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Published in:
Environmental Innovation and Societal Transitions

DOI:
10.1016/j.eist.2014.11.001

2015

Link to publication

Citation for published version (APA):
Hansen, T., & Coenen, L. (2015). The Geography of Sustainability Transitions: Review, Synthesis and Reflections on an Emergent Research Field. *Environmental Innovation and Societal Transitions*, *17*, 92-109. https://doi.org/10.1016/j.eist.2014.11.001

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2

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The Geography of Sustainability Transitions: Review, Synthesis and Reflections on an Emergent Research Field

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This is a post-print (i.e. final draft post-refereeing) version of the paper, now published in Environmental Innovation and Societal Transitions

http://www.sciencedirect.com/science/article/pii/S2210422414000835

DOI: 10.1016/j.eist.2014.11.001

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Abstract

This review covers the recent literature on the geography of sustainability transitions and takes stock with achieved theoretical and empirical insights. The review synthesises and reflects upon insights of relevance for sustainability transitions following from analyses of the importance of place specificity and the geography of inter-organisational relations. It is found that these contributions focus on the geography of niche development rather than regime dynamics, and that there is an emphasis on understanding the importance of place-specificity at the local level. While there is a wide consensus that place-specificity matters there is still little generalizable knowledge about how place-specificity matters for transitions. Most contributions add spatial sensitivity to frameworks from the transitions literature, but few studies suggest alternative frameworks to study sustainability transitions. To address this, the review suggests promising avenues for future research on the geography of sustainability transitions, drawing on recent theoretical advancements in economic geography.

Research highlights:

- Synthesises insights on the importance of place specificity for sustainability transitions
- Highlights different perspectives on the role of the geography of inter-organisational relations
- Points to important future research areas within the field of the geography of sustainability transitions

Keywords:

Geography, sustainability transitions, space, place, scale, proximity

1. Introduction

The last decade has seen a burgeoning academic interest in the topic of sustainability transitions (Markard et al. 2012). However, until recently, spatial dimensions of sustainability transitions have been largely ignored in this literature (Coenen et al. 2012; Smith et al. 2010). Why do transitions occur in one place and not in another? How do transitions unfold across different geographical contexts? What is the importance and role of relations at different spatial scales for transition processes? These questions, which are typical for a geographer's perspective (Scott 2000), remained more or less below the radar in the pioneering work on sustainability transitions. While key initial contributions were made in the specific area of urban sustainability, city infrastructures and low-carbon transitions (Bulkeley et al. 2011; Hodson and Marvin 2009), a broader, more general engagement with the geography of transition, similar to that on the geography of innovation (Asheim and Gertler 2005), was lacking.

Within most recent years, however, a number of contributions have been made that outline in broad terms possible contours of a research agenda for the geography of sustainability transitions (Lawhon and Murphy 2012; Nevens et al. 2013; Raven et al. 2012; Truffer and Coenen 2012). Moreover, there has been a poignant interest in geographical aspects of transitions at the latest three international conferences on sustainability transitions in terms of special sessions, thematic discussions and paper contributions (Lund, Copenhagen and Zürich). In addition, numerous empirical studies have been made that in various ways explicitly dealt with and partly also theorised about transitions' spatial aspects, including a special issue in European Planning Studies (2012) and this issue.

In light of this increased attention, research on the geography of sustainability transitions is developing and expanding rapidly with contributions from many fields, using different approaches. This heterogeneity offers both advantages and disadvantages. On the one hand, cross fertilisation of insights from multiple traditions and disciplines avoids short-sightedness and cognitive lock-in and provides scope for analytical refinement and conceptual renewal, especially bearing in mind the interdisciplinary legacy of the transitions literature. A lot of novel theory development within the transitions literature originated at the intersection of evolutionary economics and more constructivist approaches in studies of technology and science (STS), resulting in the key conceptual frameworks of technological innovation systems (TIS), the multi-level perspective (MLP) and strategic niche management (SNM). On the other hand, the importation and translation of 'external' ideas may be criticised for sometimes resulting in rather haphazard and fuzzy conceptualisation (Lagendijk 2006). Different approaches assign dissimilar meanings to similar terms or similar meanings to dissimilar terms. This can be illustrated by various seemingly geographical metaphors found in the

MLP framework, such as 'landscapes', and the 'local-global' distinction in niche development dynamics (Geels and Raven 2006). Though initially introduced in the transitions literature without an explicit spatial connotation, these concepts are easily mistaken for having a quite specific meaning within geography (Bridge et al. 2013).

Thus, considerable ambiguity may follow when terms are imported from their origins in geographical thought into a sustainability transitions framework. Further, even within geography, different parts of the literature point to rather dissimilar meanings of key notions used to analyse and explain spatial phenomena and processes. Within economic geography, for example, we have seen quite dramatic shifts ranging from an institutional to a relational and, most recently, towards an evolutionary turn, which each have a different conceptualisation of space. Given this internal heterogeneity it is not entirely clear what a geographical perspective on sustainability transitions implies, how it can be applied in empirical studies and what it entails in terms of additional insights. This review emphasises economic geography, because it is the subdiscipline within geography that has done most work on mapping and explaining the uneven geographical landscape of innovation and technological change. Here it is important to note that economic geography is not narrowly concerned with economic issues of innovation activities, but also includes social, institutional and to some extent cultural dimensions.

Similarly, it would be useful to identify opposite or conflicting findings that require further investigation and scope for cross-overs between different studies. A well-known weakness of many geographical analyses is that they celebrate the particular and focus on highly idiosyncratic case stories of specific places. It is therefore a challenge for spatial analyses of sustainability transitions to identify and formulate insights with theoretical purchase beyond the narrow domain of geography of transitions (Geels 2013). In light of this, and as a complement to papers which have focused on developing conceptual frameworks for studying the geography of sustainability transitions (Bridge et al. 2013; Coenen et al. 2012; Truffer and Coenen 2012), the objective of this review is two-fold. First, to synthesise and take stock with the theoretical and empirical insights which have been achieved so far, and second, to reflect upon and identify promising avenues for future research on the geography of sustainability transitions.

The review considers papers that explicitly combine sustainability transitions analysis with a geographical perspective. The methodological outset was taken in combined keyword search[1] on ISI Web of Science. However, this only yielded a limited amount of results. Thus, most papers were

[1] E.g. "sustainability transition" and "geography".

identified through snowballing, i.e. by examining reference lists of already known papers as well as citing papers to some of the key contributions within the field.

The remainder of this paper proceeds as follows. The next section seeks to clarify how key strands of economic geography literature have conceptualised space. Following insights from economic geography (Gordon and McCann 2000; Knoben 2009) and an earlier distinction made in the geography of transitions literature (Truffer and Coenen, 2012), the review then distinguishes between two key aspects to understand the position of geographical thought in the sustainability transitions literature: section three is focused on the contributions that consider the importance of place specificity on sustainability transitions while section four considers perspectives on relations between actors at various scales. Section 5 suggests promising avenues for future research and the paper concludes with reflections on what geographical analysis have brought to the table in sustainability transitions research.

2. Conceptualisations of space in economic geography

"Trying to think clearly about space is not easy." (Dainton 2001, p. X)

While it is impossible here to do full justice to the theoretical discussions in economic geography on the concept of space, the intention is to present the most important conceptualisations of space within economic geography, as different understandings of how space is constructed leads to emphasis on different aspects of places (place specificities, see section 3) and differences in the attention given to relations at different scales (see section 4). In this section, we introduce the conceptualisations of space found in relational, evolutionary and institutional geography.

Recent notions of space are often contrasted to the notion of space in traditional positivist geography, where space is considered an empty container waiting to be filled, e.g. with various forms of economic activity. A relational perspective emphasises the social production of space in arguing that space is constructed through social interactions between actors. The popularity of this perspective should be seen against the background of on-going globalisation in which processes of hypermobility and time-space compression due to technological change prevail. Attention has consequently shifted from a focus on proximity effects in clusters, agglomerations and industrial districts to ways in which social networks influence inter-organisational partnerships and facilitate collaboration between partners which are geographically distant (Allen 2000; Saxenian and Hsu 2001). No *a priori* privilege is given to any scale in relational geography (Boggs and Rantisi 2003) and space is considered to be non-existing in itself; thus, space is considered to be a social construction stemming from relations between actors (Amin 2002), or, alternatively, an analytical perspective

whereby the central objects of analysis, economic action and interaction, can be analysed (Bathelt and Glückler 2003). Relational economic geography takes its outset in relations and flows (of capital, knowledge, people, etc.) rather than discrete entities such as firms or nation states.

The starting point in evolutionary economic geography is different from relational geography as its ambition is *"to demonstrate how geography matters in determining the nature and trajectory of evolution of the economic system"* (Boschma and Martin 2010, p. 6). It has revived an interest in the importance of historical path dependencies for future spatial development paths (Boschma and Frenken 2006; Uyarra 2010). Building on Nelson and Winter (1982), the key analytical object is organisational routines and their development over time. Hence, space is conceptualised as the geographical distribution of routines, which is closely associated with industrial and technological specialisation. According to Martin (2010, p. 3), *"the combination of historical contingency and the emergence of self-reinforcing effects, steers a technology, industry or regional economy along one 'path' rather than another"*. Thus, in addition to spatial context, evolutionary economic geography stresses the importance of historical context.

Institutional economic geography emphasises the role of institutional variations as foundations for geographical differences in economic activity and performance. This is associated with a broader focus on culture in economic geography, where culture is highlighted as the key element that leads to spatial variations (Aoyama et al. 2010). While the understanding of what constitutes culture has been very broad and varied across contributions (see Duncan et al. 2004), a key topic has been the role of formal and informal institutions (Martin 2000). Rules, laws and regulations, as well as norms and values are seen as key constituting factors of space.[2] Together, these formal and informal institutions produce specific *"institutional settings"* (Martin 2000, p. 80), which are argued to significantly impact the economic landscape. This points to the importance of looking beyond a narrow focus on firms and account for the roles of a variety of actors, from the state to citizens, in producing and re-producing localised institutions.

One may ask what we mean by 'geographies of sustainability transitions' and why an analysis of the spatial aspects of sustainability transitions is meaningful. In this, we concur with Bridge et al. (2013), that the geography of sustainability transitions captures the distribution of different transition processes across space. Transitions are constituted spatially and unpacking this configuration will allow us to understand better the underlying processes that give rise to these patterns. This requires analysis of the particular settings (places) in which transitions are embedded and evolve, while at the

[2] The emphasis on norms and values in institutional economic geography is closely linked to the focus on practices in cultural geography.

same paying attention to the geographical connections and interactions (i.e. the spatial relations) within and between that place and other places. The conceptualisations of space presented in this section emphasise different place specificities and give different attention to relations at different scales. In the next sections, we have structured our literature review along these two themes: (1) the importance of place specificity and (2) the role of spatial relations for sustainability transitions.

3. Sustainability transitions and place specificity

Sustainability transitions are geographical processes – they are not pervasive, but happen in particular places, i.e. actual geographical locations with a materiality to them. Places can be defined at various scales – in principle from a kitchen to a continent. Traditionally, the sustainability transitions literature has given little attention to the importance of specificity of transitions in particular places. In an early conceptual contribution, Shove and Walker (2007) note the importance of contextual factors such as the political environment and the anticipatory knowledge of local transition managers for transition processes. Since then, geographers have called for a detailed examination of the importance of place specificity for sustainability transitions (Lawhon and Murphy 2012), and studies have indeed taken up this challenge. As table 1 illustrates, the importance of multiple dimensions of place specificity for sustainability transitions is now well-established. Generally, these contributions focus on the local, regional and urban scales, while considerable less attention is given to the national scale (exceptions are Angel and Rock 2009; Berkhout et al. 2009).

Table 1. Insights on the influence of place specificity on sustainability transitions

Themes	Authors	Implications for sustainability transitions
Urban and regional visions and policies	Bulkeley et al. (2011); Bulkeley and Castán Broto (2013); Carvalho et al. (2012); Coutard and Rutherford (2010); De Laurentis (2013); Dewald and Truffer (2012); Essletzbichler (2012); Faller (2014); Hawkey (2012); Hodson and Marvin (2009, 2010, 2012); Lagendijk and Boertjes (2013); Maassen (2012); McCauley and Stephens (2012); Monstadt (2007, 2009); Quitzau et al. (2012); Rohracher and Späth (2014); Shove and Walker (2007); Smith (2007a); Späth and Rohracher (2010, 2012); Truffer and Coenen (2012); Uyarra and Gee (2013)	• Urban and regional policies are central to facilitate the embedding and diffusion of niche technologies • Policy generally aims to combine ecological goals with economic competitiveness • Often, such policies also stimulate industrial development of cleantech industries • The governance of transitions encompasses multiple policy areas, thus, they are contested and negotiated between multiple public, quasi-public and private territorial actors • Rather than considering visions as underpinned by consensus among multiple stakeholders, these are also contested and results of struggles and intermediation efforts
Informal localised institutions	Angel and Rock (2009); Berkhout et al. (2009, 2011); Binz et al. (2012);	• Development and diffusion of environmental innovations are conditioned by informal localised

	Bridge et al. (2013); Coenen et al. (2010, 2012); Dewald and Truffer (2012); Faller (2014); Lagendijk and Boertjes (2013); Maassen (2012); Murphy and Smith (2013); Ornetzeder and Rohracher (2013); Shove et al. (2014); Späth and Rohracher (2010, 2012); Truffer and Coenen (2012); Wirth et al. (2013)	institutions • Niche formation is embedded in localised social practices • Informal localised institutions positively influence the regulatory push on the development and adoption of environmental regulation • Importance of recognising differences in informal institutions even within local or urban territories, resulting in struggles over sustainability visions
Local natural resource endowments	Bridge et al. (2013); Carvalho et al. (2012); Essletzbichler (2012); Murphy and Smith (2013); Späth and Rohracher (2010, 2012); Trutnevyte et al. (2012)	• Resource scarcity stimulates investments in renewable energy development and diffusion • Resource endowments influence choices between renewable technologies
Local technological and industrial specialisation	Binz et al. (2012); Bridge et al. (2013); Carvalho et al. (2012); Coenen et al. (2010); Essletzbichler (2012); McCauley and Stephens (2012); Monstadt (2007); Ornetzeder and Rohracher (2013); Smith (2007a)	• Industrial specialisation conditions the development of innovations necessary for sustainability transitions • The extent of knowledge spillovers in a region influences the ability of firms to develop environmental innovations • Local industrial specialisation is often the outset for selective regional policy agendas, which in turn reinforces technological and industrial specialisations
Consumers and local market formation	Binz et al. (2012); Dewald and Truffer (2012)	• Engaged local end-users are central to local market creation • Geographical proximity enables producers to obtain feedback from end-users for emergent niche technologies

Following the emphasis in institutional economic geography on the central roles of formal and informal institutions as key constituting factors of space, a number of contributions to the geography of sustainability transitions literature focus on, firstly, urban and regional visions and policies and, secondly, informal localised institutions.

A quite large number of studies examine the central role of **urban and regional visions and policies** (the edited volumes by Bulkeley et al. 2011; 2014 take a prominent position in this literature). While these contributions have a main focus on the urban and regional levels, the importance of connections to other policy levels is evident, with some authors taking an explicitly multi-level governance perspective (Hodson and Marvin 2010, 2012; Späth and Rohracher 2010, 2012; Uyarra and Gee 2013). For instance, Hodson and Marvin (2009) highlight that the visions promoted by urban government may be developed by exogenous actors such as multinational firms, which deliberately search for specific places to test them in real life. Importantly, interaction between different policy levels is not merely a top-down process, and Faller (2014) notes that urban strategic discourses can also influence policies at higher levels, thus, the relation between policy levels should be understood as a two-way influence.

The importance of urban and regional visions and policies reflects the necessity to mobilise the heterogeneous group of local actors of relevance for sustainability transitions (Essletzbichler 2012). This points to the role of intermediaries, i.e. organisations working between different social interests, to produce outcomes that would not have been realised without their involvement (Hodson and Marvin 2010). As an example, local planners may perform such intermediation, as they are centrally placed actors in the process of establishing sustainability priorities and engaging local stakeholders, even though the formation of local stakeholder networks is highly influenced by existing relations (Hawkey 2012; Quitzau et al. 2012). As governance of sustainability transitions need to encompass multiple policy areas, they are contested and negotiated between multiple public, quasi-public and private territorial actors (Coutard and Rutherford 2010; Monstadt 2007). Thus, contrary to the emphasis in for instance transition management on consensus and alignment, the contributions on urban and regional policies and visions highlight the struggles and conflicts associated with governance of sustainability transitions.

Contributing to the heterogeneous mix of actors involved in this policymaking is the close connection between sustainability transitions and physical infrastructure. This infrastructure has in many cases been privatised, thus, governance of sustainability transitions increasingly becomes a collaborative effort involving public and private actors with varied interests and incentives (Lagendijk and Boertjes 2013). This results in highly complex processes (Faller 2014; Monstadt 2007) with direct competition between different visions, which may not only disagree in terms of technologies and level of ambition, but also include struggles over the right geographical scale to develop initiatives promoting sustainability transitions (Hodson and Marvin 2012). Strong actor coalitions may lead to exclusion of otherwise central aspects from urban and regional visions and strategies (Späth and Rohracher 2010). Disagreements may also lead to alliances across different levels of government, as Coutard and Rutherford (2010) describe in the Île-de-France region where the agendas of local and national authorities align, leading to a united front against the regional authorities. This highlights the fundamental political nature of sustainability transition processes, echoing the suggestion by Shove and Walker (2007, p. 766) in a conceptual contribution that *"there is a politics to transition management, a playing out of power of when and how to decide and when and how to intervene"*. Bulkeley and Castán Broto (2013) argue that one important manner in which this power is exercised is through urban climate change experiments, and they show that the actor constellations behind these experiments vary considerable between different parts of the world. For instance, the private sector is particularly active in Asian climate change experiments.

A further characteristic of urban and regional sustainability transition policies is that they are typically aimed at combining ecological goals with economic competitiveness, often termed green

growth (Hodson and Marvin 2009; Späth and Rohracher 2010). A main way in which this dual focus materialises is through policies aimed at stimulating industrial development of cleantech industries (Carvalho et al. 2012; McCauley and Stephens 2012). As noted by Smith (2007a), this is a policy area where the regional level actually has leverage to act, by mapping and supporting cleantech clusters through e.g. research and development support, training programmes and assistance with funding applications. This mirrors the suggestion in the literature on regional innovation policy (e.g. Asheim et al. 2011) that regional actors are better able to design successful policies than national actors, due to their knowledge of place specific conditions and their ability to fine-tune policies. The argument in this literature is that almost every region has innovative potential, but that the nature of this innovative potential differs due to industrial and technological specialisations, and that policies should take this into account. Similarly, it can be argued that the potential for sustainability transitions differs qualitatively between regions, and that policies ought to reflect this.

While governmental policies can be considered a main component of a place's institutional environment, **informal localised institutions**, understood as territorially bound norms, values and practices, are an equally important factor for sustainability transitions. Naturally, the relation between governmental policies and informal localised institutions is close, as noted by multiple authors in analyses ranging from the national to the regional and local levels (Angel and Rock 2009; Faller 2014; Späth and Rohracher 2012). To exemplify, Angel and Rock (2009) note the importance of discourses, commitment to environmental improvement and citizen pressure for differences in changes to formal regulation among East Asian countries. As noted by Maassen (2012), government regulators may also – at least – envision the reverse influence, however, changing deeply embedded norms through formal regulation is a difficult and long-term project.

In other words, place-specific norms and values have important influences on the geographically uneven landscape of sustainability transitions. Empirically, this is among others highlighted by Späth and Rohracher's (2010, 2012) analysis of the transition process in the Austrian district of Murau, which is based on values embedded at different geographical levels: from the significance given by Austrians in general to self-reliance on energy, to the local importance given to the use of biomass. Similarly, Wirth et al. (2013) convincingly show the influence of geographical differences in professional cultures among Austrian farmers on regional differences in the extent and character of biogas technology diffusion. In this way, informal institutions condition the potential for different sociotechnical configurations.

Informal institutions are found to play a key role for both the development and diffusion of environmental innovations. Environmental innovation development activities, including grassroots

innovations, are situated in places characterised by specific local institutions (Berkhout et al. 2011; Ornetzeder and Rohracher 2013). Thus, localised institutional frameworks, including norms and values such as specific local cooperation cultures, should be analysed in order to comprehend the background and potential of individual transition experiments (Coenen et al. 2010). Relating this to the emphasis on collaboration across heterogeneous actors in strategic niche management, this highlights that localised informal institutions may significantly influence the ability to successfully establish such activities in niches. However, as pointed out by Smith (2007b), the transferability of innovations depends on the potential for being added on to or "slot into" mainstream practices. Thus, too strong dependence on specific informal institutions may also limit the diffusion potential of developed niche innovations, if these turn out to be very place-specific.

As noted in a conceptual contribution by Bridge et al. (2013, p. 336), *"the spatial diffusion of energy technologies is culturally contingent: how new energy technologies spread across space often depends on how these technologies (and the natural resources upon which they are deployed) are embedded in (national) systems of signification and cultural routines."* Thus, it follows that norms around consumption have important influence on the potential for upscaling of niche technologies and, we would add, the spread of unsustainable technologies. On the former, Bridge et al. (2013) mention expectations concerning cost and reliability of energy supply, and social practices associated with energy consumption as examples. Along similar lines, Binz et al. (2012) highlight the importance of the attitude to risk for the (lack of) diffusion of onsite small-scale membrane bioreactor wastewater treatment plants in China. There are also clear geographical differences in how investment decisions in new infrastructural projects are taken and legitimatised (Lagendijk and Boertjes 2013). Concerning the spread of unsustainable technologies, Shove et al. (2014) demonstrate that local practices and their development over time are central to understand the geographical diffusion of air conditioning. Further, with time, the technology also changes and becomes embedded in these practices. They suggest that an analytical outset in social practices provides key insights into the possibilities for limiting the diffusion of such unsustainable technologies.

Finally, the important role of localised informal institutions for sustainability transitions should not lead scholars to disregard the potential considerable heterogeneity in norms and values within a given place (Boschma and Frenken 2009). As an example, Maassen (2012) points to the differences in practices between architects, developers and planners collaborating on the deployment of photovoltaic technology in three European cities. This highlights that even though many informal institutions are localised, they are not necessarily pervasive across the territory, as actors may follow different institutional logics because they are part of different institutional fields. Different

institutional logics may thus confront each other in specific urban settings and this may delay or even hinder transition processes.

Relatively few contributions deal explicitly with the importance of **local natural resource endowments** for sustainability transitions, perhaps since the central role is simply too self-evident: the potential of tidal power is larger in coastal regions with large tides, of solar power in regions with many hours of sunshine, etc. Still, transition strategies do often not take local natural resource endowments sufficiently into consideration (Trutnevyte et al. 2012). The influence of natural resources is stressed by Carvalho et al. (2012) who explain how the large regional production of soya crops influenced the decision to focus on biodiesel (rather than e.g. biogas or hydrogen) in Curitiba, Brazil, while Späth and Rohracher (2010, 2012) describe the importance of the abundance of local wooden biomass for the transition process in Murau, Austria.

The potential importance of local natural resource endowments for sustainability transitions is however mediated by various factors. Within renewable energy, many forms of natural resources are concentrated in peripheral regions, where insufficient infrastructure is a significant barrier (Murphy and Smith 2013). Further, while Bridge et al. (2013) stress the influence of natural landscape features, they also highlight how social attachments may prevent the transformations of these landscapes which are necessary for sustainability transitions, for instance in the case of establishment of wind turbines.

In addition to favourable natural conditions for renewable energy generation, resource scarcity within traditional resources (e.g. fossil fuels) may also stimulate investments in sustainability transitions, as exemplified by Essletzbichler (2012) in the case of the Spanish region of Navarra. In essence, this highlights that a selective factor disadvantage can stimulate a quick transition towards innovative practices, thus, regions with little or no fossil resources have greater incentive to support sustainability transitions.

Drawing on the evolutionary perspective on space that emphasises the role of organisational routines, contributions within the geography of sustainability transitions highlight the importance of technological and industrial specialisation of places. A main argument in studies on **local technological and industrial specialisation** is that geographical clusters promote the innovations necessary for sustainability transitions (Bridge et al. 2013; McCauley and Stephens 2012). Similar to other technologies, the development, demonstration and implementation of green innovations is stimulated by agglomeration economies such as access to a pool of skilled labour, supporting intermediary organisations, research institutes and universities (McCauley and Stephens 2012). Specifically regarding universities, Stephens et al. (2008) provide a description of the various roles

they may have in sustainability transition processes and argue that these roles vary depending on national and regional conditions. They suggest that universities may for instance take key roles in addressing regional-specific sustainability challenges, but a systematic account of how these roles vary between different places is not provided in the paper.

As noted above, urban and regional policies frequently combine ecological goals with a focus on stimulating industrial development of cleantech industries. Thus, existing technological and industrial concentrations and strongholds are often the outset for policy agendas. In England, targets and activities in the various regional renewable energy plans were significantly influenced by and focusing on technologies which matched the regional industrial compositions (Smith 2007a). Likewise, the strong research milieu within the field of solar research was an important precondition for the policy focus on this industry in Berlin (Monstadt 2007). Similarly, in a comparative case study analysis, Carvalho et al. (2012) stress the role of local technological and industrial specialisation on the choice between various green urban transport technologies in Curitiba, Gothenburg and Hamburg. However, they go one step further than the influence of specialisation on the selection of technologies, and highlight the subsequent co-evolution of industries and policies in the cities, as the policies also strengthen the development of the local platforms for knowledge creation and learning. In other words, policy and industrial specialisation are mutually reinforcing, with energy and climate policies having a significant impact on *"the specialized pool of spatially rooted engineering qualifications and capability evolution over time"* (p. 388).

A number of studies within this literature specifically address the role of localised knowledge spillovers following from agglomeration economies (Essletzbichler 2012; McCauley and Stephens 2012). Fundamentally, the argument is that intra- and inter-industry knowledge spillovers are positively influenced by geographical proximity, and that the extent of such spillovers among cleantech firms located in a region will impact their ability to develop innovations that can support a transition process. However, as exemplified by the study of Binz et al. (2012), such knowledge spillovers are likely to be absent in the formative stages of innovation systems around new technologies if a support structure in the form of for instance specialised intermediaries is not in place. In line with this, Essletzbichler (2012) argues that regional sustainability transition policies should specifically address this point and make firms able to take advantage of spillover effects by e.g. strengthening regional informal networks. Similarly, McCauley and Stephens (2012) suggest that public policies should give more attention to social and cultural elements, and that a focus on cleantech clusters may facilitate knowledge spillovers to the broader community and induce social learning.

Finally, reflecting the emphasis on citizens in institutional economic geography, and closely related to the role of informal institutions, the role of **consumers and local market formation** is a final topic in the analysis of place specificity and sustainability transitions. However, it is only sporadically considered in studies on the geography of sustainability transitions, reflecting the general insufficient attention to this topic in the wider sustainability transitions literature (Shove and Walker 2007). Notable exceptions are Binz et al. (2012) and in particular Dewald and Truffer (2012). While the former notes the central role of regulatory institutional arrangements for market development, the latter argues that engaged end-users are a central supplement to the formal support programs in local market creation. Geographical proximity enables producers to obtain feedback from end-users, which is particularly important in the early stage of market formation.

4. Sustainability transitions and scale in inter-organisational relations

Inter-organisational relations are of central importance for sustainability transitions, for instance regarding formulation of joint visions or establishment of collaborative innovation projects. Such relations can take place at various scales, that is, these processes can operate at geographical levels of different sizes. Empirical and conceptual contributions increasingly highlight that relations on different scales are important for the development processes that make sustainability transitions possible (e.g. Binz and Truffer 2011; Truffer and Coenen 2012), following the general development within economic geography (e.g. Bathelt et al. 2004; Bunnell and Coe 2001). Concerning the types of relations examined, attention is mainly given to relations outside of value chains, even though some contributions examine relations along value chains between actors in developed and developing countries (Angel and Rock 2009; Berkhout et al. 2009; Berkhout et al. 2011). Thus, there is little empirical work which focuses on user-producer relations in general, and localised user-producer relations in particular (for an exception, see Dewald and Truffer 2012). Rather, emphasis is on relations concerned with issues such as development of guiding visions (Späth and Rohracher 2010, 2012), scientific collaboration (Binz and Truffer 2011), donor interventions (Hansen and Nygaard 2013), interaction between policy-makers (Hodson and Marvin 2010; Späth and Rohracher 2012) as well as learning and collaborative development of innovations (Carvalho et al. 2012; Coenen et al. 2010; McCauley and Stephens 2012; Ornetzeder and Rohracher 2013).

Reflecting the various conceptualisations of space in geography, considered in section 2, different perspectives on the spatial dimension of relations between actors are found in the literature on the geography of sustainability transitions. Generally, a distinction can be made between studies that take a perspective in line with more traditional approaches in economic geography, stressing the positive influence of geographical proximity in stimulating network formation (e.g. Coenen et al.

2010), and studies that draw heavily on relational geography, highlighting that space is socially defined (e.g. Raven et al. 2012). Evolutionary economic geography is most closely associated with the former of these positions in emphasising the regional character of industrial branching processes; however, its conceptualisation of proximity in both spatial and non-spatial terms allows the sensitivity to distant relations that is absent in traditional approaches in economic geography (see Asheim et al. 2011; Boschma and Frenken 2012).

The former of these positions emphasises the importance of relations at the local and regional scales. The fundamental argument is that geographical proximity allows continuous face-to-face interaction, which facilitates the creation of social ties, and thereby network formation (Coenen et al. 2010; Dewald and Truffer 2012; Ornetzeder and Rohracher 2013). Similarly, work on the role of industrial clusters in sustainability transition processes also highlights positive proximity effects on inter-organisational relations concerned with e.g., collaborative innovation projects, arising from co-location (McCauley and Stephens 2012). Beyond intra-industry relations, it is also argued that networks of heterogeneous actors are most easily established at the local and regional scale (Späth and Rohracher 2010, 2012), echoing arguments from economic geography that geographical proximity is necessary for relations between actors characterised by large cognitive and cultural differences, as repeated interactions are needed to facilitate collaboration (Hansen 2014a). Often, local inter-organisational network creation is furthermore shaped by intermediaries with a specific spatial focus. As an example, Hodson and Marvin (2009) demonstrate the intermediation carried out by London-based partnerships through the creation of platforms where various social interests can meet and (competing) visions can be established.

While these contributions identify crucial aspects of the geography of sustainability transitions, it has been argued that it is equally important to recognise both the potential negative consequences of inter-organisational relations in geographical proximity on sustainability transitions, and the importance of non-local relations. On the first point, Smith (2007a, p. 6273) notes the tendency for decision-making networks to be populated by *"the usual suspects"*. This highlights the inertia in such networks, which is not necessarily conducive to transition processes. On the second point, the study by Carvalho et al. (2012), exemplifies that a sensitivity to localised collaborations does not necessitate an exclusive preoccupation with this scale, but can be combined with an acknowledgement of the importance of international and global relations. Their study of sustainable transport technologies shows that geographical proximity stimulates formation of localised inter-organisational networks, which again facilitate development of external (national and global) relations. This reflects the dual attention to local buzz and global pipelines in economic geography (Bathelt et al. 2004).

Attention to the non-local scale is also evident in contributions with an explicit focus on global relations between developed and developing countries through e.g. global production networks or donor interventions, and their ability to influence transition processes in the receiving countries (Angel and Rock 2009; Berkhout et al. 2009; 2011; Hansen and Nygaard 2013; Schmidt and Dabur 2014). Also, work focusing on the governance of sustainability transitions have paid particular attention to interaction between decision makers at various scales, and the importance of global relations for local transition processes (Coutard and Rutherford 2010; Hodson and Marvin 2009, 2010; Späth and Rohracher 2012). Some authors even adopt a perspective drawing on the relational conceptualisation of space. This is exemplified by Binz and Truffer (2011), which highlight that innovation cooperation takes place at multiple scales, and considers that geography follows the social networks of actors. Similar suggestions are found in a number of key conceptual contributions to the geography of sustainability transitions literature (Coenen et al. 2012; Raven et al. 2012; Truffer and Coenen 2012). While these papers all accept the local embeddedness of relations and the existence of geographical proximity effects, they also draw considerably on relational geography in arguing that geography is socially constructed through networks of actors and that *"a spatial perspective should adopt a relational perspective emphasizing networks that are enacted and structured across different levels of spatial scale"* (Raven et al. 2012, p. 69). What is lacking in these contributions is a discussion of the compatibility between a relational conceptualisation of space and the simultaneous acceptance of the local embeddedness of relations.

5. Suggestions for future research

In the current section, we seek to outline some suggestions how the geography of transitions may benefit from theoretical advancements made in economic geography. Specifically, we argue that theoretical concepts such as related variety, natural resource-based enclaves, multi-level governance, varieties of capitalism, value creation and proximity may be valuable to the analysis of sustainability transitions.

One recurrent central theme in the reviewed contributions is that on **local technological and industrial specialisation** to explain for the formation of niches and new industries based on emergent technologies. Whereas the literature on MLP and SNM has paid little direct attention to this, it partly overlaps with one of the functions suggested in the formation of a TIS, namely the development of positive externalities such as knowledge spillovers and specialised labour markets (Bergek et al. 2008). Technological and industrial specialisation is considered an important condition for such externalities to develop and be maintained. Here, a geographical perspective adds that such externalities are bounded in space and typically found in geographical agglomerations of industries

or clusters. While conventional cluster studies on cleantech industries have only slowly started to emerge within economic geography (Cooke 2008; Fornahl et al. 2012), scholars increasingly started to question the classical argument for cluster advantages based on narrow specialisation within specific industries. This seems particularly pertinent in light of industry/niche formation given the internal heterogeneity in capabilities found in many cleantech industries or emergent technologies. Even though systematic empirical evidence is still lacking for cleantech industries specifically (though see Nygaard Tanner 2014; van den Berge and Weterings 2014), various studies point to the importance of related variety for new industry formation through processes of branching (Asheim et al. 2011; Frenken et al. 2007) and combinatorial innovation (Strambach and Klement 2013). This entails a focus away from specialisation through cognitive proximity within one sector towards 'smart specialisation' based on related sectors that have different but complimentary capabilities and are able to innovate through new knowledge combinations, i.e. related variety (McCann and Ortega-Argilés 2013). Moreover, there is strong evidence that the formation of new industries is deeply rooted in related activities that have been historically present in a region, i.e. branching (Neffke 2009). These notions of related variety and branching are hallmarks of evolutionary economic geography (Boschma and Frenken 2006). Apart from having a shared legacy in evolutionary economics, engagement with this literature is helpful in emphasising the role of place-dependence in sustainability transitions through pre-existing industrial/competence base as foundations for niche or industry formation in connection to sustainability transitions and explaining (and to some extent even predicting) that niches do not emerge out of nowhere but are marked by distinct regional path dependencies.

When determining locational advantages for cleantech industries cluster formation, the availability of **local natural resource endowments** should also be noted as distinctive for these kinds of industries, e.g. in areas related to biomass. It should however be stressed that even though these endowments may offer comparative advantage for specific places, they do not guarantee sustained competitive advantage unless localised value creation processes are in place. Otherwise there is a risk that resource-based industries are reduced to extractive natural resource-based enclaves with weak productive linkages to local firms, foreign ownership of capital and export of goods with low or no value added all of which lead to a vicious circle for local development (Arias et al. 2014). We will return to the issue of value creation below in the discussion on consumers and market formation.

Whereas the pre-existing industrial / competence base and natural resource endowments primarily address supply-side, push factors in formation processes, the review identified the importance of policy and regulation as important pull factors. **Urban and regional visions and policies** in areas such as energy, climate and infrastructure typically interact with clean industrial development strategies

following the logic of ecological modernisation that seeks to reconcile ecological sustainability with economic competitiveness (Gibbs 2000). Even though ecological modernisation has been criticised for adopting a technological fix (Gibbs 2006) there is preliminary support that progressive environmental regulation supports local industry formation in cleantech sectors as it creates 'advanced' local demand for environmental innovation (Binz et al. 2013; Martin and Coenen 2013). This partly overlaps with the so-called Porter hypothesis (Porter and van der Linde 1995) even though evidence of this hypothesis is still inconclusive and subject to fierce debate and different interpretations (Ambec et al. 2013). More important in this context is the suggestion that urban and regional policies often run ahead of national and supranational regulations in their response to climate change, which provides additional fuel to the argument that the formation of sustainability transition pathways unfolds in a geographically uneven way. Bulkeley and Broto (2012) stress that the experimental nature of these urban policy responses and add criticism to the rosy picture painted by the ecological modernisation thesis by pointing to the highly contested nature of urban sustainability transitions. Emphasis has been placed on the role of urban niches as protective environments that provide space for the development, testing and failure of novel innovations, and where new networks can be supported and sustained. While research has so far tended to focus on questions of the design and production of niches and experiments, analysing these processes requires that more attention is given to dynamics of agency and power – the practices of governance on the ground (Smith and Raven 2012). At the same time, there are growing calls for research to engage with the spatial and political contexts within which transitions evolve, and the processes through which niches and experiments are related to these wider systemic contexts (Coenen et al. 2012; Meadowcroft 2007; Shove and Walker 2007). In this regard, understanding the role of city-regions in the governance of transition pathways has become a critical area for research and action (Bulkeley et al. 2011; Coenen and Truffer 2012; Nevens et al. 2013). On the one hand, the main argument in favour of the considerable focus on these levels is that they are closer to the actors involved in sustainability transitions and more attuned to local conditions (e.g. Coutard and Rutherford 2010). On the other hand, Monstadt (2007, 2009) argues that the increasing complexity of the governance of sustainability transitions implies that the ability of urban and regional authorities to control these processes are diminishing and that central regulatory functions have been transferred to the national and European policy levels. Further, in the case of England, Smith (2007a) points out that the lack of direct control of the regional energy infrastructure and the absence of sufficient funds at the regional level for initiatives lead to a weak regional autonomy. Thus, the future roles of the urban and regional policy levels in sustainability transitions are worth further attention.

Paraphrasing Gertler (2003) on the role of culture in production, it is also necessary to move beyond **informal localised institutions** as a residual category for a largely heterogeneous set of social and cultural conditions that enable and constrain change as recently exemplified by Wirth et al. (2013). In this dimension, the risk for overemphasising particular place-specificities that is of little general purchase for theorising transitions is very high. Future research on this topic would strongly benefit from more theoretically informed empirical analysis that allows for an assessment of how particular types of territory-specific institutions influence transitions dynamics (see also paper by Dewald and Fromhold-Eisebith, this issue, which highlights the link between national innovation systems and TIS). Previous propositions have been made to relate different institutional conditions that follow from varieties of capitalism to the extent to which actors can engage in path-breaking innovation (Coenen et al. 2012) but these have not been followed up in empirical research. Similar propositions can be made with regard to the possibilities for path-deviation in institutionally thick, core regions and cities in contrast to more peripheral and institutionally thin cities and regions. In doing so, it would also be important to articulate more explicitly how certain institutional configurations impact particular kinds of activities or practices, for example in relation to collaboration, knowledge-sharing, experimentation or risk-taking (see paper by Longhurst, this issue, on alternative milieus as such an institutional configuration). Otherwise, there is a danger that not only the notion of institutions remains black-boxed but also that of sustainability transitions. This also includes a better understanding of the roles of specific actors in changing institutions (see e.g. Sine and Lee 2009 for an excellent account of the role of social movements on the emergence of the U.S. wind energy sector, and PAPER 7, this issue, which points to the influence of government and non-governmental interventions on transitions in the food system). The work done on institutional plasticity is particularly pertinent in this respect (Strambach 2010) meaning that a range of options for local path deviation or creation are open within the overarching institutional system. Research on the biotech industry has shown that such plasticity and the ways actors respond to it may differ considerably across countries (Casper and Kettler 2001).

A similar call for further specification can be made with regard to the role of **consumers for local market formation**. While a novel contribution has been made in emphasising the role of localised user-producer interaction to institutionalise markets for emerging technologies and niche innovation (Dewald and Truffer 2012) further research is needed to better understand the process of market construction across different scales. This is a key topic of concern in questions related to the 'upscaling of niche experiments' or the shift from formative towards growth phase in technological innovation systems. Recent contributions in economic geography have engaged with these questions, though not exclusively in the context of eco-innovation, by conceptualising market

formation as a multi-local valuation process that involves global circularity in knowledge, goods, services and discourse that anchor in specific places (Crevoisier and Jeannerat 2009) while also recognising the multiplicity of values that are implies in this, including functional value, exchange value, symbolic value (Pratt 2008).

Finally, the distinction between geographical proximity and multiple forms of non-spatial proximity (social, institutional, cognitive and organisational) in the economic geography literature (see Boschma 2005) can be further explored in analysing the importance of **inter-organisational relations** for transition processes. It has been suggested that one way forward in understanding the importance of geography for inter-organisational relations, is to distinguish between two mechanisms (Hansen 2012, 2014b): firstly, the substitution mechanism, where non-spatial forms of proximity (e.g. social proximity) substitute for geographical proximity. This acknowledges that geographical proximity is not a necessity in inter-organisational relations, thus, avoiding an overemphasis on the local scale. Secondly, the overlap mechanism, where geographical proximity facilitates non-spatial forms of proximity. This recognises the important facilitating effect of geographical proximity on other forms of proximity, thus, accounting for the local embeddedness of networks (see also paper by Sengers and Raven, this issue). Together, this allows an understanding of the influence of geography on inter-organisational relations which is neither over-, nor, under-socialised. This is important in order to comprehensively understand in which situations and for which purposes relations at different scales matter. As little attention has been given to regime dynamics, the role of geographical proximity for relations between agents at different levels in the multilevel framework is a key area of future research. Contributions within the geography of sustainability transitions literature (e.g. Truffer and Coenen 2012) has argued that geographical proximity between agents is particularly important in the development of niches – "[n]iches do not emerge out of nowhere" (Raven et al. 2012, p. 71). This latter position is in line with the suggestion that clusters are particularly important in the case of emerging eco-industries, thus, "synergies and interdependencies exist between cluster development and sustainability" (Martin and Mayer 2008, p. 275). It is proposed that the complexity of sustainability demands necessitates particularly close collaboration between actors (Allen and Potiowsky 2008; Johnson and Silveira 2014) and that local buzz, i.e. non-deliberate knowledge and information exchange through e.g. rumours, impressions and recommendations, may be especially important in sustainable energy clusters due to the need for cultural and behavioural change (McCauley and Stephens 2012). However, we know very little about the importance of localised networks for the ability of regimes to maintain and preserve the interests of agents that are part of these, as empirical evidence is missing on this topic.

6. Conclusion

This survey of studies of the influence of place-specificity and scale on sustainability transitions points to a number of more general observations. First of all, the greater majority of the studies have focused primarily on the geography of niche developments and formative phases in technological innovation systems whereas far less attention has been paid to regime dynamics or more mature technological innovation systems. This bias is striking, especially the lack of attention for regime-level responses to sustainability transitions or geographical dimensions in growth phases of technological innovation systems. While geographical analyses have enriched our understanding of how local place-specificity shapes formation of niches and emerging technologies in and across different scales and, thus, paved the way for a greater appreciation of variety and heterogeneity in niche dynamics, regimes maintain to be treated as more or less homogenous configurations across space. As a result, geographical variation within regimes remains an empirically and theoretically under-studied topic even though variance is prone to be expected in light of institutional differences across space. A similar observation can be made for regime-niche relations and interactions. At the same time, it should be acknowledged that the sustainability transitions literature at large has been infatuated with a 'bottom-up' approach to transitions that have primarily considered niche-based processes that lead to regime change (Berkhout et al. 2004; Geels 2011) even though recent theoretical developments increasingly stress the need to directly address the various dimensions of the sociotechnical regime (Geels 2014). This would require unpacking the various dimensions and assessing their internal alignment. Assessing whether or not these dimensions are co-located within a more or less coherent spatial unit (e.g. region or nation) and thus part of a similar place-bound logic or, rather, distributed and variable across space would be an important contribution that geographical studies on sustainability transitions are able to make.

Secondly, the review shows that the majority of the geographical analyses have zoomed in on the importance of place-specificity for transition processes. Individually, these contributions highlight that transitions are highly localised and place-dependent. The greater spatial resolution adopted in these studies takes stock with pioneering work that often took the national scale as point of departure and has helped to specify that niche formation and formation processes in emergent technologies are contingent on place-dependent factors such as local technological and industrial specialisation, local natural resource endowments, local market formation, urban and regional visions and policies and localised informal institutions. While a higher level of sensitivity concerning the importance of place-specificity is gained in these studies, it may have come with a bias towards emphasising particularities found in single case studies of distinct places. As a result, the consensus is still *that* place-specificity matters while there is still little generalizable knowledge and insight about

how place-specificity matters for transitions. There is a risk that such analyses simply observe geographical specificity and establish differences in transition dynamics as an empirical matter-of-fact without engaging with the undoubtedly daunting task of fully explaining such differences. This in turn may unduly limit the contribution of geographical analysis to sustainability transitions to that of topical contrivance: of interest to geographers but with limited reach beyond (Bridge 2008; Truffer and Coenen 2012). This suggests that there are yet un-theorised sources of spatial difference in transition dynamics observed as place-specificity (Storper 2009). To warrant a more theoretical and thus more broadly generalizable account of place-specificity, the section above seeks to point at some of the interdependencies between the singular place-specific factors and draws on wider theoretical debates in economic geography to suggest an agenda for future research.

Thirdly, it seems fair to conclude that the review shows that despite a pronounced interest in how local particularities have shaped transition processes, most studies dealing with the geography of transitions have adopted a multi-scalar perspective. In comparison, studies that have looked explicitly at global sustainability transitions are less frequent. This corresponds with the abovementioned preoccupation with primarily bottom-up approaches to transitions. At the same time, studies have been remarkably unequivocal in exposing the undue conflation of niche formation with local scale, but instead pointed to the co-existence and interdependence of local and non-local relationships. But similar to the above discussion concerning the role of place-specificity, few studies have provided a comprehensive understanding in which situations and for which purposes relations at different scales matter.

In sum, most studies on the geography of transitions have primarily layered on top of existing theory in the transitions literature, relying largely on concepts and frameworks such as MLP, TIS and SNM yet adding spatial sensitivity. Few studies in the geography of transitions field suggest alternative frameworks to study sustainability transitions and thus challenge current theorisations of transitions and its geographies.

Given these observations, future research on the geography of transitions is needed that investigates more systematically how place-specificity and scale influence transitions processes. Methodologically this would argue in favour of using comparative methods more frequently to identify similarities and differences across a range of places and scales. Theories within sustainability transitions were initially developed in and applied to developed, Western European economies (Lawhon and Murphy 2012). The fact that the recent attention to the geography of sustainability transitions coincides with the increasing usage of the framework in developing and emerging economies is probably not coincidental, as the challenges and opportunities for sustainability transitions are significantly

different in emerging economies (Johnson and Silveira 2014; Tukker 2005). Application of theories in new geographical settings generally implies that the theories need to be revised and further developed in a direction that is more sensitive to geography. Thus, as highlighted by Murphy, this issue, the increasing spread of the sustainability transitions literature to new parts of the world is likely to stimulate further interest in as well as theoretical advancement of the geography of sustainability transitions .

Acknowledgements

This paper benefitted from comments by two anonymous reviewers, the editors of this special issue, Heather Lovell and other participants at the workshop “Constructing and contesting spaces for low-carbon energy innovation” at the Eindhoven University of Technology, and at the 4th International Conference on Sustainability Transitions in Zürich, Switzerland. The authors acknowledge financial support from Nordic Energy Research (through the project *Technology Opportunities in Nordic Energy System Transitions*), The Norwegian Research Council (through the project *Role of demonstration projects in innovation: transition to sustainable energy and transport*), the Swedish Research Council (Linnaeus Grant No. 349200680) and the Swedish Governmental Agency for Innovation Systems (Grant agreement 2010-07370).

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