen (2016) have shown the decisive role of industrial and human assets from extra-regional sources and their transformation into regional assets through processes of knowledge absorption for early path development phases. Likewise Trippl, Grillitsch, and Isaksen (2018)

emphasize for new path development the importance of processes beyond endogenous mechanisms. They consider the arrival of new actors from outside as well as extra-regional knowledge linkages when analyzing how different types of regions differ in their needs for non-local knowledge and their capacities to attract, absorb and transform it into new path development.

Contributions with a multi-scalar or multi-locational perspective on path development either focus on regional or national conceptualizations and include diverse types of assets at multiple scales or zoom into the role of institutions and their relation at and between multiple scales. The former accentuate, for instance, the combination of knowledge from different locations at different spatial scales (Grillitsch and Trippl 2014) or the broader role of national state policies for new path development (Essletzbichler 2012; Dawley et al. 2015). The importance of institutions at multiple scales instead has been stressed especially if they are embedded in global production and innovation networks (Grillitsch and Rekers 2016; Zukauskaitė, Trippl, and Plechero 2017). Supra-national and national laws, regulations and development strategies provide guidelines that shape economic behavior and interaction but allow flexibility to maximize the development of local or regional institutional arrangements (Rodríguez-Pose 2013). Recent contributions emphasize how (de-)institutionalization and re-scaling mechanisms of institutional rationalities affect industrial development in a global perspective (Fuenfschilling and Binz 2018; Miörner and Binz 2021). Binz and Truffer (2017) first provided a more holistic multi-scalar territorial approach understanding an industry as being embedded in a global innovation system emphasizing the overlaps between various innovation system approaches.

This dissertation takes a regional perspective and focuses on the processes and challenges of modifying diverse forms of assets being located at multiple scales. Differences in how core and peripheral regions each tend to support (or not) agentic processes at multiple scales (Tödtling and Trippl 2005, 2013; Isaksen 2015; Isaksen and Trippl 2016b) have provided the basis for understanding regional preconditions to support interpath relations across regions in the *fourth article*. While article one acknowledges the strategic use of local as well as non-local linkages (Frangenheim, Trippl, and Chlebna 2020), article four more explicitly takes into consideration the embeddedness of a regional industrial path in multi-scalar geographical contexts (Frangenheim 2022). Replicating the influence of territorial conditions for co-evolutionary

asset building by pioneering inventors and innovators (Simmie, Sternberg, and Carpenter 2014), it reflects on the potential effects between paths of different regions via asset modification at higher scales. Pointing to similarities in multi-scalar asset needs, I emphasize that the *availability, orientation, or interpretation of assets at multiple scales* affect the orientation of path development and explore differences in regional preconditions to support paths in modifying assets at multiple scales. Considerations on the multi-scalarity of assets in *article IV* thus go beyond single industries (cf. [section 4.3](#)).

In the *third article*, we have referred to the multi-scalar character of innovative activities by acknowledging that their production must not necessarily take place in the same geographical setting as their application (Tödtling, Trippl, and Frangenheim 2020). Going beyond the consideration of regional industrial paths, we conceptualize challenges for green regional development at the production and application side that may reinforce existing or create new regional inequalities. For the production side, these refer to *poor endowments of regional assets, poor access to assets at multiple scales by regional actors or a lock-in of regional assets into old economic activities*. For both sides, *competing uses of assets* may challenge green regional development. On the application side, besides concrete asset-related aspects, *low levels of consciousness with respect to sustainability issues, a limited access to relevant knowledge and a low absorption capacity due to weak institutional structures that impede collective learning processes* have been identified as challenges for green regional development.

In accordance with the selective growth perspective seeking to reach a balance between economic growth, environmental quality and social well-being, the decline of dirty economic activities is besides green path development a necessary measure to achieve the desired environmental or societal goals. Analyses about the decline of old industrial paths have supplemented the wealth of insights on new path development (Blažek et al. 2020; Jolly and Hansen 2021). This dissertation aims to contribute to a holistic perspective of green regional development involving growth and de-growth of industrial activities.

The dynamic use and role of asset modification in processes of path development including local asset redeployment and recombination, the creation of new assets, accessing and/or transplanting non-local ones and destructing old local assets (see also Isaksen et al. 2020) has been reflected and further developed in the literature. While Baumgartinger-Seiringer, Miörner, and Trippl (2021) for instance claim that the relative importance of the various

types of asset modification changes within the dynamics of intra-path development, Kyllingstad et al. (2021) have further advanced the framework pointing out that the reuse of assets is mostly undertaken in path extension or upgrading and asset creation as well as destruction are more evident in processes of new path development. Isaksen, Langemyr Eriksen, and Rypestøl (2020) apply the framework to further conceptualize how firms' internal assets are aligned with assets at the regional innovation system level. Others have enhanced the modes of asset modification. Chen (2022) takes a closer look at asset recombination or "reconfiguration" considering the interplay of assets and how pre-existing and/or new assets are bundled into a configuration that fosters new path development. Rypestøl (2020) instead adds another category of asset modification, that is the upgrade of existing assets implying their significant improvement.

4 Reconsidering interpath relations

Topical discussions about the role of different actors and their agency, on the one hand have afforded insights on long time neglected dynamics of intra-path-developments (Chlebna and Mattes 2020; Baumgartinger-Seiringer, Miörner, and Trippl 2021; Klitkou, Capasso, and Hansen 2021) and path plasticity in transformation processes (Strambach 2010; Strambach and Pflitsch 2018). On the other hand, it helped to change the rather simplistic understanding of interpath relations. Pointing to the hitherto unknown relations between different new path development activities and its uni- or bidirectional effects, this chapter deals with the latter. First emphasis lies on the emerging perspective on interpath relations and how it changes our understanding of the geography of new regional industrial path development ([section 4.1](#)). This section provides an overview of the contributions made by this dissertation and related analyses from other authors. [Section 4.2](#) presents how the generation of interpath relations and respective challenges in regional contexts are conceptualized and [section 4.3](#) outlines processes and challenges of interpath relations across regions.

4.1 A new perspective on interpath relations

The need for broader restructuring processes across diverse industrial activities is increasingly emphasized in the context of grand societal challenges (Stern 2007; Bergek, Jacobsson, and Sandén 2008; Mäkitie et al. 2020; Rosenbloom 2020). EEG studies recently accentuate reciprocal relationships between co-evolving economic, technological, institutional, socio-cultural and market-related “arenas” (Martin and Sunley 2006) or “populations” (Gong and Hassink 2018). Consequently, the albeit very powerful approach to explain regional structural change through established conceptualizations of relatedness has been criticized for not allowing a meaningful assessment of the dynamic processes taking place in the context of regional restructuring (Hassink, Isaksen, and Trippl 2019). EEG scholars have therefore started to

broaden the concept of (technological skill) relatedness by exploring institutional and market relatedness between different paths (Tanner 2014; Boschma 2017; Carvalho and Vale 2018; Punt et al. 2021; Uyarra and Flanagan 2022). The relatedness concept, however, inherently reflects on the relation of existing (more or less mature) and emerging industries and ignores linkages between paths of different development stages (Martin and Sunley 2006, 2010).

Moreover, EEG conceptualizations of related diversification focus on reinforcing correlations between paths (Boschma et al. 2017; Hassink, Isaksen, and Trippel 2019). In more general terms, this reflects the origins of the path development literature where local conditions (Martin 2010) and territorial capacities (Boschma 2017) affect opportunities for path development. Besides diversification, however, new path development activities may occur in mature industries through renewal or transformation and may also include new path creation or importation (cf. [section 2.1](#)). While path creation or importation is not predominantly driven by formerly existing regional industrial structures, path renewal or transformation does not lead to the development of new regional industrial paths. Furthermore, mature industries may only introduce incremental innovation along established trajectories (path extension) or even loose innovative capacities and experience decline or dissolution (Grillitsch, Asheim, and Trippel 2018; Blažek et al. 2020). In sum, the understanding that old industrial structures almost deterministically lead to new path development (Gong and Hassink 2020) along with the hitherto predominant focus of EEG studies on single industries (Martin and Sunley 2006) longtime hampered a broader reflection on the reinforcing and impeding effects of path development and respective interpath relations. This can also be observed in spatially-sensitive policy initiatives that pay little attention to interpath relations. Arguably, the observation of effects of path development processes and activities (including growing and declining intra-path dynamics) on other paths of all development stages urgently asks for a more conscious reflection of wider effects for regional economies (Trippel and Frangenheim 2018a).

Early contributions to more broadly understood interpath relations include broader asset building processes covering besides knowledge production also financial assets, market formation and legitimacy creating reinforcing, as well as hindering effects for involved paths (Steen and Hansen 2018) or feedback effects from new to established paths (Fornahl et al. 2012). Again, the engagement in transition studies, focusing on barriers for desirable change,

helps to consider impeding effects of old versus new industrial structures and between emerging industrial activities at a more aggregate level, i.e. at the level of whole regional industrial paths instead of single assets. Much work can be assigned to the technological innovation system literature (often intersecting with the multi-level perspective), where attention has been recently given to the relations, interactions and affection between, of, and by different technologies and sectors at different development stages (Sandén and Hillman 2011; Bergek and Onufrey 2013; Bergek et al. 2015; Hanson 2018; Magnusson and Berggren 2018; Mäkitie et al. 2018; Andersen et al. 2020; Andersen and Markard 2020; Mäkitie et al. 2020; Markard, Geels, and Raven 2020).

I studied interpath relations from a systemic and territorial approach, implying not only industrial evolutionary dynamics but also wider, economic institutional and socio-political structures (Martin and Sunley 2015). Ron Martin and Peter Sunley already 2006 argued that paths regularly interrelate or even complement each other due to direct input-output relationships or indirect interdependencies and externalities (Martin and Sunley 2006). My interest in the scope of this dissertation has been the generation of interpath relations and the resulting one-dimensional or mutual reinforcing or impeding effects.

In the majority of cases, a RIS hosts more than one regional industrial path. Comparing interpath relations in different (types of) regions opens the view to inequalities in regional development trajectories. Places differ in the extent to which different numbers and qualities of firms, industries, knowledge organizations, and support agencies are available, which is captured by the notion of thickness of organizational and institutional structures and the degree of specialization in RIS (Isaksen and Trippel 2016b; cf. [section 2.1](#)). This widely acknowledges the need for region-specific policies (Tödtling and Trippel 2005). Whereas in diversified core areas with a heterogeneous industry mix, abundance of diverse assets and strong innovation capacities (Isaksen and Trippel 2016b; Xiao, Boschma, and Andersson 2018) all types of path development and diverse interpath dynamics can be expected to be important, patterns look different in non-core areas. More specialized regions feature by definition a lower number of industrial paths and fewer new path development activities. One could expect to observe in particular dynamics between mature and new paths. In old industrial regions that are prone to regional lock-in (Hassink 2010b), established paths will rather constrain the

rise of new ones. Industrial regions succeeding in reorienting towards cleaner production and converging environmental and high-tech industries (Grabher 1993; Cooke 2008; Tödtling, Höglinger, C., Sinozic, T., and Auer 2014) may profit from new paths that help to renew established paths (Isaksen and Trippel 2017a).

In peripheral regions, path importation may be the result of external investments or the inflow of knowledge through the transplantation of firms and research institutes (Isaksen and Trippel 2014; Isaksen 2015). Research suggests that “industries are more likely to enter a region if they are technologically related to the industries that were already present in that region” (Neffke, Henning, and Boschma 2011, 251). Imported paths related to existing industries may, however, also set in motion reinforcing or impeding effects on other paths through spillover or increased demand or supply. Boschma and Iammarino (2009) have shown that related variety initiates employment growth in Italian regions. Moreover, the transplantation of natural resource industries within Latin America has initiated the establishment of upstream or downstream organizations via input-output relationships (Marin, Navas-Alemán, and Perez 2015). By contrast, the importation of industries may also lead to a competitive use of assets, such as human and financial resources, resulting in weakened opportunities for local new path development. As a third option, Simmie (2012b) has shown for the wind power industry, imported into the Danish periphery, that it was unrelated to the existing regional paths.

The next two sections outline the contributions made by this dissertation through its published articles. I distinguish between different types of RIS and related path development activities and reflect on related recent contributions by other authors to this debate. While [section 4.2](#) takes center stage relations between emerging paths in the same RISs, [section 4.3](#) compares a diversified core with a peripheral region in Austria and focuses on relations between diverse (mature and emerging) path types embedded in those two and other regions. Please refer to [section 6.2](#) for related policy implications.

4.2 Interpath relations in regional contexts

In the *first article*, my co-authors and I have zoomed into interpath relations between emerging paths embedded in the same region to specifically understand potentials and challenges of regions experiencing diverse new path development activities (Frangenheim, Trippel, and Chlebna 2020). In line

with the broad understanding of assets, we emphasize interpath linkages as resulting from the paths' reliance (i) on assets available in the RIS and (ii) on local or non-local markets. Again, inspired by contributions of the transition literature, we point out that (system) assets may be abundant or scarce in supply (Sandén and Hillman 2011). Whereas scarce assets may be subject of competition between paths, abundant assets constrain or enable many path development activities in parallel. Interpath linkages are described in a continuum from very strong over weak to not existing and here agency comes into play. If agents modify assets, competitiveness may be strengthened, supportive relationships may be created or linkages can also be neutralized – with respective reinforcing or impeding effects for concerned paths.

The competing use of diverse assets, though explicitly conceptualized in transition studies, is a rather unconventional perspective for EEG scholars. It has put forth recent debates by opening the view for impeding effects of interpath relations (Hassink, Isaksen, and Trippel 2019) and for challenges on both, the production, as well as on the application side of regional development as in the *third article* of this dissertation (Tödtling, Trippel, and Frangenheim 2020). Diverse forms of interpath relations are vividly debated among economic geographers and innovation scholars. In the following, I will focus on contributions that are most related to the interpretation of the topic by this dissertation.

Chlebna, Martin, and Mattes (2021) identify key dimensions of co-evolution in regional transformative development facing crises and grand societal challenges. They add to interpath relations, interregional and multi-scalar development dynamics, and the interdependence between industries and society. Exploring interdependencies between paths and transitions, they offer a set of interesting research questions on the relation of multiple paths and transition processes about beneficial combinations of regional industries for transformative change, e.g. to reflect on assets and drawbacks of certain industry mixes and to tackle material and waste reduction. Similar to Breul, Hulke, and Kalvelage (2021), they point to possible cumulative and combined effects of interpath relations to account for their impact on whole regions. Drawing on our conceptualization of interpath relations, Breul, Hulke, and Kalvelage (2021) develop a framework to reveal how the creation, importation and reallocation of key resources for an emerging tourism path in the Zambesi region of Namibia modified the regional production environment for

agricultural activities thus causing reinforcing as well as impeding reformation processes based on relations with the established agriculture path.

Maintaining that emerging paths are rarely unlinked, also Stihl (2022) emphasizes the role of agency and how it shapes interpath relations. In the small, resource-rich town Kiruna, specialized around iron ore mining activities, the emerging tourism path has been initially hindered and later enabled by the well-established mining industry. Stihl points out that despite the two regional industrial paths may be seemingly unrelated (they produce for different markets and need different skills and competencies), they still have linkages due to scarce assets such as labor. The mining industry constrains tourism development by limiting the growth in human assets and by their real estate. An own school education program builds mining skills and the locally pronounced feeling of stability prevents entrepreneurs to invest. The municipality of Kiruna aimed at industrial diversification, which was reasoned in the wish to make the town more resilient to future crises. Interpath linkages have been overseen because they could not be categorized in established classifications of related and unrelated industries. As a result, the municipality has fallen into the trap of reproductive agency and has overlooked the need to neutralize constraining interpath linkages.

Capturing claims to better account for dark phases of regional (path) development, Jolly and Hansen (2021) study legitimacy spillovers from contextual structures, such as other regional industries, broader regional sectors, the industrial development in other geographical contexts and the wider political context. Regarding interpath relations, similar to our claim and as interpreted by Stihl (2022), they define relations in very broad terms. In regional contexts, they point out legitimacy challenges for emerging industries fulfilling similar functions or requiring similar inputs as other well-established regional industries. Moreover, they emphasize effects on the legitimacy of a regional industry through multi-scalar relations to industries of other regions and nations, e.g. through displaying collaborations with leading or more mature actors, showcasing commercial success or because of competition or unfortunate industry developments in other contexts. Therewith, they point to extra-regional, but intra-industrial relations that have been also discussed in the *fourth article* of this dissertation.

4.3 Interpath relations across regions

Regional industrial path development is conceptualized as a place specific process. Though evolutionary economic geographers heavily stress the reinforcing influence of geographic proximity in stimulating branching processes, non-spatial forms of proximity take into consideration distant inter-organizational relations (Boschma 2005; Asheim, Boschma, and Cooke 2011). More recent contributions have begun to acknowledge the role of intra-industrial effects across regions (Binz and Truffer 2011; Binz, Truffer, and Coenen 2016; Isaksen and Trippl 2017a; Heiberg, Binz, and Truffer 2020; Miörner and Binz 2021). Chlebna, Martin, and Mattes (2021) correctly point out that regional restructuring processes occur in different regions at different times and speeds, which raises questions about inter-regional learning, competition and collaboration. To take into account the important claim to move beyond regional fetishism (Martin and Sunley 2006; Binz, Truffer, and Coenen 2016), I take stock of interpath relations based on similar asset needs at multiple scales, incorporating the same or different industries affecting each other across regions and within or across countries in the *fourth article* (Frangenheim 2022). Instead of highlighting effects on regions induced by interpath relations as undertaken by Breul, Hulke, and Kalvelage (2021), the framework developed explains how regional preconditions may support or hinder reinforcing or impeding effects of interpath relations across regions.

While the regional perspective in the *first article* acknowledges different RIS capacities to modify the local asset base and to import and anchor non-local assets (Frangenheim, Trippl, and Chlebna 2020), the *fourth article* asks how regional preconditions differ in terms of their capacities to modify assets also at higher scales (Frangenheim 2022). Considering regional differences in capacities to attract, absorb and transform knowledge into new path development (Trippl, Grillitsch, and Isaksen 2018), also the preconditions to benefit from inter-regional learning or collaboration or to shield regional paths from competition provoked by industrial paths embedded in other regions vary significantly.

Taking a RIS perspective, I argue in this article that whether effects of interpath relations are reinforcing or impeding depends on the outcome of agentic processes of asset modification at multiple scales undertaken by diverse actors with different intentions. Regional capacities to support asset modification affect whether assets are interpreted towards, oriented at and used by regional

paths. This may limit or enable the access and usability of assets for certain paths and induces benefitting or detrimental effects for them. These arguments are supported by empirical results about the availability and modification of assets at multiple scales from the extant literature. Since assets needed for path development located at multiple scales are inter-connected (Maskell and Malmberg 1999a), their modification result in the need to (re-)interpret, (re-)orient and (re-)use the remaining asset base by complementary asset modification. Here my own empirical investigation shows that regional preconditions to modify assets at different scales play a crucial role. The RIS concept provides useful insights on how core and peripheral regions each tend to support (or not) asset modification at different scales (Tödtling and Trippel 2005, 2013; Isaksen 2015; Isaksen and Trippel 2016b). Mechanisms of path acceleration and (re-)orientation as a reaction to reinforcing or impeding asset modification at multiple scales by other paths are dynamic and policy recommendations for challenges resulting from this perspective differ for core and peripheral regions (see [section 6.2](#)).

To sum up, the emerging perspective on interpath relations within and across regions questions established perspectives on the driving and hindering forces of regional industrial path development. Arguably, a more open debate on the dynamics between multiple emerging, emerging and established and/or declining paths would enhance our understanding of reinforcing and impeding outcomes of asset modification in particular and path development processes in general. Reinforcing and impeding effects of interpath relations counteract established perspectives and their consideration add to our understanding of wider regional restructuring in the face of societal challenges in four ways: Firstly, the modification of assets by actors working for different paths may lead to RIS dysfunctionalities in the form of absent or not accessible assets for other paths thus constraining wider regional restructuring. Secondly, interpath relations may alleviate impeding effects of what has been called the “dark side of new path development” (Phelps, Atienza, and Arias 2018; MacKinnon, Dawley, Pike, and Cumbers 2019). Negative effects of uneven regional development and path decline may be alleviated when released assets can be redeployed and recombined by other paths. Thirdly, if interpath relations are not well considered in path selection processes, unintended policy effects on directly or indirectly related paths may occur and fourthly, interregional and multi-scalar decision-making processes may be affected by interpath relations.



UNDERSTANDING REALITY-
A THEORY-BASED ANALYSIS

5 Research design

As in any social science, theory building in economic geography responds to changes in its subjects of empirical investigation. Over the past three decades, economic geography has experienced a growing diversity of subject matters, theoretical perspectives, epistemologies, concepts, and methodological approaches and there is no linear relationship from a particular ontology to epistemologies, theories, methods or purposes of research (Martin 2021). The largest denominators are alternative and heterodox conceptions that evolve out of distancing from positivistic thinking in spatial economics.

The particular view of reality by the researcher influences the design of a framework as well as the choice of methodology. It relates to questions of philosophy of sciences including the researcher's position concerning the nature of reality and how to investigate it (ontology) and her or his understanding of the nature of knowledge, of what can be known and how (epistemology). Together, they form a paradigm. After presenting the epistemological and ontological perspectives of this dissertation ([section 5.1](#)), the methodology and methods will be outlined in this chapter ([section 5.2](#)). A specific emphasis will be given to the conceptual and empirical contributions made in the scope of this dissertation. [Section 5.3](#) presents the cases analyzed in the scope of this dissertation and explains how abstraction has been undertaken.

5.1 Philosophical grounding: ontology and epistemology

This research is informed by a critical realist philosophy, which is placed in between positions that regard social science as different from natural science and those that treat both equally (Sayer 2015). This philosophical grounding is influential in natural and social science although their respective entities differ in nature, which influences the choice of research methods. Critical realism is a distinct version of the realist philosophy and goes back to Roy Bhaskar (1975, 1979) who proposed transcendental realism for natural science and critical realism for social science. Its epistemological emphasis lies on explanation

instead of prediction (as in positivism) or interpretation (as in interpretivism). Since the 1980s, critical realism has an impact on geographic methodology, although since the turn of the millennium, nonrealism and other kinds of realism have gained parallel importance (Sayer 2015).

Contrasting with theoretical approaches grown by the scientific revolution of geography, such as location theory and spatial analysis with their regularity-based view of causation, for critical realists “causation is a matter of what produces change, not a matter of empirical regularities in sequences of events” (Sayer 2015, 278). As such, critical realist epistemology has an alternative conception of causation that focusses on the powers of objects and their activation, yet acknowledges that their irregular results depend on contexts (Sayer 2015). Instead of determinism, regularity or the search for empirical order, the focus of interest lies on contingency and necessity. Whether powers of objects are activated, as well as their particular effects depend on contingent (i.e. neither necessary nor impossible) conditions. In other words, whether the same causal mechanism leads to different events or the same event results from different causal mechanisms depends on circumstances in the causal properties or on the power of an entity. Yet, inherent properties of entities with multiple causal mechanisms create a tendency to produce particular outcomes (Sorrell 2018). Critical realists search for necessity and possibility or potential in the world, i.e. they seek to identify things that must go together or those that could happen, given the nature of the objects of analysis (Sayer 2000).

Striving to explain irregular processes, for human geography being concerned with inequalities and spatial disparities in general, and this dissertation in particular, makes the critical realist perspective attractive – not only to differentiate from equilibrist models and generalizations across time and space. What is furthermore instructive in this view, is that system elements are subject to qualitative change (e.g. actors knowledge development and influence) and their relations, or networks, are evolving or dissolving pointing to evolutionary change and systemic openness (Sayer 2015).

The critical realist ontology assumes that a reality exists independent of the researcher’s knowledge of it and in addition that causal powers attribute to human reasons and social structures. Bhaskar (1975) made the fundamental distinction between a transitive and an intransitive dimension. Regarding the intransitive dimension (the object of analysis), proponents of critical realism reject relativism in social and scientific discourses as it is evoked by postmodern views also entering human geography since the 1980s (Sayer

2000) (realist epistemology). Nevertheless, epistemic relativism is accepted in its transitive dimension (theories and discourses about the object of analysis, such as social phenomena) in so far as (conceptual as well as empirical) knowledge is provisional, socially produced, historically transient and fallible (Sayer 2000). Different from what is proposed in relativism, the critical realist claims that despite that all knowledge is fallible, it is not equally fallible (Yeung 1997). Rational grounds help to prefer some explanations over others (judgmental rationalism) (Sorrell 2018). The distinction between transitive and intransitive dimensions of science explains the rejection of pure empiricist views applied in empirical realism. The latter assume that reality is what can be experienced as it consists of observable atomistic objects, events and regularities among them. In empiricist views, critical realists particularly miss the structure or power of objects and the existence of their unobservable qualities. In turn, critical realism should not be confused with literary realisms ignoring conceptually-mediated or theory-laden character of experience (Sayer 2000). In effect, the world becomes available to the researcher by means of a theory-based analysis of it.

Theories, as well as social phenomena including innovation are considered as being socially defined objects. They might transform over time (Bhaskar 1979) and at any point in time it is possible to compare the adequacy of different theories (Sayer 2015) by means of judgmental rationalism. This implies that science can make progress in explaining the world or, as social phenomena transform, theory around them need to be adapted. Martin (2021) refers to the later work of Thomas Kuhn (Kuhn 2000) to explain the increasing multiplicity of specialisms and subfields in economic geography and how progress in science is nurtured by the proliferation of (theoretical) niches. As an “open-ended cumulative process of developing (and sometimes discarding) new theories and perspectives on particular aspects of the spatial socio-economy”, he sees pluralism as a productive process and an epistemic resource advancing explanatory insights of cases and instances (Martin 2021, 9).

This dissertation is informed by the fallibility in the transitive dimension of critical realism as follows. Its conceptual framework is based on existing theories in EEG and innovation system studies. For the analysis of regional economic change in the face of societal challenges, and to answer the research questions inspired by current changes in our social world or realities, existing concepts are re-extended through insights from adjacent streams of literature (and empirical analyses, see [section 5.2.2](#)). Broad notions or concepts like path

dependency, innovation, green regional development, agency, and multi-scalarity are used to serve as a boundary object adopted by scholars in different, but ontologically and epistemologically related fields (Martin 2021). To obtain insights needed to undertake this research, EEG and RIS concepts have been combined with recent accounts of technological innovation system studies, geographical political economy and transition literature, among others.

Critical realists distinguish not only between the world and our experience of it, but between three domains to reality (Bhaskar 1975). “The actual” are those events (and non-events) that exist whether or not anyone is there to observe them. “The empirical” is the subset of events, such as perceptions, impressions, or sensations that can be observed and experienced. Finally, “the real” are the mechanisms and structures, powers and liabilities that generate “the actual”. The real consists of different entities of physical (e.g. infrastructure, natural resources), social (e.g. actors, firms, bureaucracies) or cultural nature (e.g. norms and values). Its identification and explanation are the main goals of the transitive dimension in critical realism, e.g. what types of actors are able to undertake what kind of agency in virtue of structure (such as in an innovation system perspective). This research is instructed by this perspective in the sense that it is interested in the continuous (re-)production of mechanisms and structures through human agency affecting regional economic change. In line with Bhaskar (1979), I expect the underlying structures to condition human agency and at the same time reproducing the outcome of it. Economic change in this view results from actions of skilled actors, rather than being a mechanical consequence of (regional) pre-conditions.

More recent critical realist scholars have pointed out the nature and role of material parts in systems of social analyses. The causal power of constituent entities, such as organizations or assets depends on both human and non-human material parts and their intentional or spatial relations (Elder-Vass 2017). As examples of socio-technical entities and their causal powers, Elder-Vass (2017) mentions an orchestra playing a symphony, a navigation system that fixes the position of a ship, or a social group enforcing a particular norm, all consisting of people as well as material artefacts or technical devices to generate respective emergent properties. This broad understanding of entities including both people and non-human material parts is in line with recent conceptualizations of path development acknowledging the need of broadly

defined human and material assets, including physical resources and human built infrastructures. Broadly speaking, analyses about opportunities and constraints resulting from differing access to material resources, knowledge, skills, normative or regulative defined preferences (e.g. those providing new opportunities for green path development vs. supporting path dependency) provides explanations about the orientation and speed of new path development.

To summarize the overall epistemic objective of a critical realist: It is to explain sequences and outcomes in terms of complex and contingent links and ties between social and material entities and their associated causal powers. In an innovation system perspective, this involves conceptualizing and describing the relevant entities of the system components (actors, networks and institutions), their power to modify assets (e.g. in relation to their industrial and organizational structures) and investigating how they combine to produce the observed outcomes (e.g. how does agency come into being, who or what is involved under which conditions). The analyzed processes and mechanisms tend to develop towards certain outcomes that can be conceptualized by defining ideal types. In other words, there is contingency in how, when and what way they combine and how particular context conditions at multiple scales affect those outcomes.

5.2 Methodology and methods

Critical realism does not claim for a particular methodology. Rather, theory building and methodology is left to each social science. Therefore, also the choice of methods depends upon the nature and causal mechanism of “the real” and the research question to be answered. Nevertheless, Yeung (1997, 57, original emphasis) pleads for “methodological pragmatism by arguing specifically that in the practice of critical realism certain methodological guideline are *more* relevant and useful than others”. He further points to the need of constant reflection and criticism and summarizes three most practically adequate methodological avenues. “Iterative abstraction” is used to discover and conceptualize generative mechanisms by abstracting the relation between concrete phenomena and deeper causal structures. “Grounded theory method” in critical realist terms helps resorting the rather deductive iterative abstraction by mediating between theory and practice through inductive grounding of generative mechanisms in concrete data. Yeungs third methodological avenue is the use of “triangulation”, entailing the use of multiple methods or data.

Empirical or research instruments, such as qualitative interviews, open or closed questionnaire surveys, participant observations etc., according to Yeung (1997) support analyses of collected empirical data through iterative abstraction, grounded theory method and triangulation. “Iteration” refers to the revision and reaffirmation of abstraction by means of empirical evidence until theoretical saturation is reached. The groundwork of abstraction has been a comprehensive and ongoing literature review during the work on this dissertation project. This allowed to regularly discuss and challenge existing concepts, analytical frameworks and lines of arguments and ensured repetition of own theoretical reasoning and conceptualization, as well as to prove validity and relevance of research findings. The empirical material for this research – based on cases from the literature as well as stemming from own empirical investigation – has been collected against the background of this theory-laden approach (Gong and Hassink 2018). It describes the mechanisms that produce or condition the observed phenomenon until no further explanation or conceptual knowledge could have been gained.

“Grounded theory method” in critical realist terms (which is different from its use in qualitative sociology) aims at abstracting data in conjunction with substantive theorization and immanent review to generate knowledge about mechanisms or relations between causal categories (Yeung 1997). For this dissertation, empirical evidence served to complement and revise conceptual framings where appropriate. Its intensive (qualitative) research design has been crucial for theory development (cf. Sayer 2000).

Finally, the “triangulation” of methods, data sources and theoretical perspectives has gained importance in recent EEG (Denzin 1970; Yeung 1997). A vast body of quantitative studies in fields of related and unrelated variety is facing a wealth of empirical knowledge recently brought about by qualitative, intensive, multidimensional case studies about regional industrial path development. Although the combination of qualitative and quantitative data sources in single studies is still rare (see Yeung 1997 for a critical appraisal of cautions), discourses and exchange between proponents of the two approaches constantly deepen and broaden conceptualizations of regional economic change (cf. [section 2.1](#)). In this dissertation, interview data, case studies of the existing empirical literature and documents from a wide range of sources have been analyzed and combined to observe different facets of concrete phenomena, compare the results of different cases and identify differing causal properties across regions. The collaboration with other

researchers from Vienna and beyond, as well as the consultation of different theoretical streams ensured and enhanced the validity of experiences and interpretations. Finally, also the attendance at diverse scientific conferences, workshops and seminars dedicated to young researchers, allowed to ensure validity and relevance of research findings when expanding conceptualizations of new path development and broader regional restructuring.

5.2.1 Theory development and conceptual contribution

As indicated, economic geography is not only a pluralistic field; its explanatory insights are constantly evolving through theoretical and conceptual development and the import of theories and concepts from neighboring disciplines (Barnes and Christophers 2018). The starting point of a critical realist to develop theoretical knowledge is the identification of a phenomenon to be explained or conceptualized by means of a prior defined theoretical framework that guides its observation (Gong and Hassink 2020). As a common approach of theory development, the researcher argues about an internally incoherent or incomplete theoretical or conceptual understanding with respect to the phenomenon under consideration. He or she then elaborates other theories or concepts or re-theorizes the existing one and, in this way, proposes to fill the observed gap. Economic geographers regularly contribute conceptual papers drawn on multiple theories and concepts from different literature streams, usually supported by empirical insights from the extant literature. Just as with publications providing original empirical evidence, conceptual articles must be grounded in a clear research design, presenting in detail the role of its elements to make the logic of its findings explicit and indicating the paper's positioning and how its contribution should be evaluated (Jaakkola 2020). To make the chain of evidence visible to the reader, Jaakkola (2020) proposes the following key questions reflecting the argument of conceptual papers:

- How is the studies phenomenon conceptualized?
- What are the study's implicit assumptions, stemming from its theoretical underpinnings?
- Are the premises and axioms used to ground the argument sufficiently explicit to enable another researcher to arrive at similar analytical conclusions?

This dissertation contains three conceptual articles and another one that provides in addition to a conceptual contribution original empirical material. Although all work with empirical illustrations, they offer different methodological approaches to answer the questions posed by Jaakkola (2020). The *first conceptual article* (Frangenheim, Trippl, and Chlebna 2020) seeks to amend an existing theory through the importation of theories and concepts from other disciplines (“theory adaptation paper” according to Jaakkola 2020). Its point of departure is the problematization of i) how relations between different regional industrial paths are conceptualized in the existing literature and ii) the overwhelming focus on the development of single industries. Shown by the review and analysis of illustrative empirical examples, interpath relations in regional contexts are presented as a significant phenomenon to be considered in regional economic change. My co-authors and I claim that this new perspective needs an adaptation of EEG concepts to better consider interpath relations and their implications for policy. To guide this shift, we draw on recent contributions at the intersection of EEG and RIS that broaden conventional perspectives and align arguments with those from the literature on technological innovation systems. While established concepts of EEG and RIS studies are used to develop the conceptual framework, insights on inter-industrial relations from technological innovation system studies rather serve as a tool to provide an alternative frame of reference to expand the conceptual scope (Jaakkola 2020).

The *second conceptual article* (Trippl et al. 2020) is closely related to what Jaakkola (2020) calls a “typology paper”. Starting from established types of path development, my co-authors and I translated these to the green economy. We found inspiration in the existing EEG, RIS and technological innovation system literature to provide a nuanced understanding of how different types of green regional industrial path development tend to evolve out of existing RIS structures based on different types of asset modification. Its methodological aim contains the reduction of complexity through categorizing extant knowledge and the provision of an explanation about drivers, outcomes or contingencies of particular variants of the phenomenon (Jaakkola 2020). The theory-based typology has been illustrated by three cases from the existing literature and informed further conceptualizations and empirical applications (cf. [section 2.2](#)).

The *third conceptual article* (Tödtling, Trippl, and Frangenheim 2020) comes closest to what Jaakkola (2020, 21) calls a “theory synthesis paper” since it

charts “a new or unstructured phenomenon that has previously been addressed in piecemeal fashion across diverse domains or disciplines.” For the study, my co-authors and I undertook a broad literature review to unravel (and exclude inconsistent) components of production and application side challenges of green regional development. We summarized, integrated and synthesized the building blocks of different theoretical perspectives that conceptualize regional challenges at both sides. Illustrative cases from the literature supplemented conceptualization based on the extensive set of theories and provided evidence for the new theoretical umbrella.

The *fourth article* (Frangenheim 2022) provides original empirical evidence (see next section). Nevertheless, conceptual extensions have also been a main goal. The article draws on theoretical considerations and concepts provided by the first and second articles and extends them with insights from recent contributions at the intersection of regional and technological innovation system studies. It integrates a multi-scalar perspective into the framework and extends it by proposing causalities about regional preconditions to influence interpath relations across regions.

5.2.2 Empirical contribution

An important influence of critical realism on geography has been on its empirical research designs (Sayer 2015). The alternative conception of causation dissociates it from the study of empirical regularities by means of extensive research designs, e.g. through the selection of taxonomic groups of objects, such as certain types of industries, on the basis of similarities. Related and unrelated variety as core concepts of EEG and source of inspiration for the more recent literature on new regional industrial path development are extensively measured by indicators regarding sector classifications, patent data, or labor flows (Content and Frenken 2016). Gong and Hassink (2020) lately pointed out their ontological roots in positivist science, which explains their focus on empirical regularities rather than causal mechanisms. Enabling to understand how unique, as much as repeated events can be caused, the paradigm shift resulted in a wave of hitherto discriminated intensive (qualitative) empirical research.

Since the main intention of this dissertation is to focus on causal rather than taxonomic groups, I consulted statistical data only to embed the studied phenomenon into the broader picture. To understand causal connection between different kinds of heterogeneous system components, such as

different kinds of actors, networks and assets I opted for a more exploratory, intensive research design and applied comparative case studies. Indeed, the main focus of this dissertation, the analysis of new regional industrial path development in the context of societal challenges, makes it difficult – if not impossible – to apply quantitative methods. Industrial classification, innovation indicators, and innovation scoreboards provide little clue about relevant causal mechanisms of emerging and transforming industries. Nevertheless, I want to reiterate that the scientific discourse and exchange between proponents of the quantitative and qualitative approach in EEG has produced fruitful explanatory insights of cases and instances. Against the background that critical realism is placed in between the two opposing philosophical positions regarding how researchers find out about the world (relativism and positivism, also referred to as subjectivism and objectivism) (Sayer 2000), its perspective is well suited to further advance this cross-fertilization.

The use of illustrative cases

In the literature on industry emergence, qualitative case studies, focusing on the whole complex development process of an industry, are meanwhile a main source of evidence (Gustafsson et al. 2016). Since theory building has been a concern in this dissertation, as well as in economic geography overall, the review and analyses of scientific publications from the full source of cases in the literature has been important to search for evidence. The consideration of a broad range of the extant empirical literature well supported an extensive exploration of challenges and beneficial properties for regional industries that emerge to tackle current societal challenges or are concerned by them. In three articles, my co-authors and I have drawn on existing cases to prove so far overlooked theoretically assumed causal relations as being evident. Although this could be considered as a limitation, it helped evading time consuming empirical investigation and allowed us to synthesize a much higher number of cases. It has hence been an appropriate method to prove regularity of patterns to a certain extent.

As with other investigations, the selection of illustrative cases, as well as the method of analysis must be based on clear methodological considerations. A suitable case must contain a sufficient description of all components of the conceptual framework and support to answer the research questions. Considering the plurality and multitude of analyses in economic geography and adjacent fields engaging in the study of (sustainable) economic

development, the availability of officially published and other material has not been a barrier when the objective was to support evidence for generally acceptable theory building that responds to changes in its subjects of empirical investigation. Taking that into account, its effort lies in the comprehensive and ongoing literature review during the work to collect appropriate cases. Moreover, case selection from the extant literature, different from what is commonly accepted (Seawright and Gerring 2008), does not need an in-depth familiarity of cases. Rather, the search for common lines of arguments regarding the phenomenon under consideration in the case analysis section of considered pieces of literature is necessary to find representative and comparable cases that help producing own conceptual arguments. Methodologically, the use of illustrative cases serves to test and verify, rather than enhance the theoretically developed framework.

Case studies approach to collect and analyze primary data

From a critical realist perspective, case studies provide clear scientific value since phenomena can be explained independent on whether they are unique or widely replicated (Sayer 2015). According to Yin (2009, 18), case studies are defined as empirical inquiries that investigate contemporary phenomena in depth and within its real-life context, especially when the boundaries between the phenomenon and its context are not clearly evident. He further underlines the need to priorly develop theoretical propositions to guide data collection and analysis and to use multiple sources of evidence to ensure data convergence in a triangulation process. The selection of cases for the *fourth article* has been inspired by considerations undertaken within the research process for the first and second articles and further specified with the aid of a literature and document analysis, as well as three explorative expert interviews. Inspired by Seawright and Gerring (2008), two most similar cases according to conceptually defined background conditions, differing only in terms of their regional preconditions, have been selected.

To apply the case studies, I collected a diverse set of evidence through own empirical investigation. Besides statistical overview data to integrate the cases in the broader picture, this included different qualitative data sets. Firstly, to ensure a context-specific understanding of cases in different national and/or regional contexts, a review and analysis of international, national and regional policy documents and reports on firm-policy cooperation, EU regulations and databases, educational material and reports on (industry-)research projects has been undertaken. Knowledge on industrial dynamics, market

developments and demand side dynamics could be acquired through secondly, the study of industry reports, firm websites and related documents and thirdly, the attendance, observations and discussions, as well as provided material in the scope of open or closed network events facilitated by industrial and non-industrial actors. The latter turned out to be an important source of data since both cases have been in a very early stage lacking established visions, values and norms, as well as network structures, which complicated the identification of entering actors based on literature review and recommendation. The participative observation at events allowed to get a feeling for actor hierarchies and emerging cooperation networks. Fourthly, semi-structured interviews with actors having a broad understanding of the Austrian food sector as well as with those involved in or influencing the new path development processes, including firm actors and representatives of advocacy groups, regional and national policy actors and representatives of agricultural chambers, scientists, representatives of educational bodies, training organizations and environmental organizations generated primary qualitative data.

During the field studies period between January 2019 and September 2020 the alternating data collection methods enabled successive and interrelated information gathering and triangulation about ongoing activities with diverse actors involved. The preparation of semi-structured interview guides, as well as planned (but not always pre-arranged) conversations with particular actors at events have been theoretically informed. During the exchange, an open and flexible questioning ensured the collection of information about the domain of “the actual” provided by the interviewee and at the same time to assemble information that helps building knowledge about “the real”. The conceptualization of “the real” has been made explicit by means of data processing and analysis. In the re-theorizing and abstraction process, particular attention has been paid to the role of contingent conditions that influence processes in regional industrial path development this dissertation is focusing on.

The interviews lasted between one and two and a half hours and – apart from one telephone call – they predominantly took place at the actors’ premises, where it was often possible to also visit experimental or industrial sides. Participation in industrial and policy events allowed for mostly planned and some random fieldwork conversations before and after planned interviews. Besides enabling me to establish contacts and to keep in contact with actors

over time, informal conversations served as background information. Confidentially treated information allowed for more tailored interview questions. Immediately after data collection, interview records have been transcribed and memos of conversations have been complemented from memory and based on presentation slides, if available. A chronologically organized logbook with short notes on the local context, atmosphere, participants involved or listening to discussions documented expert interviews, conversations at events, presentations and speeches, and written information such as event or workshop minutes or presentation slides helped me to interpret the data. Official documents, material of events and interview transcripts have been confronted with a coding system, deductively derived from the analytical dimensions of the conceptual framework, and inductively complemented by empirical data where appropriate. To control the data saturation process, I used MaxQDA for the first round of the qualitative content analysis. To flexibly (re-)categorize and order the coded data during the triangulation process I then exported the text to an excel file, which allowed me to theorize the elements of “the real” domain.

5.3 Cases and their abstraction

In the process of revising existing concepts developed at the intersection of EEG and RIS studies, proposed frameworks developed in the scope of this dissertation have been challenged and enhanced with case studies in diverse geographic contexts (table 1). Critical realism distinguishes abstraction from generalization to characterize the latter as a quantitative measure to be understood as descriptive summaries of situations or extrapolations (Sayer 2010). To identify causal mechanisms in contextual conditions, abstractions are a more appropriate approach for critical realists. Gong and Hassink (2020, 480) summarize abstraction as the “process needed to discover (...) deep ontological structures and related causal powers” that depend on contingent circumstances. Re-theorizing is often carried out as a result “of empirical, context-sensitive research results showing unpredicted outcomes that go beyond the explanatory power of the original theory” (Gong and Hassink 2020, 581).

The re-theorizing of concepts and theories is thus a common approach of economic geographers who regularly introduce concepts from other disciplines in a context-sensitive way to answer questions arising in economic geography or to make use of context-sensitive empirical work to rework existing concepts (Gong and Hassink 2020). This dissertation benefits from this

previous work of economic geographers by initially consulting the wide availability of context-sensitive empirical research to criticize, revise and improve or add to established understandings. While the application of case studies based on secondary data may be considered a limitation from the perspective of qualitative research designs, re-theorizing in line with the critical realist approach has provided broad, yet context-sensitive feedback to theory through the triangulation of different industry cases at different development stages and in varying regional contexts. This has helped to answer the research questions relating to different types of path development, as well as considering more than one path in regional or interregional contexts. Inspired by the conceptual considerations undertaken within the former research process, I also collected original empirical data to critically assess and further develop my own previous work.

Table 2. Cases, scope and contribution to theory development, own elaboration

<i>Article</i>	<i>Case industries</i>	<i>Scope of application</i>	<i>Contribution to theory</i>
1	Emerging green and non-green paths	Worldwide	Broadens established perspectives on interpath relations and conceptualizes it as a regular, hitherto overseen phenomenon
2	Green established and new paths	Worldwide?	Provides a conceptualization of green development processes at the regional level
3	New green initiatives	Austria, related contexts?	Includes application side besides production side challenges into analyses of green regional development and compares policy options for different types of regions
4	Diversifying and established green food paths	Food sector in Europe	Demonstrates differences in the capabilities of urban and peripheral regions to shape interpath relations and resulting reinforcing or impeding effects across regions

The cases have been selected based on their accuracy to test and provide insights to the theoretically developed conceptual frameworks (cf. [section 5.2.2](#)). Questions of national or international context matter in regional case studies and my co-authors and I had to decide about the specific requirements for each analysis. For *the first article*, we consulted existing case studies of

green and non-green industries to provide general evidence for relations between emerging paths in regional contexts. We focused on North-Western Europe but also observed the phenomenon in Australia. Others, like Harvey and Pilgrim (2011) have focused on competition about the natural asset land between the food and the energy sector and its conflicting regional, national and global interests and respective effects in the USA, Brazil and Europe. Breul, Hulke, and Kalvelage (2021) have provided evidence for interpath relations in Namibia. In our article, we have consulted different renewable energy paths from Germany, the digital gaming industry and the new media industry in Scania, Southern Sweden, alternative transport fuel paths in Sweden, urban water provision paths in Australia, and creative industry paths in Berlin, Germany. They all emerge in the industrialized world. This is not because interpath relations do not exist elsewhere but it was rather necessary to focus its interpretation and the derivation of policy recommendations. In fact, interpath relations seem to be a worldwide phenomenon.

To demonstrate the role of favorable or unfavorable environments to support asset modification for different types of green path development, the *second article* compared two cases from Norway and one from Beijing, China. To gain further insights into how green path development is facilitated by combinations of firm-level and system-level agency, additional empirical examples have been included. While cases of vessels with fuel cell technology in Western Norway and the Norwegian solar PV industry provided insights on how firm-level agency triggers green path development, the offshore wind industry in Germany and the biogas industry in Southern Sweden exemplified the role of system-level agency in initiating green path development. As a third important insight, the case of environmentally harmful industries in Germany have been chosen to demonstrate the role of system-level agency in destabilizing old non-green paths. Since the aim of the second article was to understand more comprehensively green restructuring processes at the *regional* level, the national or international scales have not been subjects of deeper attention. Rather, the availability of cases from the literature that allow describing the phenomenon under consideration in a context-sensitive manner explains their choice. The broad literature dealing with sustainable economic development indeed finds application in worldwide contexts. I therefore expect the framework to be applicable worldwide, though this needs still to be confirmed by further research.

The *third article* focused on one country and three different types of regions to consider the same national institutional and policy contexts when comparing policy options for challenges occurring in peripheral, diversified and old industrial regions. Evidence for proposed policy options has been provided by analyzing the application of e-mobility in the diversified industrial region Vorarlberg, the development of green technologies in the former old industrial region of Styria and the development and application of biomass heating in the peripheral district of Murau in Upper Styria. The choice of cases is closely oriented at the presented RIS typology. Since challenges at the application and production side of green regional development have been theoretically derived from the international literature, they might be transferred to other contexts, which would still be subject to further investigation. The application of green initiatives nevertheless strongly depends on the respective institutional policy contexts at multiple scales, i.e. financial or strategic impulses from higher spatial scales, national and supranational institutional barriers and the importation of innovations developed elsewhere. This makes the presented policy options a context-sensitive issue. Though some bold policy recommendations have been provided for diversified, old industrial and peripheral regions, it requires well targeted combinations of measures and instruments fine-tuned to the respective RIS specificities, as well as the awareness of the population and the innovation and absorption capacity of regional firms and society.

The fourth article extends the framework of article I beyond single regions. It aims at better understanding spatial complexities in interpath dynamics by digging into regional preconditions of core and peripheral regions to shape interpath relations resulting from similar asset needs at multiple scales. The article provides new evidence for a hitherto under-researched spatial topic by analyzing cross-regional and cross-country relations.

It has been shown that interpath relations are a regular and worldwide phenomenon. As regards the industries under consideration, the first three articles have included new and established, green and non-green paths from different sectors in different countries. For the fourth article, I considered diversifying and emerging innovative activities in the food sector of Austria and other countries. For this analysis, I collected primary data of the emerging insect-based food and feed path in Vienna and the diversifying aquaculture path in the peripheral region of Waldviertel, Lower Austria. Based on the statements of interviewees, publications on insect-based food and feed path

development in the Netherlands and by means of information collected in EU databases and funding programs, I found evidence on reinforcing and impeding effects of interpath relations across regions for both cases.

Like other foundational industries, the food sector is in need to restructure its production and application side to cope with challenges, such as climate change resulting from human activities, the loss of biodiversity, or health issues. EEG, however, has so far largely neglected innovative activities in this sector (exceptions are Martin and Martin 2021; Baumgartinger-Seiringer et al. 2022), which is a research gap I have contributed to fill by providing original empirical material.

As in other sectors, global dynamics in the production and consumption of food have evolved rapidly during the last decades (Santeramo et al. 2018). Nevertheless, the sector shows some particularities that shape its geography. With the EU accession of Austria in 1995, the food sector became gradually embedded into the international institutional framework regulated by the EU and World Trade Organization, which led to rising international competition and the accessibility of research programs and funding. More recently, the sector receives much attention in international policy initiatives, such as the Sustainable Development Goals, Food 2030, EU Green Deal, EU Farm to Fork Strategy, EU Biodiversity Strategy for 2030, IPES Food, Milan Urban Food Policy Pact. Especially in urban regions, we observe increasing experiments with disruptive innovations, e.g. from its combination with bio- or nanotechnologies or genetic engineering (Berghofer, Schönlechner, and Schmidt 2015). Consumer trends like the request for fast and convenient food, changing households and food-related consumption behavior but also an increased awareness about the effects of food on health and wellbeing, changing values towards animals, and consumer engagement additionally drive innovations in agricultural production and food processing (Wepner et al. 2018).

Resulting from these developments the urban-rural geography of the food sector changes. Established food paths, such as agricultural production, dairy and meat located in peripheral regions are increasingly confronted with innovative activities, such as novel foods, the use of plant-based or animal-based cell cultures or recirculating technologies that originate in urban research institutes or firms (Frangenheim 2022). The production of fish in recirculating aquaculture systems and insect protein, in Austria as well as elsewhere, is considered to supposably contribute to the broader restructuring

of our food systems (BMLFUW 2012; van Huis et al. 2013; Engelhardt, Brüderl, and Deppe 2020; Haack et al. 2020). Both comprise small food producers and other actors with strong association to their origin who recently receive much public and national subsidies (Frangenheim 2022).

The two cases selected for this article are particularly suited to provide insights for theory building in the scope of this dissertation: Firstly, the actors involved have strong interest to offer solutions for societal challenges. Secondly, the case paths are embedded in a peripheral and an urban region, which provides useful information to test conceptual considerations about differing regional preconditions to affect asset modification at, and its complementarity across, multiple scales. Finally, obvious and perceived relations to paths in other regions prove that innovation-based regional industrial change in the face of societal challenges involves the development of several interacting paths within and across regions. Nevertheless, these results have to be seen against the background of the particular EU food sector context. Further context-sensitive abstraction of empirical material from other industrial and regional settings will be required to verify and adapt the framework.

6 Conclusion

This chapter summarizes the main findings of the dissertation made by the four research articles and the framework text at hand. Table 3 provides an overview of the articles constituting this dissertation by listing its research questions, methods and highlights. What follows, is a section on policy implications (6.2). Considering the increasing interest in the geographically uneven and unsustainable development of our economies, I critically reflect on how the contributions made by this dissertation affect regional innovation policy strategies. Finally, [section 6.3](#) provides an outlook proposing avenues for further research.

6.1 Main findings

This dissertation contributes to the flourishing debate on innovation-based regional industrial change in the face of societal challenges. Tackling unresolved questions revealed by recent contributions at the intersection of EEG and RIS studies, it adds knowledge on how different path development processes relate within and across regions, on the diversity of green regional restructuring processes and respective challenges in different regional contexts. I adopt a critical realist research design to provide answers to the overall research questions by means of four articles published in internationally recognized peer-reviewed journals (figure 3).

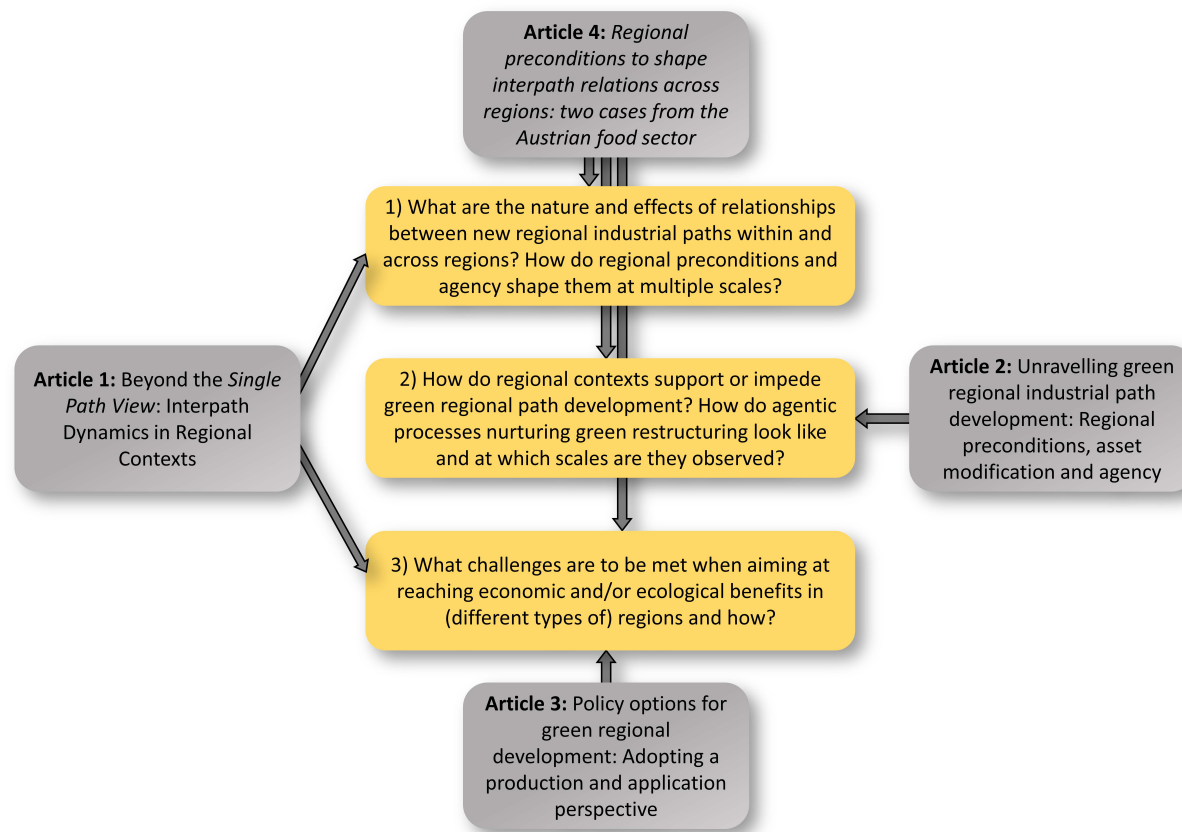
The first set of research questions, on the one hand, has engaged with recent criticism of the relatedness concept for not allowing a meaningful assessment of the enforcing and hindering dynamics in regional restructuring processes. On the other hand, it is derived from an overwhelming focus on single path development processes. Taking a systemic and territorial approach, this dissertation contributes to a better understanding of so far theoretically underemphasized but empirically observed relations between paths within and across regions and respective one-dimensional or mutual reinforcing or impeding effects.

Table 3. Overview of the four articles, own elaboration based on the four articles

<i>Article</i>	<i>Research questions</i>	<i>Method(s)</i>	<i>Highlights</i>
Frangenheim, Trippl, and Chlebna 2020	What is the meaning and nature of relationships between multiple new regional industrial paths? What are the challenges and potentials in regions that experience diverse new path development activities?	Theory adaptation: import of concepts from technological innovation system studies to amend existing EEG theories; review and analysis of illustrative empirical examples	- Established perspectives on interpath relations are too narrow to capture diversity of empirical observations. - Acknowledging the competing use of diverse assets contrasts established perspectives on related diversification. - Agency at the level of the RIS may result in favoring specific paths over others. - Regional innovation policies may benefit from taking into account promising interpath relations and taking corrective actions.
Trippl et al. 2020	How does green restructuring unfold in regional contexts?	Typology development: reduction of complexity through categorizing extant knowledge in EEG, RIS and technological innovation system studies, illustrated by three cases from the existing literature	- Green regional industrial path development is highly variegated in its unfolding. - Regional innovation system structures provide enabling or constraining conditions for green regional path development. - Regions transform their innovation systems through different modes of asset modification. - Mutually dependent local and non-local firm-level and system-level agency is key.
Tödtling, Trippl, and Frangenheim 2020	How do problems and challenges of green development differ between various types of regions? What is the role of industrial and innovation policies for stimulating green regional development and what policy options can be identified in particular regional settings?	Theory synthesis: charting an unstructured phenomenon previously addressed in piecemeal fashion across disciplines; summary, integration and synthesis of theoretical building blocks; illustrative cases from the literature supplement conceptualization	- Green regional development is a heterogenous phenomenon with different orientations, linked to different sectors. - Green innovations can have regional or non-regional sources and economic and/or ecological benefits in the region. - Production and application side challenges are key in analyses of green regional development. - Place-based policy approaches for green regional development require well-targeted combinations of measures.

Frangenheim 2022	How are reinforcing or impeding effects of interpath relations across regions generated? How affect regional preconditions the outcome of interpath relations across regions?	Conceptual extensions of the interpath framework; comparative analysis of two case studies, most similar across conditions relevant to interpath effects based on statistical overview data and diverse qualitative data sets	- The multi-scalarity of assets imply interpath relations across regions. - Regional preconditions affect whether interpath relations across regions are reinforcing or impeding. - Interpath relations are dynamic and therefore affect acceleration and (re-)orientation processes of involved paths, thus initiating further restructuring processes. - Urban and peripheral regions differ in their needs to be able to benefit from reinforcing effects of interpath relations.
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Figure 3. Research questions related to published articles, own elaboration



While considering the competing use of assets nurtures debates about impeding effects between several paths, supportive relationships between paths who share and jointly modify the same assets open the view for a more integrative regional development. Concepts, such as the distribution of agency and the orientation of agents towards the future have been applied to understand how heterogeneous actor groups and networks join forces to build, access, and deploy assets or shape markets with the aim of fashioning interpath relations within and across regions. Since assets needed for path development are located at multiple scales, their availability, orientation, or interpretation affect the orientation of path development in several regions and likewise are affected by them. From transforming interpath relations within and across regions thus emanate dynamic restructuring processes.

The second set of research questions addressed the deficient understanding of how green restructuring, conceptualized through the notion of green regional path development, unfolds in regional contexts. The contributions of this dissertation have been inspired by the recent opening of how economic change is conceptualized to consider its confrontation with societal challenges. It is increasingly acknowledged that a reaction at the regional level need besides the rise of new regional industrial paths and the renewal of existing ones a destabilization of non-sustainable regional industrial activities. To do justice to such a selective growth perspective, a nuanced understanding of the modification of assets that on the one hand support green innovative activities and on the other hand destabilize dirty or outdated industries has been provided in the scope of this dissertation. This includes the redeployment and recombination of regionally or extra-regionally created assets, as well as the re-use, creation and destruction of assets at multiple scales. I further underline the crucial role of regional differences in preconditions to support paths in modifying assets at multiple scales. Considering that RIS simultaneously stimulate different (green and non-green) paths whose actors modify assets and markets at multiple scales, resulting reinforcing or impeding effects play a crucial role in green restructuring processes.

The third set of research questions is inspired by the changing requirements on innovation research and policies to be coordinated with economic and/or ecological value creation in times of recurring challenges. In this dissertation, I take the argument derived from economics and transition studies that structural change to meet societal challenges includes the development and interaction of several industrial activities seriously. I provide insights on the

uni- or bidirectional effects of interpath relations within and across regions and resulting dynamic processes of and challenges for path acceleration and (re-)orientation. The ecological dimension is included into policy options to support regional development by taking into account besides greener production methods also the adoption and use of green technologies.

To understand causal mechanisms, I applied a rather exploratory, intensive research design using comparative case studies. Theory building has been a concern in this dissertation. My co-authors and I worked through the full source of cases in the literature to search for evidence for, verify and test theoretically assumed causal relations and prove regularity in causal patterns, at least to a certain extent. In my last article, I collected evidence through own empirical investigation to enhance former theoretical conceptualizations of spatial complexities and to provide information on the hitherto under-researched food sector. Particular noteworthy is the changing urban-rural geography observable in this sector due to recent innovations in urban production and consumption patterns. I dealt with this aspect through analyzing relationships between an emerging urban insect-based food and feed path and a diversifying rural aquaculture path. While the first three articles have a quite broad scope of industrial and geographic application, the fourth article only considers cases of the food sector in Austria. Although this allows deep insights on innovation-based transformation processes in one sector, it may require further context-sensitive abstraction of empirical material from other industrial and regional settings ([cf. section 6.3](#)).

Overall, this dissertation has contributed to the debate on how innovation-based regional industrial change is affected by and tackles societal challenges from an economic geography perspective. Understanding regional restructuring through the development of regional industrial paths in a RIS perspective allows the consideration of wider economic institutional and socio-political structures and provided important considerations on spatial inequalities of industrial change processes and the ways by which such dynamics contribute to regional development. The findings provide important insights to reconsider established spatially sensitive innovation policy strategies that are presented in the next section.

6.2 Implications for policy

The uneven development of economic prosperity, social welfare, individual well-being and environmental sustainability has remarkably increased the

engagement of economic geographers with regional innovation policy issues and vice versa (Martin 2021). This is accompanied by an emerging and renewed interest in more inclusive and sustainable regional innovation policies (Schlaile et al. 2017; Mazzucato 2018; Schot and Steinmueller 2018; Tödtling and Trippel 2018; Raven and Walrave 2020). Indeed, societal challenges resulting from climate and environmental change and recurrent economic and financial crises are of global nature and pervasive across Western societies. Nevertheless, their actual appearances differ strongly across regions and they are optimally tackled at lower spatial scales (Tödtling, Trippel, and Frangenheim 2020; Wanzenböck and Frenken 2020). They “remain detached from local realities if they are not made operational and concrete in ways that relate to the public” (Uyarra, Ribeiro, and Dale-Clough 2019, 2363). For that reason, Uyarra, Ribeiro, and Dale-Clough (2019, 2369) correctly point out the need to overcome the “spatial blindness of new innovation policy rationales” by including context-specific directionality through addressing questions of responsibility, leadership and collaborative governance.

To avoid underestimating the importance of regions to tackle societal challenges, I concentrated on the regional policy scope. Nevertheless, regional paths are considered as being more or less open to extra-regional industrial influences resulting from interactions between particular places, regions, states or international confederations of states such as the European Union (Essletzbichler 2012; Miörner and Trippel 2017; Chlebna and Simmie 2018; Miörner et al. 2018; Afewerki, Karlsen, and MacKinnon 2019), and the influence and control of regions is not overestimated (Martin, Martinelli, and Clifton 2022).

Conceptualizations at the intersection of EEG and the RIS approach have provided much insights into spatially sensitive innovation policy options and in particular inspired smart specialization as the most important European policy instrument to facilitate new path development and regional restructuring. The process of smart specialization aims at building comparative advantages for a region through the “selection of policy priorities” and is carried out by the inclusion of diverse regional stakeholders that seek to develop a shared vision of priorities in which regional restructuring processes should be supported, called “discovery process” (European Commission 2014; Foray 2014a, 2014b).

Regional policy objectives change when they are about to resolve the contested and contextual aspects of problem-identification and challenges. Foray (2018)

points out the differences between innovation policies increasing the “rate” of innovation or those influencing the “direction” of innovation aiming at certain technological, social, environmental, or industrial objectives. According to Foray starting the process of supporting innovation with a specific objective involves the principles of non-neutrality (preferential intervention), direction (predetermination of domain) and the adoption of a systems approach. Although the RIS approach traditionally takes a neutral position towards innovation and does not suggest specific domains to be supported, scholars recently enter the debate and argue for the consideration of future needs and potentials to tackle societal challenges in RIS studies (Tödtling, Trippl, and Desch 2021).

This dissertation takes a selective growth perspective acknowledging the need to destabilize outdated and environmentally damaging regional industrial paths while simultaneously stimulate green regional path development to ameliorate environmental and social problems. The new perspectives and insights on interpath relations, green path development and green regional development provided by this dissertation add to current debates on spatially sensitive policy approaches concerning considerations for policy priorities ([section 6.2.1](#)) and the discovery process ([section 6.2.2](#)). Moreover, [section 6.2.3](#) provides an overview on region-specific recommendations and [section 6.2.4](#) on considerations for interregional policy perspectives.

6.2.1 Priority selection

If public support is concentrated on a few transformative activities (aiming at renewing established paths or developing new ones), the new perspective on interpath relations points to dynamic and unpredictable, possibly unintended effects on other regional or extra-regional paths. The selection of priorities causes changes in the availability and orientation of assets shared with other paths, which entails reinforcing or impeding effects. This may occur unintentionally. Being aware of the regular existence of interpath relations within regions, however, may allow agents to deliberately shape them towards supportive or competitive relationships (article I, Frangenheim, Trippl, and Chlebna 2020).

Foray (2018) suggests to choose a “level of granularity when selecting priorities” below the sector level and rather focus on transformative activities. Reconsidering this with the results of this dissertation, I argue that priorities for regional development should be selected based on their ability to create

supportive relationships and reinforcing effects to the benefit of green paths. Examples to support transformative activities at the production side could refer to the development of a new study or research program relating to the development of new forms of animal- or plant-based protein to contribute to overall more sustainable human diets (including upstream feed chains). At the application side, it could be the establishment of funding schemes or experimental spaces that support the development of place-based combined, but more sustainable forms of mobility (i.e. combination of private and public transport, car and bike sharing).

Alltogether, policy makers are asked to balance supportive, reinforcing and competitive, impeding relationships between paths in a way that green regional restructuring is more effectively supported. Competitive relationships that impede green path development, e.g. because human resources or financial assets are locked in unsustainable energy, building, mobility or food paths should be consciously neutralized. This may be enabled by offering new or adapting existing educational programs, providing financial resources for greener activities, support search processes for alternative local or non-local markets or encourage firms to source and anchor non-local assets. Competitive relationships that impede environmentally-destructive economic activities, however, may be further strengthened to destabilize paths with adverse environmental conditions. While competitive funding mechanisms enhance competitive relationships, nonneutral support schemes may be used to particularly support green path development. Moreover, turning competitive relationships into supportive relationships between green paths, e.g. through promoting cross-industrial knowledge flows in networking events, innovation platforms or possibilities to experiment with combined applications may be a valid strategy when several linked paths exist in regions.

Moreover, if path development shall be supported within the region, it must be ensured that it is not impeded at higher scales, due to competitive relations with paths from other regions (article IV, Frangenheim 2022). It is also advisable, if cross-regional interpath relations have the potential to drive green regional path development, to support complementary asset modification at lower scales (article IV, Frangenheim 2022).

A selective growth perspective asks for choosing priorities that enable green regional restructuring by bringing about positive spillover effects between different paths. Green shift include various forms of path development,

including the greening of existing paths, the rise of new green industries and the emergence of new green economic activities (article II, Trippel et al. 2020) with manifold interpath linkages. The sum of path development activities in regions should, besides creating regional economic value, enable more environmental value creation than damage. In addition to the support of green path development, policy makers should therefore discontinue the support of outdated paths by cutting R&D and innovation funding, removing subsidies and regulatory reforms (Kivimaa and Kern 2016).

To reach regional targets of green restructuring, policy makers should make sure that impeding interpath relations in a regional context will not counterbalance positive effects of green path development. Considering green regional restructuring as the sum of (green and non-green) path development activities, the so-called dark side of regional industrial path development (Blažek et al. 2020) appears in a different light: If assets released by declining paths are made available for other paths, social implications, such as unemployment may be alleviated when released human assets can be accommodated in other paths. Nevertheless, it seems evident that not all types of assets are equally modifiable. What has been shown is the need to consciously modify system assets by transforming organizational support structures and institutional configurations and at the same time allow firm actors or external investors to introduce greener production processes, and green technologies. This includes asset creation and the re-use of existing assets to support green path development, but also implies the destruction of assets needed by outdated paths (article II, Trippel et al. 2020).

6.2.2 Discovering place-based priorities

Sjøtun and Njøs (2019) have demonstrated that “normative policy routes of green reorientation” may be driven by top-down regulations and policy changes or bottom-up initiatives and deliberate agency. To encourage green regional development, they emphasize the role of demonstration projects, multi-level and multi-actor agency, and discourses. The entrepreneurial discovery process in smart specialization strategies is indeed an interactive process in which market forces and the private sector discover and produce information about new activities (European Commission 2022). Against the background of changing environmental conditions, the discovery process of priorities is open-ended, which requires new forms of engagement and networks between public, private and third sector actors (Schot and Steinmueller 2018). Once, a strategic direction has been chosen, the smart

specialization process indicates that changes or modifications are possible when new information or developments make it advisable (European Commission 2022).

This dissertation provides evidence that interpath relations can alter the direction and orientation of path development (article IV, Frangenheim 2022), which necessitate to not only explore but continuously monitor their effects and flexibly alter priorities in a collective, progressive and democratic manner. Involved actors must constantly question whether path development is aligned with regional development strategies to possibly engage in the creation or reorientation of needed assets. Overall, innovative activities at production and application sides are continuously structured and restructured by multiple asset modification activities and in need for consensus-oriented initiatives. Rather than technology push strategies, this asks for bottom-up diffusion and co-production activities (Coenen, Hansen, and Rekers 2015; Frenken 2017) in established fora that allow regular and long-term exchange between diverse actors, supported by more active government intervention promoting new and more inclusive development paths (Uyarra, Ribeiro, and Dale-Clough 2019).

Technological innovation may compensate for the ecological effects of current economic growth, green regional development, however, additionally requires changes in life-style, such as daily mobility, the use of water, energy, foods and other resource practices by consumers and professional users. To find place-based solutions (instead of problems) in a progressive manner, Grandadam, Cohendet, and Suire (2021) point out the need to engage with formal, as well as informal actors involved in common practice and networks with market and non-market interaction. To involve diverse actors, the aim of policy is, according to Grandadam, Cohendet, and Suire (2021), not to define agents or networks to be involved but to create opportunities and platforms for formal and informal actors to experiment collectively and to allow for flexibility and adaptability of solutions on the one hand and regarding the composition of actors who find them on the other. This might also help to overcome barriers at the application side of green regional development by rising the innovation and absorption capacity of regional firms and society and increasing awareness and consciousness with respect to sustainability issues in the population.

6.2.3 Region-specific policy recommendations

To structure insights gained from this dissertation for policy makers acting in different regional contexts, I interpret the results against the RIS typology that orients at the thickness of organizational and institutional structures and the degree of specialization (Isaksen and Trippel 2016b). The typology differentiates between thick and diversified RIS that can be regularly found in urban or core regions, thick and specialized RIS, found in old industrial regions and thin RIS that often prevail in peripheral regions (cf. [section 2.1](#)).

Core RIS

Diversified core regions tend to have heterogeneous industrial structures, diverse innovative actors and economic, knowledge and support structures leading to overall good preconditions to nurture the development of new regional industrial paths. Strong exploration capacities explain the existence of several different regional industrial paths with diverse asset needs at multiple scales, in different development stages and with manifold interpath linkages. Lacking focus of policy and other actors, however, provoke innovative activities to suffer from too little exploration (Isaksen and Trippel 2016a) and limited complementary modification of assets across scales (Frangenheim 2022). If this challenges green restructuring, green technologies, business models and behaviors have to be facilitated through the development of diversified industrial and institutional infrastructures. These should be capable to support the cooperation between desired paths and at the same time to find the right balance of nurturing and alleviating competition between green and environmentally-destructive path development activities. To concentrate strategic development in diversified regions, the integration of several linked paths by encouraging supportive relationships, e.g. by facilitating networking, supporting combined applications and removing barriers preventing paths to connect, may be beneficial. If the lack of industrial focus leads to a mismatch of existing and needed assets, fostering competitive relationships through competitive funding mechanisms may be an option. Overall, policy makers need to make sure to constantly broaden and redefining the policy scope. Cross-industrial networking events or respective educational support may help to not overlook promising new industrial fields and to support paths to reorient to reinforcing relations with other paths. The identification and communication of most promising existing paths is of high strategic importance in order to prevent agents from uncertainty and

instability and avoid an ineffective waiting for complementary asset modification.

While such asset-rich regions have strong capacities to develop green industries (Barbieri and Consoli 2019), they also face environmental problems related to congestion, car traffic, and the loss of green space (article III, Tödtling, Trippl, and Frangenheim 2020). To support the production side of green regional development, policy makers should stimulate the redeployment of existing assets but also make sure to support broad asset modification across scales to warrant complementarity of needed asset stocks. At the application side, legitimization of new technologies or industrial paths and regional market creation are crucial. The competition about scarce assets with other fields of application can be tackled through the collective development of long-term regional visions. Resistance from dominant business players may be overcome through environmental policy tools, such as restrictive land use, consequent transport policies and efficient energy use measures for buildings, households, and businesses. Where useful these measures may be combined with incentives for established players to renew their industrial activities.

Industrialized RIS

Thick and specialized RIS are assumed to have lower innovation and path development capacities. They face major renewal challenges and profit from industrial renewal activities that may be supported by promoting new, related paths. Since related variety is barely present in the region, exogenous development impulses through extra-regional knowledge networks, or by attracting foreign direct investment should be high on the policy agenda (Isaksen and Trippl 2016a). For those regions, interregional cooperation as well as the support of reinforcing interpath relations across regions may be valuable strategies. Nevertheless, it must be assumed that emerging paths may struggle with asset modification at higher scales, which make them prone to impeding interpath relations across regions. The capacities to modify institutional, educational, financial or other assets at higher scales and access markets in other regions may be supported by building-up research, education and local networking initiatives. In some cases, a path reorientation towards other, more reinforcing interpath relations might be supported. Knowledge spillover can be supported by encouraging labor mobility within and from outside the region (Asheim, Boschma, and Cooke 2011), e.g. through joint

education programs or other forms of joint knowledge and material infrastructure.

Specialized regions likely face environmental problems related to their previous industrial development, including the pollution of air and water, land and green areas in the neighborhood of environmentally-destructive industrial activities (article III, Tödtling, Trippl, and Frangenheim 2020). Since assets in these regions are often locked in old and established industries (Grabher 1993; Isaksen and Trippl 2016b), policy makers are asked to balance the creation, importation and redeployment of existing assets with the purposive destruction of outdated assets that inhibit change. Aiming at reorienting such regions towards modern, possibly greener forms of production by means of path interaction requires policy makers to act as intermediaries enabling different forms of assets to spillover and diffuse. If path destabilization policies, such as the withdrawal of public support for mature sectors and institutional reconfigurations are collectively and democratically determined and if actor constellations are broadened through the inclusion of actors from other paths, chances to exclude formerly incumbent influences on governance arrangements increase. Desirable new industrial paths and forms of application can then be legitimized and supported by increasing their competitive position through nonneutral support schemes, subsidies and tax incentives. Their adoption may be also supported through demonstration projects, testing facilities, and the involvement of formal and informal actors, including the civil society and end users.

Peripheral RIS

Thin RIS are assumed to have lower innovation and path development capacities and are prone to be dependent on assets from outside the region (Isaksen 2015; Isaksen and Trippl 2016a). Due to their limited capacities to modify assets at higher scales, they also tend to be prone to impeding interpath relations across regions, which needs supportive activities to modify assets at higher scales or help paths to reorient. Like old industrialized regions, peripheral regions are however also well suited to benefit from reinforcing interpath relations with paths from other regions. Due to the weak capabilities to modify assets at higher scales, this needs the conscious support of policy makers at multiple scales by adopting policy instruments that bridge scales and paths and enable knowledge spillover to existing regional or extra-regional paths. Supporting the establishment of upstream or downstream

organizations of natural resource industries may be an appropriate answer to the increasing demand for the exploration, extraction and transportation of natural resources and a valuable strategy for resource-rich peripheral areas.

Whether thin regions face environmental problems is very much dependent on their use of industrial agriculture and soil sealing leading to difficulties related to contaminated cropland and water and the loss of biodiversity (article III, Tödtling, Trippl, and Frangenheim 2020). Such regions tend to have weak capacities to develop green regional paths due to the absence of needed infrastructures, highly qualified labor, higher education institutes, and supporting organizations (Isaksen and Trippl 2016b). Nevertheless, they have important potential to develop green paths, e.g. organic agriculture and food (Goodman 2004), soft or green tourism, or eco-energy activities (Gibbs and O'Neill 2017). Even more promising, they are well suited to develop activities that bridge the mentioned paths, such as the example of multifunctional agriculture emerging at the crossroads of agriculture and tourism or healthcare paths (Hassink, Grin, and Hulsink 2013).

Policy makers are asked to support innovative activities at the production as well as application side (article III, Tödtling, Trippl, and Frangenheim 2020). At the production side, this includes the provision of the necessary (social) infrastructure, such as transportation and energy networks, primary education facilities and health care, financial support, and the stimulation of interregional knowledge transfer, external investments, inflow of external knowledge and technology to create new green paths. Another task would be to shift competitive relationships, e.g. between food, energy and environment for land (Harvey and Pilgrim 2011) towards supportive relationships through, e.g. the promotion of biodiverse agriculture or the combination of agriculture and solar power. Application side policies may, instead of defining actors to be involved, create opportunities and platforms for diverse formal and informal actors to experiment with solutions and continuously adapt them. The search for place-based solutions may be supported by the provision of finance and labor qualification measures as well as the collective development of formal and informal institutional structures for supporting green path development and relations between green innovative activities.

6.2.4 Policy for interregional perspectives

Regional policy approaches are indeed of high relevance to tackle local societal challenges. Their effectiveness nevertheless strongly depends on the

coordination with national and international policy initiatives (Dawley 2014; Binz, Truffer, and Coenen 2016). So far, we do not know well what is within and what is beyond the scope of regional innovation policies and what is influenced by policy at higher scales. The results provided by this dissertation add some considerations that go beyond the established RIS typology of thin and thick, specialized and diversified regions. Envisaging territorial interdependencies resulting from interpath relations across regions, I briefly outline considerations on policies in multi-scalar and interregional perspectives.

Tendencies of economic isolation, exclusion of regions and struggles of old industrial districts may be alleviated by enhancing relations to bright sides of regional economic development (Phelps, Atienza, and Arias 2018). In the second article, we zoomed into the complex relations between green path development and set-ups of innovation systems to understand how regions facilitate or hamper green restructuring (Trippel et al. 2020). To take into account how (and which types of) RIS support regional and extra-regional interpath relations, additionally points to the need to orient in complex multi-scalar and interregional governance mechanisms and to align with respective policy strategies (article IV, Frangenheim 2022). While regional preconditions play a meaningful role in enabling asset modification at multiple scales, regions rely on national support to enable complementarity in the multi-scalar asset stock for path development. To allow for a sound inter-connectedness of assets across scales, calls for more coordinated and integrated policy approaches across scales.

A danger of current spatial policy frameworks, such as smart specialization is the tendency to favor regions that are advantaged in relation to policymaking capacities (Martin, Martinelli, and Clifton 2022). Considering interpath relations across regions point to possibly unintended effects of regional innovation policies on industrial path development in other regions. Regional innovation policies should therefore not only ensure regional environmental value creation but beyond that consider possible combined effects of multiple industrial paths (Chlebna, Martin, and Mattes 2021). Being aware that they contribute, together with higher-scale policies, to changes in global markets, social, cultural and institutional settings (Mörner and Binz 2021), they should also ensure to prevent adverse impacts on green regional development or, whenever possible, support green path development elsewhere. In addition,

effects from other regions on old path decline should be taken into consideration.

A valuable strategy to support economically disconnected regions could be the transplantation and importation of paths into other regions (Grillitsch, Asheim, and Trippel 2018). A combined development of paths in different regions via interpath relations, however, might be in some cases an even more realistic and more feasible strategy. Instead of coordinating the inflow of knowledge or the modification of the multi-scalar regulative framework from one region, a collaboration with policy makers from other regions may enhance effectiveness in asset modification as well as mutual learning outcomes. Moreover, taking more seriously the interconnectedness of (different types of) regions would help to overcome all too demarcated views like the urban-rural binary (Baird 2022). The value of outward looking approaches and coordinated interregional policies is widely recognized, yet long-term collaborations between regions are rare despite of their promotion by smart specialization policies (Uyarra, Marzocchi, and Sorvik 2018). This calls for a variety of interregional policy instruments that better help bridging ties between scales and paths. Examples include open university curricula and research programs for topics specifically relevant in different types of regions as well as joint education programs or the support of students' or researchers' mobility not only between cities but also between cities and peripheries or specialized regions. Moreover, it may include the establishment of dedicated joint knowledge infrastructures, such as incubators, competence centers and living labs, as well as determined networking events and conferences accompanied by a functional physical infrastructure including public transport.

6.3 Avenues for further research

In this closing section I will provide some overarching reflections on future research avenues and subsequent work.

The green economy and the resource-based view

Our knowledge on the effects of sustainability innovations in RIS structures, legitimation processes for green innovative production and application and adapted policy scopes on diverse green path development activities is still very limited. The ability of regions to nurture green path development and cope with multiple crises differs strongly (Martin, Martinelli, and Clifton 2022). With this dissertation, I provide insights on how different types of

regions (and their innovation systems) support asset modification at multiple scales in a very general (and neutral) manner. Innovative regions, however, do not per se support green path development (Capasso et al. 2019). Investigating how different types of regions differ in their capacity to modify assets that are particularly relevant for green restructuring processes would enhance our understanding of regional inequalities in accomplishing green restructuring.

Moreover, green path dynamics vary depending on the industry in focus. Subsequent work would benefit from integrating insights from sectoral innovation systems to better account for industry-specific development trajectories and respective multi-scalar institutional environments. Future work might focus on how contextual factors affect green restructuring and how system-level agency is able to modify these contextual factors at multiple scales.

The economic and environmental effects of green restructuring remain poorly understood. How does green restructuring affect the economic prosperity and competitiveness of regions? Is there a difference between green renewal and green path development or are some types (or combinations) of (modified) assets more important when aiming at reaching ecological sustainability in regions? What allows policy makers to decide between several sustainable alternatives, such as different drive (propulsion) systems? Should they open up opportunities for the promising but immature alternative path in the preformation phase, or should they continue to support an already more established path in the path development phase? To answer these questions, it seems necessary to clarify what actually means 'green' and whether some paths are 'greener' than others. To really investigate the effects of path development on the ecological sustainability of regions would require interdisciplinary approaches to allow for sustainability assessments, e.g. by means of indicators that measure diverse environmental sustainability themes.

This also points to questions of how people interact with their environment, which puts the relation of natural and institutional assets center stage. Rarely given prominent attention in EEG and innovation studies, critical realists relate causal powers of constituent entities increasingly to both human and non-human material parts and their intentional or spatial relations (Elder-Vass 2017). Research indicates that individual behavior is connected to the relationship with nature (Braito et al. 2017). Extending region-specific analyses

about opportunities and constraints resulting from differing accesses to natural assets by also considering the relationship of human beings to nature, or indirectly through a common regional ecological value system (similar to the social capital of a region), would allow to estimate whether regions are more or less likely to support green restructuring.

Selective growth and interpath relations

The conceptual considerations in this dissertation allow for a real selective growth understanding in regional contexts where outdated paths may be destabilized and alternative, more sustainable paths can be stimulated. Acknowledging that interpath relations may have positive as well as negative effects at the level of the region points out the complexity in regional restructuring processes towards sustainability. While the framework for green regional restructuring provided in article II involves several types of green path development, the mechanisms of path decline have been analyzed elsewhere (e.g. Blažek et al. 2020). Subject to further investigation would be to combine growth and decline of paths in regional and possibly also interregional contexts. What are reinforcing or impeding effects between outdated or unsustainable industrial activities and established or emerging green regional development paths? How can established paths renew as a result from interpath relations with emerging green paths and are competitive relationships more impeding for non-green or green paths? To what extent does agency shaping interpath relationships increases or decreases barriers to green path development?

Besides region-specific contexts, also industrial contexts have been widely acknowledged to matter for regional restructuring (Isaksen and Trippel 2017b). Industries differ markedly in the extent to which they rely on regional assets and markets. The more industries that make up a region's economy are linked into complex networks and relationships with firms, markets and institutional frameworks in other places, the more they will develop independently of one another (Martin and Sunley 2006). Does this indicate that a high importance of interregional interpath dynamics implies a low importance of regional interpath dynamics? Industries differ in many aspects, such as their knowledge linkages and how far knowledge flows over different geographical distances (Isaksen and Trippel 2017b). In addition, they differ in their needs for different types of assets, market access, and technology legitimacy (Binz and Truffer 2017). Positive and negative effects, as well as the strength of inter-path linkages and their wider regional effects can therefore be expected to vary

significantly depending on the industries under considerations and further research is needed to understand these differences.

Moreover, what has not been considered in the scope of this dissertation are interpath relations within value chains. For instance, under what conditions foster renewal activities in raw products, end products, distribution channels or types of usage that serve as input or output for each other green renewal activities in other parts of the value chain? Mäkitie et al. (2020) find that how strong path development is driven by such interdependencies also depend on sector characteristics. Overall, there is yet no comprehensive understanding of how interpath relations differ within and across value chains of specific industries.

This dissertation provides evidence that interpath relations can alter the direction and orientation of path development (Frangenheim 2022). To understand the right policy implications, we would have to investigate what direction or orientation of path development (and which interpath relations) would be most effective in terms of ecological value creation and at the same time is still economically rewarding for involved actors. The opportunity space of actors is highly place-specific (Grillitsch and Sotarauta 2020) and has to be informed by experience and learning of multiple actors, including civil society and users (Schot and Steinmueller 2018). To find the right direction and orientation of path development, we should involve those actors who hold precious knowledge on what constitutes place-specific green restructuring and who will then also be responsible for its implementation. To bridge scientific expertise with societal actors' perspectives requires the integration of scientific with practical knowledge as it can be achieved through transdisciplinary research approaches. To co-learn conditions of change and co-produce solutions to renew certain industries or create reinforcing relations would help to better assess opportunities and challenges to reach green regional restructuring and provide more tangible regional policy recommendations.

From regional to interregional perspectives

This dissertation has emphasized that relations between paths resulting from manifold multi-scalar interdependencies may evolve across regions. Some regions, especially peripheral ones, tend to be dependent on external investments and the inflow of knowledge and technologies from external sources to create new paths (Isaksen 2015). As has been shown by article IV

supportive relationships between urban and rural paths may support path development not only in peripheral but also in urban regions. The emerging urban insect-based food path reorients towards peripheral aquaculture to benefit from reinforcing interpath relations. The new perspective on interpath relations across regions thus reveals some unresolved questions, which require further research: Under which conditions can (green) regional industrial path development be supported in other places? What are specificities of interpath relationships between the same and different types of regions? How do broader national or international institutional contexts affect interpath relations across regions? To answer these questions could bring us closer to more nuanced and fine-tuned regional typologies.

The decline of old industrial paths is a much-contested issue in sustainability debates, especially in industrialized and specialized regions where a large proportion of the working population is engaged in activities related to dominant industries. The question is, how to degrow such paths in a socially compatible manner? Investigating how positive interpath relations across regions may be used to mitigate negative effects of path decline on regions would provide valuable answers to this policy problem.

Moreover, besides uni- or bidirectional effects of interpath relations, other, more differentiated forms have been conceptualized. Sandén and Hillman (2011) define besides competition, five other basic modes of interactions, such as symbiosis, neutralism, parasitism, commensalism and amensalism. Overall, to better understand interpath relations in space would prepare the ground for more thorough considerations of multi-scalar policy alignment and challenges and barriers of up- and outscaling mechanisms of green industrial activities.

Foundational economies, such as the food sector

Rising societal challenges and increasing intra- and interregional inequalities point to the need to review our main approach to study regional development and innovation and to improve related policy recommendations (Tödtling and Trippel 2018; Sjøtun and Njøs 2019; Hansen 2022). This also includes to direct our attention to foundational sectors that are not characterized by high technologies but rather support our everyday life in local or regional cycles (Bentham et al. 2013). I contributed to this broad effort through the provision of original empirical evidence and conceptual analysis of the food sector. Nevertheless, my conceptualization has been strongly related to existing EEG

and RIS frameworks. Proponents of agricultural innovation system studies, however, emphasize less consensual and streamlined processes involving multiple solutions to tackle societal challenges. Further engagement with this literature would be valuable.

Moreover, the empirical results of article IV have to be seen against the background of the food sector context. There exists much evidence on the interconnectedness of the food sector to other fields such as energy, water, or mobility at different geographical scales (Klerkx and Begemann 2020). To what extent are the results applicable to interpath relations with other industries or to those within other sectors? To verify the framework and better understand interpath relations across regions, further context-sensitive abstraction from other industrial settings is therefore needed.

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Article I

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Beyond the *Single Path View*: Interpath Dynamics in Regional Contexts

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abstract

Recurrent economic and financial crises, globalization, digitalization, and climate change are posing major challenges for regional economies to constantly renew their industrial structures. Over the past few years much progress has been made in understanding how new path development unfolds in a regional context. Earlier contributions to the path development literature have acknowledged that multiple industrial paths developing within a region are interdependent and coevolving. However, most conceptualizations and empirical analyses to date have mainly been focused on one new path or path development activities in one nascent industry only. Potential relationships between emerging paths have received little attention, and, as a consequence, little is known about how new paths shape each other's evolution. This article draws on recent contributions that broaden conventional perspectives on regional structural change and develops a framework to analyze the dynamic interdependencies between multiple new regional growth paths. We explore the nature of interpath linkages and discuss the role of agency in creating or shaping the relationship between linked paths to be either supportive, competitive, or neutral toward each other. By means of illustrative empirical examples, we show that interpath relationships in a regional context are a significant phenomenon to be considered in regional structural change and conclude by discussing policy implications and identifying avenues for future research.

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Regions across the world are confronted with the constant challenge to renew their industrial structures and to develop new growth paths to compensate for the stagnation and decline of mature industries. Recurrent economic and financial crises, globalization, digitalization, and climate change are further intensifying this pressure. This has sparked interest into the factors that favor and hinder processes of *new regional industrial path development* (or *path creation* as it is also termed in the literature), which is referred to in this article as “the emergence and growth of new industries and economic activities in regions” (MacKinnon et al. 2019, 114).

Arguably the question of which economic activities settle and become industries in which regions and why some regions appear to be better at attracting new industrial growth paths than others is at the core of economic geography (Storper and Walker 1989; Chapman and Walker 1991). Over the past few years much progress has been made in understanding how and where new regional industrial paths emerge and develop over time. An industrial path can be defined as “a set of functionally related firms and supportive actors and institutions” (Steen and Hansen 2018, 191; see also Binz, Truffer, and Coenen 2016). This article focuses on emerging paths, that is, industries that are in an early path development stage (Martin 2010).

A growing body of literature in evolutionary economic geography (EEG), innovation studies and adjacent academic fields has produced new insights into the forms, mechanisms, and geographic patterns of new path development. EEG frameworks, most notably the development of a *path as a process* model (Martin 2010) and the literature on related and unrelated diversification (Boschma 2017) have proven to be powerful approaches in this regard. Recent work has forged a link between EEG and the regional innovation system (RIS) concept to better understand why some types of regions are more likely than others to develop new growth paths (Isaksen and Trippl 2017; Trippl, Grillitsch, and Isaksen 2018). Other scholars have proposed a stronger integration of EEG with the global production network (GPN) approach (MacKinnon 2012), geographic political economy frameworks (Dawley 2014; Dawley et al. 2015), and the technological innovation system (TIS) concept (Binz, Truffer, and Coenen 2016) to incorporate a wider

set of factors into analyses of new path development (Hassink, Isaksen, and Trippel 2019; MacKinnon et al. 2019).

Earlier contributions to the path development literature have identified the analysis of multiple industrial paths developing within a region as a promising field of research (Martin and Sunley 2006, 2010), not least because there is clear evidence that regions, in particular those with diversified economic and institutional structures and strong innovation capacities (Isaksen and Trippel 2016; Xiao, Boschma, and Andersson 2018), tend to host a variety of new path development activities in different fields. Simmie et al.'s (2008) analysis of the Cambridge region (UK) is telling in this regard. The authors identify not fewer than fifteen new industrial paths that developed in four waves between 1971 and 2001 in that region. They investigate local conditions and a range of factors affecting the emergence (as well as stagnation, resurgence, and decline) of different paths, paying however insufficient attention to the extent and ways in which multiple paths influenced each other over time.

The vast majority of conceptualizations and empirical case studies have adopted a *single path view*, that is, they have been focused on one path or new path development activities in one industrial sector only. This focus has only recently been criticized (Steen and Hansen 2018; Hassink, Isaksen, and Trippel 2019; MacKinnon et al. 2019) and a comprehensive discussion of interpath dynamics and an outline of respective implications for empirics and policy are still missing. With this article, we seek to stimulate the debate over interpath interactions.

EEG studies of industrial diversification aiming at uncovering regularities or patterns of co-occurrence by means of extensive research designs have indeed been concerned with path interdependencies. However, they focus either on existing industries, exploring to what extent they are related to each other (related versus unrelated variety) or investigate in which ways emerging paths are related to the existing industrial base (related versus unrelated diversification) (Boschma and Frenken 2011; Boschma 2017). As a result, less attention has been paid to the relation between simultaneously emerging regional industrial paths, and as a consequence little is known about how they shape each other's evolution.

Inspired by contributions at the intersection of EEG and RISs to explain new path development, this conceptual article aims to shed light on the meaning and nature of relationships between multiple new regional industrial paths. While our framework is broad enough to include any form of interpath relationships, we intentionally focus on emerging paths to specifically understand challenges and potentials in regions that experience diverse new path development activities. We explore the nature of interpath linkages and suggest that agency may create or shape supportive, competitive, or neutral relationships between linked paths. We also discuss the policy implications and challenges that emanate from this perspective. Understanding interpath relationships provides a sound basis for a broader, more integrative innovation policy approach, and points to the need to proactively build connections and balance competition and cooperation between emerging paths.

The remainder of this article is organized as follows. The first section starts out by providing a short overview and critical appraisal of current accounts of new path development and multiple (regional) industrial paths. This is followed by a discussion of recent advances made in the EEG and innovation studies literature, which offer a more comprehensive understanding of regional industrial path development and—as will be shown—serve as a stepping stone for a broader conceptualization of interpath dynamics. The second section examines conceptually—and illustrates by empirical examples—the nature and strengths of interpath linkages, and asserts that

emerging regional paths are more often than not linked to other regional paths. In the third section, we explore the role of agency in shaping supportive, competitive, or neutral relationships between new paths. The concluding section discusses implications for innovation policy and suggests avenues for further research.

New Regional Industrial Path Development and Interpath Dynamics

Since Martin and Sunley's (2006) seminal article on path dependence and regional economic evolution, EEG has made significant progress in explaining processes of regional economic change. This section provides an overview on current debates of new path development, specifically focusing on emerging paths. We also provide a synthesis of what is known from the EEG literature on the relationship of multiple industrial paths, and how this might be enriched by more recent work on new path development and findings from innovation system studies.

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Current Accounts of New Regional Industrial Path Development and Relatedness

Key contributions to evolutionary economics have been made by theorists of path dependency (David 1985; Arthur 1989) who emphasize historic events and attribute change in economies mainly to external shocks. Martin (2010) deviates from these canonical perspectives and suggests viewing path development as an ongoing process where change is understood as inherent. By integrating path dependency in an evolutionary perspective on industrial change (Martin and Sunley 2006, 2010), current EEG models acknowledge that new paths build on assets inherited from previous ones. The process through which new industrial paths emerge out of technologically or skill-related preexisting industrial structures (termed *regional branching* or *related diversification*; Boschma and Frenken 2011; Neffke, Henning, and Boschma 2011) has received enormous attention over the past few years. More recently, scholarly work has begun to explore the role of *unrelated diversification*, that is, the development of new industries that are unrelated to the existing regional industrial base (Boschma 2017).

A number of EEG contributions do recognize the possibility or even inevitability of multiple industrial paths developing within a region (Martin and Sunley 2006; Simmie et al. 2008; Martin 2013). Martin (2013) suggests that such multiple paths ought to be seen as interdependent, and potentially mutually reinforcing and coevolving. Martin and Sunley (2006, 411) define as a key question whether different paths can coexist within a region and what the nature of "interpath coupling" is. They also question the aggregate effect of the interrelatedness and interdependency between multiple paths for regional path dependency and suggest that "path interdependence" may occur "where the path-dependent trajectories of particular local industries are to some degree mutually reinforcing" (Martin and Sunley 2006, 413).

Path interdependencies are also recognized in scholarly accounts of related variety and in the literature on regional diversification. By looking at trade data, sector classifications, patent data, labor flows, or co-occurrence (see Content and Frenken 2016 for a detailed overview on data sources in related variety studies), path interdependencies in the form of related variety between established industrial paths have been described and analyzed. Whereas related versus unrelated variety captures the extent of how industries that exist in a certain region are related to each other, related

versus unrelated diversification observes in which ways emerging regional paths are related to established ones (Boschma and Frenken 2011; Boschma 2017).

These accounts of interpath dynamics are not without their shortcomings. First, potential relationships between multiple new paths have so far been neglected in the literature on new path development and industrial diversification. Second, existing concepts only consider positive relationships between paths whereas negative path interdependencies are left out (Boschma et al. 2017; Hassink, Isaksen, and Trippel 2019). Third, interpath linkages are narrowly conceptualized. Technological and skill relatedness take center stage at the expense of other forms of interpath relations. What is more, conventional perspectives appear to view interpath relations as being static and are thus poorly equipped to provide a meaningful assessment of dynamic interactions between several paths.

The article looks at the relationship between emerging paths, since this is a largely disregarded aspect in the literature. As will be argued in “Toward a Broader Understanding of Linkages between Multiple (Regional) Industrial Paths,” in analyses of interpath dynamics, it is vital to consider further assets beyond knowledge and skills, and to acknowledge that assets may have local and external sources. With our framework, we intentionally take into account the possibility of negative interpath relationships and correspondingly not only look at positive linkages between paths but also recognize rival relationships. In light of this, it is of vital importance to attribute assets, as well as markets, a prominent role in discussions about interpath dynamics.

Toward a Broader Understanding of Linkages Between Multiple (Regional) Industrial Paths

This article aims to deepen the analysis of new path development by looking at relationships between new industrial growth paths in a regional context. Before doing so, we first need to specify what the key characteristics and challenges of the early development stage of a new path are, what assets are needed, and which activities and processes are usually involved. The early path development stage may be seen as unfolding in different phases, each with different conditions, triggers, and challenges (Gustafsson et al. 2016). Martin (2010) divides the early path development stage into a *path creation phase* and a subsequent *path development phase*. The former is characterized by experimentation and competition among local agents. The latter is based on local increasing returns and network externalities. He asserts that new path development is about identifying, harnessing, and converting historically evolved local conditions to match new market opportunities. Similarly, Boschma (2017) argues that new industrial paths are embedded in region-specific capabilities; they result from activities by entrepreneurs who draw on and combine existing capabilities.

In conventional EEG frameworks, the early stage of path development is thus often a matter of the deployment and conversion of existing local assets and capabilities. Recent work suggests that repurposing of existing assets is often complemented by other activities that also lead to a modification of the regional asset base. Scholars have pointed to the significance of creating new assets locally and importing and anchoring nonlocal industrial and knowledge assets, financial investment, and legitimacy (Tödtling and Trippel 2013; Dawley 2014; Dawley et al. 2015; Binz, Truffer, and Coenen 2016; Neffke et al. 2018; Trippel, Grillitsch, and Isaksen 2018).

Following Martin (2010) we argue that new paths encompass a *path creation and path development phase*. We relate with emerging EEG perspectives by acknowledging that the capabilities and assets needed for new path development may come from local

and external sources (Trippel, Grillitsch, and Isaksen 2018), or they may still have to be created regionally or locally in the early path development phase(s). We incorporate two more approaches to broaden EEG perspectives on regional structural change, namely, (1) emerging perspectives that extend the focus on assets beyond industrial and knowledge-related ones (Maskell and Malmberg 1999; MacKinnon et al. 2019; Trippel et al. 2019) and (2) the role of different actors engaging in local and nonlocal market formation to enable the development of new paths (Binz, Truffer, and Coenen 2016; Binz and Truffer 2017).

36 First, in line with emerging perspectives, we advocate a broader understanding of local conditions (Martin 2010) and territorial capabilities (Boschma 2017) than that suggested by established EEG perspectives. These place-based characteristics could involve a variety of local assets, ranging from natural resources to infrastructural factors, technological and other forms of knowledge, skills, capital, innovation capacity, institutional endowments, and networks (Maskell and Malmberg 1999; Dawley 2014). Acknowledging that various new regional paths may be linked through their dependence on broadly defined assets and/or markets, we accord with recent work that argues for taking into account other forms of relatedness than technological and skill relatedness, including institutional relatedness, natural resource relatedness, and market relatedness (Carvalho and Vale 2018; Hansen, Klitkou, and Tanner 2018). Second, we widen the EEG perspective to actors who engage in market formation beyond the firm, and recognize that markets for radically new technologies and products are also actively supported by state actors (Kemp, Schot, and Hoogma 1998; Dewald and Truffer 2011; Karnøe and Garud 2012; Binz, Truffer, and Coenen 2016).

Arguably, two or more paths may interrelate at several dimensions, including diverse firm and nonfirm actors, networks, institutions, and markets. Originating from our analytical interest in the role of agency in shaping interpath relations, we highlight modification processes of broadly understood assets and markets. In this way, we acknowledge that new path development may involve a broad set of activities undertaken by heterogeneous actor groups. Developing new paths is not only about the creation and diffusion of sector-specific knowledge and skills. The literature reviewed above suggests a broader conceptualization to include a wide range of activities (those aiming at institutional change, sourcing, mobilizing, and anchoring of diverse other local and nonlocal assets, as well as the creation of local and nonlocal markets) that may be essential in nurturing a new growth path.

This allows for considering other types of interpath linkages than those discussed in conventional EEG perspectives. Both, positive and negative impacts (in the form of competition for scarce assets or markets) may be frequent phenomena. Similar ideas can be found in the TIS literature. Bergek et al. (2015) point to a coevolution of several TISs in the form of competition or complementarities. In that sense, the composition and success of possibly related industries in regions decide upon their actual situation at a particular time. Moreover, interrelationships change over time, and we agree with Bergek et al. (2015) who consider the early phase of a TIS as being particularly predisposed to the influence of other TISs. This can be explained by the fact that emerging paths often have difficulties in terms of their initial performance and cost competitiveness.

A precondition for interactions between emerging technologies or TISs is that they either provide similar outputs, that is, they fulfill the same function, or they are horizontally related because they draw on the same inputs in the form of assets (Sandén and Hillman 2011; Bergek et al. 2015). Sandén and Hillman (2011) point to the important differentiation between nonexclusive goods (e.g., nonpatented

knowledge) or such goods that are in abundant supply. They further specify that neutral relationships (i.e., simple coexistence of paths) may be found, resulting, for instance, from different geographic orientation.

Our approach puts emphasis on interpath linkages resulting from the access to markets and the assets available within a RIS. RISs vary in terms of assets and organizational constellations (actors and networks) and thus in their capacity to actively support new growth paths. More precisely, they differ in their capacity to (1) modify the local asset base and to import and anchor nonlocal assets (Binz, Truffer, and Coenen 2016; Tripl, Grillitsch, and Isaksen 2018) and (2) access local as well as nonlocal markets (Binz and Truffer 2017). Complementing the RIS perspective, which sheds light on the *availability* of assets and the market potential within the region, by an industry perspective, allows considering also the *transferability* of assets across space (for example, spatially *sticky* tacit versus codified, globally available knowledge; Asheim and Isaksen 2002) and varying opportunities to access distant markets (see, e.g., Binz and Truffer 2017). As Binz and Truffer (2017) remind us, industries differ substantially in the extent to which they rely on regionally available assets and regional markets. Distinguishing between local (prevalence of doing–using–interaction mode) and global (dominance of science–technology–innovation modes) *innovation subsystems*, on the one hand, and local (customized markets) and global (standardized markets) *valuation subsystems*, on the other hand, Binz and Truffer (2017) identify four ideal-type system configurations: (1) spatially sticky systems (both the innovation subsystem and the valuation subsystem are locally configured), (2) production-anchored systems (local innovation subsystem combined with a global valuation subsystem), (3) market-anchored systems (global innovation subsystem combined with a local valuation subsystem), and (4) footloose systems (both innovation and valuation subsystems are globally configured). Since our interest is in interpath linkages in a regional context, our analysis does not capture footloose industries. It is, however, also worth mentioning that in the early phases of path development—which is in focus in this article—many industries show a relatively strong reliance on regional assets and markets (see, e.g., Feldman 2000; Binz and Truffer 2017).

We argue that agency can play a major role in shaping interpath collaboration and competition (or its avoidance) for markets and assets within or outside the RIS. Before elaborating in more detail on intentions and outcomes of agency in the context of interpath relationships, we first shed light on the nature and strength of interpath linkages in regional contexts.

The Nature and Strength of Interpath Linkages in Regional Contexts

Our point of departure is to consider the nature and strength of interpath linkages in a regional context being determined primarily by the respective paths' reliance on markets and broadly understood regional assets. To unpack the nature of interpath linkages in a regional context, we thus follow Sandén and Hillman (2011) and Bergek et al. (2015) and differentiate between two key dimensions, the market dimension (demand side) and the asset dimension (referring here to assets required for developing novel products and solutions, reflecting the supply side). Incorporating both dimensions into the analysis is crucial and well in line with recent calls in the innovation studies literature to complement conventional *production-side driven explanations* of innovation-based path development by accounts of the demand side and processes through which novel products or technologies become a valuable solution for users

(Jeannerat and Kebir 2016). Binz and Truffer (2017) note that market access, financial investment, and legitimacy are key elements of such valuation processes. In our analysis, the market dimension is reflected in the question whether or not two or more paths produce the same output (or function), that is, goods, services, or solutions that target the same market. The asset dimension refers to place-based characteristics in the form of input factors needed in the development and production process of goods, services, or solutions, including, for instance, natural resources, technological and other forms of knowledge, skills, financial capital, and so on). In line with Sandén and Hillman (2011), we distinguish between scarce and abundant (nonexclusive) assets. If scarce regional assets are accessed by actors in one path, they cannot be used in other paths. Examples are skilled labor, private risk capital, or real estate. Abundant assets imply that their use in one path does not restrict their use in other paths (e.g., nonpatented knowledge, place-based values or norms). We argue that the specific characteristics of new paths concerning these two dimensions crucially influence the nature of interpath linkages and (potentially) resulting relationships between emerging paths (see Table 1).

38 The strength of linkages between several emerging regional industrial paths depends on how strongly they rely on the same markets and/or the same scarce or abundant assets. Paths that rely on the same markets and on the same scarce assets are *very strongly linked* (box A in Table 1). Paths that target the same market but do not require the same scarce assets are *strongly linked*. They may use the same abundant assets (box B, Table 1), different scarce assets (box C, Table 1), or different abundant assets (box D, Table 1). Paths that are linked through the market dimension have an inherently competitive relationship. By means of agency, the competitive relationship can either be further reinforced to the benefit of one (or several) path(s), or it can be weakened and turned into a neutral relationship. Empirical findings provide evidence that strongly linked paths can also enter supportive relationships (cf. “Shaping Interpath Relations: The Role of Agency”).

Paths that offer solutions to different markets but rely on the same scarce assets are *strongly linked* through these assets (box E in Table 1). The inherently competitive relationship may, by means of agency, be shifted toward supportive, more competitive or neutral relationships. Another category of linkages is among paths that rely on different markets and draw on the same abundant assets (box F in Table 1). They are *weakly linked* and their relationship may be neutral in general but can, under certain circumstances, also be turned into a supportive one.

Linked paths in a region may affect each other in manifold ways. The first scenario, where different paths have very strong linkages, refers to emerging industries that draw on the same scarce assets and provide for the same market (box A in Table 1). An example is the emergence of different renewable energy paths in Germany (Jacobsson and Lauber 2006). Biogas, wind, and solar power all profited from financial resources, guidance, and legitimacy provided by the state with the feed-in tariff regulation¹ and offer products for the same market (energy) (Bergek et al. 2015). Both scarce assets (particularly national financial resources available in all German Bundesländer) and the focus on the same market signified very strong interpath linkages (highly competitive relationships) between the emerging renewable energy paths.

¹ The feed-in tariff regulation has been designed to accelerate investment in renewable energy technologies by offering guaranteed prices for fixed periods of time to renewable energy providers based on the cost of electricity generation per technology (Couture and Gagnon 2010).

Table I

Interpath Linkages and Relationships

	Same Scarce Assets		Same Abundant Assets		Different Scarce Assets		Different Abundant Assets	
Same market	Linkages	A Very strongly linked (through both markets and assets)	B Strongly linked (through markets)	C Strongly linked (through markets)	D Strongly linked (through markets)	D Strongly linked (through markets)	D Strongly linked (through markets)	
	Relationships	Competitive relationship <i>Agency oriented at:</i> • further strengthening competition • creating supportive relationship • neutralizing relationship						
Different markets	Linkages	E Strongly linked (through same scarce assets)	F Weakly linked (through same abundant assets)	G Unlinked	H Unlinked			
	Relationships	Competitive relationship <i>Agency oriented at:</i> • further strengthening competition • creating supportive relationship • neutralizing relationship	Neutral relationship <i>Agency oriented at:</i> • creating supportive relationship	Neutral relationship	Neutral relationship	Neutral relationship		

In the second scenario where paths draw on the same scarce assets, but provide for different markets (box E in Table 1), interpath linkages are still strong in nature. Much depends on the extent to which several paths are in need of the respective regionally available assets. Miörner and Trippel (2017) provide an example of two new paths (the digital gaming industry and the new media industry) in Southern Sweden that serve different markets but are strongly linked through a dependence on the same scarce human assets, namely, software specialists.

In further scenarios, multiple emerging paths draw on (same or different) abundant assets or different scarce assets but offer products to the same market (boxes B, C, D in Table 1). As noted above, being linked via markets leads to competitive interpath relationships. The cases of alternative transport fuels in Sweden (discussed in "Shaping Interpath Relations: The Role of Agency") and of the Australian urban water sector are exemplary for competition over markets. The case of the urban water sector in Australia suggests that as a response to extreme dry weather conditions, two paths (recycling technologies for wastewater and large-scale seawater desalination plants) have emerged to provide the needed water (Fuenfschilling and Truffer 2016). Market competition shaped path development activities even more when the multiyear drought ended and thus the market declined.

When two or several paths rely on the same abundant assets but not on the same markets (box F in Table 1), they may be weakly linked by the particularities of their environment, characterized through the composition of abundant assets. Exemplary is the rise of creative industries, ranging from media, advertising, design, and fashion in mixed-use urban neighborhoods. The type of knowledge needed by creative industries is characterized by a strong tacit component and is referred to as symbolic knowledge (Asheim 2007). It is "incorporated and transmitted in aesthetic symbols, images, (de)signs, artefacts, sounds and narratives" (Asheim 2007, 226). Creative industries draw on abundant assets, such as cultural facilities, public transportation, streets with great walkability, but also youthful in-migration found in highly diverse environments (Jacobs 1961; Spencer 2015; MacKinnon et al. 2019) where symbolic knowledge can circulate and be exchanged between actors.

Arguably, emerging regional paths are rarely *unlinked* (boxes G and H in Table 1), which would mean that they rely on neither the same markets nor the same scarce or abundant assets. Unlinked paths refer to the mere coexistence of multiple emerging paths in a region that develop independently of one another. New industrial paths remain unaffected by the rise and growth of other paths in the region. Their relationship is neutral.

The strength of interpath linkages may change over time as the characteristics of the paths themselves change, their markets evolve, or needed assets may be used up or newly added to the regional asset base (Sandén and Hillman 2011; Musiolik et al. 2018). Besides changing context conditions (as in the case of the Australian urban water sector), agency is an important driver of shifting linkages to specific relationships.

Shaping Interpath Relations: The Role of Agency

In this section we seek to unravel the important role of agency in shaping the relationship between linked paths. After discussing scholarly contributions on agency and purposive behavior, which have recently been integrated into EEG and innovation system frameworks (Sotarauta 2016; Isaksen and Jakobsen 2017; Carvalho and Vale

2018; Isaksen et al. 2018), we analyze the rationale for and the actions aimed at establishing specific interpath relationships.

Agency concepts have only recently been taken up in EEG and innovation studies (Strambach and Halkier 2013; Martin and Sunley 2015; Boschma et al. 2017). Drawing on the seminal work by Emirbayer and Mische (1998), recent contributions on agency suggest considering not only the past and the present but also ideas and visions of the future (Steen 2016; Sotarauta and Suvinen 2018; Grillitsch and Sotarauta 2019). Emirbayer and Mische (1998) argue that actors who encounter problematic situations that require the exercise of imagination and judgment, gain a reflective distance from received patterns, which allows for greater imagination, choice, and conscious purpose. Assuming that the dominant temporal orientation of actors belonging to emerging paths is the future, agentic orientation does “not merely repeat past routines” (Emirbayer and Mische 1998, 983), but rather invents “new possibilities for thought and action” (Emirbayer and Mische 1998, 984). Of particular importance for setting directions in emergent paths are therefore actors’ expectations about future development in agentic decision-making processes. Agency for new path development has been conceptualized as being intentional or purposive (Sotarauta 2016; Sotarauta and Suvinen 2018). Nevertheless—and in line with Emirbayer and Mische’s (1998) assessment that besides purpose, routine and judgment are also important agency dimensions—the strategies of agents to develop specific outcomes at the system level are said to be dependent on initial asset constellations (Musiolik et al. 2018).

Garud and Karnøe (2003) employ the notion of bricolage (see also Carvalho and Vale 2018) to accentuate that multiple actors take part in innovative activities, the development of complementary assets, and microlearning processes. The concept of distributed agency has recently been incorporated in conceptual discussions of path development (Boschma et al. 2017; Isaksen et al. 2018). Agency involves a broad range of actors including firm and firm-related actors, as well as organizations of collective agency from the state, governance, and community, who “anticipate, react and transform” regional development processes strategically (Bristow and Healy 2014, 928–29). The existence of long-term links between heterogeneous actor groups in the form of networks enables them to join forces (Musiolik, Markard, and Hekkert 2012) to eventually shape markets and modify the region’s asset base.

Agency that nurtures new path development is understood by taking a RIS perspective, which is crucial when considering interpath relationships in a regional context. Literature on regional restructuring suggests that new path development calls for RIS changes and modification of the regional asset base (Tödtling and Trippl 2013), brought about by what in this strand of literature is called *system level agency* (Isaksen and Jakobsen 2017; Isaksen et al. 2018). Changing assets or market configurations in the RIS can exert influence on more than one path. This is due to the fact that the region’s support structures containing research and education programs, a specific skill base, dominant policy approaches, and institutional set-ups may be used—as emphasized throughout this article—by several paths. What is more, several paths may also produce for the same market. Furthermore, the RIS perspective enables consideration of multiple actors involving firm and nonfirm actors such as research and educational institutes, policy actors, as well as support organizations for analyzing path development activities (Trippl, Grillitsch, and Isaksen 2018; Hassink, Isaksen, and Trippl 2019). These actors can either belong to one particular regional industrial path, or—what we want to specifically emphasize—they come from different industrial paths and undertake agency through interaction.

Building on the arguments raised above, our conceptualization of interpath relationships takes into account the role of agency in molding assets and/or shaping markets to the benefit of path development. We understand RIS transformation as a result of asset modification and market creation. Such processes may be initiated by actors from one emergent path (see, e.g., the case of the gaming industry in Scania; see “Toward Neutral Relationships”) or they might result from interpath collaboration (Musiolik et al. 2018) as is the case for several renewable energy paths in Germany (see “Toward Supportive Relationships”). We specifically focus on agency undertaken by multiple actors who build, access, and deploy assets or shape markets with the aim of fashioning interpath relationships. Since internal and external influences play a role in shaping new path development, that is to say, new paths are part of complex multiscalar processes of industry formation (Markard and Truffer 2008; Binz and Truffer 2017), local as well as nonlocal linkages might be strategically used to mold relationships to other new paths.

42 As a result of agency, the relationship between linked paths may take various forms (cf. Table 1). When paths are linked through reliance on the same scarce assets, actors from one path may strengthen competitive pressure on other paths, or they may create supportive relationships by joining forces to modify these assets. The same strategic options are available when several paths compete for the same market. Paths that are weakly linked via the same abundant assets but do rely on different markets may join forces to modify the locally available abundant asset base. Neutral relationships do not only exist if paths are unlinked (see “The Nature and Strength of Interpath Linkages in Regional Contexts”), they might also be the result of neutralization strategies undertaken by actors belonging to one or several linked paths.

To exemplify potential rationales and strategic options to shape interpath relationships, we further elaborate on the cases of linked paths described in “The Nature and Strength of Interpath Linkages in Regional Contexts.” They show that as a result of agency, the strength of interpath linkages may increase or decrease over time, which may also be affected by the evolution of the respective paths. Interpath relationships may shift being supportive, competitive, or neutral (as in the case of renewable transport fuel paths, which initially supported each other in creating markets, were later subjected to market competition, and finally neutralized their relationship), or the three forms may even occur simultaneously (as in the case of renewable energy paths, which compete for financial resources and at the same time collaborate to strengthen legitimacy and to create markets).

Toward Supportive Relationships

Actors nurture new path development by purposely modifying assets and markets and thus transforming RIS structures. If such actors belong to different but linked emerging paths, establishing cooperative relationships to improve the support structure to meet their specific needs may be an obvious strategy. They might jointly create additional assets or modify existing ones through, for example, new educational programs or research activities at universities, work together to initiate institutional coevolution and change, or join forces to increase demand.

A prominent example for collaboration between actors from multiple paths refers to the German feed-in tariff. Despite the fact that different renewable energy paths—that is wind power, solar, biogas—competed for the same public financial resources (cf. “The Nature and Strength of Interpath Linkages in Regional Contexts”), evidence suggests that wind and solar associations and advocacy coalitions, including

conventional industry associations as well as independent environmental organizations,² at one point decided to work together “to initiate, maintain and strengthen the feed-in tariff” at the national level (Bergek et al. 2015, 56; see also Jacobsson and Lauber 2006). Accelerated by the nuclear accident in Chernobyl in 1986, the German parliament exerted pressure on the government to make funding available for demonstration and research projects (Jacobsson and Lauber 2006). Later, massive demonstrations organized by broad coalitions of metalworkers, farmers, and church groups, as well as environmental activists and solar and wind associations, led to a reapproval of the feed-in law and thus not only substantially strengthened legitimacy, value, and vision-building for all renewable energy paths but also removed uncertainty resulting in further market expansion (Jacobsson and Lauber 2006). The Renewable Energy Sources Acts in 2014 and 2017, however, replaced feed-in tariffs by a system of tendering, which undermined the potential for supportive relationships between solar and wind paths. Similar observations have been made by Sandén and Hillman (2011, 411) in Sweden for renewable transport fuels where during the path creation phase, farmers’ organizations purposely joined forces to lobby “for more favorable policies, such as general tax exemptions that were to benefit several ... fuels, mainly ethanol, biogas and rapeseed methyl ester.” Moreover, the authors provided evidence that various actor groups and networks (including firm actors, associations, and advocacy groups) that had been formed around “ethanol and methane vehicles helped one another to stimulate the build-up of a market for ‘clean vehicles’” (Sandén and Hillman 2011, 411)

An example that demonstrates that different paths that are weakly linked by abundant assets may also establish a supportive relationship is provided by MacKinnon et al. (2019) for the creative industries in Berlin. Diverse start-ups, freelancer and other innovative entrepreneurs from media, creative arts, and entertainment, information and communication technologies, education and research, and tourism created alternative and experimental spaces where these new actors could meet and benefit from building connections to established players such as major research universities, corporate headquarters, and philanthropic foundations. The Berlin state complemented these activities with respective campaigns and branding activities. As a result, abundant assets, such as alternative cultural norms and practices, have been created through various activities undertaken by actors with similar objectives, and in this way successfully supported the development of diverse cultural and media-related paths in the city.

Strengthening Competitive Relationships

Actors operating in emerging paths that draw on the same scarce assets or that seek access to the same market may opt for activities that reinforce the inherently competitive relationships. This could take two forms. On the one hand, actors from one path may actively seek to build assets for their own needs (Miörner and Trippel 2017). On the other hand, they might aim to undermine the development of other paths. Associated activities to reinforce competition could include organized lobbying. Such activities could also be aimed at de-legitimizing the rivals for local, regional, and national assets, for example, funding schemes.

² Among the key actors were the Institute of Ecology, which provided counterexpertise to nuclear power; the Förderverein Solarenergie, which developed the concept of cost covering payment in the feed-in regulation; and Eurosolar, a politically independent organization, which campaigned for the support of renewable energies within the political structure.

- 44 An example where agency strengthened the competition over markets between two emerging paths is the case of the recycling technologies for wastewater and large-scale seawater desalination plants in the Australian urban water sector (cf. “The Nature and Strength of Interpath Linkages in Regional Contexts”). Fuenfschilling and Truffer (2016) show how actors on behalf of both paths engaged in institutional work *for* their own path development as well as *against* the development of the competing path. For desalination plants, multinational water companies, some utilities, as well as farming and mining firms mainly advocated the water security argument, which has been considered much stronger than criticism about water quality, economic efficiency, and environmental and social sustainability. Destructive agency against desalination plants has in turn been undertaken by nongovernmental organizations and green parties who established “desalination as environmentally problematic,” by economists who framed the solution as “financially unsustainable,” and by expert economists and consultancy groups, who “advised against desalination” (Fuenfschilling and Truffer 2016, 308). Different research alliances, such as the Urban Water Security Research Alliance, the Australian Water Recycling Centre of Excellence, and the Centre for Water Sensitive Cities, together with scientific advisory boards and experimental projects (Rouse Hill and Salisbury), supported recycling technologies by constructing normative networks and mobilizing resources, advocacy, changing normative associations through the diffusion of information and technology demonstration, and theorizing water sensitive urban design. Destructive agency against recycling technologies in turn focused on a policy ban and on collectively organized political campaigns. In the small town of Toowoomba in Queensland, the strong competition over the urban water market in Australia culminated in a nondemocratic political decision that discriminated against the wastewater-recycling path (Fuenfschilling and Truffer 2016).

The case of several alternative transport fuels in Sweden described by Sandén and Hillman (2011) is also an instructive example for agency oriented toward deepening competition. Analysis of this case suggests that after an episode of interpath collaboration (manifested in joint lobbying for favorable policies and building up the relatively small market for clean vehicles [see “Toward Supportive Relationships”]), a period of increasing interpath competition for markets at the municipal level followed. Once both industries have entered the development phase, infrastructural needs forced policy actors at the urban level to focus their political attention on one alternative fuel only. This has led to a change of relationships from being collaborative toward becoming more competitive, reflected in increasing attempts by actors belonging to different paths to influence the municipalities’ choice of alternative fuels through lobbying and legitimization activities.

Toward Neutral Relationships

RIS structures can hinder path development if spatially sticky scarce assets are effectively bound in other paths. In order to escape or to reduce the resulting competition caused by other emerging paths that rely on the same assets and/or markets, actors might try to *unlink* their industrial path from others. One strategy could be to simply *change geography* in order to escape competition over markets by supplying a different region. Another strategy would be to reconfigure the RIS by creating additional assets to mitigate the scarcity of resources and thereby to ensure that several emerging paths have access to the required assets. This can take various forms, including the provision of funding, educational facilities that build human assets, or support programs that

provide infrastructural assets. Policy actors or intermediaries might strategically refrain from modifying assets in a way that benefits one path at the expense of other paths. In this way, they intentionally keep the competitive relationship weak and thus work toward a neutral relationship, thereby enabling the possible survival of a diversity of paths.

Sandén and Hillman (2011) show for the case of different alternative transport fuel paths in Sweden, that after the short period of competition at the municipal level (see “Strengthening Competitive Relationships”), the different paths have at one point neutralized their relationship through the creation of different geographic niches. Urban administrative actors being influenced by the different actors lobbying for their respective paths played a key role in this regard by prioritizing particular transport fuel paths over others, thus influencing which path has further developed in different municipalities.

As shown in “Shaping Interpath Relations: The Role of Agency,” the development of the digital gaming industry in Scania (Sweden) has suffered, amongst other things, from a competition over scarce assets in the form of policy support and human assets. Miörner and Trippl (2017) note that over time, the gaming industry has nevertheless experienced rapid growth, including high-profile acquisitions. One reason why policy makers ignored the specific needs of the gaming industry in comparison to other nascent industries was their sense that the emerging path is not a “serious business” and they intentionally refrained from creating new support organizations and initiatives (Miörner and Trippl 2017, 490). A local private entrepreneur tackled this shortcoming by establishing an annual game development conference (called Nordic Game Conference [NGC]), which marketed Scania as a “game development region” (Miörner and Trippl 2017, 491). Circumventing the regional policy level, support for NGC was mobilized at higher spatial scales, more precisely, the Nordic Game Program funded by the Nordic Councils of Ministers. In this way, a first step to neutralize the gaming industry from the scarce asset *regional policy support* had been taken. When the need for skilled workers became more pronounced, the foundation of the advanced vocational training school, The Game Assembly, improved the situation for the emerging gaming path considerably. For this permanent new facility in the regional support structure, Massive Entertainment (one of the largest gaming firms in the region), an extraregional educational body, and other key actors (such as the Swedish National Agency for Higher Vocational Education) at the national level jointly enabled the establishment of the school that helped to educate workers. This was a second important step to escape from competition with the new media industry where the scarce human assets were bound. Finally, the establishment of a privately funded cluster initiative (Game City) initiated by a group of key industrial actors who mobilized support from both big and small game development firms has helped to coordinate actors, facilitate joint initiatives within the industry, and increase the awareness of the industry among policy makers at the regional level. Agency in this respect was directed toward the creation of new assets and enabled the further development of the emerging industry by overcoming barriers emanating from competition over skilled labor and regional policy funding with other emerging paths.

Conclusions and Implications

Recurrent economic and financial crises, globalization, digitalization, and climate change intensify the constant pressure on regions to renew their industrial structures and to develop new growths paths. We have argued in this article that it is important in

the context of new path development to concentrate not just on the emergence and development of single paths alone but to consider how multiple paths emerge within a region, how they are related, and which interactions and interdependencies determine their development. With this article, we seek to open the debate and hope to stimulate further research by proposing a basic framework.

46 EEG studies have been concerned with path interdependencies between existing industries (related versus unrelated variety) as well as with relations between old and new regional industries (related versus unrelated diversification). The interdependence between more or less simultaneously emerging regional industrial paths has, however, received limited attention in EEG and innovation studies. We argue that by taking a RIS perspective, it becomes obvious that not only the existing industrial base but also early path development activities occurring in other sectors have an influence on an emerging path resulting from the common need for diverse, possibly scarce assets and the potentially limited access to shared markets. Our analysis therefore suggests that the development of regional emerging paths depends on the nature and strength of linkages to other regional emerging paths, which is determined by two dimensions: the assets they draw on and the markets that they produce solutions for. Unlinked paths, in this perspective, are a rare phenomenon.

Regional restructuring requires changes in the support structures of the RIS and the regional asset base. In this article, we argue that interpath relationships play a role in developing assets and markets insofar as agency aiming at changing both dimensions for path development can result from actions taken from diverse actors belonging to different paths. Moreover, agency at the level of the RIS means a *modification* of the regional support structure that may result in favoring specific paths over others. In concrete terms, our framework considers that regional actors have to deal with various linked (and some unlinked) new paths. Dependent on their strategic aims and regional opportunities, they choose measures, which are directed at one of three types of relationships between paths: First, they may aim to promote cross-path collaboration to foster a supportive relationship in order to develop assets and markets, to exploit synergies, or to help legitimate novel solutions. Second, actors may seek to lobby and control assets in order to maintain dominance on a market and improve the competitive position of a specific path. Finally, agents may seek strategies, which result in a neutral relationship between paths. Paths can be unlinked by changing geography, seeking assets and markets elsewhere, thereby circumventing unwanted competition.

The novel perspective on interpath relationships proposed in this article may also add to current debates on new policy approaches for innovation and structural change. New path development ranks high on the agenda of regional, national, and supranational policy actors (Asheim, Boschma, and Cooke 2011; European Commission 2012). Innovation and industrial policies—smart specialization in particular—aim for the development of new regional specializations (that is, new paths) to ensure future growth (Foray 2014; Trippl, Zukauskaitė, and Healy 2019). The selection of *domains* of competitive advantage (that is, emerging industrial paths) in smart specialization strategies, is based on a thorough analysis of the specific regional or national innovation capacity. We contend that regional or national smart specialization strategies and place-based innovation policies more generally truly benefit from considering interpath relationships. This is due to the opportunity to take into account promising interpath relationships during the policy discovery process. Competition for assets and markets can be made visible to either be used as an enabling factor for path development or to inform policy makers about necessary corrective actions.

Policy should play a strategic and proactive role in (1) balancing competition, cooperation, and neutralization between new paths; and (2) facilitating and coordinating interpath relationships. In terms of policy measures, this implies the development of diversified industrial and institutional infrastructures that support interpath cooperation or neutralization, and at the same time to find the right balance of nurturing and alleviating competition between emerging paths. Different types of regions have different rationales for strategically shaping interpath relationships. A rationale for encouraging mutually supportive relationships between linked paths may be to further integrate development in diversified regions with several linked paths. Policy instruments for encouraging supportive interpath relationships would include the facilitation of networking through, for example, innovation platforms as well as targeted support of combined applications. Explicitly bringing together actors involved in different new path development activities and removing barriers that prevent emerging paths from connecting are sound policy strategies. Supporting viable paths in diversified regions, where there are a number of different industries and that lack any particular industrial focus can be reached by fostering competition, for example, by means of competitive funding mechanisms. In specialized regions where existing industries are prone to lock-in, bringing new technologies to the market and preparing the respective paths for competition are critical aspects of regional development strategies. Explicitly supporting desirable paths by increasing their competitive position may be achieved through the use of nonneutral support schemes. At certain stages of development, a neutral relationship with other linked paths may be most beneficial. This could help to broaden the industrial base and enhance the future diversification potential and resilience of specialized regions. Policy instruments to neutralize interpath relationships could include the provision of additional resources, supporting linked paths in accessing resources and markets outside the region, or demand-side interventions through public procurement or the stimulation of private demand by offering subsidies and tax incentives. Overall, it is clear that there is not one strategic option for a whole region but that a combination of measures must be implemented, which should also be adaptive to changes in interpath relationships.

The aim of this article has been to broaden the debate over interpath dynamics in regional contexts. We have done so by contributing a framework that may be the basis for further research. Different types of regions have different rationales and capacities for fashioning interpath relationships. More in-depth studies of how place-specific characteristics influence the options available for actors to promote interpath relationships may be a subject of further research. Empirical research on the emergence of multiple paths within a region, ideally comparing dynamics across different types of regions and industries, would undoubtedly produce important insights to complement, refine, and improve the framework, and would help to enhance understanding of how policy actors and the state influence interpath dynamics.

In our framework, the nature and strength of interpath linkages depends on how emerging paths relate to local and regional assets and markets. Yet, we appreciate that the distinction made in Table 1 is often not easily drawn. Moreover, the regional asset base and markets, as well as the relationships between emerging paths themselves, are subject to change over time, as it has been shown for the case of alternative transport fuels in “Shaping Interpath Relations: The Role of Agency,” where, in the course of time, supportive competitive, and neutral relationships have been observed. It follows that regional path development and strategic choices for path relationships are not only place sensitive but also time sensitive, which would warrant closer examination, especially as part of empirical work.

We have alluded to the opportunity of linked paths that draw on assets from different local and nonlocal sources but have not in full considered the influence of multiscale influences and nonlocal actors on the interactions and interdependencies between multiple emerging paths in regions. The case of the gaming industry in Scania has shown how regional asset creation may be pushed by coalitions of local and national actors, bypassing regional policy makers. More research is required to better understand the roles played by extraregional actors (such as national or supranational policy actors, intermediaries, and support organizations operating at higher spatial scales, powerful multinational companies, and so on) in regional interpath development. In addition, the reliance on spatially sticky and regionally available assets and regional markets varies markedly between different industrial paths (Binz and Truffer 2017). While we considered the possibility to unlink regional paths by accessing distant markets or sourcing assets from abroad, more research is needed to unravel how and why industries differ in their capacity to employ such neutralization strategies.

Our framework also gives limited consideration on how sociocultural factors, local and regional institutional arrangements, and environmental factors impact the scope for strategic action of actors. Gaining a better understanding of the ways in which those factors influence agentic processes and interpath dynamics is a key challenge for future research.

Finally, our framework focuses on linkages resulting from the common reliance on scarce assets and/or markets. Interpath dynamics may, however, also be the result of input–output relationships, indirect interdependencies, or externalities (Martin and Sunley 2006). Moreover, actors may simultaneously engage in different business areas (that is, they may belong to and operate in several paths), which might considerably affect their goals and strategic orientation when undertaking agency. Future studies could open up to incorporate such wider sources of interdependencies and examine how they influence new path development. A broadening of the framework, including not only regional interpath dynamics between emerging industries—which was in focus in this article—but also interregional interpath linkages, as well as relations between mature paths or between mature and emerging paths, would bring important insights into how regional structural change processes unfold and would allow for drawing more comprehensive policy implications.

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Michaela Trippel provided the initial research idea and question and contributed to its conceptualisation. She supported the PhD candidate in all other tasks. She contributed 30% of the work.

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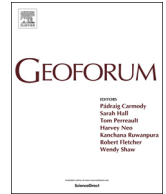
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Unravelling green regional industrial path development: Regional preconditions, asset modification and agency



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ABSTRACT

Regions across the world are searching for ways to fashion new green growth paths and to promote green shifts in mature industries. The article aims to explore conceptually and based on illustrative empirical examples from the literature how green restructuring unfolds in regions. We propose a framework that explicates how regional preconditions in form of pre-existing industrial structures, organisational support structures, institutional set-ups and natural assets are transformed into various types of green path development through agentic processes of asset modification.

1. Introduction

Driven by concerns over climate change, resource depletion and other adverse environmental impacts of economic development, green restructuring has become a core topic of interest in both academic and policy circles. Although it is highly disputed whether environmental problems can be solved by generating green growth (see, for instance, Bina, 2013; Caprotti and Bailey, 2014; Gibbs and O'Neill, 2017; Kenis and Lievens, 2015; Krueger et al., 2017), regions and countries across the world are searching for ways to renew their economic structures by nurturing new green industries.

Over the past years, a substantial body of literature has dealt with green innovation and green regional development. Much progress has been made to establish the field of environmental economic geography (see, for instance, the seminal contributions by Bridge 2008; Gibbs, 2006; Hayter, 2008; Soye and Schulz, 2008 amongst others). There is also a flourishing literature on the geography of sustainability transitions (Hansen and Coenen, 2015; Murphy, 2015; Raven et al., 2012; Smith et al., 2010; Truffer and Coenen, 2012; Truffer et al., 2015) and transformative innovation policies (see, for instance, Schot and

Steinmueller, 2018).

This article seeks to contribute to a better understanding of how green restructuring unfolds in regional contexts. We conceptualise green restructuring through the notion of green path development. This notion is claimed to encompass both the rise of new green growth paths (through various forms such as green path creation, diversification and importation) and the 'greening' of existing industries, that is, the transformation of established sectors to produce 'greener' products and services and/or produce in more environmentally friendly ways.

Analyses of new path development have primarily been framed in the evolutionary economic geography (EEG) approach. EEG studies suggest that (new) regional paths are essentially influenced by past rounds of industrial development (Martin, 2010), placing much emphasis on local pre-conditions and processes like the inherited economic structures, local knowledge circulation and regional branching (Boschma and Frenken, 2011). With some notable exceptions (see, for instance, Patchell and Hayter, 2013), EEG has long tended to ignore environmental matters. In their pioneering article, Patchell and Hayter (2013) argue for an integration of EEG and environmental economic geography and propose a compelling framework that links multiscale

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and co-evolutionary socio-ecological perspectives. Other scholars have begun to complement EEG with the technological innovation system concept, transition approaches and the literature on global innovation and production networks to analyse green restructuring in various spatial contexts (Binz and Truffer, 2017; Binz et al., 2016; Dawley et al., 2015; MacKinnon et al., 2019a; Simmie, 2012a; Steen and Hansen, 2018).

In this article, we seek to develop a broader understanding of green path development in regions by combining EEG with the regional innovation system (RIS) approach. Integrating insights from the RIS approach allows for moving beyond firm-oriented and industry-centred views propagated by EEG towards incorporating a wider set of factors and influences into analyses of regional industrial change (Isaksen and Tripl, 2016). We explicate how such an approach – when applied to green restructuring – helps to cast light on regional structural preconditions for green path development. Employing the RIS concept enables to gain a more comprehensive understanding of enabling and constraining preconditions, comprising not only industrial structures (as emphasised by conventional EEG models) but also organisational support structures and institutional configurations.

Recognizing that favourable pre-existing structures do not automatically lead to new path development, our framework elucidates how opportunities and potentials found in and provided by structural preconditions are transformed into (various forms of) green path development. It also explicates how barriers emanating from unfavourable regional structural preconditions are overcome. We conceptualise such change processes as modification of the regional asset base. In doing so, we depart from a broad understanding of assets (Maskell and Malmberg, 1999) and interpret them as products of the RIS (MacKinnon et al., 2019a). Our framework directs attention to how different forms of asset modification for green path development are brought about by agency performed by multiple actors. In short, we argue that broadly defined historically grown RIS structures provide a platform for different types of green path development and have an influence on what is possible in terms of asset modification through agentic processes.

The remainder of this article is organised as follows. Section 2 contrasts conventional with emerging research perspectives on new path development, focusing in particular on recent attempts to extend EEG by insights provided by the RIS approach. Section 3 casts light on various forms of green path development. This is followed by a discussion of how pre-existing RIS structures provide either enabling or constraining conditions for green restructuring in Section 4. In Section 5, we zoom in on processes of asset modification (distinguishing between the re-use, creation/transplantation and destruction of assets) that are at the centre of green path development. Section 6 investigates the role of local and non-local firm-level and system-level agency in asset modification for green restructuring. Finally, Section 7 concludes by outlining a set of key issues for future research.

2. Regional restructuring and path development in the Evolutionary Economic Geography literature

Expounding how new regional industrial paths emerge and how established ones are transformed over time is a core focus of enquiry in economic geography. Advances made in EEG such as the ‘path as a process model’ (Martin, 2010) and the literature on regional diversification (Boschma, 2017) provide valuable insights into the conditions and mechanisms that fuel the development of new economic activities in regions. New paths are portrayed as being embedded in place-specific conditions (Martin, 2010) and territorial capabilities (Boschma, 2017), which are often inherited from past rounds of regional development. Conventional EEG models are, however, not without their limitations. They have been criticised for giving primary attention to firm-led processes and technological and skill relatedness in their explanations of regional structural change (Hassink et al., 2019). EEG perspectives have also been contested for overrating local factors and

processes and downplaying non-local influences on new path development in regions (Dawley, 2014).

Recent work has sought to develop broader conceptualisations of new path development. Scholars have begun to combine EEG with insights from regional and technological innovation systems, socio-technical transitions, global production and innovation networks and sociological perspectives (Binz et al., 2016; Boschma et al., 2017; Hassink et al., 2019; Isaksen and Tripl, 2016; MacKinnon et al., 2019a). This has helped to move beyond related and unrelated diversification as explanatory patterns for the rise and transformation of regional industries, pointing to other forms of path development, including path renewal, path creation and path importation (Isaksen et al., 2018b). Furthermore, challenging the strong focus of EEG on endogenous processes, a growing body of work examines how exogenous actors, resources and influences are shaping new regional industrial path development (Tripl et al., 2018). Emerging perspectives also include assets and processes other than industrial and knowledge-related ones, highlighting, for instance, the role of market formation, financial investments and the creation of legitimacy (Binz et al., 2016). Such processes are increasingly seen as outcome of strategies employed by multiple actors. This has led to overcome firm-centred views dominant in EEG accounts in favour of more systemic and multi-actor perspectives that incorporate non-firm actors such as research bodies, policy and support organisations and their (system-level) agency (Isaksen and Jakobsen, 2017) into analyses of new path development.

In this article, we complement EEG with insights from the RIS approach. A RIS consists of the firms and industries located in the region (industrial structure), the ensemble of support organisations, including universities, educational bodies, intermediaries, policy actors, and so on (organisational support structure) and socio-cultural and institutional set-ups, covering both formal institutions such as laws and regulations and informal institutions like norms and values (institutional configuration) (Asheim et al., 2019). Adopting a RIS perspective enables one to extend conventional EEG models and their predominant focus on firms and industry structures to incorporate organisational support configurations and institutional set-ups into analyses of regional path development. This allows for greater clarity and more specification of regional structural preconditions and potentials for and barriers to new path development. Arguably, this does not imply to neglect that various factors and influences at higher spatial scales affect regional industrial path development. Regions are inserted into global value chains, production networks and multi-level governance systems (Patchell and Hayter, 2013). In line with this, protagonists of the RIS approach conceptualise RIS as ‘open systems’ (Asheim et al., 2019) and emphasise that regional innovation and new path development are essentially influenced by inflows and outflows of non-local knowledge and other assets (through extra-regional networks, activities by multi-national companies and labour mobility), inter-regional industrial relations, supranational institutional structures and regulatory frameworks and policy actions set at higher spatial scales (Asheim et al., 2019; Tripl et al., 2018; Zukauskaitė et al., 2017). Accordingly, while we are shedding light on how regional structures are used and altered for green path development, our framework also acknowledges the role of exogenous actors and influences.

In a next step, we distinguish between different forms of green path development (Section 3) and apply the RIS approach to green restructuring (Section 4) to gain a better understanding of how regional industrial structures, organisational support configurations and institutional set-ups influence green path development.

3. Types of green path development

As noted in Section 2, recent contributions provide a differentiated understanding of regional structural change. Various typologies exist that distinguish between different forms of path development (Grillitsch et al., 2018; Isaksen et al., 2018a,b; Martin and Sunley, 2006;

Tödting and Trippl, 2013). Here we focus on four main forms that are central in most typologies, that is, path renewal, diversification, importation and creation, and we apply them to the ‘green economy’.

Greening of existing industries through **path renewal** processes mainly refers to intra-path changes involving e.g. the introduction of green technologies, organisational innovations or business models that introduce eco-efficient practices in established sectors. Examples of the unfolding of such dynamics are the process industry (Kyllingstad and Rypestøl, 2018) and the shipbuilding industry (introduction of fuel cell technology) in Norway (see Sections 5 and 6).

The rise of new green industries through **path diversification** points to processes through which knowledge and other assets from existing green industries or brown sectors are transferred to emerging green industries that might be either related or unrelated to the established economic structures. There are various examples of diversification into green industries such as the rise of environmental technology sectors in Upper Austria (Tödting et al., 2014) and the Ruhr area in Germany (Grabher, 1993), which branched out from established mechanical industries (in the Austrian case) and the old steel and mining sector (in the German case). Another case in point is the development of the offshore wind industry in Norway, which largely reflects diversification processes from the oil and gas sector (Steen and Hansen, 2018) and the one in Northern Germany (Fornahl et al., 2012), which emerged out from the onshore wind sector (see Section 5 for a more detailed discussion). The former illustrates a move from a ‘dirty’ industry into a greener one, while the latter demonstrates the transfer of assets from an established green industry to a new green sector.

The rise of new green industries through **path importation** points to the settlement of green industries that are new to the region, resulting from inflows and anchoring of non-local firms, talent, knowledge and other assets (see, for instance, the cases of the offshore wind industry in North East England (Dawley, 2014) and the on-side water recycling sector in China (Binz et al., 2016) to be further discussed below).

Finally, the rise of new green industries through **path creation** implies the rise of totally new green industries. Path creation often rests on academic spin-offs and new green firm formation. Examples of such processes include the formation of the photovoltaic industry in Norway (see Section 6) and Germany (Dewald and Truffer, 2012).

4. RIS structures: enabling and constraining conditions for green regional path development

RIS structures are seen to provide vital preconditions for the unfolding of green path renewal, diversification, importation and creation. To begin with, historically grown regional **industrial structures** may provide either an enabling or constraining environment for green path development. There are strong reasons to assume that regions that host already green industries provide favourable conditions for achieving further rounds of green path development through diversification because of the green character of the existing industrial base (Fornahl et al., 2012; Grillitsch and Hansen, 2019). However, green economic activities may also emerge in regions hosting non-green sectors such as the IT industry (when IT firms diversify into green technologies as highlighted by Cecere et al., 2014) and regions dominated by dirty industries. In the latter case, the need to cope with environmental damages caused by brown sectors (and the pressure dirty industries face to undergo green path renewal) could provide opportunities for the development of green industries as observed in the old industrial Ruhr area in Germany (Grabher, 1993). Regions with highly diversified industrial structures and a vibrant entrepreneurial climate are expected to offer good conditions for green path creation through re-combinations of diverse skills, knowledge and other assets and through spin-off activities. Such conditions often prevail in metropolitan regions.

Arguably, the pre-existing industrial base may not only facilitate the

rise of new green industries through the transfer of assets from old sectors to new ones as emphasised by the diversification literature. It may also hamper green path development. One can distinguish between two potential sources. First, the presence of strongly developed mature industrial structures can impede the rise of new paths and the renewal of old ones.¹ Constraining factors may, for instance, be embodied in vested interests of powerful incumbents dominating old industries, who protect their past investments and resist change (Boschma et al., 2017; Grillitsch and Trippl, 2018). Second, poorly developed industrial structures and the absence of capable firms, skills, knowledge and other assets constitute barriers to endogenous green path development. Under such conditions, which are often found in peripheral areas, one might observe a stronger reliance on green path importation. Regional industrial structures thus matter in manifold ways. Furthermore, regional industrial structures are often connected to the ‘outside world’ through market linkages, input-output relations and other networks. These inter-regional connections may be important drivers for green shifts (helping for instance to prevent negative lock-ins resulting from an overreliance on localised (possibly brown) routines (Maskell and Malmberg, 2007; Zhu et al., 2017). However, they could also be a source of rigidification, when regional industrial structures are locked into unsustainable path dependent inter-regional production and innovation linkages (Martin and Sunley, 2006).

The organisational support structures and the institutional set-ups of RISs may also facilitate or hamper green path development. The **organisational support structure** includes financial organisations (banks, venture capital providers, etc.) and non-firm actors such as universities, educational bodies, intermediaries and policy actors. The presence (absence) of such actors with capabilities to promote green path development (Capasso et al., 2019) and their connections to organisations at higher spatial scales (Zukauskaitė et al., 2017) are assumed to trigger (hamper) green shifts. In the context of green path development (and in line with recent calls to opening up the innovation system framework to new actors (Warnke et al., 2016; Weber and Truffer, 2017), civil society organisations (CSOs) like environmental non-governmental organisations (ENGOS) and social movements (which are often neglected in conventional RIS studies) require due attention in analyses of green restructuring. They may not only positively affect green path development (for instance by building support for green policies, triggering shifts in political and consumer awareness of sustainability matters and shaping cultural values and beliefs). They could also hamper green innovation and path development, for example by opposing the implementation of green technologies as observed in the case of wind farms (Köhler et al., 2019).

Turning to the **institutional set-up**, both formal institutions such as environmentally friendly laws and regulations and informal institutions like values, visions, attitudes and consciousness with regard to issues of sustainability (Hansen and Coenen, 2015) matter. Formal institutions are often the outcome of policy processes at higher spatial scales (e.g. national or supra-national laws, regulations and policy programmes) (Dawley, 2014). Yet, regions are not ‘passively receiving and locally implementing policies’ (Matti et al., 2017, 664). Institutions shape, but also are shaped by the places they are embedded. Constraining effects may emanate from highly institutionalised regulations and norms, and subsidies that favour brown industries (Köder and Burger 2016, see below). Also informal (local) institutions such as unsustainable behavioural attitudes and consumption patterns can be hindering factors in local economic development (Späth and Rohrer 2012).

¹ In transition studies, negative effects of existing structures on new path development have been intensively discussed. New industrial paths are confronted with diverse forms of mainstream selection pressures which may cause structural disadvantages for path breaking innovations e.g. in the form of industrial routines, technical standards, market rules, institutions and regulations (Smith and Raven, 2012).

Regional organisational support structures and institutional configurations have often co-evolved with and are strongly adapted to the region's current economic structure (Isaksen et al., 2018a). They tend to provide existing industries with competence and other assets and thus support continual improvements within established industrial paths. In other words, past rounds of industrial development are reflected in the region's research and education programmes, its skill base, dominant policy approaches and informal institutional setups. It follows that if support structures are strongly aligned with dominant industries that are not 'green', optimisation of the current configurations is the wrong route. For green shifts to occur, the organisational and institutional setups must undergo changes.

In summary, pre-existing RIS structures may either enable or impede (different forms of) green path development. Constraints residing within industrial structures and/or the organisational and institutional set-up necessitate a RIS reconfiguration for green path development to occur. Even if favourable preconditions exist, the opportunities and potentials need to be transformed into green path development. This directs attention to the vital but still poorly understood question of how such processes take place. We propose to conceptualise such change processes as modification of the regional asset base. The RIS elements outlined above are seen as the structures that provide a broad range of assets (Miörner and Trippl, 2019), ranging from industrial assets to infrastructural, material, human and institutional ones (Maskell and Malmberg, 1999). In the context of green path development, there are strong reasons to also consider natural assets. Both their availability and their absence might play a role. The path a region may choose is often dependent on endowments of natural resources. However, investment in green path development may also be triggered by the scarcity of natural assets (Hansen and Coenen, 2015).

Assets are thus interpreted as products of the RIS, which are used by different firm and non-firm actors for specific purposes (MacKinnon et al., 2019a). We contend that green regional industrial path development requires a modification of the regional asset base (Section 5) that is brought about by different types of agency performed by multiple actors at various spatial scales (Section 6).

5. Asset modification for green path development

In this section, we elaborate on asset modification processes that are at the centre of green path development. While conventional EEG models are mainly focusing on the importance of technological or skill related assets, emerging literature highlights the significance of a broader set of assets for regional path development to unfold. Following Maskell and Malmberg (1999) and MacKinnon et al. (2019a), we distinguish between (i) natural assets (resources), (ii) infrastructural and material assets (buildings, machines, networks and infrastructure), (iii) industrial assets (technology and firm competencies), (iv) human assets (labour skills, costs, knowledge), and (v) institutional endowments (rules, routines, norms, values and culture).

Local assets reflect past forms of regional economic development and are seen as products of the broader regional environment (MacKinnon et al., 2019a) and the regional innovation system. They can only promote new path development if they are identified, used and valorised (MacKinnon et al., 2019a) and modified by 'the deliberate and purposeful action of individuals and groups within or outside the area' (Maskell and Malmberg, 1999, p. 10). Furthermore, accessing, transplanting and anchoring non-local assets (particularly human and industrial assets) and the strategic destruction of old assets may also play a key role in new path development (Binz et al., 2016; Miörner and Trippl 2019).

Departing from the insights outlined above, we claim that green path development is inextricably linked to what might be termed 'asset modification processes'. Such processes may take three forms, namely

- redeployment and the recombination of local assets);
- creating new local assets and/or accessing/transplanting non-local assets;
- destructing old local assets.

The relative importance of these three types of asset modification processes is expected to be contingent on pre-existing RIS structures and regional asset bases, which might provide either favourable or constraining conditions for (different types of) green path development.

In the following, we discuss three cases that illustrate how region-specific preconditions influence the modification of assets in green restructuring processes. The cases include (1) the greening of the mature metallurgical and chemical industry in Southern Norway (Kyllingstad and Rypestøl, 2018); (2) the diversification from oil and gas to offshore wind in Norway (Steen and Hansen, 2018); and (3) the industry formation for on-site water recycling in Beijing (Binz et al., 2016). These cases have been selected analytically to examine processes of asset modification in different contexts. They represent different types of green path development (see Section 3) in both enabling and constraining environments (see Section 4). Furthermore, empirical evidence documented in studies of these three cases is rich enough to gain a fine-grained understanding of how different types of asset modification are combined to facilitate green path renewal, diversification and importation.

5.1. Asset modification for green path renewal in a favourable environment

Kyllingstad and Rypestøl's (2018) analysis of the greening of the metallurgical and chemical process industry in the Agder region of Southern Norway provides insights into green path renewal in a favourable environment. The Agder region has developed a well functioning RIS characterised by strong local research system linkages, intense regional firm collaboration and innovation activity (Herstad & Sandven, 2017). Trust-based regional collaborations provided enabling conditions for green path renewal, and this, combined with generous access to green energy, may contribute to explain the 'greening process' that took place in the metallurgical and chemical process industry in Agder. In this specific case, the process of becoming a more sustainable industry was triggered by increasing pressure from civil society organisations and national governmental regulations and orchestrated by large units of multinational companies in collaboration with the administration of a formal local cluster (Eyde). The process included activities and sub-processes that challenged a wide set of local assets. First, a greening process required a significant process of institutional asset modification. Such modification was needed because the cluster firms did not have a joint understanding of what characterises sustainable industrial production. To create a more common worldview amongst the firm leaders, the cluster partnered up with the local university and launched an education programme for sustainability for Eyde managers. Growing popularity of this programme has helped to gradually develop a more consistent understanding of how greening and sustainability could be promoted and implemented amongst the cluster firms. Further, the greening of the metallurgical and chemical process industry in Agder also raised several challenges that called for new meeting places like seminars and workshops, as well as new collaborations where material assets like laboratories and test equipment were shared. Moreover, the modification of the human asset base was crucial for the greening process in Agder. This modification was fuelled by a range of joint R&D programmes that created new knowledge and skills. Two successful R&D programmes were the Eyde Zero-Waste initiative and the Eyde Biocarbon programme. Eyde Zero-waste was a circular economy project where the cluster firms researched how to transform waste into becoming a valuable raw material, while the Biocarbon programme focused on replacing fossil coal with biocoal from Norwegian woods in the smelting industry.

- re-using existing local assets (this might entail both the

5.2. Asset modification for green path diversification in an initially favourable environment

A process of green path diversification is exemplified by [Steen and Hansen \(2018\)](#) who studied the branching of the offshore wind power (OWP) industry from the well-established offshore oil and gas (O&G) industry in Norway. During the last forty years, Norway has developed a strong oil and gas sector and become world leader in rough environment offshore oil-related activities. An important element in this successful industrial advancement is a well-developed and highly specialised oil and gas-related asset base that includes cutting edge environment technology and equipment, advanced knowledge and skills, an expedient infrastructure and supportive institutions which provided favourable conditions for industrial path diversification. Significant elements in the OWP branching process were national government incentives and the establishment of two state-supported cluster initiatives. The new cluster administrations ‘were explicitly aimed to develop OWP industry capabilities on the basis of experiences from the offshore O&G, maritime, and power sectors’ ([Steen and Hansen, 2018, p. 16](#)). Important processes of asset modification in this branching process included an increase of available financial assets, a modification of institutional assets through increased governmental support and public legitimacy, and a significant upgrade and redeployment of human assets through increased R&D. Further, this process of related diversification was also recognised by significant reuse of material assets as existing machines and technology previously used in the O&G industry were put to alternative use in the emerging OWP industry. Such material asset reuse was important to reduce risk in this high-risk manoeuvre ([Steen and Hansen, 2018](#)). In their 2010–2011 survey, the authors found that more than 50 per cent of the branching firms labelled OWP ‘a future target area’ implying that a process was started that would eventually lead to the destruction of some specialised O&G related assets. However, changing context conditions (rising O&G prices on world markets and new discoveries of O&G fields in Norwegian waters) have led to a revitalisation of the O&G sector and to the withdrawal of assets used in the offshore wind path. Thus, this case also demonstrates how initially favourable conditions turned into unfavourable ones due to factors ‘out of reach’ of regional actors, thereby bringing processes of asset modification for green path development to a halt ([Steen and Hansen, 2018](#)).

5.3. Asset modification for green path importation in an initially unfavourable environment

The rise of new green industries through path creation or path importation can be expected to include processes that support local asset creation, transplantation of non-local assets as well as the destruction of old ones. Such processes will be evident as these more radical alternatives are the ones least related to the existing regional asset base and RIS structures. Path importation is of particular importance in constraining environments due to the unfavourable asset base and the limited capabilities to support endogenous path development. Industry formation for on-site water recycling (OST) in Beijing ([Binz et al., 2016](#)) exemplifies path importation. This industry was founded on well-developed technological components, but relevant business models and operation and maintenance concepts were initially missing. Thus, the development of this embryonic industry relied not only on R&D intensive innovations but also on the development of new concepts for service and maintenance, new business models and regulatory and institutional innovation supported by international knowledge flows and innovation networks. In essence, the analysis of the importation of the OS technology in Beijing showed that success was the result of four main asset modification processes. Firstly, the industry managed to launch activities to upgrade the human asset base by creating new technological knowledge and related competencies. Secondly, the rise of the new industry was successful because the industrial pioneers

succeeded to change existing institutional endowments and create a new market for OS technology. Thirdly, they succeeded in embedding the new technology in the existing institutional structure, and fourthly, the emerging industry managed to launch activities that mobilised and allocated substantial financial investments. Finally, the OST case in Beijing also exemplifies the importance of asset destruction for new green path development. The introduction of the new technology within the existing institutional structure required alterations of laws, regulations and habits. The destruction of institutional assets was needed to open up and promote an internationally attractive niche market. The case of OST in China thus demonstrates how a variety of different but interdependent processes of asset modification turned initially rather unfavourable structures into more favourable ones.

To summarise, the review of empirical cases shows that depending on pre-existing RIS structures different types of green path development are inextricably linked to distinct forms and geographies of asset modification processes.

6. Green path development: The role of agency

The past few years have witnessed a growing recognition that structural accounts of new path development need to be complemented by agency perspectives. The question of ‘agency, that is about how economic and other actors create, recreate, and alter paths’ ([Martin, 2014, p. 619](#)) is gaining in importance in contemporary work on regional restructuring and also takes centre stage in our approach. Agency can be defined as an ‘... action or intervention by an actor to produce a particular effect’ ([Sotarauta and Suvinen, 2018, p. 90](#), based on [Emirbayer and Mische, 1998](#)).

Building on [Garud and Karnøe \(2001\)](#) and [Garud et al. \(2010\)](#), [Simmie \(2012b\)](#) argues that new paths are created by knowledgeable inventors and innovators who mindfully deviate from past practices and engage in the introduction and diffusion of new technologies. To this end, they set in motion change processes in the regional environment by removing technological, economic and institutional barriers to new path development. [Bristow and Healy \(2014, p. 930\)](#) maintain that ‘purposive adaptation in regions go beyond firms and firm-related actors, and also incorporate a variety of other self-organizing institutions of collective agency’. In a similar vein, other studies have examined how firm and non-firm agents including state actors and public policy deliberately create favourable regional environments for the emergence of new paths ([Dawley, 2014](#)). More recently, EEG scholars have also begun to forge a link to the literature on institutional entrepreneurship ([Battilana et al., 2009](#); [DiMaggio, 1988](#)) to explain how institutional change processes, which are often necessary for new path development, take place ([Boschma, 2017](#); [Boschma et al., 2017](#)). This literature sheds light on how institutional entrepreneurs mobilise resources, competences and power to create new institutions and transform existing ones. The concept of institutional entrepreneurship helps to elucidate the institutionalisation of new beliefs, practices and activities within an innovation system during the development of new paths ([Sotarauta and Mustikkamäki, 2015](#)). Together with Schumpeterian innovative entrepreneurship and place leadership, institutional entrepreneurship is seen as a key form of agency for shaping new path development ([Grillitsch and Sotarauta, 2018](#); [MacKinnon et al., 2019a](#)). Taking a technological innovation system perspective, [Musiolik et al. \(in press\)](#) emphasise the role of system builders who intentionally create, maintain and change system resources that help building, diffusing and further developing new technologies.

Current accounts of agency in path development research thus acknowledge that it is not only firms that engage in agentic processes. Multiple non-firm actors should also be considered. They seek to alter the regional environment and implement changes at the system-level to facilitate new path development. Therefore, we propose to distinguish between firm-level agency and system-level agency ([Isaksen and Jakobsen, 2017](#); [Isaksen et al. 2018a](#)). Both firm-level agency, that is,

actors who found new firms or introduce innovative activities within existing companies, and system-level agency, that is, actors who transform innovation systems, may initiate asset modification processes (Isaksen et al. 2018a). However, for new path development to unfold, both types of agency need to be combined. Thus, green path development is conceptualised as a result of deliberate and purposeful action of firm-level and system-level actors within or outside the region. The examples in Section 5 highlight the manifold roles actors on both the firm-level and the system-level can play for initiating asset modification processes that underpin green path development. In the metallurgical and chemical process industry in Agder firm-level and system-level agency took various forms, ranging from asset creation processes (educational programmes, awareness, collaboration) to the redeployment of existing assets (shifting resources to joint R&D programmes). In the offshore wind power industry in Norway, system-level agency included the establishment of two state-supported cluster projects as well as the creation of legitimacy, while firm-level actors mainly pursued asset redeployment strategies. Firm-level agency and system-level agency were also combined in the case of the on-site-water recycling industry in Beijing. Industrial pioneers built their own firms, while modification processes were initiated by system-level actors to adapt existing institutions and to create new markets.

In order to gain further insights into how green path development is facilitated by combinations of firm-level and system-level agency, we have selected a number of additional empirical cases documented in the extant literature (Table 1). The cases discussed below have been chosen because (1) they demonstrate how firm-level agency may trigger green path development (cases of vessels with fuel cell technology in Western Norway and the Norwegian solar PV industry); (2) they exemplify the role of system-level agency in initiating green path development (cases of the offshore wind industry in Germany and the biogas industry in Southern Sweden), and (3) they provide insights into the role of system-level agency in destabilising old non-green paths (case of environmentally harmful industries in Germany).

6.1. Green path development initiated by firm-level agency

Firm-level agency may, in general, be performed by home-grown incumbents who introduce greener production processes, and local start-ups that produce for instance renewable energy technologies. However, firm-level agency may also be performed by non-local actors, when external investors (such as multinational companies) establish a subsidiary in the region, which is most often accompanied by the transplantation of external assets into the region.

An example of ‘green’ firm-level agency is case of emerging processes of green path renewal in the maritime industry in South-Western Norway, a region with favourable conditions (long tradition in ship-building, financial support, cluster initiatives). In 2009, an innovative ship-owner built an offshore supply vessel that became ‘the first commercial ship ever with a fuel cell technology specially adapted for maritime use’ (Holmen and Fosse, 2017, p. 507). This initiative was soon accompanied by system-level agency by companies and regional and national policy makers. System-level agency was geared towards the alteration of assets in the organisational support structure and in the institutional configuration, leading to the establishment of a Maritime Clean Tech cluster project and a ‘change in public tenders for new maritime transport based on zero emission principles’ (Holmen and Fosse, 2017, p. 508) nationally. The case illustrates the fact that firm-level and system-level agency are often mutually dependent. The ship-owner who developed a new type of offshore supply vessels planted the seeds for the greening of an established path. However, for green path renewal to further unfold, other firms that produce similar products or services or utilise similar technologies need to follow. This will most often require asset modification by system-level actors. In the case under consideration, system-level agency played a major role in implementing new public tenders that include zero emission principles.

Table 1
The role of firm-level and system-level agency in green regional industrial path development.

Case	Type of green path development	Preconditions	Asset modification through firm-level agency	Asset modification through system-level agency
Fuel cell technology in vessels in Norway	Path renewal	Green path development initiated by firm-level agency Favourable (industrial setup, support structure)	Search for and experimentation with new vessels	Creation of cluster programme, changes in public tenders
Solar PV industry in Norway	Path diversification	Favourable (industrial setup, cheap resources)	Development of new and adaptation of existing technology	Knowledge creation and diffusion by universities and R &D-institutes
Offshore wind power industry in Germany	Path diversification	Green path development initiated by system-level agency Initially unfavourable (institutional setup)	Reorientation and redeployment of assets towards offshore wind power	Creation of new policy support initiatives that e.g. protect emerging markets
Biogas industry in Scania	Path diversification	Favourable (industrial setup, institutional setup)	Reorientation and redeployment of assets towards biogas	National and regional policy programmes geared towards creation of markets and legitimacy
Renewal energy industries in Germany	(Paving the way for) green path creation & diversification	Unfavourable (institutional setup)	Incentives for asset creation and redeployment for green path development, destruction of assets related to brown industries	Disruption of institutional setup, withdrawal of subsidies for environmentally harmful industries

Source: own compilation.

Another example of firm-level agency supported by system-level agency is the emergence of the Norwegian solar Photovoltaic (PV) path. The rise of this industry was based on historically developed competencies in metallurgical industrial production and relatively cheap hydroelectrical, ‘green’ energy. Some initial conditions were thus favourable. It grew to become a considerable player at the world market at the beginning of the 2000s (Klitkou and Coenen, 2013), however experienced decline from 2011 onwards (Hanson, 2018). The historical origin of this industry in Norway rests on asset modification processes by firm-level agents, more specifically on R&D and innovation activities in one established firm (Elkem) and the fast growth of two spin-offs companies from Elkem founded by one entrepreneur. The industry grew, particularly in the Oslo region, through a number of further spin-offs and the establishment of knowledge-based service and consulting firms. Industrial branching and interregional knowledge spill-overs (including labour mobility) from incumbent process industry firms have initiated new PV-firms also in other parts of Norway. The start-up phase ‘also involved adaptation and improvement of technologies from foreign providers through incremental process innovations’ (Klitkou and Coenen, 2013, p. 1804). Large Norwegian universities and R&D institutes have acted as important system-level actors for the Norwegian PV industry through the creation and provision of knowledge-related assets.

6.2. Green path development initiated by system-level agency

System-level actors aim to transform organisational support structures and institutional configurations so that these provide the assets needed for green restructuring. This will include asset creation and re-use of existing assets, but might also imply activities oriented towards the destruction of assets (Kivimaa and Kern, 2016). System-level agency may also be performed by non-local actors, who transplant non-local assets to the region. Such activities are performed by, for example, national policymakers and politicians when new nationwide laws and regulations are introduced and when national policy instruments are targeting specific regions, implying a modification of institutional assets.

System-level agency was key to the development of the offshore wind energy industry based on diversification processes in Germany as part of the country’s ambitious *Energiewende* (MacKinnon et al., 2019b). While the German onshore wind industry emerged in the 1970s from relatively small-scale projects driven by innovators and entrepreneurs (that is, firm-level agency), the offshore wind industry has relied from the start on public support initiatives. Demand-side instruments to stimulate and protect the emerging market for renewable energy (like offshore wind) were of particular importance to ensure long-term security for cost-intensive firm-level asset redeployment processes. Various R&D and demonstration projects were established by the federal government to stimulate market confidence and industrial development. Thus, key system-level actors have been national and federal policy makers and politicians. However, modifications through system-level agency (in this case to create and protect markets for renewable energy) require firm-level agency to materialize into new green path development, i.e. asset modification by companies and entrepreneurs to take advantage of new opportunities.

Another example of system-level agency is the development of the biogas industry in the Scania region in Sweden from the late 1990s. This development was triggered by a national policy programme that targeted local initiatives to reduce greenhouse gas emissions and which legitimated the need for technological change (Martin and Coenen, 2015). Regional policies contributed, in particular through creating demand for locally produced biogas from the regional public transport system. Scania had favourable preconditions in related industries that diversified into biogas production. The policy initiative ‘led subsequently to increased cooperation and a need for further knowledge development among both public and private actors in the region’

(Martin and Coenen, 2015, p. 2024), amongst others in a regional association for biogas stakeholders. System-level agency by national and regional policy makers and politicians created a market for biogas which encouraged firms to experiment with biogas related infrastructure and pursue redeployment strategies.

6.3. Destabilisation of non-green paths by system-level agency

Due to competitive disadvantages of green industries compared to brown industries, the creation of new assets or the redeployment of existing ones might be insufficient in some cases. Kivimaa and Kern (2016) draw attention to the possible disruptive side of system-level agency in their work on innovation policy mixes for sustainability transitions. Accordingly, ideal innovation policies to stimulate sustainable shifts focus not only on providing momentum for new industries via support instruments, but also implicitly by disrupting old, non-renewable industries, thereby reducing their value and/or competitiveness. This might include breaking up established actor-network structures, installing control policies (like emission taxes) or withdrawing assets/support for dominant industries. Essentially, the development of new green industrial paths is therefore likely to require system-level agency also oriented towards the destruction of old institutional configurations benefiting brown industries.

An interesting case in this respect is the potential withdrawal of subsidies for environmentally harmful industries in Germany. In a report for the German Ministry for Environment, Köder and Burger (2016) found that such industries were supported with subsidies of at least 57 billion Euros in 2012 directly (tax reductions, grants), but also indirectly, for instance by providing goods at prices that do not correspond to market prices. Additionally, due to legal restraints, it is not always possible to abolish such subsidies easily (Köder and Burger, 2016). These institutional factors are not only environmentally damaging but also lead to competitive disadvantages for green industries, thereby impeding green path development activities.

7. Conclusions

Green restructuring has become an urgent priority in many regions across the world. This article examines in a conceptual way and based on illustrative examples documented in the extant literature how the emergence of new green growth paths and the ‘greening’ of existing industries take place in regions.

Scholarly work has begun to bring together established EEG models with environmental economic geography (Patchell and Hayter, 2013) and insights from other literatures (including among others, technological innovation systems, transition studies, and sociological perspectives) (Binz and Truffer, 2017; Boschma et al., 2017; Steen and Hansen, 2018) to offer broad conceptualisations of regional restructuring. This article builds on and further advances work that combines EEG with the RIS approach.

In showing what our approach can bring to economic geography research on green path development, this article makes three contributions. First, we champion a nuanced understanding of ‘green industrial dynamics’ by acknowledging that green shifts may unfold through various forms of path development, including the greening of existing sectors through path renewal processes, the rise of green industries through path diversification and the emergence of new green economic activities through path creation and importation. Second, we take account of the complex relation between green path development and set-ups of innovation systems. The article casts light on how established RISs, that is, pre-existing industrial structures, organisational support configurations and institutional set-ups may facilitate or hamper green restructuring. And thirdly, we argue for complementing the focus on pre-existing structures by a process perspective that directs attention to different modes of asset modification through mutually dependent local and non-local firm-level and system-level agency to

explain how regions develop and transform their asset base towards green fields. We maintain that agency might not solely be engaged in the re-use of existing local assets but also in the creation (or trans-plantation) of new assets and in asset destruction.

In summary, the proposed approach helps to illuminate how various types of green path development unfold in regions, attributing explanatory power to pre-existing RIS structures, various forms of asset modification and the role of local and non-local firm-level and system-level agency in shaping these processes and outcomes. Future work could further operationalise this framework and apply it to different regional contexts. Investigating how and why various types of regions (and their innovation systems) differ in their capacity to modify assets through agentic processes would enhance understanding of why some places succeed in undergoing green restructuring processes while others fail. Findings from empirical analyses and applications of the concept may also serve as a basis to further refine the framework.

Such an application of our proposed approach would require moving beyond quantitative analysis and opening up research on new path development to qualitative research methods (Hassink et al., 2019). As Dawley (2014, p. 99) points out in his analysis of new path development in the wind industry, qualitative research designs can capture and ‘get inside’ the process and causalities of path development. Accordingly, we consider qualitative methods better suited to unravel the complexity of asset modification and (firm-level as well as system-level) agency that is underpinning green path development.

In conceptual terms, the framework could be advanced by integrating insights from sectoral innovation systems to gain a better understanding of how green path dynamics vary depending on the industry in focus. Further, incorporating broader context conditions that influence green path development in different types of regions is a key challenge for future research. We have limited knowledge about the role of multi-scalar institutional environments and reconfiguration of innovation systems at higher spatial scales (see also Hassink et al., 2019; Patchell and Hayter, 2013; Steen and Hansen, 2018). Exploring in more detail what contextual factors affect green restructuring most and unravelling how they may be ‘manipulated’ by system-level agency are core issues for future research.

Moreover, deeper conceptual and empirical analyses of inter-path conflicts in asset modification processes and competition between new green path development activities over scarce assets (such as skilled labour, policy support or risk capital) and markets are needed (Frangenheim et al., 2020). Future studies should also consider competition between old (dirty or green) paths and new green economic activities. Addressing this issue would bring further insight into barriers to asset modification for green shifts.

The environmental effects of green restructuring remain poorly understood and require more attention in future work. To what extent are the rise of new green paths and the green renewal of established paths contributing to achieving greater ecological sustainability? This is a hotly contested issue. Some scholars depict the green economy as a neoliberal growth-focused approach and question its potential to address environmental problems (see, for instance, Bina, 2013). More critical discussions and debates in EEG and innovation studies about the limitations of green restructuring and reflections on alternative approaches are high in demand (Caprotti and Bailey, 2014; Kenis and Lievens, 2015; Krueger et al., 2017).

Finally, more work is needed to understand the policy implications of the views propagated in this article. Regions across the world have developed an array of policies designed to promote green restructuring. Yet, there is still little consensus about the types of policy approaches and measures that should be adopted (Gibbs and O'Neill, 2017; Capasso et al., 2019). Our approach suggests that policy may play a key role in facilitating asset modification for green shifts but that the importance given to fostering the re-use of existing assets, the creation and trans-plantation of new assets and the destruction of old assets should vary, depending on pre-existing RIS structures and the type of green path

development under consideration. Key challenges for future research are to examine how such policies are shaped by legacy of policy practices and institutional capacities inherited from the past. Further, exploring what is within and what is beyond the reach of regional innovation policy and what is influenced by policy at higher spatial scales requires more attention in future work. Examining how regional green innovation policies interact with national and supranational innovation and industrial policies and how they can best be aligned with other policies such as sectoral and environmental policies should rank high on future research agendas.

CRedit authorship contribution statement

Michaela Trippl: Conceptualization, Writing - original draft, Writing - review & editing, Supervision. **Simon Baumgartinger-Seiringer:** Methodology, Resources, Writing - original draft. **Alexandra Frangenheim:** Writing - review & editing. **Arne Isaksen:** Investigation, Writing - original draft. **Jan Ole Ryppestøl:** Investigation, Writing - original draft.

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Co-author declaration for the following joint paper

This declaration states the research contribution (e.g. research idea and – question; data compilation, manipulation and modelling; design and preparation of graphics, maps and tables; writing of text) of the candidate, the main supervisor (where he/she is an associate author) and the other authors.

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Has this paper been, or will this paper be part of another doctoral degree thesis?

Yes: ☐

No: ☒

If yes, please elaborate:

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Article III

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Policy options for green regional development: Adopting a production and application perspective

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Abstract

Green and sustainable developments have received increasing attention in recent years due to challenges emanating from climate change and worsening environmental conditions. Although these are problems of global nature, actions have to be taken often at lower spatial scales. We focus on innovation and industrial policies and on the regional level since green development often can be supported here by respective policies. However, effective policies have to consider that individual regions face different kinds of challenges for moving towards a ‘greener’ future. This article develops a framework that allows taking such differences into account. We distinguish between the production side of ‘green technologies’ (i.e. the industries that develop and produce such technologies) and the application side (i.e. the adoption of such technologies by firms and the wider society), and we investigate what challenges might prevail on both sides and explore the potential role of policies for different types of regions.

Key words: green regional development; innovation policy; place-specific challenges; production of green technologies; application of green technologies

1. Introduction

Green regional development has received increasing attention in recent years due to problems such as climate change and environmental degradation. Arguably, this notion is the subject of vivid discussions and contestation (see, for instance, Gibbs and O’Neill 2017). In this article, green regional development is referred to as activities and processes that are driven by the generation, production, and application of green technologies. Green regional development—as defined above—thus includes both an ecological and economic dimension. The generation and production of green technologies reflect the economic dimension through the development of green industries and the creation of green jobs. The application of green technologies relates to the ecological dimension since such activities could contribute to shifts towards more ecological sustainability. However, it may also stimulate economic development, for example in the form of productivity gains, enhancement of firm competitiveness, or new employment opportunities.

We seek to unravel the heterogeneous nature of such processes, and we disentangle two dimensions or ‘sides’ of green development activities, that is the production side and the application side. The production side encompasses the firms and industries that produce

green technologies. The application side includes the adoption and use of green technologies by firms and non-firm actors to reduce problems such as pollution, waste, and environmental degradation. Arguably, green technologies are an umbrella term that includes a wide range of very different technologies. We deliberately define ‘green technologies’ in a broad way to cover not only sophisticated high-technology products but also new organisational solutions (such as setting up regional bioenergy systems) that help to solve environmental problems.

Although environmental issues are problems of global nature, actions have to be taken often at lower spatial scales, that is local, regional, or national ones (Wanzenböck and Frenken 2020). In this article, we focus on industrial and innovation policies and on the regional (subnational) level since green development activities often emerge at this spatial scale in the form of green industries (production side) or experimentation with the adoption of green technologies (application side). Effective policies have to appreciate that different types of regions face distinct challenges for producing and adopting green technologies due to different industrial structures, institutional settings, and environmental situations. We advocate a framework that allows taking such differences into account, and we consider the spatial nature of green development activities, that is

their regional or non-regional character. The article addresses the following research questions:

- how do problems and challenges of green development differ between various types of regions? and
- what is the role of industrial and innovation policies for stimulating green regional development and what policy options can be identified in particular regional settings?

We are going to deal with these questions both conceptually and empirically by critically reviewing relevant bodies of literature and by drawing on empirical examples from Austria. The aim of this article was to better understand the diversity and heterogeneous nature of green development in a regional context. Particular attention is paid to various challenges and policy options for boosting such processes. The empirical cases discussed in this article provide further insights into their variegated character from a more concrete and practical perspective. The article is organized as follows. In the next section, we demonstrate options for green regional development by differentiating between the production side and the application side of green technologies. Based on theoretical achievements in economic geography, innovation, and transition studies, particular challenges on both sides are identified. Section 3 explores place-specific policy approaches for green regional development and examines the role of industrial and innovation policies in specific regional contexts. Section 4 explores empirical evidence from Austrian cases. In Sections 5 and 6, we provide a synthesis of our findings and draw some conclusions.

2. Green regional development: Towards a policy framework

Green regional development (as defined above) is a very heterogeneous phenomenon. It differs markedly between societal contexts, sectors, and regions. Here, we consider it as vital to distinguish between the production side and the application side of green technologies that help to mitigate climate change and other environmental problems. In addition, we consider the spatial nature of green development activities, that is their regional or non-regional (multiscalar) nature (Section 2.1). This serves as a point of departure for identifying key challenges and opportunities for green regional development in different types of regions (Section 2.2).

2.1 Disentangling green regional development: Production and application of green technologies

The production side of green regional development encompasses the industries and companies that develop and produce green technologies. Over the past years, many studies have examined the generation of eco-innovation (Schiederig et al. 2012; Calza et al.

2017) and the development of clean-tech clusters that might contribute to both economic development and ecological improvements (Cooke 2008; Marra et al. 2017). Various theoretical approaches (ranging from cluster theory to work on regional diversification and the RIS concept) have been invoked to gain a better understanding of where green industries emerge and how they evolve over time (see Section 2.2). The application side in contrast reflects the adoption and use of green technologies produced within the region or elsewhere to solve concrete environmental problems. Examples are initiatives geared towards the implementation of electric mobility, renewable energy, and water technologies to name just a few. Like the development and production of green technologies, also their application involves significant learning and innovation activities associated with the experimentation, testing, adaptation, and eventually wider diffusion of new technologies within the region (Hodson et al. 2017). This may lead, for example, to a lower use of material inputs, reduction of energy consumption and waste, enhancing the ecological performance of the region. Arguably, such activities could also result in economic benefits. They may enhance the productivity and competitiveness of firms, and lead to new employment opportunities, among others. In addition, green activities and technologies can have a regional or non-regional (multiscalar) character (see also Binz and Truffer 2017). One can distinguish between three potential routes (Table 1):

- green technologies produced in the region are applied there to solve concrete environmental problems (Box A in Table 1). This may create both economic and ecological benefits in the region. Cases in point are the environment protection industry in the Ruhr area (Nordhause-Janz and Rehfeld 1995) or in Upper Austria (Tödtling et al. 2014);
- green industries located in the region may produce for global markets (Box B, Table 1). This has economic benefits for the region, whereas ecological benefits accrue elsewhere. An illustrative example is the wind industry in Norway (Steen and Hansen 2018);
- regions may import and implement green technologies developed elsewhere (Box C, Table 1). This may lead to a better ecological performance in the region but could also generate economic benefits in form of new jobs, etc. Examples are the installation of Chinese solar panels in local housing projects or regional experiments with electric mobility in various Austrian provinces (Climate and Energy Fund 2015).

Thus, regions can embark on very different green development routes. These routes feature distinct requirements and challenges as will be shown in the following section.

Table 1. Green regional development: production and application side and spatial dimension.

		Application	
		Regional	Non-regional
Production	Regional	A: Application of regionally produced green technologies within the region	B: Production of green technologies for the global market
	Non-regional	C: Regional application of green technologies produced elsewhere	

Source: own compilation.

Table 1 presents different green development options in a stylised way. In reality, one may find interactions between production and application (e.g. user-led innovations) as well as multiscalar interactions from regional to national and global levels.

2.2 Green regional development: Regional variations of challenges

Green regional development can mean quite different phenomena in different contexts (Patchell and Hayter 2013) and also challenges for producing and applying green technologies vary substantially as the following subsection demonstrates.

2.2.1 Challenges on the production side of green technologies

As noted above, in this article, we use the notion of the ‘production side’ to put emphasis on the firms and industries that develop and produce green technologies. Green industries are often seen as a new source of economic growth and job creation. Regions differ in the pressure they face to develop such industries to compensate for stagnation and disappearance of mature sectors. The need to grow new industries is particularly pronounced in old industrial areas suffering from the decline of their traditional key industries and in peripheral regions with a weak economic basis. Failure to achieve this goal might cause economic, social, and political troubles. However, regions differ in their capacity to nurture new industries in general (Isaksen and Trippel 2016) and green industries in particular (Barbieri and Consoli 2019; Corradini 2019; Santoalha and Boschma 2019). Regional variations in boosting green industries can partly be explained by differences in the endowment of relevant assets such as natural resources, technologies, qualifications and skills, and institutional factors (Capasso et al. 2019).

Many empirical studies in this field have been informed by the cluster approach (Porter 2008). The cluster approach has been applied to investigate environmental technology industries such as the Californian clean-tech cluster (Burtis et al. 2004) or the water technology cluster in Oulu, Finland (Lehtinen et al. 2006). In the latter case, an emerging cluster has been identified based on small firms that are linked to and supported by IT firms and universities. Beside endowments of specific assets, also environmental legislation has been a main driver for the growth of this industry.

Recent work has begun to apply insights from Evolutionary Economic Geography (EEG) and innovation studies to explain the geographical patterns of green industry emergence and growth (see, for instance, Grillitsch and Hansen 2019; Santoalha and Boschma 2019). EEG protagonists highlight the significance of related diversification processes for industry emergence, that is the transfer of competences from old to new sectors (Boschma and Frenken 2011). In a study covering seven EU countries and ninety-five regions, Santoalha and Boschma (2019) applied these ideas to study green growth and found strong and robust evidence ‘... that new green activities are more likely to develop in regions where related capabilities are available’. These findings corroborate other studies that point to a strong role of relatedness for the emergence and development of green industries (van den Berge and Weterings 2014; Tanner 2016; Colombelli and Quattraro 2019; Corradini 2019). Barbieri and Consoli (2019), in addition, found that both related and unrelated variety had a positive impact on green employment growth in US Metropolitan Areas. Unrelated variety seems to be more relevant in the early stage of the green technology life cycle, while related variety becomes more important as the technology matures. Other scholars have moved beyond the distinction between

related and unrelated diversification. Trippel et al. (2020) for instance suggest differentiating between green path creation, importation, and (un-)related diversification to capture various mechanisms and outcomes of green industrial path development activities. Cooke (2008, 2012) argues that transversality (as a more active and social agency-driven dimension of related variety) and platforms of innovation (characterised by horizontal knowledge flows between sectors) are important for the emergence of green industries. His analysis is based on a comparison of the Danish region of North Jutland that has developed a local green platform in energy markets and the peripheral region of Norrland in Sweden with a technology platform based on forest products and process industries such as biofuels, substitute cotton, food, and construction materials.

The regional innovation system (RIS) approach offers additional insights into the evolution of industries. Besides the existing industries of a region, it refers to the regions’ knowledge organizations, universities and schools, and intermediaries, among others. It emphasizes the role of formal and informal institutions as well as of government bodies (Cooke et al. 2010; Tödtling and Trippel 2013). The approach thus helps to understand how multiple actors shape different forms of green industrial path development and what types of networks and institutions drive or hinder such activities. An instructive example is Cooke’s (2010) comparative analysis of green-tech industries in Northern Jutland and California.

In addition to such varying preconditions, the capacity of multiple actors to modify regional assets for green industrial path development matters. Such asset modification processes can take different forms, ranging from the redeployment of existing assets to the creation of new assets, the importation and anchoring of non-regional assets, and the (strategic) destruction of old assets (Trippel et al. 2020). Regional assets in this context are broadly defined (Maskell and Malmberg 1999; MacKinnon et al. 2019), covering natural assets (resources), infrastructural and material assets, industrial assets (technology and firm competencies), human assets (labour skills, costs, knowledge), and institutional endowments (rules, routines, values, and norms). These assets are often inherited from previous rounds of industrial path development and innovation activities and are portrayed as ‘products’ of the broader regional environment (MacKinnon et al. 2019) and innovation system (Trippel et al. 2020). The modification of the regional asset base is often contested and may well fail. This could be due to competition over scarce assets between the new green path in focus and other emerging regional industries on the one hand, and between old paths and the new green path on the other hand (Frangenheim et al. 2020).

Based on this discussion, we can identify three main challenges on the production side:

- the start-up challenge refers to barriers that emanate from a poor endowment of assets that are required for nurturing and growing green economic activities and industries. Such assets include the skill base in the existing industrial structure, universities (providing knowledge and qualified workers) and the presence of support structures (incubator space, finance, consultancy and services for new green start-ups: Corradini 2019; Giudici et al. 2019). Such conditions are often not found in peripheral regions that tend to show characteristics of ‘organisationally thin innovation systems’ (Tödtling and Trippel 2005; Isaksen and Trippel 2016). Furthermore, institutional conditions (such as regulations, behavioural attitudes, consumption patterns) and the availability

of natural assets matter for starting green initiatives and firm formation (Capasso et al. 2019);

- the lock-in challenge refers to barriers to green path development that are related to the lock-in of assets into old economic activities, resulting in competition over assets between established industrial paths and emerging green economic activities. There might also be institutional inertia as well as resistance from dominant players in industry and government preventing a necessary modification of assets and support of new green activities. Such a situation is often found in old industrial regions with specialized and rigid innovation systems and institutional structures (Grabher 1993; Hassink 2010); and
- the competition challenge relates to barriers to green industrial path development resulting from competing use of assets in other nascent industries, leading to inter-path competition between different emerging economic activities. This is often the case in metropolitan areas and growth regions with a diversified industrial structure, strong universities, and institutional set-ups that favour entrepreneurial dynamism (Audretsch and Belitski 2017). However, the focus in such regions is often more on a favourable positioning of the urban economy in global sectors such as finance, tourism, research, and IT (Klaesson et al. 2013) and to a lesser extent on green industries.

It is worth mentioning that the extent to which challenges emanating from the availability of assets within the region (including endowment of assets, lock-in of assets, and competition over scarce assets) make an impact is also contingent on the industry under consideration. This argument is supported by Binz and Truffer (2017) who advocate a multiscale conceptualization of innovation systems and claim that industries differ in their dependence on regionally available assets (and customised vs standardised markets). Some industries feature a strong embeddedness in regionally configured innovation systems (and thus depend more on the availability of spatially sticky tacit knowledge and other assets in the region), while others are strongly inserted into globally configured innovation systems and production networks (and thus rely more on globally available knowledge and other assets that are transferable across space). However, it is also important to add that many industries exhibit a relatively strong dependence on regionally available assets and markets in their early stages of development (Feldman 2000; Binz and Truffer 2017).

To summarize, there are strong reasons to claim that conditions and challenges prevailing in different regional contexts and industries strongly shape opportunities for developing green industrial paths in regions.

2.2.2 Challenges on the application side of green technologies

The application side refers to two main groups of users, namely the firm sector and the wider society. The former includes companies in all sectors that adopt green technologies and produce goods and services in a more environmentally friendly way. The latter includes the end consumer and new patterns of consumption. Factors such as dissatisfaction with existing products and an increasing demand for new ones (promising improved service and a better price/performance ratio, energy independence, and user freedom) has been found to play a role (Clausen and Fichter 2019).

Regions differ in their needs to apply green technologies due to varying environmental problems or requirements to secure an intact and healthy environment including clean air, water, and green spaces. Regions facing environmental problems to a high degree first

and foremost include metropolitan areas and old industrial regions. In metropolitan regions, problems often arise from the density of activities, traffic jams, and other environmental externalities. In old industrial areas, it is often the contamination of soil, water, and air by older polluting industries that cause environmental problems. Peripheral areas are usually better off, although some of them (particularly those places that are home to dirty resource-intensive industries or those with agricultural or touristic monocultures) may also face substantial environmental problems.

Similar to the production side, also the capacity to apply green technologies might vary across regions. There is a widespread agreement in the transitions literature that consciousness of firms and society with regard to issues of sustainability plays an important role in the uptake of green technologies (Hansen and Coenen 2015; Capasso et al. 2019). A closely related factor is the acceptance of green technologies and willingness to introduce them. Arguably, this is not only determined by 'sustainability consciousness' and (regional) values and norms favouring the use of green technologies but also by other factors such as a favourable cost-benefit ratio of green innovations and their relative advantage in comparison with existing technologies (Clausen and Fichter 2019). Acceptance and willingness of green innovations might be negatively influenced by the presence of powerful incumbents and users with vested interests who protect their past investments and resist shifts to green technologies (see, for instance, Clausen and Fichter 2019). Development and implementation of green innovation 'generates' winners and losers (Smith and Stirling 2018), and the latter might well contest and lobby against their uptake.

Furthermore, the absorption and learning capacity of potential adopters and users has been found to play a vital role in the diffusion of green technologies. Core processes encompass the absorption of relevant knowledge (and other resources) and collective learning through the accumulation of experience by a variety of actors, who often have different motivations and priorities (Schot and Steinmueller 2018). Recent research suggests that often the absorption and adoption of green technologies does not suffice. They need to be adapted to the particular context by users who—rather than being passive consumers—actively adjust and further develop green innovations (Köhler et al. 2019).

Finally, the capacity to apply green technologies in regions is determined by the availability of natural and other assets. The availability of assets does not only influence choices between green technologies, and it may also stimulate investments in the application capacity (Hansen and Coenen 2015). Moreover, the existing configuration of assets, for example infrastructures and the complementary institutional configurations, is likely to mobilise new or extra-regional assets and capabilities that help embedding green innovations (Hodson et al. 2017). Competition of scarce assets between green innovation and other purposes might be fierce and can obstruct their diffusion.

Based on this review, three main challenges on the application side can be identified:

- awareness and acceptance challenges: barriers to the application of green technologies may be related to low levels of consciousness with respect to sustainability issues and a lack of acceptance of and willingness to introduce green technologies;
- absorption and adaptation challenge: The application of green technologies can be a challenge if the access of regional actors to relevant knowledge and their absorption capacity are poor, if weak institutional structures impede collective learning processes

and if the adaptation of green innovation to the particular context of users fails; and

- asset mobilisation challenge: barriers to the application of green technologies may be due to a lack of assets and resources to introduce such technologies (finance, qualified labour, etc.). Competition over scarce assets with other fields of application may also suppress the implementation of green technologies.

Some regional variation of challenges on the application side can be expected between urban, peripheral, and old industrial areas. Awareness and acceptance challenges might be more severe in peripheral and old industrial areas. What is more, firms and households might have less knowledge and complementary assets to introduce and apply green technologies (absorption, adaptation, and asset mobilisation challenges). Such challenges might be met by supporting demonstration and implementation projects, the provision of testing facilities, or the involvement of end users in working groups and public events (Truffer and Coenen 2012: 11).

In urban and metropolitan areas, in comparison, we tend to find more ‘green minded’ groups of people and firm managers that are aware of environmental problems. In addition, such areas benefit from a rich asset base to deal with such problems. At the same time, competition over scarce assets might be particularly strong, when diverse actors engage in very different experimentation and application activities of green and non-green innovations.

3. Place-specific policies for green regional development

The two dimensions sketched out above are the objective of industrial and innovation policies. Stimulating the rise and growth of green industries that develop green technologies (production side) as well as the use of green technologies (application side) is, however, also promoted by environmental policies and related programmes. There is a large body of literature on new mission-oriented and transformative innovation policies (Mazzucato 2018; Schot and Steinmueller 2018), rationales for policy interventions (Weber and Rohrer 2012), policy instruments (for an overview, see for instance, Capasso et al. 2019), and governance approaches (such as Transitions Management and Strategic Niche Management, Kemp et al. 1998; Loorbach 2010) for green innovation and sustainability transitions. This work has highlighted the role of both conventional policy instruments (such as taxes on pollution emissions, subsidies to support the introduction of green technologies, and environmental regulations), and new policy instruments like transition arenas (which foster collective learning processes, network building, and the development of joint visions) (Köhler et al. 2019). There is also a substantial body of literature (for a synthesis, see, Capasso et al. 2019) on the effects of technology-push instruments (i.e. technology and innovation policy instruments, R&D expenditures), and demand-pull instruments (instruments targeting consumer awareness, consumption behaviour, user innovation, public procurement, environmental regulation, market regulation, etc.).

While research has sought to grasp how particular combinations of instruments (policy mixes) affect the generation and diffusion of green technologies and the development of green industrial paths, recent work also emphasises the need for ‘regime destabilisation policies’ or ‘old path disruption policies’ (Hepburn et al. 2014; Kivimaa

and Kern 2016; Tödtling and Trippel 2018), for instance, by withdrawing subsidies for ‘brown industries’ and ‘dirty’ technologies.

There is also a debate about what can realistically be done at the regional policy level and what is beyond the reach of that level (Essletzbichler 2012). Furthermore, scholarly work has zoomed in on multiscalar institutional configurations and new governance networks which form the context in which the setting up of plans for the uptake of green innovation and wider regional transitions takes place (Hodson et al. 2017). Multiple policy areas at various spatial scales are dealing with governance of sustainability transitions, pointing to the need of horizontal and vertical policy coordination. Participation of quasi-public and private actors in governance arrangements is also crucial (Hansen and Coenen 2015). In this article, we are neither focusing on policy coordination nor on governance failures but rather reflect upon broad strategies at the regional policy level for promoting green innovation.

We argue that policies for the production and application side of green technologies (as well as their combination) should be designed as place-based approaches, because economic as well as environmental challenges vary significantly between different types of regions. Admittedly, this claim is hardly new (Tödtling and Trippel 2005; Barca 2009) and has become a key principle of modern policy approaches such as smart specialisation. While this argument has thus far mainly been made for the production side, we see the need to extend it to the application side. Place-specific policy approaches for green regional development, thus, call for different combinations of industrial and innovation policies that are fine-tuned to the distinct challenges prevailing in regions. These should be complemented by place-specific environmental policies. Different kinds of regional typologies can be relevant in this context. Here, we apply one that takes the densities and structure of RIS into account. Such an approach has previously been used in an innovation policy context (Tödtling and Trippel 2005; Isaksen and Trippel 2016). These region types were conceptually derived reflecting different preconditions for and barriers to innovation. They represent ideal types that are more differentiated in the real world. Since they have different densities of economic activities and industrial structures, they tend to face also different kinds of ecological problems. These, however, were not among the defining criteria.

‘Thick and diversified regions’ tend to have a high potential for innovation and new industrial path development activities (Isaksen and Trippel 2016). Due to high industry and population densities, they face many environmental problems that are related to congestion, car traffic, and the loss of green space, among others. Since these are asset-rich regions, they have strong capacities to develop green industries (Barbieri and Consoli 2019). Policies to stimulate the production side of green technologies might focus on the elimination of specific bottlenecks for the emergence and growth of green industrial paths (e.g. venture or seed capital, and qualifications needed) and support the knowledge exchange and networking of actors within and beyond the region. Also, policies that stimulate the creative redeployment of existing assets are in high demand. Attention should also be given to solving the challenge of inter-path competition between various emerging sectors within the region. In addition to the promotion of knowledge-related activities, investment, support of legitimisation of new technologies, and industries as well as support for regional market creation or for accessing

global markets matter (Binz et al. 2016) to stimulate both the production and application side of green regional development. Application side challenges such as competition over scarce assets with other fields of application may be tackled through developing long-term regional visions. In addition, environmental policies and sound spatial planning are often needed in congested regions, but they face a high resistance from dominant business groups, real estate, car drivers, and others. Useful environmental policy tools include restrictive land use and a consequent transport policy that favours public transport, cycling, and pedestrians over individual car driving. Efficient energy use in buildings, households, and business is another important policy area.

'Thick and specialised regions' also may face grave environmental problems that are frequently related to their previous industrial development patterns. Whereas regions specialised in green industries or business services might have less of such problems, specifically in 'old' industrial regions, typical problems include the pollution of air, and water from mature established industrial activities, as well as the contamination of land and green areas in the neighbourhood of such activities. Often such regions have weak capacities to develop green industries since assets are often 'locked' in old and established industries (Grabher 1993; Tödting and Tripl 2005). As regards production side challenges, such a situation might call for a sound mix of new path development and old path destabilisation policies (Kivimaa and Kern 2016) as outlined, for example, by Nordhause-Janz and Rehfeld (1995) for North-Rhine Westfalia, Tödting et al. (2014) for Upper Austria or Gibbs and O'Neill (2017) for Styria. 'Path destabilisation policies' encompass a wide array of initiatives such as withdrawal of public support for mature sectors, exclusion of incumbents from collective governance arrangements and policy advisory councils, institutional reconfiguration (Kivimaa and Kern 2016). On the application side, demonstration projects, testing facilities, and the involvement of end users might be useful tools to support the adoption of green technologies. In addition, environmental policies might be needed in such places including the repair of damaged landscapes and soil, the reduction and elimination of air and water pollution, and support for the introduction of clean and energy efficient technologies.

'Thin regions' seemingly face fewer environmental problems due to lower firm and population densities. However, some peripheral regions are confronted with environmental problems that are related to the use of insecticides and fertilizers in industrial agriculture, leading to challenges such as the loss of biodiversity and contaminated land and water. Overuse of natural resources and a high pollution could be challenges in peripheral tourist areas. Due to the absence of needed assets such as infrastructure, highly qualified labour, higher education institutes, and supporting organisations (Tödting and Tripl 2005), such regions tend to have weak capacities to develop green industries. Still, there is some potential to grow green industrial paths, such as organic agriculture and organic food (Goodman 2004), forms of 'soft' and green tourism, or the development of eco-energy activities (Gibbs and O'Neill 2017). To support the production side of green regional development, industrial, and innovation policies can facilitate such activities through the provision of necessary infrastructure (transport, energy, schools, etc.), financial support, and stimulation of non-regional knowledge transfer. Application side policies may, besides the provision of finance and labour qualification measures, focus on the development of formal and informal institutional structures for supporting green technologies. Environmental policies also matter, in particular

through the protection of landscapes and nature areas, regulation of land use, and building control (tourist areas).

4. Green regional development initiatives in Austria

4.1 Methodology

In this section, we investigate three green regional development initiatives in Austria. We intentionally focus on one country only, because such initiatives strongly depend on the respective national institutional and policy contexts. Our case selection was based on three criteria. First, we selected cases that represented different initiatives at the production and application side with regional and/or non-regional reach (see Table 1, Section 2). Secondly, we chose cases from each region type (i.e. diversified metropolitan, specialised industrial, and peripheral areas). A third criterion was the availability of published and other material on the respective cases. Indeed, our analysis is mainly based on secondary data sources, such as official publications, reports and websites from regional and national government bodies, as well as from other stakeholders and policy organisations. Where available, we have also drawn on academic publications on the cases. The analysis of the three cases serves to demonstrate how different types of green initiatives have been put into practice, and what the role of policies at the various spatial scales has been for overcoming particular challenges at the production and application side.

4.2 The Austrian E-Mobility region 'Vlotte': Regional application of green technologies produced elsewhere

During the last decade, the diversified industrial region Vorarlberg faced more and more environmental problems due to an increasing firm and population density. Furthermore, in 2009, the federal state's parliament decided to reach energy autonomy by 2050 (Vorarlberger Landesregierung 2015), increasing the pressure on the publicly owned regional energy service provider Illwerke VKW to search for new business areas (Martin 2018). EU regulations and national financial incentives (Climate and Energy Fund 2015) provided a favourable multiscalar institutional and regulatory context to apply green technologies in the region. The region followed an e-mobility strategy among others. Key technologies and products (electric cars) were imported from Japanese manufacturers and made available through leasing contracts by the Illwerke VKW. Together with the regional production of renewable energies, the strategy aimed at lowering CO₂ emissions through the application of e-mobility (cf. Table 1).

Adoption of these technologies in the region has been a challenging task in the pioneering phase since it involved new network formation between rather diverse actors, such as private and public service providers, policy actors, research organisations, and consumers. Policy actors supported interactive learning processes at regional, national, and international levels. The institutional and cultural environment in the relatively small region of Vorarlberg facilitated quick decision processes and trust building among different actor groups.

A major regional potential for green development results from the strong environmental consciousness of the population as well as the openness to new and sustainable technologies (Martin 2018). Awareness raising, an increase of acceptance of green technologies, and the willingness to introduce them (e.g. through events and public presentations) were essentially facilitated through the

establishment of a mobility centre and activities by environmental associations. Moreover, policy agents acted as role models in using e-mobility and articulating their broad consent as regards its future development. Introduction of leasing and sharing models and insurance for batteries supported an increase in acceptance of new technologies among users. The combination of diverse innovative e-mobility solutions such as electric cars, bikes, mopeds, buses, and commercial vehicles supplemented by consulting activities and implementation projects created a favourable environment for learning about end user needs. Nevertheless, a malfunctioning interplay between infrastructural needs to build the regional charging infrastructure and existing building regulations posed challenges to implement e-mobility in Vorarlberg. To allow an effective cost–benefit ratio, financial incentives were provided to build the needed infrastructure for the use of e-vehicles.

The objective of energy autonomy at the national level (BMVIT et al. 2016) led to the requirement that nationally supported e-mobility in Vorarlberg uses renewable energy sources. In this way, national funding has been pooled and made available for green energy and e-mobility providers. Besides the implementation of e-mobility, new photovoltaic panels and a new hydropower plant have been installed.

4.3 ‘Green Tech Valley’ Styria: Production of green technologies for the global market

Within the last four decades, one of Europe’s leading green-tech clusters has been developed in the former old industrial region of Styria. Problematic air qualities and pollution from old industrial activities led to environmental protest and motivated network activities between firms producing green technologies. Located in and around the second largest city and administrative centre of the region, Graz, the Green Tech Cluster has become a hotspot of energy and environmental technologies, in particular hydro and solar thermal power and recycling technologies and systems. Existing firms diversifying into environmental technologies contribute to economic growth in the region (cf. Table 1; Gibbs and O’Neill 2017). This case is an instructive example for the development of a green-tech cluster with global reach and for investigating potentials and challenges on the production side.

The development of a green regional industrial base initially faced strong challenges resulting from missing assets. Whereas solar thermal technologies have been developed as a result of regional bottom-up experiments, later supported by R&D activities through research institutes and companies, biomass technologies have been developed by established organisations related to agricultural activities including the Styrian chamber of agriculture (Schreuer et al. 2010). The main important intermediary actor, the government-supported Eco World Styria created a regional network of related green industrial paths and enabled their positioning in international green economy networks. This facilitated the creation of new opportunities and assets at various levels (e.g. export opportunities and inward investments, mobilisation of human resources). The development of an institutional environment of shared rules and visions supported a self-reinforcing process by means of ‘discursive dynamics and innovative concepts, international recognition and awards, and public appreciation of the eco-city identity’ (Rohracher and Späth 2014).

Challenges related to the de-locking of assets from established industries have been met through old path destabilisation activities, including the withdrawal of financial support, de-legitimisation as

well as institutional reconfiguration. Along with the establishment of specialised competence centres funded by the state, traditional economic interest organisations, most notably the chamber of commerce changed their orientation. Over time, they became less obstructive and subsequently more supportive towards renewable energy technologies (Schreuer et al. 2010).

4.4 ‘The Energy Vision’ in the Styrian district of Murau: Application of regionally produced green technologies within the region

Späth and Rohracher’s (2012) analysis of biomass development in the peripheral district of Murau in Upper Styria provides insights into the exploitation of regional production and application potentials, that is the combination of economic and ecological benefits (cf. Table 1). Due to its sparse population and weak industrial base, regional environmental problems were less pronounced than in the more industrial part of Styria (see Section 4.2). Nevertheless, some actors showing deep knowledge and embeddedness in international networks took the initiative to bring the international energy policy discourse down to the regional level. Strong social relations between heterogeneous actors and the lack of a dominant existing regime allowed for fundamental changes in the regional energy infrastructures and consumption patterns (Späth and Rohracher 2012).

An important initial potential has been the renewed interest in biomass heating among the established private forest owners in a region where community activities, associations and family ties on the one hand and firms as well as ambitious politicians on the other hand provided a ‘sufficiently heterogeneous actor network’ (Späth and Rohracher 2012). Pioneering actors around the Energy Agency of Upper Styria launched a broad participatory initiative to develop the ‘Energy Vision Murau’. Regional acceptance and willingness to actively contribute to energy autonomy, prospering regional economic circuits of energy production and consumption as well as a high level of public awareness have been created in the scope of the ‘Murau Energy Objectives 2015’ (Späth and Rohracher 2012). In this way, challenges related to the awareness and acceptance of as well as the willingness to introduce green technologies had been overcome. The absorption capacity of actors has been increased through knowledge building and learning in permanent working groups who worked on specific strategies (Späth and Rohracher 2012).

Both the availability and absence of assets needed for green regional development had distinct effects on the production side. On the one hand, the peripheral location ‘off the gas grid’ together with a huge woody biomass potential, primarily owned by regional farmers who have a long tradition in biomass use provided favourable conditions for developing a biomass industrial path. On the other hand, regional green industrial activities required R&D efforts, the development of new logistical infrastructures and new services, the mobilisation of funds as well as changes in the regulative frameworks and support structures at higher spatial scales (Späth and Rohracher 2012). Various self-promotional activities and international accentuation of the exemplary nature in the press enabled the district to attract national and EU R&D funding that contributed to knowledge and skill development. Moreover, official credibility could be reached through the establishment of good relationships with representatives of the provincial government and the federal ministry. An active influence on government decisions at various scales could thus be taken (Späth and Rohracher 2012).

The three cases illustrate that green development may take quite different routes in specific regions and that place-based policy approaches need different combinations of measures and instruments that may stimulate either the rise and growth of green industries (production side) or the use of green technologies (application side) in the region.

5. Synthesis

The three cases of green regional development in Austria discussed in the previous section represent different types of regional/non-regional production and application of green technologies. The Austrian E-Mobility region 'Vlotte' provides insights into the application of green technologies in the diversified industrial region of Vorarlberg that has faced environmental problems due to an increasing density of firms and population in the past decades. The 'Green Tech Valley' Styria in the region of Graz is one of Europe's leading green economy locations and represents the case of green technology production for the global market in a specialised industrial region. 'The Energy Vision' in the Upper Styrian district of Murau typifies the regional production as well as application of green technologies in a peripheral region.

Comparison of the cases shows that protests at the regional level against worsening environmental conditions can trigger initiatives by multiple actors at both the production side (case of environmental technology industries in Styria) and the application side (e-mobility in Vorarlberg). Analyses of the three cases also demonstrate how the specificities of the regional asset base shape green regional development. In Murau (Styria), it was the huge biomass potential and the interest of forest owners to exploit this potential. In Vorarlberg, it was in the form of a hydropower potential that could be used for the implementation of e-mobility, as well as an environmentally conscious population that was willing to use this technology. In the region of Graz (Styria), strong technological capabilities of firms, presence of universities and a highly skilled labour force (human assets) were enabling factors.

The three cases also offer insights into various challenges and how they were tackled. To begin with, distinct challenges on the production side—both in form of lacking assets and locked-in assets—could be observed. Absence of regional assets (and the related start-up challenge) was most pronounced in the peripheral region of Murau. Its thin RIS could not provide vitally important assets such as knowledge, qualifications, and finance. Partly, this has been overcome by engaging in interregional relations and networks for acquiring these assets. In the environmental technology cluster around Graz, the problem was more the unlocking of existing assets for the new uses (qualifications, space for new firms).

Turning to the application side, the cases of bio-energy case of Murau and e-mobility in Vorarlberg are instructive examples of the place-specific character of challenges and policy approaches to tackle them. Awareness challenges in Murau were dealt with by linking up to international energy networks, as well as by developing a shared vision among public and private stakeholders. In Vorarlberg, such challenges were met by measures geared towards increasing acceptance of energy autonomy as long-run goal as well as by the engagement of environmental associations. Adoption challenges in Murau were tackled by setting up working groups for knowledge transfer and learning, as well as by accessing national and EU R&D funding. In the e-mobility case of Vorarlberg, also learning networks have been formed and a publicly supported

competence centre was established. The challenge of asset mobilisation for implementing bio-energy in Murau could be overcome by financial support from the province (regional level), Austria, and the EU. In addition, regulative changes were needed at the regional and national levels. This was partly similar in the e-mobility case of Vorarlberg where we also find financial support and regulative changes on all three levels. In addition, there was a need for major investments by the regional energy provider as well as for the creation of new infrastructure for e-mobility.

Taken together, the three cases reflect the heterogeneous nature of green regional development in terms of overall orientation and the sectors, actors and technologies involved. They also reveal how regional policy actors and other stakeholders may take these variations into account when designing place-specific initiatives and mobilising support from multiscalar policy and institutional contexts.

6. Conclusion

This article analyses potential routes and policies for 'green regional development', which refers to both the production and application of green technologies. Despite the global nature of these problems, actions have to be taken often at the regional level. However, different types of regions face distinct industrial and environmental challenges. The article develops a framework that takes such variations into account. We investigate what the role of industrial and innovation policies at the regional level is for green development initiatives, and which kinds of policy options and measures in particular regional settings can be identified. We draw a distinction between the production and the application side of green technologies. The production side includes the industries and companies that develop and produce such technologies, whereas the application side refers to the adoption of green technologies by firms and the wider society. Both the development and production of green technologies and their application involve learning and innovation activities within the region and beyond. We distinguish in a stylised way between three potential routes and apply them to analyse green development initiatives in Austrian regions:

- green technologies are produced in the region and are applied also there (case of eco-energy in the peripheral region of Murau, Styria);
- regional firms produce green technologies for the global market (case of the environmental technology cluster around Graz, Styria); and
- regions may import and implement green technologies that are developed outside the region (case of electric mobility in the diversified region of Vorarlberg).

We identify three challenges on the production side. First, the start-up challenge, which results from a poor endowment of assets and structures (skill base, knowledge providers, support structures for green start-ups, etc.) for nurturing green industries. Many peripheral regions are confronted with this challenge. Secondly, the lock-in challenge, which points to barriers to green industrial path development resulting from institutional inertia, and resistance from dominant players in industry and government. Such problems are often found in old industrial regions with specialised innovation systems and rigid institutional structures. Thirdly, the competition challenge, which relates to the competing use of assets in other green and non-green industries. This is typically the case in larger urban regions with a diversified industrial structure, where the focus is

often more on a favourable positioning in global sectors than on developing green industries. We also spot three challenges on the application side. First, awareness and acceptance challenges may hinder the application of green technologies. Secondly, absorption and adaptation challenges, such as limited access of regional actors to relevant knowledge (and other assets) and a poor absorption capacity, weak institutional structures for collective learning processes, and the neglect of the particular user context, could form barriers to apply and embed green technologies in regions. Thirdly, the asset mobilisation challenge, such as a lack of resources to introduce green technologies (finance, qualified labour, etc.) or competition over scarce assets with other fields of application could inhibit or slow down the application of green technologies. Regional variations in application challenges tend to manifest themselves in a limited awareness and acceptance of green technologies as well as a poor asset base in peripheral and old industrial areas. In metropolitan areas in comparison, one can expect to find more 'green minded' people and a rich asset base.

The empirical part of the article analyses place-based policy approaches for green regional development in Austria. Such policies may stimulate the rise and growth of green industries (production side), they may support the use of green technologies (application side) in the region, or they may promote both routes simultaneously. Arguably, these routes depend on different kinds of preconditions and they involve different challenges. It requires well-targeted combinations of measures and instruments that are fine-tuned to the specificities of the regional production system, the organisational support structures, and the institutional configuration of the RIS including the awareness of the population and the innovation and absorption capacity of regional firms and society. A place-based strategy for green development has to take these conditions into account, according to particular attention to the regional availability of assets, the need to unlock assets from previous industrial activities and regimes, and the potential to mobilise needed assets from higher spatial scales (i.e. the provincial, national, and international levels). The relative importance of these activities varies depending on the specificities of green industries/technologies under consideration.

In diversified regions, industrial policies might focus on the elimination of specific bottlenecks for the growth of green industrial paths and support the exchange of knowledge and other assets within and beyond the region. Further useful policy areas that are not in the focus of this article include spatial planning, energy policy, as well as the improvement of public transport. Old industrial regions are 'locked' in mature industries and have weak capacities to develop green industries. This calls for a combination of new path development and old path destabilisation policies, such as a withdrawal of support for mature sectors and institutional reconfigurations. Environmental policies for such places include the repair of damaged landscapes and soil, the reduction of air and water pollution, and the introduction of green technologies. Thin regions tend to have relatively weak capacities to develop green industries due to a lack of infrastructure, highly qualified labour, and supporting organisations. Nevertheless, some potentials to grow green industrial paths may exist, such as organic food, 'soft' tourism, or eco-energy. Industrial policies can facilitate such activities through the provision of necessary infrastructure (transport, energy, schools, etc.), financial support, and stimulation of transfer and anchoring of knowledge and other assets.

Thus, green regional development is a quite heterogeneous phenomenon that may show different orientations, may be linked to different sectors and may be based on different kinds of technology.

Place-based policies have to take this variation and the respective regional contexts into account. Furthermore, the involvement of the various stakeholders, actor networks, and policy agents at different spatial scales (from regional to European ones) calls for a horizontal and vertical coordination among those actors and levels.

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Co-author declaration for the following joint paper

This declaration states the research contribution (e.g. research idea and – question; data compilation, manipulation and modelling; design and preparation of graphics, maps and tables; writing of text) of the candidate, the main supervisor (where he/she is an associate author) and the other authors.

If applicable, the contributions from other PhD and / or habilitation candidates who have or intend to include the paper in a thesis should be described. Contributions from master students should also be mentioned.

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First author's contribution:

Franz Tödtling has been involved in the development of the research idea and overall conceptualization. He contributed to text writing, supervised the whole research process and undertook review and editing. He contributed 50% of work.

Contributions of other authors:

Michaela Trippel has been involved in the development of the research idea and overall conceptualization and contributed to text writing. She contributed 30% of work



Contributions from other colleagues and master students

Has this paper been, or will this paper be part of another doctoral degree thesis?

Yes: ☐

No: ☒

If yes, please elaborate:

Contributions from master students:

Yes: ☐

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Article IV

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Regional preconditions to shape interpath relations across regions: two cases from the Austrian food sector

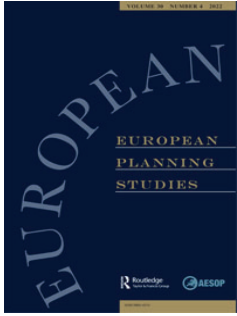
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Regional preconditions to shape interpath relations across regions: two cases from the Austrian food sector

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ABSTRACT

Regional restructuring in the context of societal dynamics involves the development of several, possibly interacting regional industrial paths. Conceptualizations in evolutionary economic geography and innovation studies analyze the effects of relating regional industrial paths in the same regional or national context. While policy makers at EU, national and regional scales support research and development of transformative activities in different regions across countries, scholarly contributions on interpath relations across regions and the role of regional preconditions to enable paths in shaping them are scarce. This article combines recent conceptualizations of interpath relations within regions with considerations about the multi-scalarity of asset availability and modification to conceptualize interpath relations across regions. A framework is developed to explain how reinforcing or impeding effects of interpath relations across regions are related to regional preconditions. Empirically, transformative food sector innovations initiated to tackle societal challenges are investigated as an under-researched topic in the path development literature. Two case studies in a peripheral and a core region provide exemplified results about regional differences in supporting asset modification at multiple scales and demonstrate reinforcing or impeding effects for path development resulting from interpath relations across regions. The article offers policy recommendations and presents avenues for further research.

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Introduction

In light of rising societal challenges, policy makers increasingly aim to support research about and the development of transformative activities evolving around new technologies or other innovations that promise to enable regional structural change towards sustainability in different regions across countries. Since more than a decade, it has been argued that regional restructuring to meet societal challenges necessitates the development and interaction of several paths based on different innovative and more sustainable solutions (Stern 2007). Relations between different existing and emerging industrial

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entities (i.e. technologies, paths, or technological innovation systems) have been studied to better understand and conceptualize the effects of complementarities and synergies as well as competitive relations on regional industrial activities (Sandén and Hillman 2011; Bergek et al. 2015; Boschma et al. 2017; Steen and Hansen 2018; Frangenheim, Trippel, and Chlebna 2020). So far, however, they focussed on relations between different paths in the same regional or national context. This ignores that assets needed for path development in different regions, such as human or financial resources or institutional settings also come from or are modified at national or international sources and scales, which points to interpath relations not only within but also across regions and countries. More recent contributions point to various cumulative or combined effects of interpath dynamics to better account for their impact on whole regions (Breul, Hulke, and Kalvelage 2021; Chlebna, Martin, and Mattes 2021). Our knowledge on regional preconditions to enable or support regional industrial paths to shape interpath relations across regions is, however, limited.

In this analysis, I draw on contributions of evolutionary economic geography (EEG) and the regional innovation system (RIS) literature to consider how regional preconditions enable path development to benefit from assets at multiple scales. Combining these insights with conceptualizations of interpath relations, the distribution of agency and the multi-scalar of asset availability and modification, I provide a framework that explains how regional preconditions shape the outcome of interpath relations across regions. Empirically, the article is positioned within the growing debate on transformative activities from the food sector as expressed in diverse international policy initiatives¹ and research projects (e.g. Wepner et al. 2018; Engelhardt, Brüdern, and Deppe 2020). Strengthening this topic in EEG, I acknowledge the recent wave of food sector innovations that aim to tackle urgent societal challenges around climate change, biodiversity loss and healthy nutrition of a growing world population. Comparing findings from two case studies of early path development located in an urban and a peripheral region in the same national context, my aim is further to contribute to knowledge development of the changing urban–rural geography in the food sector, where cities increasingly position themselves as new centres of innovation in the otherwise peripherally characterized sector. With the article, I seek to answer the following research questions: How are reinforcing or impeding effects of interpath relations across regions generated? How affect regional preconditions the outcome of interpath relations across regions?

The article proceeds by discussing conceptualizations of EEG and innovation studies about industrial change, interpath dynamics and regional preconditions. Carving out multi-scalar mechanisms and systemic relations between actor networks and assets, considerations about interpath relations within regions will be complemented by those across regions. The theoretical part concludes with regional preconditions to modify assets at multiple scales and compiles the conceptual framework. The testing of the conceptual framework is undertaken with two case studies, the diversification of aquaculture towards recirculating aquaculture systems (RAS) originating in the peripheral region of Waldviertel, Lower Austria and the creation of an insect-based food and feed path originating in the capital city of Vienna. The concluding section summarizes the results, provides policy recommendations and avenues for further research.

Interpath dynamics and regional preconditions

EEG explains the emergence, growth, transformation and decline of industries by acknowledging its dependence on previously developed industrial structures in territorial contexts (Martin 2010). A regional industrial path (Figure 1) is represented by related firms and supportive actors. It is stimulated or enabled by place-specific resources, competences, skills, and experiences obtained from previous rounds of path development (Frenken, van Oort, and Verburg 2007; Martin 2010). New path development additionally depends on institutions and policy interventions of local and non-local organizations as well as knowledge linkages to actors across scales (Binz, Truffer, and Coenen 2016; Trippl, Grillitsch, and Isaksen 2018).

This section first reflects on current accounts of industrial change and interpath relations and adds considerations on the generation of reinforcing or impeding effects of interpath relations. To better understand industrial dependencies across regions, it carves out what is known by EEG and innovation studies regarding the multi-scalarity of assets. Finally, it provides an overview of knowledge on regional preconditions to access and modify assets at multiple scales and compiles the theoretical pieces for the conceptual framework.

Processes of industrial change and interpath relations

EEG and innovation studies provide broad insights on regional preconditions, generic mechanisms, agentic processes, multiple actors and assets involved in regional industrial path development (Isaksen and Trippl 2016; Boschma 2017; Isaksen et al. 2019; MacKinnon et al. 2019; Grillitsch and Sotarauta 2020). Inherent to the path development literature is the resource-based view explaining economic competitiveness with the access to and control over assets possibly also needed by other industrial activities (Maskell and Malmberg 1999b). To understand path development in a broad and comprehensive manner, recent accounts relate to Maskell and Malmberg (1999b) who identify five types of assets: (i) human and (ii) industrial knowledge and skills, (iii) infrastructural and material assets in the shape of financial resources, (iv) natural resources and (v) formal and informal institutional assets, such as norms and values. To better understand the dynamics of path development, time-wise historical and future processes of asset development, erosion, and substitution (Maskell and Malmberg

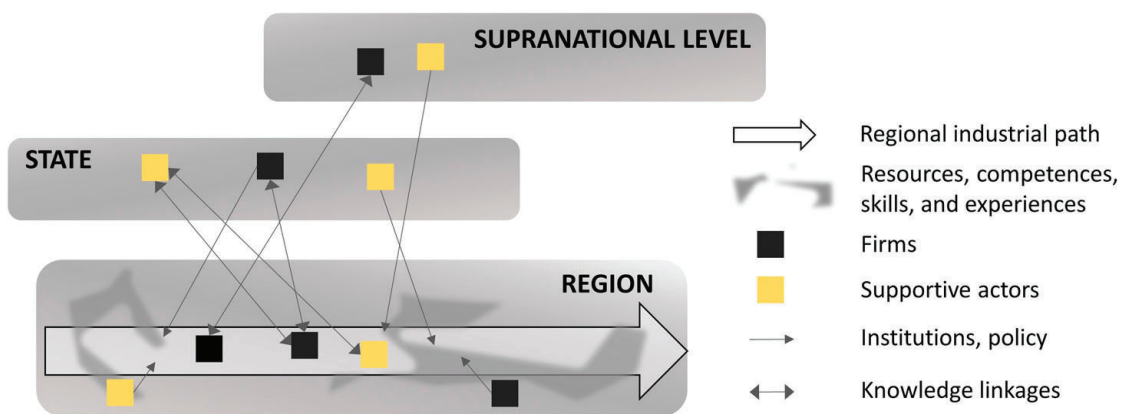


Figure 1. Regional industrial path.

1999a) are reflected in agentic processes of asset modification, more specifically the reuse, creation or destruction of assets (Trippl et al. 2020).

Interpath relations are conceptualized as resulting from the same asset needs. Whether their effects are reinforcing or impeding for regional industrial path development, arguably depends on the outcome of agentic processes of asset modification. In dynamic processes of path development, agency is understood as being distributed among firm and firm-related actors, scientific organizations and those of collective agency from the state, governance and community (Boschma et al. 2017; Isaksen et al. 2019). Acknowledging the distribution of agency among different actor groups, Frangenheim, Trippl, and Chlebna (2020) argue that assets (and markets) needed for path development are not only modified by agents working for the focal path but also by those working for other paths. Actors' involvement in distributed agency then again is unstable and with different degrees (Garud and Karnøe 2003) and the intentions and meanings of actors engaging in agentic processes are negotiated and reframed (Pesch 2015). Assets, therefore, tend to be interpreted towards, oriented at and used by specific paths, which in turn means that other paths may have limited access to them or that the modification of such assets is to the detriment of those paths. Examples are for what kind of use financial resources are available for, at which paths education, industrial standards or infrastructures are oriented at or how laws are interpreted or used. While reinforcing effects may increase the attention of path actors, impeding effects may let them reorient towards other assets and possibly also towards other, more reinforcing interpath relations.

The modification of assets by other paths, e.g. new or adapted policy interventions or regulations, elements in educational schemes, regional infrastructures or shifting consumer preferences, may however not only change the access to or orientation of single assets. Though empirical evidence suggests that in early path development stages the modification of institutions is crucial, further asset modification for path development happens in parallel, overlapping and intertwined processes of asset reuse, creation and destruction (Rypestøl et al. 2021). Due to the inter-connectedness of functionally related asset stocks with its needed coordination and learning between assets at multiple scales (Maskell and Malmberg, 1999a), concerned paths have to (re-)interpret, (re-)orient and (re-)use the remaining asset base by complementary asset modification. Hence, the outcomes of many asset modifications in the context of industrial restructuring processes affect whether and which interpath relations are reinforcing or impeding for regional industrial path development. Before elaborating on the regional preconditions to enable paths to (complementary) modify assets across scales, the next section compiles insights on the availability and modification of assets at regional, national and international scales.

Multi-scalarity of asset availability and modification

Contributions pointing out the role of extra-regional companies and skilled individuals, innovation partnerships across regions and financial or institutional assets at higher scales for regional industrial change processes (Binz, Truffer, and Coenen 2016; Trippl, Grillitsch, and Isaksen 2018) indicate the need to broaden the debate about interpath relations beyond single regions. Indeed, a regional industrial path distinguishes from other paths by specific actors' compositions and networks, regulations, values and norms, as well as access to policy and financial support. Nevertheless, different regional paths may have similarities in multi-

scalar asset needs. The recent literature at the intersection of EEG, geographical political economy and innovation system studies has brought forward valuable frameworks that contribute to a comprehensive and integrative understanding of multi-scalar industrial change processes (Binz and Truffer 2017; MacKinnon et al. 2019). Gaining from the broad collection of insights, I deepen what MacKinnon et al. (2019) summarize as regional and extra-regional assets and distinguish between regionally, nationally and internationally available assets. Moreover, while being consistent with the broad consideration of resources or assets formed in industrial development processes (Binz and Truffer 2017; MacKinnon et al. 2019), I focus on the outcome of agentic processes of asset modification distributed among actors of different paths. I argue that the availability, orientation, or interpretation of assets at multiple scales affect the orientation of path development. This is not to claim that interpath relations are a static phenomenon. To the contrary, earlier analyzes pointed out the transformability of interpath relations (Bergek et al. 2015; Frangenheim, Trippl, and Chlebna 2020). Asset interpretation, orientation and use as a result of interpath relations are subject to change over time. Hence, the same applies to the orientation of paths towards assets and interpath relations.

Different types of assets are located and modified at different scales. Due to their interconnectedness, regional industrial paths orient at complex and context-dependent multi-scalar asset stocks. Natural assets, such as water bodies, wind or solar radiation are available in the region (Isaksen, Langemyr Eriksen, and Rypestøl 2020) as far as they are identified, produced or used through knowledge interaction with actors from the same region or from beyond (Andersen 2012). Financial or infrastructural assets are positioned at multiple, often national or international scales (Isaksen, Langemyr Eriksen, and Rypestøl 2020) and agents modify them thanks to their engagement in regional, national or international political and transdisciplinary committees. Bergek et al. (2015) demonstrate the synergetic development of national funding paired with the feed-in tariff through agents of different renewable energy paths located in different German regions. Human and industrial knowledge and skills need to be harnessed and aligned from within the region as well as from outside through knowledge linkages between firms, industry-university linkages, firm-user interaction or the arrival of new actors (Trippl, Grillitsch, and Isaksen 2018). Pflitsch and Radinger-Peer (2018) show how actors of different disciplines and sectors but with shared interests contribute to developing region-specific research topics and integrating sustainability aspects into university's teaching activities. Finally, institutions exist at various scales (Binz and Truffer 2017). Fuenfschilling and Binz (2018) demonstrate with a case study of Chinese wastewater that international institutional assets must be transferred, (re-)interpreted and implemented at national or regional scales. Moreover, institutional rationalities emerge and gain influence beyond their place of origin in the form of international, institutionalized structures, i.e. institutional asset modification undertaken by regional path' actors also relates to regulative changes at national or supra-national scales.

Regional preconditions for asset accessibility and modification at multiple scales

A conceptual lens to analyze the structural preconditions that influence actors' involvement, capabilities, knowledge and their networks nurturing path development is the RIS. Besides advocating multi-actor approaches (Isaksen and Trippl 2016), RIS studies

increasingly point to multi-scalar industrial, political, educational or financial dynamics (Trippl, Grillitsch, and Isaksen 2018) and path development has been conceptualized as evolving in an open RIS (Asheim, Isaksen, and Trippl 2020). Against this background, it is evident to also look at the regional support structure for modifying assets at national and international scales.

To understand differences in regional preconditions to support paths in modifying assets at multiple scales, the article contrasts a typical RIS of peripheral regions with one of core regions. In the following, idealistic capacities of both RIS types are distinguished and insights will be combined with the multi-scalarity of asset modification to assert their propensity for reinforcing or impeding interpath relations across regions. Adding the considerations of asset interpretation, orientation and use from the point of view of different paths and the need to complementarily modify assets across scales to adapt to or benefit from interpath relations helps building the framework to understand how regional preconditions relate to reinforcing and impeding effects of interpath relations across regions.

Peripheral regions tend to have weak endowments with knowledge generation and diffusion organizations and accordingly little, predominantly local knowledge exchange (Isaksen 2015; Isaksen and Trippl 2016). Internal coordination and learning between asset modification activities, i.e. building complementarity in asset modification, across scales is therefore limited as well as beneficial modification of human, financial or formal institutional assets at higher scales. Peripheral regions access external opportunities resulting from newly created or adapted assets at higher scales thanks to local organizations with boundary-spanning functions, who contribute to knowledge spillovers and build crucial competence internally by linking to resourceful firms, national or international customers, R&D organizations and experts (Isaksen 2015; Isaksen and Trippl 2016). Complementary asset modification within the region is likely supported by the existence of networks with strong bonding social capital that keep actors together by similar values and norms (Isaksen and Trippl 2016). On the downside, strong bonding ties and the existence of only few industrial paths may limit innovation and change and even risk falling into negative lock-in when regional policy interventions are lastingly oriented at established paths (Isaksen and Trippl 2016). While limited asset modification capacities at higher scales make peripheral regions prone to impeding effects of interpath relations across regions, the acceleration of path development as a reaction on externally created or adapted assets is likely through complementary asset modification within the region.

In larger and more centrally located regions, besides bonding social capital also bridging networks exist that link actors from different groups or organizations (Isaksen and Trippl 2016), thus providing high potentials for interpath relations. According to Isaksen and Trippl (2016), they are equipped with diverse and geographically open knowledge networks involving providers of information about new markets and technologies, organizations offering counselling services, bridging organizations, technology transfer agencies, incubators, and others. They provide favourable conditions to benefit from assets created or adapted by other paths at multiple scales. As core centres of continuous change, they nonetheless risk exploring new industrial activities without their exploitation due to the existence of multiple paths at different development stages and differing orientation of regional policies. According to Isaksen and Trippl (2016), this may result in a lack of

policy focus hindering emerging industries to achieve a critical mass. Moreover, the empirical results of this analysis show that a restrictive focus of policy actors towards existing regulative frameworks may limit modification and reorientation of assets to meet new requirements (cf. structural maintenance agency, Jolly, Grillitsch, and Hansen 2020). While emerging paths in core regions might be well equipped to benefit from reinforcing interpath relations across regions, a lack of focus or attention by policy and support organizations can limit complementary asset modification across scales, i.e. adapting the orientation of research and educational programmes, policy support structures, financial sources or laws and regulations accordingly to accelerate path development.

The conceptual framework (Figure 2) understands path development as being stimulated by an open RIS but in need of accessible, interpretable and usable assets at multiple scales. Depending on how well the RIS enables path actors to shape the outcome of asset modification at higher scales, regional industrial paths are rather constrained or reinforced by interpath relations across regions. If needed assets are interpreted for, oriented at or used by extra-regional paths, impeding interpath relations may result in a stagnation or decline of path development (cf. diversification of aquaculture towards RAS in a peripheral region). If assets, modified by extra-regional paths or in cooperation with them, are instead interpreted and oriented in favour of, or possibly used by the regional path, reinforcing interpath relations provide opportunities for path development. Nevertheless, their uptake is not given, if complementary modification of the inter-connected asset stock fails (cf. insect-based food path creation in a core region). As long as reinforcing effects attract the attention of path actors, the path may orient at respective assets. Impeding effects in turn may let path actors reorient towards other assets and possibly also towards other, more reinforcing interpath relations (cf. synergetic relations between aquaculture and insect-based feed).

Methodology of case study comparison

When focussing on a contemporary phenomenon within a real-life context, posing ‘how’ or ‘why’ questions and having limited control over behavioural events, the case study

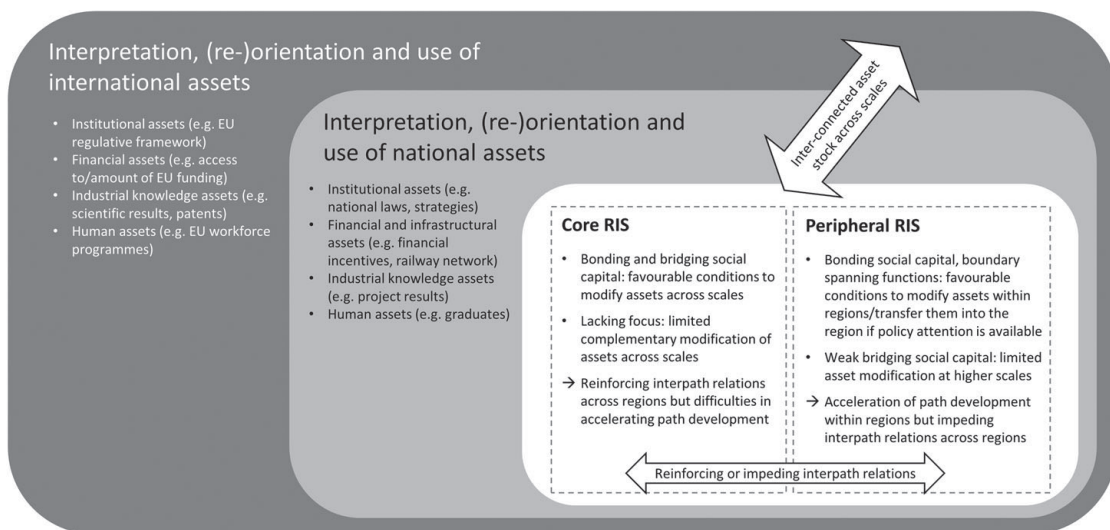


Figure 2. Conceptual framework.

method is the preferred strategy (Yin 2009). The selection of cases has been guided by the theoretically developed framework and undertaken by means of a literature and document analysis, as well as three explorative expert interviews with actors from the City of Vienna, a research institute, and a food sector consulting firm. To ensure familiarity with the Austrian food sector and enable the choice of two appropriate cases, emerging Austrian food paths have been investigated as regards the two main conceptual parts of the framework, regional preconditions and interpath relations across regions. Inspired by Seawright and Gerring (2008), two cases that are most similar across their background conditions, relevant to reinforcing or impeding effects of interpath relations across regions, have been selected: Both emerging paths have external relations to other paths within Austria as well as in other EU regions. Both belong to the same sector, their activities are at a very early stage (less than ten years) and they focus on ecological sustainability. How regional preconditions shape interpath relations across regions is exemplary assessed through the comparison of the diversifying aquaculture in the peripheral region of Waldviertel with insect-based food and feed path creation by urban actors located in Vienna.

16 qualitative interviews with experts identified based on the literature review and recommendations followed between June 2019 and September 2020. Interviews included questions structured along three blocks, namely potentials and barriers for path development at different scales, efforts made to support potentials or overcome barriers, other path development activities across regions and how they are supported by regional preconditions. Including site visits, interviews lasted between one and two and a half hours and – apart from one telephone call – they took place at the actors' premises, where often a visit of the experimental or industrial activities has been possible. Since new path development is in a very early stage lacking established structures, the rather small network of actors exchanges informally at open or closed networking events. During the field studies period, the participation in industrial and policy events allowed for mostly planned, some random fieldwork conversations including ongoing activities by earlier interviewees. Transcribed interviews and systematically documented discussions and presentations at industrial and policy events have been confronted with a coding system, derived from the analytical dimensions of the conceptual framework and complemented empirically where appropriate. Within the qualitative content analysis, re-theorizing helped to consolidate the conceptual framework.

Case rationale

The non-alpine Austrian peripheral regions accommodate large parts of traditional economic activities, such as agricultural production, dairy, meat, milling, bakery, sugar and starch. Established food sector structures with high path dependency are confronted with more and more innovative activities, often originating in cities and aiming to react to urgent societal challenges, such as climate change, loss of biodiversity and an increase in food-related diseases (IR-NAT2). Initiated by Austria's EU accession in 1995, food sector innovation is also a consequence of the gradual embedding of the sector into the international institutional framework regulated by the EU and WTO, accompanying rising international competition, the accessibility of research programmes and funding. Fish production in RAS and the production of insect protein are among the

emerging transformative activities in Austria, which are – despite their only modest number of actors and activities – internationally considered as potentially contributing to the transformation of our food systems (van Huis et al. 2013; Engelhardt, Brüdern, and Deppe 2020). Both emerging paths belong to the group of small food producers, being associated with the places where they originate, who recently gain public national and EU subsidies. Table 1 provides an overview of both cases and the consulted empirical material.

Diversification of aquaculture originating in a peripheral region

Fish production in Austria is a small, yet very old sector with over 500 years of fishpond cultivation and 50–60 years of flow-through systems. With 4.250 tons of edible fish produced by 500 aquaculture operators in 2019, the degree of self-sufficiency is only around 6% (AP-NAT2). Carp production traditionally depends

Table 1. Case description and empirical material.

	Diversification of aquaculture towards RAS	Insect-based food/feed path creation
Case description		
Initiating event	Participative development process of the national aquaculture strategy (2012)	International report on edible insects published by the FAO (van Huis et al. 2013)
Main actors of change	A farmers' cooperative, policy and educational organizations with key network position in traditional fishpond production activities	University scientists and a few start-ups
Region	Peripheral region of Waldviertel	City of Vienna
Empirical material		
Documents analyzed	EU European Maritime and Fisheries Fund Operational programmes of Austria, Slovakia and Hungary and accompanying national reports and presentations (AP-EU) National strategic aquaculture policy documents (AP-NAT1) Project reports of firm-policy cooperation (AF1-REG) RAS educational material (AE1-REG) Reports and data on aquaculture production of Statistik Austria (AP-NAT2)	EU novel food application database (IP-EU) National Guideline for Cultivated Insects as Food and its amendments (IP-NAT1) National policy documents on new processes and techniques in food production and novel foods (IP-NAT2) Project report on larvae cultivation for feed production for fish, poultry and pig by Global 2000 (INGO-NAT)
Material of open or closed network events	Protocols and presentations of three aquaculture dialogue platform events (AP-NAT3) Own notes from and conversations at the Air Liquide food club industrial event 2019 (AF2-INT)	Own notes from and conversations at the Air Liquide food club industrial event 2019 (IF-NAT1) Protocols and presentations of conferences of the Austrian working group insects (IF-NAT2) and at the spring conference of the Austrian Association of Food and Biotechnology (IR-NAT1)
Interviews	Three RAS firm actors (AF3-REG, AF4-REG, AF5-REG) Farmers' cooperative (AC-REG) Advocacy group representing traditional fish production (AA-NAT) Federal Ministry of Sustainability and Tourism (AP-NAT4) Federal Agency for Water Management (AP-NAT5) Federal Environment Agency (AP-NAT6) Regional chamber of agriculture (AP-REG) Agricultural training organization (AE2-REG)	Two firm actors (IF-REG1; IF-REG2) Federal Ministry of Labour, Social Affairs, Health and Consumer Protection (IP-NAT3) Austrian Agency for Health and Food Safety (IP-NAT4) University of Natural Resources and Life Sciences (IR-NAT2) University of Applied Sciences in Graz (IR-NAT3)

on the limited availability of 683 fishponds larger than one hectare (and some not counted smaller ponds) owned by rather few small- and medium-sized family businesses localized in the peripheral regions of Waldviertel, Lower Austria, close to the Czech border, as well as in Southern Styria (AP-NAT1). While carp production stagnates at less than 700 tons per year, trout production in streams or small rivers, mostly located in Upper Austria, Styria and Carinthia, has a slightly larger growth potential (AP-NAT1; AP-REG).

The diversification of aquaculture towards RAS in the peripheral region of Waldviertel has been driven by carp producers and supportive actors who have been involved in the participative development process of the national aquaculture strategy in 2012. This strategy has set ambitious targets to mitigate climate and environment-related challenges, such as rising water temperatures and scarcity and the occurrence of predators, as well as meeting the growing Austrian demand for healthy and sustainable fish products (BMLFUW 2012; (AP-REG)). RAS have been identified as most promising in terms of environment-friendly and rising production rates (AP-NAT1) and soon, fish production in RAS has been exported to other Austrian regions. In 2019, 500 tons of regional fish species like carp and zander as well as foreign species like African catfish or tilapia have been produced by 10 bigger RAS operators and some smaller ‘garage projects’ located in Upper Austria, Lower Austria, Vienna and Burgenland and the production rate is predicted to grow (AP-REG).

Regional innovation system preconditions

In the peripheral region of Waldviertel, diverse firm, public and educational actors have been traditionally engaged in fishpond carp production. The RIS supports these activities with a longtime established network of education facilities, a publicly supported research institute and the regional chamber of agriculture. Peripheral carp production has been characterized by strong informal networks with similar values and norms of actors that well support the aquaculture path in incrementally adapting to changing natural foundations of the economy, such as dryness and the occurrence of predators (AP-NAT4; AP-NAT5). A small number of actors and the limited accessibility of natural resources for long time impeded knowledge exchange, experimentation and learning with, or the entry of new actors, therefore, enforcing mere path extension. Firm as well as public interviewees described the established, inward-oriented path as being characterized by informal knowledge transfer and closed regional networks that are neither well organized, nor are they supported by a functioning articulation beyond the region or are scientifically backed (AF2-INT; AF3-REG; AF4-REG; AF5-REG; AP-NAT6).

Successful complementary asset modification within the region, failed at higher scales

Involved in the participative development process of the aquaculture strategy 2012 (BMLFUW 2012), a farmer’s cooperative and distribution partner of many pond farmers located in Waldviertel, became aware of the opportunity to increase fish production through water-reduced, medication-independent, climate- and predator-resistant RAS (AC-REG). Engaging in regional industrial knowledge development through

excursions to and cooperation with RAS path actors in Burgenland, German, Czech and Dutch regions, the cooperative had an important boundary-spanning function contributing to knowledge spillovers from resourceful extra-regional firms (AP-REG). Building on long-term established cooperation structures, the cooperative, the Federal Agency for Water Management and the chamber of agriculture in Lower Austria (an organization of the federal state) organized a conference at an agricultural training organization located in the center of Waldviertel. They invited several regional and extra-regional speakers and key firm actors of the region to initiate knowledge and skill development (AP-NAT5). Resulting from these discussions, a publicly supported training and testing plant was built by the cooperative who imported knowledge from plant operators located in the regions of Saxony (Germany) and Burgenland (Austria) and cooperated with an association of the Government of Lower Austria and a regional agricultural school (AC-REG; AP-REG; AP-NAT5; AF1-REG). The fact that this plant was built by the cooperative, representing traditional fish farmers, has been initially contested:

Established fish farmers have been very critical so that we had to prove ourselves. We knew, we showcase ourselves with the project and from that perspective, its success has been very important. (AC-REG)

The broad process of complementary asset modification within the region involved knowledge building in established firms and educational bodies by offering workshops, harnessing extra-regional knowledge through excursions to German, Czech and Dutch RAS plant operators, inviting external lecturers, as well as the production of information material including a movie, which attracted also much media attention (AP-NAT5; AP-REG; AE2-REG; AE1-REG).

In 2019, though rooted in Waldviertel, RAS is known beyond the region for its high potential to increase production in an economic and environment-friendly way (AP-REG):

Knowledge transfer happens automatically through our educational offerings, since many trainees come from the rest of Austria to complete the training here in Waldviertel. (AC-REG)

Education and awareness in the peripheral region of Waldviertel has been successfully developed and could even be exported to other regions. When it comes to the modification of international and national financial assets, however, the peripheral region does not have enough resources and capabilities to engage in lobbying or policy strategy development at the national or EU scale:

My role in preparing information and educational material is central in Austria since most other chambers of agriculture do not have the resources to employ a specialised consultant. (...) Beyond that, the capacities to engage in EU negotiations are very limited (... and) despite of first dialogues, there is no association of RAS producers yet. (AP-REG)

Also, human asset modification capacities at higher scales are limited, which restricts complementary asset modification across scales. Interviewees lamented about an insufficient modification of university education in core regions (AA-NAT; AC-REG). Graduates of agricultural schools or universities, who work for advocacy groups or public bodies at the national scale would miss an overall knowledge about RAS potentials and challenges. Often, they hold rather conservative attitudes (AP-NAT6) and

(w)ithout appropriate training and education about innovative solutions, university graduates working in public authorities view RAS with scepticism (...), are reluctant to engage in financial resource development, (or) oversee the need to adjust regulations. (AP-REG)

Impeding interpath relations across regions

The limited asset modification capacities at higher scales make the diversifying aquaculture path prone to impeding interpath relations across regions. Out of more than 200 graduates from the Agricultural training organization, only few firm actors establish RAS in Waldviertel or beyond due to limited financial and (EU) policy support (AE2-REG). The empirical analysis revealed that scarce financial assets and regulations from national and EU scales are used by or oriented at (1) other food paths in Austrian regions, (2) aquaculture (including RAS) paths in other EU regions and (3) traditional trout production in streams or small rivers located in other Austrian regions.

First, the attention of Austrian agricultural policy actors is oriented at other, larger and better organized paths. Although the demand for fish is rising, it is still negligible in comparison to other agricultural paths. This prepares the ground for agricultural lobbyists to pressure politicians to maintain rigid institutions and results in limited resources of national policy actors to engage at the EU level for increasing financial resources from the European Maritime and Fisheries Funds (EMFF) (AP-NAT4):

It is not only a matter of the single wish of aquaculture but Austria's agriculture has also other topics, such as alpine farming etc. In the end, it is a political issue. If Austria decides to engage in EU Agriculture Policy to support farming, then there are less resources to engage for increasing financial resources from the EMFF. (AP-REG)

Second, policy actors and advocacy groups from other EU landlocked countries intensify EU funding disparities through engaging in EMFF funding negotiations to their favour (AP-NAT4; AP-REG). Slovakia produces approximately one third of fish products compared to Austria but receives almost double the funds and also Czech Republic and Hungary receive appreciably higher funds (AP-EU).

Third, there was no reorientation in the implementation strategies of the EMFF at national and regional scales from established fish production methods towards RAS as needed to finance the high investment costs. Interviewees underlined the strong resistance against RAS by firms, public policy representatives and the Austrian fisheries association in favour of trout production in flow-through systems (located in Upper Austria, Styria and Carinthia). They feared competition about the limited financial assets and losing reputation of domestic production in close touch with nature (AP-NAT6; AA-NAT) – reflecting modern brandings around naturally produced food. The Austrian 2014–2020 EMFF operational programme still includes only 16% of funding for RAS activities (as compared to 45% in Slovakia) (AP-EU).

Insect-based food and feed path creation originating in Vienna

Insect protein production in Vienna, as well as in other EU regions found inspiration in a seminal report entitled *Edible insects: Future Prospects for Food and Feed Security* published by the Food and Agriculture Organization of the United Nations (FAO) (van

Huis et al. 2013) and its accompanying first ‘insects to feed the world conference 2014’, organized by the FAO in Wageningen, the Netherlands. Insect-based food path production and distribution in Vienna is represented by a slowly emerging, internationally embedded, university-driven path borne by few Viennese start-ups and two research institutes of the University of Natural Resources and Life Sciences Vienna and the University of Veterinary Medicine in Vienna (IR-NAT2; IP-NAT4). Soon, initial network building and market creation activities by pioneering actors prompted the production of insects as human food in established and new firms located in rural areas of Vorarlberg, Burgenland, Carinthia and Upper Austria (Gugerell and Penker 2020; (IF-REG1; IP-NAT4)). In 2018, a group of researchers at JOANNEUM University of Applied Sciences in Graz started engaging in the integration of insect protein into the Austrian food chain (IR-NAT3). To circumvent restrictive regulations in the food sector, firm and research actors occasionally navigate between insect-based food and feed production (IF-REG2; IR-NAT3).

Regional innovation system preconditions

In the recent past, research and educational organizations combine biotechnological knowledge with competences relevant for food industries thus contributing to a changing urban-rural geography in the food sector, in which cities increasingly position themselves as new centres of innovation in the otherwise peripherally characterized sector (IP-NAT4; IR-NAT2). Vienna builds on a long tradition of food-related university-industry cooperation and recently gets involved in the production of novel foods, plant-based and alternative animal protein, aromas, enzymes, and genetically modified products (IR-NAT2; IP-NAT2). The RIS has favourable conditions to modify industrial skills within the region and access human, institutional and financial assets at higher scales. Firms and universities profit from knowledge exchange at network events and industrial working groups, they attract workers from all over the world, as well as EU funding (IF-REG2; IF-NAT1; IF-NAT2; IR-NAT1). As a downside, research-intensive, technology-driven food-related activities are disfavoured by food policies aligned with existing, rather low-tech food paths, such as alpine farming, forestry or grain farming (AP-NAT4) – a tradition that is strengthened by modern brandings favouring naturally produced foods. Limited attention of policy actors and support structures restrain complementary asset modification across scales. Insect-based food path creation with its technological innovations and foreign species has a difficult starting position also due to a centralistic and strict interpretation of regulations in the sector and a long-term established food identity associated with nature and regionality (IP-NAT4; IF-NAT1; IF-NAT2; IR-NAT1).

Failed complementary asset modification across scales

The international debate about insects as a sustainable protein source initiated by the widely received FAO report (van Huis et al. 2013) motivated the EU to adopt the novel food regulation in 2015. With its implementation in 2018, the decision of which species and form of insects may be sold as edible has been rescaled from the member states to the EU. Viennese firm actors and their cooperation partners have put great

hope in using new institutional assets created at higher scales, however, the translation of institutional assets to lower scales has led to rigid interpretation and shows only low innovative ambition (IF-REG1; IF-REG2; IR-NAT3). The ‘National Guideline for Cultivated Insects as Food’ (BMGF 2017) restricted the sale for human food to whole insects despite of claims to allow their processing by involved scientific partners and firm actors in the working group (IP-NAT2; IF-REG1; IF-REG2; IP-NAT3). Arguing for consumer protection, this restrained further complementary development of region-specific industrial knowledge and skills in the form of product development like pasta, flour or meat substitutes (IF-REG1; IF-REG2; IP-NAT1).²

The working group insects as food (coordinated by the Federal Ministry of Labour, Social Affairs, Health and Consumer Protection) has not changed the direction (...), because until we do not know the needed criteria for food safety, such foods should not come onto the market. (IP-NAT3)

Moreover, policy support structures responsible for developing national legal guidelines are not understood as being subject of modification and reorientation to meet new requirements. Instead, emerging path development activities are understood as not sufficiently matching the existing institutional framework:

The European Union supports much research and innovation. Only later, actors understand that in terms of legal conditions, the new activities are not well aligned to the existing (national) regulative framework (...) guided by the very old, strict and rigid Austrian Food Code. (IP-NAT4)

Institutional asset modification at the national scale has been restrained by the limited attention of policy and support organizations. While in the Netherlands actors from academia, policy and business, organized in the regional Dutch edible insect network, translated their specific requirements for novel food approvals to the EU (House 2018), novel food applications from Austria are a matter of firm engagement alone:

The economic chamber and other advocacy groups bat the ball of legal processing effort back and forth. (...) Firm actors miss legal and technical advice and assistance in providing scientific evidence for risk assessment or demonstrating the safe use of new products. (IP-NAT4)

Reinforcing interpath relations across regions

Path agents follow two strategies to benefit from reinforcing interpath relations. First, since complementary modification of institutional assets at the national scale failed in the first instance, Viennese firm actors adopt a passive attitude waiting for the creation of further novel food approvals at the EU level, e.g. extracted insect protein or fat by non-Austrian or supra-national actors (IP-EU):

Austrian actors wait for applications made by large breeding establishments or the IPIFF (International Platform of Insects for Food and Feed) at the EU level, since it is also a question of financial and other expenses. (IP-NAT3)

As a second strategy to benefit from reinforcing interpath relations, economic activities around insect-based food path development reorient towards feed production where industrial knowledge and skill development is not legally restricted and a great market potential is expected:

Insects as livestock feed are currently allowed for fish but soon regulations will be adapted for chicken and then pigs. The more markets can be served, the more actors will enter the field. (IF-REG2)

Insect-based food path agents reorient to establish reinforcing interpath relations with the peripheral aquaculture path and build industrial knowledge and skills in producing insects for feed. A slow but steadily rising demand for sustainable feed alternatives to the increasingly scarce and expensive oceanic fishmeal has let researchers, diversifying firms, start-ups, environmental NGOs and public bodies, located in Vienna as well as in Austrian peripheral regions and related to both paths, join forces to explore specific feed requirements for RAS (IR-NAT3; NGO-NAT). A core support for cooperation between both paths is regular dialogue platforms organized by the Federal Environment Agency and the ministry responsible for agriculture (AP-NAT6; AP-NAT3). The development is further nurtured through market building cooperation between diverse firms and a big supermarket chain in Austria to jointly develop an antithesis to the delegitimization efforts by the ‘more close-to-nature’ producers:

We want to place a whole range of products and tell a story of how insect-based food and feed is able to solve sustainability problems along the food supply chain – from using old bread to feeding insects producing fish, human food, dog snacks, and fertilizer, among others. (IF-REG2)

Discussion and conclusion

Regional restructuring to meet societal challenges involves the development of several, possibly interacting regional industrial paths. In this article, I build on EEG conceptualizations of interpath relations ‘within’ regions and combine them with recent insights from EEG and innovation system studies on the multi-scalar availability and modification of assets to conceptualize interpath relations ‘across’ regions and countries. Conceptualizing interpath relations as resulting from the same asset needs, their modification decides upon whether interpath relations have reinforcing or impeding effects on involved paths. This is because the modification of assets at multiple scales is distributed among different actor groups working for different industrial paths evolving in different regions and its outcome specifies for which paths assets are accessible, usable, can be best interpreted, or at which paths they are oriented at.

The article contributes a reflection on the dynamic mechanisms of acceleration and (re-)orientation of path development as a reaction to reinforcing or impeding asset modification by other paths. When reinforcing interpath relations increases the attention of path actors, the inter-connectedness of functionally related asset stocks (Maskell and Malmberg, 1999a) impels them to (re-)interpret, (re-)orient and (re-)use the remaining asset base by complementary asset modification. Impeding interpath relations instead stimulate paths to reorient towards other assets and possibly also towards other, more reinforcing interpath relations. Considering the need to modify institutions in the early phase of path development (Rypestøl et al. 2021), the insect-based food case proves the significance of interpath relations in processes of path (re-)orientation when actors navigate between insect-based food and feed production, the latter benefiting from relations with the RAS path.

To build the conceptual framework, I employ the RIS approach to analyze how regional preconditions tend to affect the outcome of asset modification at national and international scales. Comparing the RIS of a peripheral with a core region stimulating two intertwined cases of early path development in the food sector, I contribute empirical material of a rather under-researched topic in EEG (recent exceptions are Martin and Martin 2021; Baumgartinger-Seiringer et al. 2022). The results emphasize that regional preconditions play a meaningful role in complex multi-scalar governance mechanisms. In return, regions rely on national support to enable complementarity in the multi-scalar asset stock for path development. This leads to the question of how the multi-scalar asset availability and modification needed for path development can be reflected in regional and national innovation policies. The aquaculture case has demonstrated that limited competencies in the peripheral region to modify national education schemes and EU financing has contributed to the non-achievement of the objectives in the national aquaculture strategy. The insect-based food and feed case in Vienna revealed a lack of focus by policy and supporting organizations that limited the attention for complementary modification of the national and international regulative framework. In order to capture a competitive advantage for new path development in light of interpath relations across regions, the need to support (complementary) asset modification across scales deserves more attention (i) in urban regions to support the acceleration of path development but also in (ii) peripheral regions to enhance their capacities to modify assets at higher scales and thus their engagement in interpath relations across regions. To begin with, policy should more explicitly consider the tendency of different types of assets to exist at multiple scales. To not only support path agents to make use of externally created assets but also to take care of multi-scalar policy strategy alignment, interventions should take a more integrated approach acknowledging the inter-connectedness of different types of assets across scales.

The empirical analysis showed that the reorientation of both paths towards each other helps complementing missing pieces of the asset stock. On the one hand, regulative barriers can be circumvented by producing animal feed instead of human food until needed institutional asset modification at the EU scale is completed by insect-based food paths evolving in other EU regions. On the other hand, the increasingly scarce, expensive and unsustainable oceanic fishmeal can be replaced with insect-based feed for aquacultures to close the loop in regional fish production. This demonstrates that besides regional preconditions to support path development, relations between several industrial paths evolving in different regions should not be overlooked by structural change policies. To support paths in benefitting from reinforcing interpath relations, policy actors should strategically balance and coordinate the timing of letting path agents wait for further asset modification by other paths (e.g. of the regulative framework, insect-based food) and supporting them to reorient to other reinforcing interpath relations by initiating the debate and providing networking events and support structures (e.g. synergetic development of industrial skills, insect-based feed and aquaculture). To avoid impeding interpath relations, policy actors should question whether path development is in line with their strategic policy orientation to then possibly engage in the creation or reorientation of needed assets (e.g. financial support for RAS to meet the objectives of the national aquaculture strategy).

Food sector innovations do not only increasingly restructure the food production system to cope with urgent societal challenges. Moreover, due to the changing urban-rural geography accentuating the role of cities as new centres of innovation in the peripherally characterized sector, there is scope for policy intervention. Synergetic relationships between the urban insect-based food and feed path and the diversifying rural aquaculture path triggered the establishment of new firms, cooperation projects with NGOs and policy actors in core as well as peripheral regions. These insights point to policy interventions that specifically aim to strengthen core–periphery linkages and bridging ties between scales and paths. Examples could be to open university curricula and research programmes for topics specifically relevant in peripheral regions, to establish dedicated organizations, platforms and living labs and provide determined networking events and conferences.

The focus on two most similar case studies allowed a confirmation as well as empirical complementation of the conceptual framework (Seawright and Gerring 2008), reflecting on idealistic capacities of core and peripheral RIS to modify assets at national and international scales. Nevertheless, this is also a limitation of the analysis that points to the importance of future cross-country comparative studies within the food sector and beyond to prove and extend conceptualizations of how interpath relations are shaped by place-specific preconditions, also taking into account other types of regions and industries. Moreover, the article points to the need for complementary asset modification due to the inter-connectedness of asset stocks. How different (types of) assets across scales are related to each other has, however, not been captured by this article and would warrant further examination.

The role of RIS to influence the routes of path development has recently been further investigated (Trippel et al. 2021). In this article, I accentuate opportunities as well as barriers evolving from interpath relations across regions. This reflects that also the preconditions of other regions may have unintended spillovers on regional industrial path development. I therefore argue that RIS studies should be more open to the influence of RIS beyond the considered region including also questions of rationality or directionality of innovation-based change (Tödting, Trippel, and Desch 2021). In this way, combined effects of multiple paths (Chlebna, Martin, and Mattes 2021) on cross-regional sustainable development could be addressed, which is specifically desirable in the context of rising societal challenges.

Notes

1. Sustainable Development Goals, Food 2030, EU Green Deal, EU Farm to Fork Strategy, EU Biodiversity Strategy for 2030, IPES Food, Milan Urban Food Policy Pact
2. The national guideline for cultivated insects as food is regularly updated and due to institutional asset modification activities by firm and research actors, regulative changes are expected.

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