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

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Abstract

Green and sustainable development has 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, such as local and regional ones. In this paper we focus on innovation and industrial policies and on the regional level, since green development often emerges here and can be supported by respective policies. However, effective policies have to consider that individual regions face different kinds of industrial and environmental challenges for moving towards a 'greener' future. This article develops a framework that allows taking such differences into account. Furthermore, we distinguish between the production and application of 'green technologies' and consider their spatial nature. We investigate factors and challenges for green regional development and we 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 solutions

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1 Introduction

Green and sustainable development has received increasing attention in recent years due to problems such as climate change and environmental degradation. Much attention has been directed to the 'green economy' in this regard. This notion is the subject of vivid discussions and contestation (see, for instance, Bina 2013; Caprotti and Bailey 2014). Gibbs and O'Neill (2017) state that the '... green economy has led to a policy focus upon the potential for change to existing socio-economic development pathways. A major component of this has involved low-carbon initiatives – attempts to reduce greenhouse gas emissions and so mitigate climate change – and the development of a low-carbon economy'.

In this article, we invoke the notion of 'green regional development', which is claimed to encompass both the production of green solutions and their application to solve concrete environmental challenges. We therefore consider the production and/or application of technologies, products or solutions in regional economies and societies that help to reduce environmental problems such as CO2 emissions and other forms of pollution and environmental degradation. This includes also more sustainable consumption and mobility patterns as well as energy efficient housing, settlements and transport systems, among others.

Although these are generally problems of global nature, actions have to be taken often at lower spatial scales, that is, local, regional or national ones. Both, environmental and industrial policies matter in order to meet such challenges and thus enable regions to move towards greener forms of economic and societal development. In this article we focus on industrial and innovation policies and on the regional level since green development activities often emerge at this spatial scale in the form of eco-clusters or other initiatives. Effective policies have to take into account that different types of regions face distinct challenges, barriers and supporting factors for establishing or adopting green development activities due to different environmental situations, industrial structures and institutional settings. We will develop a framework that allows taking such differences into account. Furthermore, we distinguish between the production and application of relevant technologies and solutions and we consider their spatial nature, that is, their regional or interregional character. We will address the following research questions:

- What is the role and importance of industrial and innovation policies at the regional scale for the emergence and development of green initiatives and activities?

- Which kinds of policy options and measures can be identified in particular regional settings in order to stimulate green regional development?

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 Austrian regions. The article is organised as follows. In the next section, we differentiate between the production side and the application side of green regional development. Based on theoretical achievements in economic geography, innovation and transition studies, respective challenges for the production as well as the application of green technologies and solutions 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 engages in a discussion of empirical evidence from Austria. The final section provides a synthesis of our arguments and concludes.

2 Green Regional Development: Towards a Policy Framework

We consider it as vital to distinguish between two dimensions of 'green regional development'. There is a production (supply) side and an application (demand) side of new technologies and solutions that help to mitigate climate change and other environmental problems (section 2.1). This serves as a point of departure for identifying various 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 and solutions

The production side of green regional development encompasses the industries and companies that develop and produce green technologies and solutions. Over the past years, many studies have examined the generation of eco-innovation (Calza et al. 2017; Schiederig et al. 2012) and the development of clean-tech clusters (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 and solutions 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 and solutions within the region (Hodson et al. 2017).

As shown in Table 1, the two dimensions outlined above may or may not overlap in regions. One can distinguish between three potential constellations:

- Green technologies or solutions produced in the region are applied there to solve concrete environmental problems (box A in Table 1). 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 regional industries or companies may produce for international markets (box B, Table 1). An illustrative example is the wind industry in Norway (Steen and Hansen 2018).
- Regions may import and implement green technologies and solutions developed elsewhere (box C, Table 1). 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).

Table 1: Green regional development: production and application side - local and global dimensions

		Application	
		Local	Global
Production	Local	**A: Regional economic and ecological value creation:** Use of locally produced green solutions within the region	**B: Regional economic value creation:** Production of green solutions for the global market
	Global	**C: Ecological value creation within the region:** Use of green solutions produced elsewhere within the region	

Source: own compilation

2.2 Green regional development: regional variations of challenges

Many regions across the world are confronted with – albeit in different forms and intensities – environmental problems and challenges. One can observe pollution of air, water and soil, and a loss of ecological variety in metropolitan, industrial as well as rural regions. Whereas more densely populated places face high ecological footprints due to industrial and consumption practices, resource exploitation in peripheral areas may provoke massive environmental damage (Patchell and Hayter 2013). In this subsection we focus on the challenges for the development and production as well as the application and use of green technologies and solutions.

Challenges on the production side of green technologies and solutions

Green activities and industries are often seen as a new source of economic growth and job creation. Regions differ in the pressure they face to develop such new 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 (Rodríguez-Pose 2018).

However, regions differ in their capacity to nurture new industries in general (Fritsch and Storey 2014; Isaksen and Trippl 2016), and green new industries in particular (Barbieri and Consoli 2019; Corradini 2019; Santoalha and Boschma 2019). Regional variations in boosting green industrial path development 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 of regional green growth have been informed by the cluster approach (Porter 2008), scholarly work on related variety and regional diversification (Boschma and Frenken 2011), and the RIS concept (Cooke 2008; Trippl, Baumgartinger-Seiringer, Frangenheim et al. 2019).

The cluster approach has been applied to investigate growing 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 is 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; Trippl, Baumgartinger-Seiringer, Frangenheim et al. 2019). EEG protagonists highlight the significance of related diversification processes for industry emergence, that is, the transfer of competences from old to new sectors (e.g. through the branching of firms, spin-offs, labour mobility and networking). In a study covering seven EU countries and 95 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 (Colombelli and Quatraro 2019; Corradini 2019; Tanner 2016; van den Berge and Weterings 2014). 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. Trippl, Baumgartinger-Seiringer, Frangenheim et al. (2019) for instance suggest differentiating between green path creation, importation and (un-)related diversification to capture various mechanisms and outcomes of green 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 cleantech 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 bio-fuels, 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 organisations, universities and schools, and intermediaries, among others. It emphasises the role of formal and informal institutions as well as of government bodies (Cooke et al. 2010; Tödtling and Trippl 2013). The approach thus helps to understand how multiple actors shape branching processes and other forms of 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 three forms, ranging from the redeployment of existing assets to the creation of new assets and the (strategic) destruction of old assets (Trippl, Baumgartinger-Seiringer, Frangenheim et al. 2019). Regional assets in this context are broadly defined (MacKinnon et al. 2019; Maskell and Malmberg 1999), 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 (Trippl, Baumgartinger-Seiringer, Frangenheim et al. 2019). 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 (Frangenheim et al. 2019) on the one hand, and between old paths and the new green path on the other hand (Trippl, Baumgartinger-Seiringer, Frangenheim 2019).

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. Such assets include the skill base in the existing industrial structure allowing for branching into green industries, 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' (Isaksen and Trippl 2016; Tödtling and Trippl 2005). Furthermore, institutional conditions and assets (such as regulations, behavioural attitudes, consumption patterns) and the availability of natural assets matter for starting green initiatives or firms (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 traditional industrial regions with

specialised and rigid innovation systems and institutional structures (Grabher 1993; Hassink 2010; Tödtling et al. 2014; Tödtling and Trippl 2005).

- The competition challenge relates to barriers to green 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.

There are strong reasons to claim that the firm and non-firm activities to develop a green industry are contingent upon the conditions and challenges prevailing in different regional contexts. In other words, growing a green regional industrial path requires overcoming place-specific barriers and setting in motion distinct asset modification processes. Relative importance of asset creation, importation, de-locking or redeployment can be expected to vary significantly depending on the dominant challenges sketched out above.

Challenges on the application side of green solutions

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 solutions and produce goods and services in a more environmentally friendly way (for instance, by introducing clean technologies with the aim to reduce their environmental impact), that is, green path renewal. The latter includes the end consumer and new patterns of consumption. Factors such as dissatisfaction with existing products and changing demand have been found to play a role, especially when these are linked to modern forms of value creation such as improved service, quality of life issues, a better price/performance ratio, energy independence and user freedom (Clausen and Fichter 2019; Turnheim and Geels 2012).

Regions differ in their needs to apply green technologies and solutions 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 the former areas, problems often arise from the density of activities, traffic jams, and other environmental externalities. In the latter group of regions, it is often the contamination of soil, water and air

by older polluting industries that causes 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.

Similarly to the production side, also the capacity to apply green technologies and solutions to meet environmental issues 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 solutions (Capasso et al. 2019; Hansen and Coenen 2015). A closely related factor is the acceptance of green solutions and willingness to introduce them. Arguably, this is not only determined by 'sustainability consciousness' and (local) values and norms favouring the use of green solutions but also by other factors such as a favorable cost-benefit ratio of green innovations and their relative advantage in comparison to 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 solutions (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.

Further, the absorption and learning capacity of potential adopters and users has been found to play a vital role in the diffusion of green solutions. 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 new solutions 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 solutions in regions is determined by the availability of natural and other assets. The availability of assets does not only influence choices between green solutions, it may also stimulate investments in the application capacity (Hansen and Coenen 2015). Moreover, the existing configuration of assets, e.g. 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 pointed out:

- Awareness and acceptance challenges: barriers to the application of green solutions may be related to low levels of consciousness with respect to sustainability issues and a lack of acceptance of and willingness to introduce green solutions.
- Absorption and adaptation challenge: The application of green solutions can be a challenge if the access of regional actors to relevant knowledge and their absorption capacity is poor, if weak institutional structures impede collective learning processes, and if the adaptation of green innovation to the particular context of users fails.
- Asset mobilisation challenge: barriers to the application of green solutions may be due to a lack of assets and resources to introduce green solutions (finance, qualified labour, etc.) or competition over scarce assets with other fields of application may suppress the implementation of green solutions.

Some regional variation of challenges on the application side can be expected between urban, peripheral and 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 and solutions (absorption, adaptation and asset mobilisation challenges). 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 (challenge-led) 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 (production side) as well as the use of green technologies and solutions (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 Rohracher 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 contributed to a better understanding of the role of both conventional policy instruments (such as taxes on pollution emissions, subsidies to support the introduction of green solutions, and environmental regulations) and new policy instruments like transition arenas (which foster collective learning processes, network building and the development of joint visions) in supporting green growth and its diffusion (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, etc.) and demand-pull instruments (instruments targeting consumer awareness, consumption behaviour, user innovation, public procurement, environmental regulation, market regulation, etc.).

While research has sought to better understand how particular combinations of instruments (policy mixes) affect the generation and diffusion of green innovation and the development of new 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 Trippl 2018; Turnheim and Geels 2012), 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). Further, scholarly work has zoomed in on multi-level 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 paper, 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 both policies for the production and policies for the application of green solutions 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 (Barca 2009; Tödtling and Trippl 2005) and has become a key principle of modern policy approaches such as smart specialisation (McCann and Ortega-Argilés 2015). 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 respective and 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 regional economic activities into account, and that we have previously used in an innovation policy context (Tödtling and Trippl 2005).

Diversified and thick regions tend to have a high potential for innovation and new industrial path development activities (Isaksen and Trippl 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 development 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 and other asset mobilisation, support of legitimisation of new technologies and industries as well as support for local 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 such 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.

Specialised and thick regions also face grave environmental problems that are frequently related to their previous industrial development. Typical problems include the pollution of air and water from 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; Tödtling and Trippl 2005). As regards production side challenges, such a situation might call for a sound mix of new path creation and old path destabilisation policies (Kivimaa and Kern 2016) as outlined e.g. by Nordhause-Janz and Rehfeld (1995) for North-Rhine Westfalia, Tödtling et al. (2014) for Upper Austria, or by 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, etc. Growing new green industries might take different forms, ranging from path branching to path importation and unrelated path diversification. Application side challenges may be met by demonstration and implementation projects, the provision of testing facilities and the involvement of end users in working groups and public events to create awareness for sustainable solutions and ensure the adaptation of green innovation to the particular context of users. 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 their lower firm and population densities. However, a closer look often reveals environmental problems 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. We also find an 'overuse' of ecological resources and a high pollution in peripheral tourist areas. Due to the absence of needed assets such as infrastructure, highly qualified labour, higher education institutes and supporting organisations (Tödtling and Trippl 2005), such regions tend to have weak capacities to develop green industries (Trippl, Baumgartinger-Seiringer, Frangenheim et al. 2019). Still, there is some potential to grow green paths within and beyond existing sectors, such as organic agriculture and organic food (Goodman 2004), forms of 'soft' and green tourism, development of eco-energy activities (Gibbs and O'Neill 2017), etc. 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 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 solutions. Environmental policies also matter, in particular through the protection of landscapes and nature areas, regulation of land use, and building control (tourist areas).

4 Initiatives for Green Regional Development

In the following, we are investigating three Austrian cases representing different types of local/global production/application combinations of green technologies and solutions (see table 1, section 2). As regards the selection of cases, we intentionally decided to focus on cases from one country, since local and regional development initiatives strongly depend on the respective national institutional and policy framework. Moreover, based on previous empirical studies, the authors well know the investigated regional and Austrian settings. In this section. particular attention will be paid to policy actions and strategies implemented to harness regional potentials and tackle challenges at the production and application side.

4.1 The Austrian E-Mobility region 'Vlotte': Policies for ecological value creation

During the last decade or so, 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 (Amt der Vorarlberger Landesregierung 2015). During this time, the articulation of critical voices against energy consumption increased 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 multi-scalar institutional and regulatory framework to apply green solutions 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 local production of renewable energies, the strategy aimed for ecological value creation through the application of e-mobility (cf. table 1).

Regional adoption of these new solutions 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 benefited from quick decision processes and trust among the actors enabling the adaptation of green innovations.

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 solutions 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 an 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.

4.2 'Green Tech Valley' Styria: Policies for economic value creation

Within the last four decades, one of Europe's leading green economy locations 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 green economy firms. 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 who branched into environmental technologies contribute to economic value creation in the region (cf. table 1; Gibbs and O'Neill 2017). This case is an instructive example for the development of a global green tech cluster 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 an ongoing professionalisation of R&D and the establishment of specialised competence centres funded by the state, traditional economic interest organisations, most notably the chamber of commerce changed their orientation. Over the time, they became less obstructive and subsequently more supportive towards renewable energy technologies (Schreuer et al. 2010).

4.3 'The Energy Vision' in the Styrian district of Murau: Policies for combining ecological and economic value creation

Späth and Rohracher's (2012) analysis of biomass development in the peripheral district of Murau in Upper Styria provides insights into the exploitation of local production and application potentials, that is, local economic and ecological value creation (cf. table 1). Due to its sparse population and weak industrial base, local 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 local level. Strong social relations between heterogeneous actors and the lack of a dominant existing regime allowed for fundamental changes in the local energy infrastructures and consumption patterns (Späth and Rohracher 2012).

An important initial potential has been the renewed interest in biomass-heating among 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’. Local 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 has 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 solutions had been overcome. An important step was the identification of concrete measures to achieve the defined objectives. 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 local farmers who have a long tradition in biomass use provided favourable conditions for developing a biomass path. On the other hand, local 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 place-based policy approaches for green regional development may have different orientations and combinations of measures and instruments that either may stimulate the rise and growth of green industries (production side) or the use of green technologies and solutions (application side) in the region.

5 Synthesis and conclusion

In this article, we investigate potential routes and policies for ‘green regional development’, which refers both to the production and application of green solutions to solve environmental challenges. Despite the global nature of problems such as climate change, actions have to be

taken often at the local and regional level. However, different types of regions face distinct industrial and environmental challenges, and our framework has taken this into account. We have investigated 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. For this purpose, we have critically reviewed relevant literature and distinguished between a production- and an application side of green technologies and solutions. The production side includes the industries and companies that develop and produce such technologies, whereas the application side refers to the adoption and use of green technologies by firms and the society. Both the development and production of green technologies and their application involves learning and innovation activities within the region and beyond. We have distinguished between three potential constellations that were applied to analyse green path development in Austrian regions:

- Green technologies or solutions are produced in the region and are applied also there (case of eco-energy in the peripherally located region of Murau / Styria).
- Regional firms produce green technologies for international markets (case of the environmental technology cluster around Graz / Styria).
- Regions may import and implement green technologies that are developed outside the region (case of electric mobility in the diversified region of Vorarlberg).

Based on a literature review three main challenges are identified on the production side. First, the start-up challenge, which results from a poor endowment of assets for nurturing green economic activities. This refers to the skill base, knowledge providers, and support structures for green start-ups and firms, that are often less available in peripheral regions. Second, the lock-in challenge, which points to barriers to green development resulting from institutional inertia, and resistance from dominant players in industry and government hindering the growth of new green activities. Often, such a situation exists in traditional industrial regions with specialised innovation systems and rigid institutional structures. Third, the competition challenge, which relates to the competing use of assets in other (non-green) industries. This is often the case in metropolitan areas and growth regions with a diversified industrial structure and entrepreneurial dynamism, where the focus is often more on a favourable positioning in global sectors than on developing green industries. On the application side we identify three types of challenges. First, awareness and acceptance challenges, such as a low acceptance of sustainability issues and a lack of willingness to introduce green solutions may hinder the

application of green solutions. Second, absorption and adaptation challenges, such as limited access of regional actors to relevant knowledge and a poor absorption capacity, weak institutional structures for collective learning processes, and a neglect of the particular user context, could form barriers to apply and embed green solutions in regions. Third, the asset mobilisation challenge, such as a lack of resources to introduce green solutions (finance, qualified labour, etc.) or competition over scarce assets with other fields of application could inhibit or slow down application of green technologies. There might be also a regional variation due to a limited awareness and acceptance of green solutions in peripheral and old industrial areas, and there might be fewer assets to apply green technologies. In metropolitan areas in comparison we often find more 'green minded' people and a rich asset base.

Policies for green regional development, therefore, should be designed as a place-based approach that is fine-tuned to the distinct opportunities and challenges prevailing in the regions. In diversified and thick regions industrial policies might focus on the elimination of specific bottlenecks for the growth of green development paths and support the knowledge exchange and networking of actors within and beyond the region. Further useful policy areas include spatial planning, energy policy, as well as the improvement of public transport. Thick and specialised regions also face grave environmental problems. Typical problems include the pollution of air and water from old industrial activities, as well as the contamination of land and the loss of green areas. Often such regions are 'locked' in old industries and have weak capacities to develop green industries. This calls for a combination of new path creation and old path destabilisation policies, such as a withdrawal of support for mature sectors and an institutional reconfiguration. Path branching, path importation and unrelated path diversification are potential new routes. Environmental policies for such places include the repair of damaged landscapes and soil, the reduction of air and water pollution, and the introduction of clean technologies. Thin regions often face environmental problems related to industrial agriculture or intensive tourism, leading to a loss of biodiversity, contaminated land and water, and an 'overuse' of ecological resources. Due to a lack of infrastructure, highly qualified labour, and supporting organisations, such regions tend to have weak capacities to develop green industries. Nevertheless, some potential to grow green paths exists, such as organic food, 'soft' tourism, and eco-energy, among others. Industrial policies can facilitate such activities through the provision of necessary infrastructure (transport, energy, schools, etc.), financial support, and stimulation of knowledge transfer.

The paper analyses three explorative examples of green regional development in Austria representing different types of local/global production and application of green technologies

and solutions. Attention is paid to policy actions taken to tackle the specific challenges. The Austrian E-Mobility region 'Vlotte' represents the application of green technologies in a 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 represents a case for the local production as well as application of green technologies in a peripheral and thin region. Comparing these cases we find that triggering events for starting green development initiatives were relevant in the form of protests against worsening environmental conditions in the cases of the environmental technology industry in Styria as well as for the e-mobility initiative in Vorarlberg. Enabling conditions have played a role in all three regions. In Murau / Styria this was the huge biomass potential and the interest of some 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 the high technological capabilities of the region in the form of technologically advanced firms, universities and a highly skilled labour force were enabling factors.

As regards challenges on the production-side we can observe a lack of necessary assets most strongly in the district of Murau, due to its peripheral location and thin RIS (lack of 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 resources for the new uses (qualifications, space for new firms). Challenges on the application side could be observed in the bio-energy case of Murau as well as in the e-mobility case of Vorarlberg. Awareness challenges in Murau were reduced by linking up with international energy networks, as well as by developing a shared vision among relevant actors. In Vorarlberg such challenges were reduced 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 reduced 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 (Land), Austria and the EU. In addition, regulative changes

were needed on local, province and Austrian 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, but in addition there were major investments by the regional energy provider as well as new infrastructure for e-mobility needed.

The three cases illustrate that place-based policy approaches for green regional development can take different routes: They may stimulate the rise and growth of green industries (production side), they may support the use of green technologies and solutions (application side) in the region, or they may promote both ways. However, these routes have different kinds of preconditions and they face different challenges that have to be overcome. It requires well-targeted combinations of measures and instruments that depend on the quality of the local production system and the RIS, and the institutional configuration of the region including the awareness of the population and the innovation and absorption capacity of local firms. A place-based strategy for green development has to take these conditions into account as well as the local 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 three cases have demonstrated that heterogeneous actor-networks that include activists, firms, interest organisations, policy actors, and researchers among others are able to initiate and promote green regional development in different types of regions and even in adverse situations, if necessary assets get mobilised and place-specific challenges are overcome.

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