PEGIS

Papers in Economic Geography and Innovation Studies

2019/01

Green path development, asset modification and agency: towards a systemic integrative approach

Michaela Trippl, Simon Baumgartinger-Seiringer, Alexandra Frangenheim, Arne Isaksen, Jan Ole Rypestøl

University of Vienna | Vienna University of Economics and Business | Austrian Academy of Sciences | University of Agder | Kiel University

Green path development, asset modification and agency: towards a systemic integrative approach

Draft version
January 2019

Michaela Trippl, Department of Geography and Regional Research, University of Vienna (Austria) and Department of Working Life and Innovation, University of Agder (Norway); email: michaela.trippl@univie.ac.at *

Simon Baumgartinger-Seiringer, Department of Geography and Regional Research, University of Vienna (Austria) email: simon.baumgartinger-seiringer@univie.ac.at

Alexandra Frangenheim, Department of Geography and Regional Research, University of Vienna (Austria); email: alexandra.frangenheim@univie.ac.at

Arne Isaksen, Department of Working Life and Innovation, University of Agder (Norway); email: arne.isaksen@uia.no

Jan Ole Rypestøl, NORCE Norwegian research centre (Norway); email: jary@norceresearch.no

* corresponding author

Abstract

Regions across the world are facing to an ever-increasing extent the pressure to find solutions to adverse environmental impacts of economic development. Tackling such challenges requires major restructuring efforts by nurturing new green growth paths and promoting green shifts in mature industries. The paper aims to explore conceptually and based on illustrative empirical examples from the literature how green restructuring unfolds in regions. We propose a systemic integrative approach that distinguishes between various types of green path development and links them to reconfiguration processes of innovation systems. Our framework elucidates how green restructuring and system transformation are related to various types of modifying the region's asset base and provides insights into the role of agency at the firm and system level in bringing about such changes.

Key words: green restructuring; new path development; innovation system reconfiguration; asset modification; firm level agency; system level agency

JEL codes: O33, R11, R58

1 Introduction

Green restructuring has become a core topic of interest in both academic and policy circles. Driven by concerns over climate change, resource depletion and other adverse environmental impacts of economic development, regions and countries across the world are searching for ways to renew their economic structures and to grow new green industries.

Over the past few years, a substantial body of literature has dealt with green innovation and green regional development, ranging from contributions that seek to set new research agendas in the regional studies literature (Gibbs and O'Neill, 2017) to work on green (environmental, eco-) innovation (Calza et al., 2017; Kemp and Pearson, 2007; Schiederig et al., 2012) and green-tech clusters (Cooke, 2008; Marra et al., 2017). There is a flourishing literature on the geography of sustainability transitions (Hansen and Coenen, 2015; Murphy, 2015; Raven et al., 2012; Smith et al., 2010; Truffer, 2008; Truffer and Coenen, 2012; Truffer et al., 2015) and green innovation policies, including new mission-oriented policies, market creation policies and transformative innovation policies (Mazzucato, 2016; OECD, 2015; Schot and Steinmueller, 2018).

This paper conceptualises green restructuring through the concept of green path development. This notion entails both the rise of new green growth paths 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). Recent scholarly work has spotted the need to develop more comprehensive conceptualisations of new path development by complementing EEG with innovation system concepts, transition approaches and the literature on global innovation and production networks (see Hassink et al., 2018 for an overview).

Attempts to apply such extended frameworks to green restructuring have contributed to a better understanding of preconditions, processes and mechanisms of 'new green path development' (Binz and Truffer, 2017; Binz et al., 2016; Dawley et al., 2015; Grillitsch and Hansen, 2018; Hansen and Coenen, 2015; MacKinnon et al., 2018a; 2018b; Simmie, 2012a; Steen and Hansen,

2018). The aim of this paper is to further advance the debate by proposing a conceptual framework which we refer to as 'systemic integrative' (SI) approach. This approach builds on new – but still poorly connected – research perspectives on new path development and brings them together in a coherent framework. More precisely, it pays attention to the way different types of green path development are linked to the reconfiguration of innovation systems and how local and non-local firm level and system level agency may shape the modification of the asset base that is needed for green restructuring and system change to take place.

The remainder of this paper is organised as follows. Section 2 contrasts conventional with emerging research perspectives on new path development and introduces the SI approach. The subsequent sections discuss its core elements in more detail. Section 3 casts light on various forms of green path development. This is followed by section 4, which examines the relation between green path development and the transformation of (regional) innovation systems. 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 restructuring and system reconfiguration. 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 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 flourishing literature on regional diversification (Boschma, 2017) have provided valuable insights into the conditions and mechanisms that fuel the development of new economic activities and industries 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 simple accounts of agency and for overemphasising technological and skill relatedness in their explanations of regional structural change (Hassink et al., 2018). 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; Trippl et al., 2018).

Recent work has sought to develop broader conceptualisations of new path development and argued for creating bridges between EEG and other perspectives. 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., 2018; Isaksen and Trippl, 2016; MacKinnon et al., 2018a). 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, such as path creation or path importation (Isaksen et al., 2018b). Furthermore, the strong focus of EEG on endogenous processes has become challenged, by drawing attention to how exogenous actors, resources and influences are shaping new path development. Emerging perspectives also extend the focus on 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 (Trippl et al., 2018, p. 688) 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.

Table 1: Established and emerging perspectives on regional structural change

	Established perspectives	**Emerging perspectives**
Types of new path development	Related & unrelated diversification (path branching)	Path upgrading/renewal (various forms), path diversification (related & unrelated), path importation, path creation (Grillitsch et al., 2018; Isaksen et al., 2018b; Martin and Sunley, 2006)
Actors and systems	Firm-centred views	Multi-actor approach & systemic (RIS) views (Dawley et al., 2015; Isaksen and Trippl, 2016; Tanner, 2014)
Assets	Focus on technological & knowledge-related (skill) assets	Broader view on assets and asset modification (MacKinnon et al., 2018a; 2018b; Maskell and Malmberg, 1999)
Scales	Endogenous (local) assets and processes of asset modification	Endogenous and exogenous (multi-scalar) resources and processes (Binz and Truffer, 2017; Binz et al., 2016; Boschma et al., 2017; MacKinnon et al., 2018b; Zukauskaite et al., 2017)
Agency: pioneers of change	Firm level agency (Schumpeterian entrepreneur)	Firm-level and system level agency (Isaksen et al., 2018a; MacKinnon et al., 2018a)

Source: own compilation

We propose a comprehensive conceptualisation of green regional restructuring that combines several of the emerging perspectives summarised in Table 1 into what we call 'systemic integrative' (SI) approach. Our framework consists of four elements and the following key propositions:

- Variegated nature of green path development: in line with recent calls for a differentiated view on restructuring (see, for instance, Isaksen et al., 2018a), it champions a nuanced understanding of 'green industrial dynamics' by acknowledging that green shifts may unfold through various forms of path development, each of them driven by distinct mechanisms.
- Innovation system reconfiguration: building on recent debates on the constraining effects of innovation systems (Tödtling and Trippl, 2013) and established industries (Boschma et al., 2017) on regional structural change, it provides insight into the need and forms of system changes for green restructuring to take place.
- Asset modification: we interpret system reconfiguration for green restructuring as asset modification process. In doing so, our framework departs from a broad understanding of assets (MacKinnon et al., 2018a; 2018b) and brings further insight into the ways assets become modified by distinguishing between re-use of existing assets, creation/transplantation of new assets and destruction of old assets.
- Role of agency: invoking an agency perspective and building on the distinction between firm level and system level agency (Isaksen and Jakobsen, 2017), we conceptualise asset modification as the outcome of agentic processes performed by multiple actors at various spatial scales.

In the subsequent chapters, we elaborate on these four elements step by step and merge them into a robust conceptual framework for explaining green regional structural change. The SI approach ties new green path development to the transformation of innovation systems and explicates how firm level and system level agency may lead to the modification of the asset base for green restructuring and system change to occur.

3 Green regional industrial path development

As noted in section 2, recent contributions provide a differentiated understanding of regional structural change by distinguishing between various forms of path development (Grillitsch et al., 2018; Isaksen et al., 2018a; Isaksen et al., 2018b; Isaksen and Trippl, 2016; Martin and Sunley, 2006; Tödtling and Trippl, 2013). In this section, we apply these types of path development to the 'green economy'.

A recent contribution by Grillitsch and Hansen (2018) indicates that 'green regions' (that is, places that host already green industries) face fewer challenges of achieving further rounds of green path renewal and related diversification because of the green character of the existing industrial base. Empirical findings, however, suggest that green path development also takes place in specialised regions with non-green industries (Tödtling et al., 2014), in peripheral regions (e.g. Dawley, 2014) as well as in diversified regions hosting both green and non-green industries (e.g. Dewald and Truffer, 2012). Branching into new green paths represents only one out of several potential routes towards green structural change. In order to capture how restructuring occurs in variegated regional contexts, one also needs to take account of other types of green path development. We suggest distinguishing between the following main forms of green regional restructuring.

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 processes** points to processes through which knowledge and resources 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 (Tödtling 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 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 moves from a 'dirty' into a green industry while the latter illustrates the transfer of resources from an established green industry into a new green sector.

The **emergence of new green industries through path creation and path importation processes** implies the rise of totally new green industries (path creation) or the settlement of green industries that are new to the region (path importation). Path importation results from inflows and anchoring of non-local firms, talent, knowledge and other resources (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 in section 5). 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 Norwegian (see section 6) and German regions (Dewald and Truffer, 2012).

4 Innovation system reconfiguration for green path development

The SI perspective advocated in this paper suggests that green path development can only be fully understood by taking heed of reconfiguration processes of innovation systems. There is a growing recognition that new path development – particularly more radical forms – requires changes in the RIS (Tödtling and Trippl, 2013). Scholarly work suggests that RISs tend to back innovation processes in existing regional industries but are poorly equipped to support new industrial activities (Isaksen and Jakobsen, 2017; Isaksen et al., 2018a). Knowledge and support structures have often co-evolved with and are strongly adapted to the region's current economic structure. They provide already strong industries with competence and resources and thus support continual improvements within established industrial paths. In other words, past rounds of path development are reflected in the region's research and education programmes, its skill base, dominant policy approaches and informal institutional setups. 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).

It follows that if support structures are strongly aligned with dominant industries that are not green, optimisation of the current RIS is the wrong route. For green shifts to occur, the RIS and its core elements, that is, actors, networks and institutions, must undergo changes. Debates on the link between green restructuring and RIS transformation might also draw inspiration from burgeoning work on the purposefulness of innovation systems (Schlaile et al., 2017; Weber and Truffer, 2017). A core question in this regard is how directionality of change can be persistently anchored within a RIS. Studies of photovoltaics in Germany (Dewald and Truffer, 2012) and wastewater in China (Yap and Truffer, 2018) demonstrate that successful processes of embedding directionality systemically are carried out by constellations of quite different actors (such as customers, alliances, companies, etc.). In a similar vein, drawing on institutional theory, Fuenfschilling et al. (2018) advance the idea to understand industrial restructuring as a process of (de-)institutionalisation. Accordingly, formal and informal mechanisms are creating 'rules of the game' which favour the old over the new and therefore need to be adapted or disregarded, while new ones need to be aligned and institutionalised. Informed by these contributions, anchoring directionality towards a green turn in a regional innovation system make a case for policy intervention (regulations, sectoral policies, etc.), institutional entrepreneurship and system level agency (see section 6) on various spatial scales.

5 Asset modification for green restructuring

Green path development requires a broad range of assets. While conventional EEG models are mainly focusing on the importance of technological or skill related assets for regional path development, emerging literature highlights the significance of a broader set of assets. Following Maskell and Malmberg (1999) and MacKinnon et al. (2018a; 2018b), we distinguish between (i) natural assets (resources), (ii) infrastructural and material assets, (iii) industrial assets (technology and firm competencies), (iv) human assets (labour skills, costs, knowledge), and (v) institutional endowments (rules, routines, norms).

Local assets reflect past forms of regional economic development and are seen as products of the broader regional environment (MacKinnon et al., 2018b) and innovation system. They 'can only foster successful path creation if they are identified, harnessed and valorised' (MacKinnon et al., 2018b, p. 4) 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) may also play a key role in new path development (see, for instance, Binz et al., 2016; Miörner and Trippl, 2018; Trippl et al., 2018).

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

- re-using existing local assets (this might entail both the redeployment and the recombination of local assets);
- creating new local assets and accessing/transplanting non-local assets;
- destructing old local assets.

The relative importance of these three types of asset modification processes can be expected to be contingent on the type of green path development (see section 3) under consideration (Table 2).

Table 2: Processes of asset modification and new green path development

	RIS reconfiguration: modification of asset base			Outcome
	Re-using existing local assets	Creating new local assets; accessing /transplant. non-local assets	Destructing old local assets	
Greening of mature industries	**X**	x	x	Path renewal
Rise of new green industries	**X**	x	**X**	Path diversification
	x	**X**	**X**	Path creation/ importation

Source: own compilation
Note: **X** … key processes; x … complementary processes

Table 2 suggests that greening processes in mature industries are largely based on re-using existing local assets. However, for path renewal to occur, other forms of asset modification complementing these processes need to be in place. Kyllingstad and Rypestøl's (2018) analysis of the greening of the process industry in the Agder region of southern Norway is telling in this regard. In Agder, this industry underwent a 'greening process' that was initiated and orchestrated by large units of multinational companies in collaboration with the administration of a formal local cluster. In this specific case, the process of becoming a more sustainable

industry included activities and sub-processes that aimed to create a common worldview amongst the firm leaders, initiatives that launched new meeting places like seminars and creative workshops, and collaborations that led to the sharing of infrastructural elements like laboratories and test equipment. Important to this process was also the introduction of a range of joint R&D programmes. 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. The process industry in Agder has also spilt over their knowledge to other industries, and cluster firms have contributed significantly to raise the vision of the Norwegian process industry to become a zero-emission industry by the year 2050.

Re-use of existing local assets and destructing of old assets are required to support the rise of new green industries through path diversification (see Table 2). Path diversification is exemplified by Steen and Hansen's (2018) study of the emergence of the offshore wind power (OWP) industry in Norway[1]. The authors find that the emerging OWP industry branched out from a well-established offshore oil and gas (O&G) industry. An important part of the branching process was the establishment of two state supported cluster initiatives "which 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 in this branching process was also a substantial range of R&D projects significant to create new knowledge as well as a change in the regulatory context for maritime renewable energy production. The regulations were important to conduct a legal frame for future implementation of OWP farms. Finally, in their 2010-2011 survey, the author finds 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.

As shown in Table 2, 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 of asset creation, transplantation and destruction will be evident as these more radical alternatives are the ones least related to the existing regional asset base. Industry formation for on-site water recycling

[1] We find that the emerge of an OWP industry in Norway is illustrative and relevant even if the emerging industry experienced significant barriers and has yet not established itself as a sustainable industry (Steen and Hansen, 2018).

(OST) in Beijing (Binz et al., 2016) can act as an example of path importation. This industry is founded on well-developed technological components but the relevant business models and operation and maintenance concepts are not. Thus, the development of this embryonic industry relies 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 that is best supported by international knowledge flows and innovation networks. The OST case in Beijing also exemplifies the importance of asset destruction to new green path development as old habits, laws and regulations had to be demolished and replaced in order to open up an internationally attractive niche market in the local hotel sector.

To summarise, the conceptual arguments and review of empirical cases show that different types of green path development are inextricably linked to distinct forms and geographies of asset modification processes. In order to bring further insight into how such processes take place, the next section employs an agency perspective and suggests conceptualising the modification of the asset base for green path development and system reconfiguration as result of deliberate and purposeful action of firm-level and system-level actors within or outside the region.

6 Green path development and RIS reconfiguration through asset modification: 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 SI approach. Agency can be defined as an '… action or intervention by an actor to produce a particular effect' (Emirbayer and Mische, 1998; Sotarauta and Suvinen, 2018).

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 deliberatively create favourable regional environments for the emergence of new paths (Dawley, 2014; Simmie et al., 2008). 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., 2018a). Taking a technological innovation system perspective, Musiolik et al. (2018) emphasise the role of system builders who intentionally create, maintain and change system resources that help building, diffusing and further developing new technologies.

The SI approach advocated in this paper builds on the distinction between firm-level agency and system-level agency (Isaksen and Jakobsen, 2017; Isaksen et al., 2018a; Njøs and Fosse, 2018). New path development is argued to require both types of agency, that is, firm (industry) actors who found new firms or introduce innovative activities within existing companies (firm level agency) and actors who transform innovation systems to support new path development (system level agency).

Firm-level agency may be performed by home-grown incumbents that for example introduce greener production processes (Kyllingstad and Rypestøl, 2018) and local start-up companies that produce for instance renewable energy technologies. Such firms re-use (and/or destroy) existing and create new local assets as a by-product of their green innovation activities. Local firms may also acquire non-local assets by establishing interregional and international networks to R&D organisations and firms or by establishing branches abroad. However, firm-level agency may also be performed by non-local actors, when external investors, e.g. multinational corporations, establish an organisation in the region, which is most often followed by the transplantation of external assets into the region.

An example of 'green' firm-level agency is the initiative by a ship-owner in Western Norway to build an offshore supply vessel in 2009 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 led to changes in institutional endowments, locally by the establishment of a Maritime Clean Tech cluster project and nationally by 'change in public tenders for new maritime transport based on zero emission principles' (op. cit., p. 508). Another example is the establishment of the Norwegian solar Photovoltaic (PV) industry. It grew to become a considerable player at the world market at the start 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 R&D and innovation activity in one old process firm (Elkem) and the fast growth of two spin-offs from Elkem (REC and Norsun) established by one entrepreneur (Table 3). 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' (op. cit., p. 1804). Large Norwegian universities and R&D institutes have acted as knowledge providers for the Norwegian PV industry, and these organisations have connections with foreign research organisations.

While firm-level agency results in asset modification as a consequence of innovation and entrepreneurial activities, system-level agency modifies assets more directly. System-level actors aim to transform innovation systems so that these better support green restructuring. This will include asset creation and re-use, but might also imply activities oriented towards the destruction of existing assets (Kivimaa and Kern, 2016). System-level agency may also be performed by non-local actors, who transplant non-local assets to the region or influence local asset modification from outside. 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.

System-level agency was key to the development of the offshore wind energy industry in Germany as part of the country's ambitious *Energiewende* (MacKinnon et al., 2018b). While the German onshore wind industry emerged in the 1970s from relatively small-scale projects

driven by innovators and entrepreneurs, the offshore wind industry has relied on public support initiatives. Important has been demand-side instruments to help stimulate and protect an emerging market for renewable energy, including offshore wind. Various R&D and demonstration projects were established by the federal government to stimulate market confidence and industrial development. German firms have diversified into production of offshore wind products, but their value chains also include foreign organisations. 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, (op. cit., p. 2024), amongst others in a regional association for biogas stakeholders.

While the two cases of Germany and Scania shed light on the creation of new and the re-use of existing assets, Kivimaa and Kern (2016) draw attention on 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. Asset destruction through system-level agency might include breaking up established actor-network structures, installing control policies (like emission taxes) or withdrawing resources/support for dominant industries. These takes on agency that destabilises existing paths strongly coincide with the aforementioned approach to grasp industrial restructuring as processes of (de-)institutionalisation of the 'rules of the game' (Fuenfschilling et al., 2018). Essentially, the development of new green industrial paths is therefore likely to require system-level agency oriented towards the destruction of old, institutionalised assets.

A highly 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 highly institutionalised regulations and norms are not only environmentally damaging, but also lead to competitive disadvantages for green industries. Destructing said constraining institutional endowments is thus seen as an important measure to pave the way for new green industrial paths.

Table 3: Examples illustrating the role of agency in asset modification for green path development

Example	**Type of agency**	**Asset modification**	**Type of green path development**
Development of maritime fuel cell technology	Firm-level; building of a new vessel	New cluster programme and change in public tenders	Path renewal
Establishment of the Norwegian PV industry	Firm-level; spin-offs from a large firm	Development of new and adaptation of existing technology	Path creation
Development of the German offshore wind industry	System-level; market creation and protection	New policy support instruments	Path diversification
Development of the biogas industry in Scania, Sweden	System-level; legitimation and market creation	Increased cooperation between public and private actors	Path diversification
Retraction of subsidies for environmentally harmful industries, Germany	System-level; disruption and de-institutionalisation	Withdrawal of subsidies and competitive benefits	Paving the way for path creation, importation & diversification

Source: own compilation

The examples point to the fact that firm-level and system-level agency are mutually dependent. Firm-level actors, such as the ship-owner who developed a new type of offshore supply vessels, can initiate new growth paths. However, growth paths demand several firms that produce similar products or services or utilise similar technologies. This will most often require system resources, i.e. commonly available assets. In the 'ship-owner example' public tenders for maritime transport were changed to include zero emission principles. Similarly, system-level agency with the objective of better supporting new growth paths, such as to create and protect markets for renewable energy, need individual actors, i.e. companies and entrepreneurs who take advantage of new opportunities for their own part.

7 Conclusions

In the face of climate change, environmental damages and resource depletion, green restructuring is an urgent priority in many regions across the world. The paper 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 on new path development has begun to bring together established EEG models and insights from other literatures (most notably innovation systems, transition studies, global production and innovation networks, sociological perspectives) to offer broad conceptualisations of regional restructuring. This paper builds on and further advances this work by combining emerging research perspectives into what we call a 'systemic and integrative' (SI) approach.

In showing what the SI approach can bring to economic geography research on green path development, this paper makes three contributions. First, it highlights the need to recognise that green restructuring is highly variegated in its unfolding. The SI approach acknowledges different forms of green restructuring 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, it takes account of the complex relation between green path development and set-ups of innovation systems. By shedding light on how established RISs may hamper green restructuring, the SI approach appreciates how RISs (have to) change to support green shifts. And thirdly, it 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 industrial base towards green fields. Importantly, it contends that agency might not solely be engaged in the re-use of existing local assets and the creation (or transplantation) of new assets but also in 'asset destruction', aiming for instance at desinstitutionalising old 'rules of the game'.

In summary, the SI approach helps to illuminate how various types of green path development unfold in regions, attributing explanatory power to system reconfiguration, 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 should empirically test the SI framework by applying it to different regional and green industrial contexts. Investigating how and why various types of regions (and their innovation systems) differ in their capacity to modify assets through agentic processes and examining how such dynamics vary depending on the industry in focus would enhance understanding of why some places and sectors 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 SI approach.

In conceptual terms, the SI approach could be advanced by incorporating broader context conditions that influence green path development in different types of regions. 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., 2018; MacKinnon et al., 2018a; 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 scare resources (such as skilled labour, policy support or risk capital) and markets are needed (Frangenheim et al., 2018). 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 system change and green shifts.

The economic and 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? How does 'green restructuring' affect the economic prosperity and competitiveness of regions?

Finally, more work is needed to understand the policy implications of the views propagated in this paper. 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). The SI approach suggests that policy should play an active role in reconfiguring innovation systems, facilitating the re-use of existing assets, fostering the creation and transplantation of new assets and engaging in the destruction of old assets. 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 how 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.

References

Battilana, J., Leca, B., Boxenbaum, E., 2009. How Actors Change Institutions: Towards a Theory of Institutional Entrepreneurship. The Academy of Management Annals 3 (1), 65–107. 10.1080/19416520903053598.

Binz, C., Truffer, B., 2017. Global Innovation Systems - A conceptual framework for innovation dynamics in transnational contexts. Research Policy 46, 1284–1298. 10.1016/j.respol.2017.05.012.

Binz, C., Truffer, B., Coenen, L., 2016. Path Creation as a Process of Resource Alignment and Anchoring: Industry Formation for On-Site Water Recycling in Beijing. Economic Geography 92 (2), 172–200. 10.1080/00130095.2015.1103177.

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

Boschma, R., Coenen, L., Frenken, K., Truffer, B., 2017. Towards a theory of regional diversification: Combining insights from Evolutionary Economic Geography and Transition Studies. Regional Studies 51 (1), 31–45. 10.1080/00343404.2016.1258460.

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

Bristow, G., Healy, A., 2014. Regional Resilience: An Agency Perspective. Regional Studies 48 (5), 923–935. 10.1080/00343404.2013.854879.

Calza, F., Parmentola, A., Tutore, I., 2017. Types of Green Innovations: Ways of Implementation in a Non-Green Industry. Sustainability 9, 1301.

Cooke, P., 2008. Cleantech and an Analysis of the Platform Nature of Life Sciences: Further Reflections upon Platform Policies. European Planning Studies 16 (3), 375–393. 10.1080/09654310801939672.

Dawley, S., 2014. Creating New Paths?: Offshore Wind, Policy Activism, and Peripheral Region Development. Economic Geography 91 (1), 91–112.

Dawley, S., MacKinnon, D., Cumbers, A., Pike, A., 2015. Policy activism and regional path creation: the promotion of offshore wind in North East England and Scotland. Cambridge Journal of Regions, Economy and Society 8 (2), 257–272. 10.1093/cjres/rsu036.

Dewald, U., Truffer, B., 2012. The Local Sources of Market Formation: Explaining Regional Growth Differentials in German Photovoltaic Markets. European Planning Studies 20 (3), 397–420. 10.1080/09654313.2012.651803.

DiMaggio, P.J., 1988. Interest and agency in institutional theory. In: Zucker, L.G. (Ed.) Institutional patterns and organizations. Culture and environment. Ballinger, Cambridge, Mass., pp. 3–22.

Emirbayer, M., Mische, A., 1998. What is Agency? The American Journal of Sociology 103 (4), 962–1023.

Fornahl, D., Hassink, R., Klaerding, C., Mossig, I., Schröder, H., 2012. From the Old Path of Shipbuilding onto the New Path of Offshore Wind Energy? The Case of Northern Germany. European Planning Studies 20 (5), 835–855. 10.1080/09654313.2012.667928.

Frangenheim, A., Trippl, M., Chlebna, C., 2018. Beyond the 'single path view': Inter-path relationships in regional contexts. PEGIS - Papers in Economic Geography and Innovation Studies (06), 1–26.

Fuenfschilling, L., Baumgartinger-Seiringer, S., Miörner, J., Trippl, M., 2018. Institutional infrastructure for innovation-based industrial path-renewal, 11 October 2018, Bergen, Regional Innovation Policies Conference 2018.

Garud, R., Karnøe, P., 2001. Path Creation as a process of mindful deviation. In: Garud, R., Karnoe, P. (Eds.) Path Dependence and Creation. Lawrence Earlbaum Associates, pp. 1–38.

Garud, R., Kumaraswamy, A., Karnøe, P., 2010. Path Dependence or Path Creation? Journal of Management Studies 47 (2), 760–774.

Gibbs, D., O'Neill, K., 2017. Future green economies and regional development: A research agenda. Regional Studies 51 (1), 161–173. 10.1080/00343404.2016.1255719.

Grabher, G., 1993. The weakness of strong ties: the lock-in of regional development in the Ruhr area. In: Grabher, G. (Ed.) The embedded firm. On the socioeconomics of industrial networks. Routledge, London.

Grillitsch, M., Asheim, B., Trippl, M., 2018. Unrelated knowledge combinations: the unexplored potential for regional industrial path development. Cambridge Journal of Regions, Economy and Society 11 (2), 257–274. 10.1093/cjres/rsy012.

Grillitsch, M., Hansen, T., 2018. Green industrial path development in different types of regions. Papers in Innovation Studies (11), 1–26.

Grillitsch, M., Sotarauta, M., 2018. Regional Growth Paths: From Structure to Agency and Back. Papers in Innovation Studies (1), 1–23.

Hansen, T., Coenen, L., 2015. The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field. Environmental Innovation and Societal Transitions 17, 92–109. 10.1016/j.eist.2014.11.001.

Hanson, J., 2018. Established industries as foundations for emerging technological innovation systems: The case of solar photovoltaics in Norway. Environmental Innovation and Societal Transitions 26, 64–77. 10.1016/j.eist.2017.06.001.

Hassink, R., Isaksen, A., Trippl, M., 2018. Towards a comprehensive understanding of new regional industrial path development. PEGIS - Papers in Economic Geography and Innovation Studies (2), 1–19.

Holmen, A.K.T., Fosse, J.K., 2017. Regional agency and constitution of new paths: a study of agency in early formation of new paths on the west coast of Norway. European Planning Studies 25 (3), 498–515. 10.1080/09654313.2016.1276159.

Isaksen, A., Jakobsen, S.-E., 2017. New path development between innovation systems and individual actors. European Planning Studies 25 (3), 355–370. 10.1080/09654313.2016.1268570.

Isaksen, A., Jakobsen, S.-E., Njøs, R., Normann, R., 2018a. Regional industrial restructuring resulting from individual and system agency. Innovation: The European Journal of Social Science Research 101 (2), 1–18. 10.1080/13511610.2018.1496322.

Isaksen, A., Tödtling, F., Trippl, M., 2018b. Innovation Policies for Regional Structural Change: Combining Actor-Based and System-Based Strategies. In: Isaksen, A., Martin, R., Trippl, M. (Eds.) New Avenues for Regional Innovation Systems - Theoretical Advances, Empirical Cases and Policy Lessons. Springer International Publishing, Cham, pp. 221–238.

Isaksen, A., Trippl, M., 2016. Path development in Different Regional Innovation Systems: A Conceptual Analysis. In: Parrilli, M.D., Dahl-Fitjar, R., Rodriguez-Pose, A. (Eds.) Innovation drivers and regional innovation strategies, pp. 66–84.

Kemp, R., Pearson, P., 2007. Final report MEI project about measuring eco-innovation. Lead contractor: UM-MERIT, 120 pp.

Kivimaa, P., Kern, F., 2016. Creative destruction or mere niche support?: Innovation policy mixes for sustainability transitions. Research Policy 45 (1), 205–217. 10.1016/j.respol.2015.09.008.

Klitkou, A., Coenen, L., 2013. The Emergence of the Norwegian Solar Photovoltaic Industry in a Regional Perspective. European Planning Studies 21 (11), 1796–1819. 10.1080/09654313.2012.753691.

Köder, L., Burger, A., 2016. Umweltschädliche Subventionen in Deutschland. Aktualisierte Ausgabe 2016, Dessau-Roßlau, 124 pp.

Kyllingstad, N., Rypestøl, J.O., 2018. Towards a more sustainable process industry: A single case study of restructuring within the Eyde process industry cluster. Norsk Geografisk Tidsskrift - Norwegian Journal of Geography 75, 1–10.

MacKinnon, D., Dawley, S., Pike, A., Cumbers, A., 2018a. Rethinking path creation: A geographical political economy approach. Papers in Evolutionary Economic Geography (18.25), 1–49.

MacKinnon, D., Dawley, S., Steen, M., Menzel, M.-P., Karlsen, A., Sommer, P., Hansen, G.H., Normann, H.E., 2018b. Path creation, global production networks and regional development: A comparative international analysis of the offshore wind sector. Progress in Planning. 10.1016/j.progress.2018.01.001.

Marra, A., Antonelli, P., Pozzi, C., 2017. Emerging green-tech specializations and clusters – A network analysis on technological innovation at the metropolitan level. Renewable and Sustainable Energy Reviews 67, 1037–1046. 10.1016/j.rser.2016.09.086.

Martin, H., Coenen, L., 2015. Institutional Context and Cluster Emergence: The Biogas Industry in Southern Sweden. European Planning Studies 23 (10), 2009–2027. 10.1080/09654313.2014.960181.

Martin, R., 2010. Roepke Lecture in Economic Geography - Rethinking Regional Path Dependence: Beyond Lock-in to Evolution. Economic Geography 86 (1), 1–27. 10.1111/j.1944-8287.2009.01056.x.

Martin, R., 2014. Path dependence and the spatial economy: A key concept in Retrospect and prospect. In: Fischer, M.M., Nijkamp, P. (Eds.) Handbook of regional science. Springer Reference, Heidelberg, pp. 609–629.

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

Maskell, P., Malmberg, A., 1999. The Competitiveness of Firms and Regions. European Urban and Regional Studies 6 (1), 9–25. 10.1177/096977649900600102.

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

Miörner, J., Trippl, M., 2018. Embracing the future: Path transformation and system reconfiguration for self driving cars in West Sweden. PEGIS - Papers in Economic Geography and Innovation Studies (2018/04), 1–22.

Murphy, J.T., 2015. Human geography and socio-technical transition studies: Promising intersections. Environmental Innovation and Societal Transitions 17, 73–91. 10.1016/j.eist.2015.03.002.

Musiolik, J., Markard, J., Hekkert, M., Furrer, B., 2018. Creating innovation systems: How resource constellations affect the strategies of system builders. Technological Forecasting and Social Change in press. 10.1016/j.techfore.2018.02.002.

Njøs, R., Fosse, J.K., 2018. Linking the bottom-up and top-down evolution of regional innovation systems to policy: organizations, support structures and learning processes. Industry and Innovation 12 (3), 1–20.

OECD, 2015. System Innovation: Synthesis Report.

Raven, R., Schot, J., Berkhout, F., 2012. Space and scale in socio-technical transitions. Environmental Innovation and Societal Transitions 4, 63–78. 10.1016/j.eist.2012.08.001.

Schiederig, T., Tietze, F., Herstatt, C., 2012. Green innovation in technology and innovation management - an exploratory literature review. R&D Manage 42 (2), 180–192.

Schlaile, M., Urmetzer, S., Blok, V., Andersen, A., Timmermans, J., Mueller, M., Fagerberg, J., Pyka, A., 2017. Innovation Systems for Transformations towards Sustainability? Taking the Normative Dimension Seriously. Sustainability 9 (12), 2253. 10.3390/su9122253.

Schot, J., Steinmueller, W.E., 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. Research Policy. 10.1016/j.respol.2018.08.011.

Simmie, J., 2012a. Path Dependence and New Path Creation in Renewable Energy Technologies. European Planning Studies 20 (5), 729–731. 10.1080/09654313.2012.667922.

Simmie, J., 2012b. Path Dependence and New Technological Path Creation in the Danish Wind Power Industry. European Planning Studies 20 (5), 753–772. 10.1080/09654313.2012.667924.

Simmie, J., Carpenter, J., Chadwick, A. Martin, R., 2008. History Matters: Path dependence and innovation in British city-regions. Nesta Research report, 96 pp.

Smith, A., Raven, R., 2012. What is protective space?: Reconsidering niches in transitions to sustainability. Research Policy 41 (6), 1025–1036. 10.1016/j.respol.2011.12.012.

Smith, A., Voß, J.-P., Grin, J., 2010. Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. Research Policy 39 (4), 435–448. 10.1016/j.respol.2010.01.023.

Sotarauta, M., Mustikkamäki, N., 2015. Institutional Entrepreneurship, Power, and Knowledge in Innovation Systems: Institutionalization of Regenerative Medicine in Tampere, Finland. Environ Plann C Gov Policy 33 (2), 342–357. 10.1068/c12297r.

Sotarauta, M., Suvinen, N., 2018. Institutional Agency and Path Creation. In: Isaksen, A., Martin, R., Trippl, M. (Eds.) New Avenues for Regional Innovation Systems - Theoretical Advances, Empirical Cases and Policy Lessons. Springer International Publishing, Cham, pp. 85–104.

Steen, M., Hansen, G.H., 2018. Barriers to Path Creation: The Case of Offshore Wind Power in Norway. Economic Geography 94 (2), 188–210. 10.1080/00130095.2017.1416953.

Tanner, A.N., 2014. Regional Branching Reconsidered: Emergence of the Fuel Cell Industry in European Regions. Economic Geography 90 (4), 403–427. 10.1111/ecge.12055.

Tödtling, F., Höglinger, C., Sinozic, T., Auer, A., 2014. Factors of the emergence and growth of environmental technology industries in Upper Austria. Mitteilungen der Österreichischen Geographischen Gesellschaft (156), 1–25.

Tödtling, F., Trippl, M., 2013. Transformation of regional innovation systems: From old legacies to new development paths. In: Cooke, P. (Ed.) Re-framing regional development. Evolution, innovation and transition, 1st ed. Routledge, London u.a., pp. 297–317.

Trippl, M., Grillitsch, M., Isaksen, A., 2018. Exogenous sources of regional industrial change. Progress in Human Geography 42 (5), 687–705. 10.1177/0309132517700982.

Truffer, B., 2008. Society, Technology, and Region: Contributions from the Social Study of Technology to Economic Geography. Environ Plan A 40 (4), 966–985. 10.1068/a39170.

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

Truffer, B., Murphy, J.T., Raven, R., 2015. The geography of sustainability transitions: Contours of an emerging theme. Environmental Innovation and Societal Transitions 17, 63–72.

Weber, K.M., Truffer, B., 2017. Moving innovation systems research to the next level: Towards an integrative agenda. Oxford Review of Economic Policy 33 (1), 101–121. 10.1093/oxrep/grx002.

Yap, X.-S., Truffer, B., 2018. Shaping selection environments for industrial catch-up and sustainability transitions: A systemic perspective on endogenizing windows of opportunity. Research Policy.

Zukauskaite, E., Trippl, M., Plechero, M., 2017. Institutional Thickness Revisited. Economic Geography 5 (30), 1–21. 10.1080/00130095.2017.1331703.

Department of Geography and Regional Research
University of Vienna

Contact person: Michaela Trippl
Universitätsstraße 7/5/A0528, 1010 Vienna, Austria
Tel.: +43-1-4277-48720
E-Mail: Michaela.trippl@univie.ac.at
https://humangeo.univie.ac.at/

Department of Socioeconomics
Vienna University of Economics and Business

Contact person: Jürgen Essletzbichler
Welthandelsplatz 1, 1020 Vienna, Austria
Tel.: +43-1-31336/4206
E-Mail: juergen.essletzbichler@wu.ac.at
http://www.wu.ac.at/en/department-socioeconomics

Institute for Urban and Regional Research
Austrian Academy of Sciences

Contact person: Robert Musil
Postgasse 7/4/2, 1010 Vienna, Austria
Tel.: +43-1-51581-3520
E-Mail: robert.musil@oeaw.ac.at
https://www.oeaw.ac.at/en/isr/home/

Department of Working Life and Innovation
University of Agder

Contact person: Arne Isaksen
Jon Lilletunsvei 3/A161, Grimstad, Norway
Tel.: +47-37-23-33-53
E-Mail: arne.isaksen@uia.no
https://www.uia.no/en/about-uia/faculties/school-of-business-and-law/department-of-working-life-and-innovation

Department of Geography
Kiel University

Contact person: Robert Hassink
Hermann-Rodewald-Str. 9, 24098 Kiel, Germany
Tel.: +49-431-880-2951
E-Mail: hassink@geographie.uni-kiel.de
https://www.wigeo.uni-kiel.de/en/