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Innovation Policy for Grand Challenges. An Economic Geography Perspective

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Innovation Policy for Grand Challenges. An Economic Geography Perspective

Abstract

Grand challenges such as climate change, ageing societies and food security feature prominently on the agenda of policymakers at all scales, from the EU down to local and regional authorities. These are challenges that require the input and collaboration of a diverse set of societal stakeholders to combine different sources of knowledge in new and useful ways – a process that has occupied the minds of economic geographers looking at innovation in recent decades. Work in economic geography has in particular examined infrastructural, capability, network and institutional challenges that may be found in different types of regions. How can these insights improve researchers' and policymakers' understanding of the potential for innovation policies to address grand challenges? In this paper we review these insights and then identify areas that push economic geographers to go beyond their previous focus and interests, notably by considering innovation policy in light of transformational rather than mere structural failures.

Introduction

Grand challenges are increasingly becoming the focus of policymakers at various levels: it is in particular advocated by supranational organisations such as the OECD and the European Union (EU), but is gradually also taken on board by local and regional authorities (Cagnin, Amanatidou and Keenan 2012). In a European context, the Lund Declaration (2009) played a key role in highlighting the importance of finding solutions to problems associated with ageing societies, pandemics, public health, security, global warming and the increasingly difficult access to sources of energy, water and food. Since then, grand challenges have progressively become a policy discourse, most often associated with the need for development and diffusion of innovation. Attention for grand challenges has even found its way into EU's new 2020 growth strategy which emphasises the importance of *"exploring new development paths to generate smart, sustainable and inclusive growth … Various long-term challenges such as globalization, pressure on natural resources and an ageing population are intensifying. If we are to adapt to this changing reality, Europe can no longer rely on 'business as usual"* (European Commission 2013, p. 3).

Some consider this orientation towards grand challenges as a new wave of mission-oriented innovation policy that substitutes, or at least complements a previous, more generic concern with innovation policy as an engine of economic growth (Gassler, Polt and Rammer 2008). What distinguishes challenge-driven innovation and innovation policy from historical examples of mission-oriented science, technology and innovation policies (such as the Manhattan Project or the Apollo project) is a greater appreciation of and attention for broad system transformation (Borrás and Edler 2014), demand side policies (Mowery, Nelson and Martin 2010) and transformative change, i.e. radical, long-term alterations in both production and consumption that significantly modify the functioning of society (Grin, Rotmans and Schot 2010, Schot 2015). While in mission-oriented policies, the challenge was largely framed in technical terms, challenge based policies claim to be less instrumental and refer to open-ended missions that require a mix of technological and social innovation, open up for contestation, both with respect to policy aims and means, and involve new

actor constellations that include a larger variety of actors, and consider new roles for traditional actors (Kuhlmann and Rip 2014).

Rather than pushing technological advancement and solutions or enhancing competitiveness, it seems that so-called persistent problems lie at the heart of challenge-driven innovation policy (Rittel and Webber 1973). These problems are persistent for a variety of reasons (Schuitmaker 2012). First, they are complex and multi-sided. Multiple causes and consequences co-exist often covering several societal domains. Second, they are uncertain and unstructured. Wicked problems defy easy solutions, and reduction of uncertainty by producing more knowledge is not always possible. One partial solution at one point of time may generate new, additional problems at a different point of time or elsewhere. Third, they are difficult to manage. Many different actors are involved that represent different interests, have different problem perceptions and advocate different solutions.

What these challenges have in common is that they are not only (or even primarily) searching for technological advancements, but that they necessitate transformative, system change. At a conceptual level, thinking about transformative, system change has been heavily influenced by the burgeoning literature on socio-technical transitions (Markard, Raven and Truffer 2012). The literature on socio-technological transitions analyses how transformative shifts in systems of production and consumption unfold as disruptive technological change co-evolves with changes in markets, user practices, policy, discourses and governing institutions (Kemp, Schot and Hoogma 1998, Geels 2002, Smith, Voß and Grin 2010, Markard, Raven and Truffer 2012). This literature calls attention for the co-evolution of a broad range of innovations which highlights technological, social, organisational, and business model novelty. It shares many theoretical roots with innovation studies, most notably a system perspective on innovation and a neo-Schumpeterian evolutionary understanding of change and industrial dynamics (Coenen and López 2010). However, compared to innovation system approaches, it claims to comprise a wider set of institutions and networks of heterogeneous actors including firms, user groups, scientific communities, policy makers, social movements and special

interest groups. As a result, it stresses the importance of directionality, resistance and contestation in (radical) innovation processes. The most well-known examples of such socio-technological transitions concern low-carbon transition in fields of energy and transport.

Thus, while research from a socio-technical perspective is very relevant to policymaking on the topic of grand challenges, we would argue that this is also the case for economic geography research. Innovation and innovation policy has been a topic of central concern for economic geographers (Feldman 2000) who have considered and examined the responsibility for policy action at different spatial scales (Laranja, Uyarra and Flanagan 2008). Especially at the regional level, economic geographers and scholars from cognate fields of study, have been quite successful in informing and influencing the policy agenda through approaches such as Regional Innovation Systems (RIS) (Cooke, Uranga and Etxebarria 1997, Asheim and Gertler 2005), Learning Regions (Morgan 1997) as well as other kinds of territorial innovation models (Moulaert and Sekia 2003).Still, the community has only recently started to engage more intensively with policymakers beyond the regional level through work on the rapidly proliferating EU policy notion of smart specialisation (Boschma 2014, McCann and Ortega-Argilés 2015).

Further, so far, economic geography has paid scarce attention to innovation for transformative change (see below) and primarily only in relation to sustainability transitions (see Hansen and Coenen 2015 for a review). Unfortunately, lack of engagement with an emerging topic of central importance to current policy discussions appears to be a general tendency among economic geographers. As argued by Dicken (2004), economic geography has a propensity to 'miss the boat'; for instance, it has only been of marginal importance in policy debates in relation to processes of globalisation and simply lacks visibility and voice among policymakers, despite being centrally placed to inform policy on the topic. As argued by Glasmeier and Conroy (2003, p. 182), *"[i]n spite of this natural link, few geographers are present in the high-profile global debates about key issues in the current wave of globalization"* which is instead dominated by scholars from economics and law.

Similarly, while the World Development Report 2009 (The World Bank 2009) was termed "Reshaping Economic Geography", it was written by economists. This has been attributed to the inability of economic geographers to engage in constructive dialogue around policy relevant research with high-level practitioners (Rodríguez-Pose 2010).

In light of this lineage, this paper, firstly, considers how insights from the literature on the economic geography of innovation can improve researchers' and policymakers' understanding of the potential for innovation policies to address grand challenges and, secondly, identifies research areas that push economic geographers to consider transformative change and thereby go beyond their existing understanding of innovation and innovation policy. This is important in preventing grand challenge policies from being spatially blind or failing to consider the place-based multiplicity in possible development paths. Before turning to these issues, however, the rationale for and focus of innovation policies are briefly considered.

Innovation policy – from structural to transformational failures

To study spatial dimensions of innovation, economic geographers have drawn heavily on the Innovation Systems (IS) approach. The IS approach (Freeman 1987) analyses conditions for promoting innovation and investigates which actors/organisations are involved in the innovation process, to what extent and how these are connected in networks, and which institutions enable or inhibit network formations and innovation processes. In contrast to the generally limited policy relevance of economic geography research, case-based empirical studies using the IS conceptual framework have in fact had a major influence on innovation policy (Doloreux and Parto 2005, Asheim, Boschma and Cooke 2011). As a policy rationale, an IS perspective goes beyond the neoclassical economic rationale that policy intervention is legitimate and needed due to market failure because of sub-optimal resource allocation by firms. Rather, it builds on the notion that public intervention is legitimate and needed if the complex interactions that take place among the different organisations and institutions involved in innovation do not function effectively (Laranja, Uyarra and Flanagan 2008). Thus, the main focus of innovation policy and rationale for policy intervention has

been on correcting what Weber and Rohracher (2012) call structural innovation system failures (see e.g. Georghiou and Metcalfe 1998, Jaffe, Newell and Stavins 2005). A taxonomy of such structural innovation systems failures has been proposed by Klein Woolthuis, Lankhuizen and Gilsing (2005), who distinguish between four types of failures:

- *Infrastructural failures*: insufficiencies in existing physical infrastructures needed to enable innovation activities
- *Capabilities' failures*: The lack of appropriate competencies and resources at the firm and organisational level may limit and/or prevent the generation of, access to, and exploitation of knowledge.
- *Network failures*: Intensive cooperation in closely tied networks leads to myopia and lack of infusion of new ideas or too limited interaction and knowledge exchange with other actors inhibits exploitation of complementary sources of knowledge and processes of interactive learning.
- *Institutional failures*: Absence, excess or shortcomings of formal institutions such as laws, regulations, and standards, in particular with regard to IPR and investment and lack of informal institutions such as social norms and values, culture, entrepreneurial spirit, trust and risk-taking that impede collaboration for innovation

One of the main contributions of the RIS approach has been to specify what kind of innovation policy is needed to fit and address place-based characteristics and challenges. There is no single 'best practice' policy, or mix of policy instruments, available for each and every situation, as regions and nations are very different. Thus, instruments and policy systems have to be context sensitive in being adapted to the needs and bottlenecks in different types of firms and regional circumstances. This context sensitivity is clearly articulated in the typology suggested by Tödtling and Trippl (2005), which builds on system failures found in different types of regions. This typology distinguishes between systemic problems related to organisational thinness often found in peripheral regions; problems

154 associated with technological lock-in characteristic of specialised, old industrial regions; and, finally,
155 problems connected with internal system fragmentation typically found in diverse metropolitan
156 regions. According to Tödtling and Trippl (2005) these systemic problems require tailored policy
157 support beyond 'one-size-fits-all'.

158 While the relevance of these types of failures is generally accepted, the literature on structural
159 innovation systems failure has been criticised for neglecting the challenges related to other types of
160 policy priorities beyond innovation-based competitiveness and growth (Alkemade, Hekkert and
161 Negro 2011). This reflects a growing concern and interest in the innovation studies field towards
162 considering effects of innovations at the broader societal level (Lundvall and Borrás 2005, Fagerberg,
163 Martin and Andersen 2013). To exemplify, Soete (2013) argues that many innovations cause
164 decreases in total welfare due to for instance negative environmental effects. It is therefore
165 designated as a key challenge for innovation studies to move beyond analysing innovation for
166 economic growth to innovation for sustainable development (Martin 2013).

167 Responding to this criticism, Weber and Rohracher (2012) argue that in order for innovation policy to
168 facilitate transformative change and effectively move beyond the incrementalism of business-as-
169 usual found in mainstream innovation policy (Steward 2012), focus should not merely be on
170 correcting structural innovation system failures, but also on four types of transformational systems
171 failures:

172 - *Directionality failures*: inability to steer innovations towards a particular direction of
173 transformative change
174 - *Demand articulation failures*: lack of capacity to understand user needs which inhibits the
175 uptake of innovations
176 - *Policy coordination failures*: absence of coherence between different types of policies
177 - *Reflexivity failures*: insufficient monitoring and adjustment of the development towards
178 transformational change

Conceptualising transformative change as a question of system failures could be considered somewhat mechanistic from a socio-technical transitions literature perspective, which has elaborated extensively on the requirements for institutional transformation. However, we argue that this framework is very valuable in describing some key aspects of transformative change in a manner which is accessible to policymakers in the field of innovation. Furthermore, as noted in the introduction, economic geographers appear to be rather slow to address emerging topics of central importance to current policy discussions; thus, it may be particularly useful for researchers from this field to take a point of departure in the systems failure framework. Therefore, in the following section we will review and discuss how studies in economic geography on innovation, often conducted in regional contexts, relate to and inform the above 'system failure' rationales for innovation policy.

Economic geography and innovation

Departing from the distinction between structural and transformational system failures introduced in the previous section, one can summarise the insights from the economic geography literature on innovation as being primarily related to the structural type. Economic geographers have repeatedly argued that regional characteristics and interactions at the regional scale are particularly important for knowledge creation and innovation processes. Theories on regional innovation systems, innovative milieus, learning regions and industrial districts all stress the role of localised capabilities and relations around innovation and production processes. Related to this point, as contextual factors shape the innovativeness of firms, economic development policies ought to reflect regional characteristics (Tödtling and Trippl 2005, Farole, Rodriguez-Pose and Storper 2011). In sum, the regional scale is considered the adequate scale for implementing innovation policies that target structural innovation system failures (Asheim, Boschma and Cooke 2011), and in the following, we summarise the main contributions of economic geographers for these four failure types.

Firstly, the condition of a region's physical, as well as knowledge and scientific infrastructure is often considered to form the basis of its innovative potential. This includes well-connected transportation

205 systems that allow a region to be integrated in global networks of production and innovation
206 (Saxenian 2007). It is therefore no surprise that Rodríguez-Pose and Fratesi (2004) find that
207 addressing *infrastructural failures* is the subject of a majority of programs under the European
208 Cohesion Policy, even if they find that effects of these investments are highly questionable (see also
209 Crescenzi and Rodríguez-Pose 2012). In the context of innovation, however, greater emphasis is
210 placed on the presence of knowledge infrastructure such as higher education institutions, ICT
211 infrastructure, laboratories and science parks (Feldman 1994, Feldman and Francis 2003, Smith and
212 Bagchi-Sen 2006). These require long-term investments too large for single firms to bear, and which
213 therefore depend on the public sector. As Trippl and Otto (2009) illustrate in their work on old
214 industrial regions, these knowledge infrastructural investments are of central importance for
215 allowing regions to successfully transition into new industries. Taking this one step further however,
216 policymakers are drawing up an increasing number of research infrastructure "roadmaps" to secure
217 the provision of long-term and basic knowledge production in the future (such as the ESFRI, the
218 European Strategy Forum on Research Infrastructures),and regions make investments to ensure they
219 are included and featured on these (Stahlecker and Kroll 2013).

220 Secondly, related to *capabilities failures*, the economic geography literature highlights that the
221 characteristics of the regional environment are significantly affecting the development of capabilities
222 in firms and, thus, their ability to develop innovations. Building on the seminal work of Marshall
223 (1890), economic geographers have in particular given significant attention to the role of
224 agglomeration economies for the innovativeness of firms. Firstly, the availability of a pool of skilled
225 labour is positively associated with innovativeness. Matching skill demands and labour supply is
226 easier in thick labour markets, where firms have access to highly specialised labour (Moretti 2012),
227 thus, innovativeness and creativity are higher in firms located in clusters with large employment
228 concentrations (Baptista and Swann 1998, Andersson, Quigley and Wilhelmsson 2005). Secondly,
229 knowledge spillovers, i.e. unintended flows of knowledge from one actor to another, have been
230 shown to be geographically localised (Jaffe, Trajtenberg and Henderson 1993, Sedgley and Elmslie

2004). The vehicles for such knowledge spillovers range from gossip, rumours and the possibility to observe competitors (Pinch and Henry 1999, Henry and Pinch 2000) to the mobility of labour (Almeida and Kogut 1999). On the former, economic geographers highlight the importance of geographical proximity for such informal knowledge flows (Maskell 2001, Dahl and Pedersen 2004), and it has similarly been shown that the mobility of researchers is limited, thus, they have low propensity to relocate in space, and knowledge spillovers are therefore also primarily geographically localised (Breschi and Lissoni 2009). Most recently, specific attention has been given to the type of labour mobility that facilitates knowledge spillovers. Boschma, Eriksson and Lindgren (2009) find that relatedness in mobility, i.e. inflow of new employees with skills that are related – but dissimilar – to existing competencies, have particular positive effects. This points to the importance of having related industries at the regional scale (see also Boschma and Wenting 2007).

Thirdly, economic geographers have made contribution of great relevance for understanding *network failures*. A key insight is that the interactive character of innovation processes implies that collaborations between partners located in geographical proximity have a number of advantages. As pointed out in a seminal paper by Storper and Venables (2004), geographical proximity facilitates easy face-to-face contact, which in turn allows for efficient communication, creation of trust, and loss of anonymity that makes monitoring and evaluation of collaborators possible. However, it does not necessarily follow that geographical proximity is indispensable for collaborations concerned with innovation processes: Boschma (2005) suggests in a conceptual paper that proximity along social (strong social ties), organisational (common ownership), cognitive (similarity in knowledge bases) and institutional (shared formal and informal institutions) dimensions allow for collaborations between partners separated by long distances; and an empirical analysis indeed confirms the possibility for substituting non-spatial proximity for geographical proximity (Hansen 2015). Still, these insights do not question the proposition that, all things equal, collaborations between partners located in geographical proximity is easier than collaborations between distanciated collaborators. As highlighted by Morgan (2004) and Hansen (2014), geographical proximity is particularly valuable in

highly complex innovation projects, where the exchange of tacit knowledge is necessary. At the same time, studies have shown that firms cannot rely only on proximate network ties. Following the seminal 'local buzz, global pipelines' paper of Bathelt, Malmberg and Maskell (2004) there has been a wealth of contributions that point to the interplay and complementarity of local and global knowledge ties in innovation networks even in highly specialized and geographically concentrated clusters (Gertler and Levitte 2005, Giuliani 2007). Here, Giuliani and Bell (2005) have pointed to the importance of gatekeeper organizations as critical linchpins between global and local networks.

Fourthly, related to *institutional failures*, economic geographers point out that an important regional characteristic that influences the innovativeness of firms relates to cultural aspects. As famously stated by Saxenian (1994), the culture in Silicon Valley facilitated innovation to a much greater extent than in Route 128, due to a higher degree of openness among firms which allowed for members of communities of practice distributed across different firms to exchange knowledge and engage in processes of learning through joint problem solving. According to Saxenian (1994) such 'culture' of knowledge sharing and exchange was far less developed among the more vertically integrated firms in Route 128. In a similar fashion, Storper's (1997) emphasis on the presence of 'untraded interdependencies' points to the importance of shared conventions embedded in the territory through the positive externalities generated by local institutions. Empirically Storper, Kemeny, Osman and Makarem (2015) explain the substantial difference in innovativeness and industrial renewal between Los Angeles and San Francisco since the 1970s by referring to a more widespread culture of risk taking and experimentation in San Francisco, which allowed for continuous adaptation of the industrial complex. More generally, economic geographers have tended to focus on the role of 'institutional thickness' as a driver of regional economic development. Institutional thickness can be understood as a *"combination of features including the presence of various institutions, inter-institutional interactions and a culture of represented identification with a common industrial purpose and shared norms and values which serve to constitute 'the social atmosphere' of a particular locality"* (Amin and Thrift 1995, p. 104). Institutional thickness, consisting of an interplay of

283 formal and informal institutions, is thus considered to help the capacity of any region to adapt to
284 changing conditions and generate and assimilate innovation (Rodríguez-Pose 2013).

285 The bulk of contributions made by economic geographers on conditions for innovation have primarily
286 addressed dimensions related to structural innovation system failures. It should however be
287 acknowledged that some attention has been given in recent years to transformational system
288 failures. This research is particularly focused on the geography of sustainability transitions, which is
289 concerned with understanding the importance of spatial context and relations across different scales
290 for transition processes (Coenen, Benneworth and Truffer 2012, see Hansen and Coenen 2015 for a
291 review); i.e. this research is primarily relevant for the grand challenges of climate change, resource
292 scarcity and environmental degradation. A main contribution of this literature is to highlight how
293 regional contextual factors influence the possibilities for overcoming *directionality failures*. Here, a
294 particularly important factor concerns the presence of historical regional industrial specialisations, as
295 regional innovation policies have started to combine environmental goals with economic
296 competitiveness and therefore often relate to the existing industrial and knowledge base present in
297 the region (Späth and Rohracher 2010, Carvalho, Mingardo and Van Haaren 2012, McCauley and
298 Stephens 2012). Work on *demand articulation failures* remains on the other hand very limited.
299 Nonetheless Dewald and Truffer (2012) demonstrate that engaged local end-users are central to
300 local market creation and institutional entrepreneurship. This study shows how geographical
301 proximity has enabled learning between users and producers for the build up of suitable institutional
302 configurations (i.e. a feed-in tariff) that allow for the diffusion of emerging renewable energy
303 technologies. In order to understand the risks of *policy coordination failures*, some important
304 contributions can be found in the geography of sustainability transitions literature, which point to
305 the contested nature of sustainability oriented policies, due to processes of negotiation, translation
306 and struggle between multiple public, quasi-public and private regional actors (Monstadt 2007).
307 Importantly, contestation between actors may also take place vertically, between actors at different
308 scales. To exemplify, Coutard and Rutherford (2010) describe how local and national authorities in

the case of energy transitions in the Île-de-France region form alliances against regional authorities. This highlights that tension that may follow from an increasingly complex innovation policy mix (Flanagan, Uyarra and Laranja 2011). Lastly, work on *reflexivity failures* has not really been picked up by economic geographers' work on innovation and innovation policy even though the notion of 'regional experimentalism' partly alludes to this challenge (Henderson and Morgan 2001, Coenen and Asheim 2006). Here, regional development strategies *"work in small-scale repeated interactions in an attempt to (re)define regional development support services and priorities in a collective manner, establish specific targets and responsibilities, and monitor outcomes in a way that facilitates learning on the part of those in a position to respond"* (Henderson 2000, p. 349). This notion has however found little resonance in the wider literature on regional innovation policy. Still, a possible re-appreciation may be expected given EUs current interest in the related notion of living laboratories (Cooke 2015).

Implications for studying grand challenges

So why would this body of work help us to understand ways of addressing grand challenges? We argue that the features that make these challenges challenging have a lot in common with the difficulties experienced in innovation processes when combining knowledge in new and useful ways. Grand challenges, whether it concerns climate change or healthy aging, are by nature multi-dimensional and multi-disciplinary and therefore require collaboration between many stakeholders. This implies that solutions to address such challenges are not just about technological advancements, but also about diffusion, modification and co-production of innovations by different actors and organisations. This is where the geography of innovation is able to contribute. Here we argue that the innovation system failures identified above help to identify the roots of the problems associated with grand challenges and suggest ways for policy to cope with these challenges.

Infrastructural failures, referring to physical as well as knowledge infrastructures, can manifest in grand challenges in terms of the absence or weakness of connectivity between relevant actors. In

particular when these actors are not found in the region, improved physical connectivity between regions is important and the above-mentioned investments in transport infrastructures are justified for plugging into global networks of production and innovation. In addition, universities, research laboratories, testing facilities, and other organizations that are part of a region's knowledge infrastructure (although they are only a subset of stakeholders involved in addressing grand challenges) provide vital resources and connections to other stakeholders inside and outside the region. This relates closely to *capability failures*. While the grand challenges do not confine themselves geographically, we find that the potential for solutions depends heavily on local availability of skills and firm competencies, absorptive capacities and regional culture. These characteristics may have developed in response to need or adapted from previous specialisations. An example of the former is the environmental technology industry in the Ruhr district, which developed out of a need for limiting the negative environmental effects of the heavy industry in the area (Hospers 2010). An example of the latter is the fuel cell industry, which has been found to emerge in regions where competences exist in related technological fields (Nygaard Tanner 2014).

Third, we find that grand challenges are especially prone to *network failures* where interactive learning is inhibited. Even when relevant stakeholders are present in the region and have the capabilities necessary to work together in response to localized conditions, they still require certain network conditions to have fruitful interactions. In order to stimulate, initiate and coordinate interaction between an increasing, and increasingly diverse, number of stakeholders, geographical proximity offers certain advantages (Rekers and Hansen 2015). Contrary to subjects of previous rounds of "mission-oriented investment" such as the Apollo program or the Manhattan project, our contemporary grand challenges have less clearly defined technological goals and require more disciplinary diversity in search of solutions. As Leijten, Butter, Kohl, Leis and Gehrt (2012, p. 5) argue: *"Grand challenges are not to be defined, assessed or solved by any single scientific or technological discipline or within one specific sectoral policy framework."* This implies a need for collaboration between the public and private sectors, multiple industries, and producers as well as users and

intermediary organisations (Kuhlmann and Rip 2014). In order to overcome the differences between such diverse stakeholders – and the lack of organisational and institutional proximity that is likely to be associated with such diversity – geographical proximity is an asset. This is particularly important in combination with the high degree of complexity (in the context of innovation projects) that characterises our grand challenges.

Of greatest significance when dealing with grand challenges, however, are *institutional failures*. Responses to grand challenges require the development and diffusion of innovations, which, as suggested above, is tightly coupled to characteristics of the local environment. From work on the geography of innovation, we recognise that the systemic nature of grand challenges demands policy responses that take the local institutions and context into consideration: *"the global nature of technological solutions means that the institutional, economic, and/or industrial settings within which these solutions are deployed will be enormously diverse, requiring a great deal of "localized" adaptation of these solutions"* (Foray, Mowery and Nelson 2012, p. 1701). However, too strong dependence on specific contextual factors in the development of innovations may also limit their diffusion potential, if the innovations end up being very place-specific. This is exactly the conundrum that continues to hamper the wider diffusion of so-called grassroot innovations (Seyfang and Smith 2007). To exemplify, Bridge, Bouzarovski, Bradshaw and Eyre (2013) propose that the diffusion potential of renewable energy technologies is culturally contingent as it depends on localised cultural routines. This suggestion is confirmed empirically by Wirth, Markard, Truffer and Rohracher (2013) in an analysis of biogas technologies in Austria, where it is found that informal institutions condition the diffusion potential of different forms of biogas technologies. Taking institutional factors seriously helps to understand why innovative solutions to grand challenges are likely to be rooted in (but perhaps also tied to) the particularities of places.

Recalling our earlier point on capability failures, this implies that innovative responses are highly localised both in terms of their development as well as implementation. It therefore does not come

as a surprise that we observe enormous variation between places in terms of policy responses (Leijten, Butter, Kohl, Leis and Gehrt 2012). On the one hand it is a promising sign that local and regional governments have authority and freedom to develop innovation oriented initiatives targeting grand challenges, even when general strategies may be more centrally defined (Cunningham and Karakasidou 2010, Bulkeley and Broto 2012, Leijten, Butter, Kohl, Leis and Gehrt 2012). However, this also points to a critical obstacle when tackling grand challenges: the significance of local context poses barriers to potential policy harmonisation and the transfer of best practices, the diffusion of innovative responses, and the upscaling of successful strategies beyond its place of origin. Here we can see there is considerable scope and need for economic geographers to go beyond previous work on the geography of innovation. Addressing transformational systems failures (directionality, demand articulation, policy coordination and reflexivity) is a useful next step.

Conclusion – lessons for economic geographers studying grand challenges

The increasing emphasis on grand challenges related to climate change and environmental degradation, ageing societies, public health, security, as well as water and food scarcity pushes economic geographers to go beyond the hitherto dominant focus on innovation as an enabler for economic growth. As pointed out in a critical review of the territorial innovation models (Moulaert and Sekia 2003), the emphasis in these theories is on territorial competitiveness while considerably less attention is paid to the effects of innovations on non-market aspects such as quality of life and sustainability. Addressing grand challenges, and the persistent problems that often underpin these challenges, requires a broader perspective that is not only concerned with structural failures in innovation systems and related policies (in connection to capabilities, networks and a limited set of institutional factors). In addition, more attention should be directed to analyses and policies targeting system transformation and the 'failures' associated with such transformative shifts in production and consumption.

The identified lack of attention to *demand articulation failures* points to a general negligence in economic geography to the importance of innovation diffusion. No matter how technologically advanced and superior solutions are being developed, they are of little value if they are not successfully implemented, used and diffused. This diffusion challenge is especially prominent in the case of grand challenges, and where users, decision-makers and buyers are likely to comprise a diverse group. While some bodies of work highlight the importance of users as sources and drivers of innovation (von Hippel 1976, 1988, Beise 2004, Grabher, Ibert and Flohr 2008), and others call for more demand-oriented innovation policy instruments (Edler and Georghiou 2007), there is still an overwhelming emphasis on the supply-side of territorial innovation systems (Marques 2011). Grand challenges force us to consider factors that help to explain why solutions can be more successful in one place compared to another, and why some solutions spread beyond their place of origin and scale up, while others remain trapped by local context.

Finally, the limited interest in the field of economic geography towards *directionality failures*, *policy coordination failures* and *reflexivity failures* is actually quite paradoxical, since it has been a key objective of many economic geographers to carry out policy relevant research that could inform innovation policymakers, in particular at the regional level. These failure types have in common that they to a large extent relate to the process and politics of policy-making. However, the policymaking process itself has been left largely untouched by economic geographers, who appear to assume that (or, at least, have not questioned if) this takes place in rational and seemingly technocratic ways.

In closing, it is worth emphasising that the dimensions of grand challenges we discussed in this paper, their being a mix of technological and social innovation, open to contestation and involving new actor constellations, highlight the importance of moving beyond a focus on narrow technological advancement. In other words, the need to go beyond so-called technological fixes when addressing grand challenges foregrounds the value of geographical perspectives in policy making, where the role

played by place-based social and political contexts in transformational change are explicitly acknowledged.

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