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Governing Sociotechnical Change in Regional Innovation Systems[1]

Introduction

Innovations and technological change are not only seen as a crucial element of economic competitiveness in a global environment, but also as an element of environmental modernisation and social transformations. Innovation studies usually focus on the innovative activities of firms from a predominantly economic perspective and the broader institutional preconditions that favour these activities. As Carlsson et al. (2002) point out, innovation systems can be national, regional, sectoral or technological. Nevertheless, they all focus on the creation, diffusion and use of knowledge. From a somewhat different perspective, social studies of technology and related policy-oriented approaches analyse the topic of technological change and innovation rather with a focus on specific technologies which are embedded in local social and cultural contexts, thereby highlighting the stability of sociotechnical regimes and strategies to induce and support the transformation of such sociotechnical constellations towards certain aims, such as increased sustainability.

In this chapter I will especially deal with the current challenges of regional technology policy, and will argue for a combination of regional innovation systems approaches and approaches focusing on technology-specific innovation systems and sociotechnical transformation processes within regions. The two perspectives on technological change will be discussed with a special focus on their overlapping but also complementarity, and this will result in the argument that sociotechnical analysis could enrich and broaden the regional governance of innovation and technological change.

The argument in short: The context of regional policy has been changing significantly over the past 20 or 30 years. This period has seen a growing importance of global economic competition in production (and increasingly in services), which has often been turned into a competition of regions to provide the most attractive socio-economic and cultural environment for factories, headquarters or research departments of multinational companies. This period has also seen the rise of knowledge-based economies (though their current importance compared to the 'traditional' industrial economy still is arguable) with new regional challenges with respect to the qualification of workforce, education, knowledge transfer, etc. At the same time (and partly in consequence of these developments and of broader ideological trends such as neoliberalism), the role of

[1] This article has originally been published In Tchalakov, I. – Mali, M. – Rohracher, H. (eds.): *Governing Sociotechnical Change in South-Eastern Europe. Contributions from a Science and Technology Studies Perspective*. Sofia: East-West Publishers. 2006.

the nation state as well as the organisation of the production process has been changing significantly. While traditionally the state and its administrative sub-units at a regional level had a rather central steering capacity, for example with respect to infrastructure investments in regions, financial investment incentives for companies or regional development to level out regional disparities (see HEINTEL 2004), state administration meanwhile has handed over many of these steering competencies to professional development, consulting or knowledge transfer agencies.

In this paper I will first review some of the recent discussions on regional innovation systems – an approach which sees regional institutional characteristics as an important factor for the innovative capacity and, as a consequence, economic competitiveness of companies. While these concepts (and indeed the ensuing policy strategies in many regions) point to diverse strategies to improve the economic competitiveness of regions, we will go one step further, and argue for regional strategies which do not only put competitiveness as such to the foreground, but which also focus on the type of technologies produced and their embedding in broader policy aims, such as environmental or social policy. As we will point out, such an approach, which also put a strong emphasis on the demand side – use, implementation and contextualisation of technologies –, may also have positive effects on regional development and regional innovative capacity, and may simultaneously serve other policy aims. Although both perspectives have a lot of issues and challenges in common, regional policy focusing on the governance of sociotechnical change (compared to a so far dominant focus on the institutional basis of rather generic high-tech innovations) requires additional strategies and activities, and may create a number of synergies with a mainly institutions-oriented regional innovation policy.

My comparison of these two approaches moreover will highlight two important aspects for the analysis of innovation systems: functions of innovation systems (and the extension of this concept when the types and embedding of technology becomes important too) and the increasing role of intermediary agents in current economic contexts (and the additional types of intermediation required for the governance of sociotechnical change). Thus my chapter will draw together discussions on regional innovation systems, the transition of sociotechnical systems and the requirement of intermediation and new types of governance.

1. Regional Innovation Systems

Let us first start with a short discussion of innovation systems in general, and subsequently focus on the regional level. Obviously these approaches are based on a systemic understanding of innovation processes. Innovation systems are sociotechnical constellations where technologies, institutional arrangements (e.g. regulations, norms), social practices and actor constellations (such as user-producer relations and interactions, intermediary organisations, public authorities, etc.) mutually depend on each other, and are embedded into broader contexts of cultural values, socio-economic trends (globalisation, individualisation etc.) and other sociotechnical regimes. Innovation processes are becoming increasingly complex, and are an outcome of the interaction between a multitude of actors, distributed over many different institutions and locations.

Successful innovative activities often need an environment which is characterised by both cooperation and competition of the economic actors involved. While central steering of such multi-centred systems and processes becomes increasingly difficult, processes of social learning, coordination and sociotechnical experimentation gain importance, as I will point out later.

Elements and characteristics of innovation systems

The concept of 'national innovation systems' (NIS) or its regional analogue specifically asks for the influence of region/nation specific environments (social, cultural, institutional) on innovative activities of firms. Building on the classifications of a number of authors (ARCHIBUGI and MICHIE 1997, 8–10; SHARP and PAVITT 1993, 142; LUNDVALL 1992, 13; COOKE et al. 1997, 478) we may discern the following elements of national innovation systems:

- the systems of education and training, which are usually mainly national in scope
- university research, research institutes, R&D intensity and R&D organisation (including university-industry links)
- science and technology capabilities, S&T strengths and weaknesses
- the financial system underlying the process of innovation (e.g. availability of venture capital; short or long-term orientation of financing), public and private funding organisations
- the internal organisation of firms and the method of management
- industrial structure
- interfirm relationships, co-operation of firms (supply chain, user-producer interactions)
- consultants, technology transfer agencies, skills development organisations
- role of the public sector
- norms and regulations (intellectual property rights; environmental regulation; regulation of infrastructures etc.).

With a somewhat different focus, Edquist and Hommen summarise the central characteristics of innovation systems approaches (EDQUIST and HOMMEN 1999, 65):

- they place innovation and learning processes in the centre of focus (innovation as learning process)
- they adopt a holistic and interdisciplinary perspective (not only economic, but also organisational, social, political factors)
- they employ historical perspectives (innovation systems develop over time)
- they stress the differences between systems, rather than the optimality of systems (i.e. comparison of existing systems)
- they emphasise interdependence and non-linearity (firms almost never innovate in isolation)
- they encompass product technologies and organisational innovations
- they emphasise the central role of institutions
- they are still associated with conceptual diffuseness (conceptual pluralism)
- they are conceptual frameworks rather than formal theories.

With respect to the 'looseness' and ambiguity of the NIS concept, which can be seen in the enumeration above, Sharif (2006) points to the advantage of enhancing its appeal this

way to both actor groups promoting the concept – academia and policy –, as the concept can easily be adapted to the requirements and purposes both sides try to achieve (SHARIF 2006, 752). NIS can thus also be seen as a kind of 'boundary object' mediating between science and policy.

A way of more analytically structuring innovation systems is to ask for functions they fulfil. Schienstock (unpublished manuscript, 2006) distinguishes six main functions of innovation systems which are related to the notion of national or regional innovation systems: knowledge production and acquisition (e.g. research), knowledge storage (e.g. libraries), knowledge diffusion (e.g. transfer institutions), knowledge regulation (property rights), knowledge standardisation (technical norms), knowledge transformation into products and services, knowledge use and consumption. The success of an innovation system heavily depends on the effective organisation of networks and mediation processes within these functional areas.

As these elements, characteristics and functions emphasise, successful innovative activities highly depend on a supportive environment with respect to institutions (broadly understood as norms, habits, regulations and rules which are deeply ingrained in society), specialised organisations and relations between actors in the system. The aim of policies focusing on innovation systems should be to assist 'institutional learning', as Johnson (1992) calls the capability of economies to learn about, adapt and change their institutional framework. Moreover, it should be pointed out that the institutional framework or environment only partly consists of formal norms and regulations. At least as important (or maybe more important) for innovation and learning are more deeply enculturated habits and practices. Lundvall especially stresses four types of such institutions: the 'time horizon of agents', the role of 'trust' (mutual expectations), the 'actual mix of rationality' (communicative vs. instrumental rationality), and the way 'authority' is expressed (e.g. by seniority, financial resources, skills) (LUNDVALL 1998). Specifically, the creation of intellectual capital is fundamentally depending upon social capital in terms of trust, a long run perspective, authority and discursive rationality.

However, as Nelson and Rosenberg (1993, 5) point out, the concept of a national system of innovations may be too broad (as institutions supporting different sectors of industry may have little overlap) and at the same time too small, as a number of the institutions are transnational or act transnationally. Similarly, Freeman (1995) points to the fact that there are plausible shifts in the relevance of the institutional environment to both sub-national regions (local infrastructure, local skills and labour markets, mutual trust) and supra-national levels (EC, NAFTA).

Supporting innovative activities at a regional level

Indeed, the regional dimension of innovation systems attracts growing attention from science and policy, although the question: 'Can regions function as an innovation system?', still is far from being undisputed. Nevertheless, concepts like 'flexible specialisation', 'networking' or 'post-Fordism' argue that regional production systems or technological districts are becoming increasingly important and are the basis of international specialisation and globalisation (STORPER 1995b). One of the reasons for this interest in regional systems of innovation (RSI) is that discussions of regional

development increasingly stress the role of knowledge as a development factor (universities and other knowledge infrastructures occupy key role as resource endowment within the region, but also as active participants in the construction of regional competitive advantage). As tacit knowledge is difficult to 'transport', it tends to accumulate in specific places. Such localised knowledge arising from the concentration of sectorally or cluster specific tacit knowledge is developed and shared within a socialised process involving groups of knowledgeable workers learning-by-doing, moving between firms and learning through firm-to-firm interaction (CHARLES and BENNEWORTH 2004). Related to this interest in the knowledge base and knowledge flows within regions is the attention paid to the emergence of new science based technologies, such as ICTs, biotechnology, nanotechnology, new materials etc., which are seen as a window of opportunity for regions and perceived imperative for national and regional governments.

In most cases regions are flexibly defined and do not necessarily follow administrative boundaries. Following Cooke et al. (1997, 480) we may define such regions as 'territories smaller than their state possessing significant supralocal governance capacity and cohesiveness differentiating them from their state and other regions.' Transferring the above mentioned concept of national innovation systems to the regional level, Doloreux (2002) stresses three important facts about regional systems of innovation (RSI): 'First, an RSI is essentially a social system. Second, it involves interactions between different sets of actors (private and public sectors) in a systematic way. Third, a systemic pattern of interactions is expressed in order to increase and enhance the localised learning capabilities of a region.' (DOLOREUX 2002, 247). In other words, the 'simple logic is that proximity leads to mutual experience and, in turn, this leads to trust and collaboration, and finally to the improvement of economic development' (MOLINA – MORALES et al. 2002, 318).

One of the core aspects of RSI thus is shared knowledge, which requires a high degree of trust, the sharing of common cultural, institutional and entrepreneurial activities and a high degree of social interaction – conditions which can be favoured by regional proximity (DOLOREUX 2002). These trust-based exchanges through personal networks and a shared social context are at the basis of Storper's definition of regions as a 'nexus of untraded interdependencies' (i.e. embedded in specific context, cannot be reproduced or sold) (STORPER 1995b), and may support learning processes within and between firms and other actors. Generally, learning has important specific and local characteristics, and can be improved through certain institutional changes and properly oriented active policies (COOKE et al. 1997, 490).

Concepts such as industrial districts (FARRELL and KNIGHT 2003), innovative milieus (TRUFFER and DÜRRENBERGER 1997), learning regions (MORGAN 1997) thus build on synergies and interactive learning effects from the proximity of actors (e.g. relationships with local suppliers or local authorities), cultural commonalities (as a basis for trust and sharing of tacit knowledge) and shared infrastructures. Two more RSI concepts dominate much of the discussion on regional innovation policy:

Regional clusters (PORTER 1990) have been introduced early in the regionalisation debate and are still an important concept. At its core are agglomerations of firms of a specific sector, institutions and the linkages between firms and innovation support infrastructures and amongst firms, large and small (with cooperative relations as the key).

The innovation support infrastructure often consists of specialised business services and government-supported local agencies.

Similarly the triple helix model of university-industry-government links emphasises the possibility of an innovative environment 'consisting of university spin-off firms, tri-lateral initiatives for knowledge-based economic development, and strategic alliances among firms (large and small, operating in different areas, and with different levels of technology), government laboratories, and academic research groups. These arrangements are often encouraged, but not controlled, by government […]' (ETZKOWITZ and LEYDESDORFF 2000, 112).

Focusing on the regional level of innovation systems, we however have to have in mind that regional institutions or actor constellations are always embedded and often strongly dependent on national and transnational contexts. Some of the innovation support infrastructures normally are part of a wider national infrastructure, as is the case with 'regional' actors such as universities. Similarly, specific institutions, funding opportunities etc. often are more depending on the national (or supranational, e.g. EU) level than on regional characteristics.

Moreover, important actors – multinational companies or technology-intensive firms in ICT, biotech or other high-tech fields – in many cases do not have a regional but an international orientation. Successful regional innovation systems nevertheless may tie this 'mobile capital' at least to some extent to the region. Regional networks can be regarded successful when they are binding as much of the mobile social capital as possible in the region and make it stationary this way: regionally oriented actors include globally oriented actors by linking them to their network and may establish organisational structures of trust in order to embed globally oriented actors (FÜRST et al. 2001, 49).

Organising networks and knowledge flow through intermediaries

Networking, cooperation, knowledge flow and learning between regional actors may seem like an emergent property of the proximity of a sufficiently large number of economic agents. However, in most cases it has to be organised and supported by regional government and other organisations. An important actor category with respect to these requirements of mediation and coordination (and thus an important instrument of regional policy) is specific intermediary organisations or existing regional actors which take over intermediary functions. These actors may take over various bridging functions within the innovation system, but importantly also between the regional networks and their international (or generally external) environment.

Local institutions and other local actors in the region can act as intermediary agents that play an important role in providing the district with new information and knowledge. An important function is the linkage of regional actor networks to external – national or international – networks. An example are research and technology organisations, such as the Institute of Ceramic Technology in a Spanish region (as described in MOLINA–MORALES et al. 2002, 324–25), which links the local ceramic tiles industry to international networks and knowledge flows. Local institutions may 'play the role of network intermediaries for individual firms in the region, and act as a repository of knowledge and a source of searching economies. Hence, local institutions benefit firms by facilitating the exchange

and acquisition of new knowledge, and consequently by helping them to create new knowledge' (Molina–Morales et al. 2002, 321).

Regional knowledge flow and interaction can also be significantly enhanced by knowledge intensive business services (KIBS), such as consultancies. The interaction between KIBS and manufacturing small- and medium-sized enterprises (SMEs) as their clients may stimulate the generation and diffusion of knowledge within innovation systems. As Muller and Zenker point out, 'KIBS assume a 'bridge' or interface function between the environment and their clients, and reinforce or catalyse the […] innovation capacities especially of SMEs. Going one step further, KIBS play a role of co-innovators or even 'midwives' for SMEs' (Muller and Zenker 2001, 1506).

Successful regions thus need some type of innovation organisers, as Leydesdorff et al. (2002, 9) emphasise. While this role may be taken over by special intermediaries, such as regional development agencies, other actors may assume this role as part of their portfolio. Universities for example may assume such functions in the market place, e.g. by organizing science parks and incubators. On the other hand government may take the lead in organizing venture capital.

Storper in turn suggests the establishment of regional technology foundations as a type of organisations which are widely encompassing and forward looking and whose role is to identify non-immediate technological alternatives and to develop precisely the interest in pursuing them through a variety of informational and indicative activities (Storper 1995a, 908).

Towards a regional innovation policy

Summing up this tour through concepts related to regional innovation systems, we have found that regional systems of innovation are characterised by a set of region-specific actors, institutions and infrastructures (large and small firms, public authorities, universities, consultancies; similar cultural backgrounds; joint use of research infrastructure etc.). Benefits can especially be gained from the proximity of these actors, which may result in closer interaction (between firms, with public authorities and other actors), trust and consequently improved knowledge flow and learning (including tacit knowledge through movement of persons and informal exchange of experience) within the RSI as well as to and from the outside environment.

Innovation policies at regional level primarily focus on general innovation support infrastructures such as an improved science base, financial incentives for innovation efforts, financing infrastructures, premises and infrastructure for new technology-based firms (e.g. technology parks), promotion programmes ('regional marketing'), promotion of systemic interaction around the use of new technologies (cluster management organisations; network management) as well as the establishment and support of various intermediary activities (linking research and firms; information about access to R&D funding; links with international networks, etc.). The aim of these activities is to assure that the RSI increases learning capabilities and knowledge diffusion and provides an attractive environment for knowledge and technology based firms.

However, RSI-based policies (and studies) tend to be confined to high-tech and/or manufacturing sectors, and are in many cases not integrated with other policies (such

as environmental policy, infrastructure policy) which are rather aiming at the use and application of technologies in the region. Regional innovation policies mostly have a strong supply-side focus, emphasising the general support of innovative activities of firms in the region, but are rather ignorant about the 'content' of technologies developed and their potential impact on and use in the region. A core hypothesis of this paper is that these supply-oriented policies may be complemented by policies focusing on the 'techno-structure' of the region (e.g. energy technologies, health technologies, the system of mobility or communication) comprising both development and use of technologies and aiming at specific development perspectives for the region, e.g. transition processes towards sustainability. RSI approaches are only to a limited extend useful to understanding and guiding such processes of sociotechnical transformation. In the next section I will thus shortly introduce some concepts dealing with technological (and social) change.

2. Transforming Sociotechnical Systems

To understand the change of sociotechnical systems, i.e. the interactions and relations of technologies (especially infrastructure technologies, such as energy, transport, communication, health, etc.), actors (producers, suppliers, users, policy actors, intermediaries, etc.) and institutions (norms, regulations) as well as the market introduction of technologies (not only new technologies but also 'social innovations' such as new services or institutions) we need a concept which takes into account the co-evolution of technology and its social context.

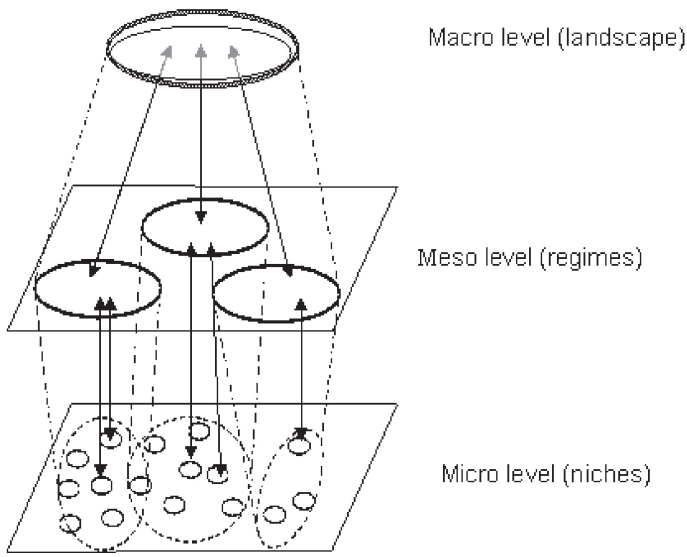
Multi-level model of innovation

One of these concepts is the multi-level model of technological change (see e.g. Rip – Kemp 1998, Geels 2004), which appears to be especially helpful for integrating the local activities and practices of users and other social players (e.g. intermediaries) with broader social and economic structures, and which provides a framework for the dynamics of technological change from innovation to adoption. The multi-level model of technological change separates the 'breeding' of new technologies in confined technological niches from a meso-level of sociotechnical regimes (e.g. the system of mobility) and a broader context of the sociotechnical landscape, which encompasses cultural norms, values or dominant economic or governance regimes (such as the present trend to liberalise former infrastructure monopolies). A 'sociotechnical regime' refers to the temporal stability of sociotechnical configurations and means a rule set or grammar that structures the sociotechnical co-evolution process. The way such a regime evolves 'is structured by the accumulated knowledge, engineering practices, value of past investments, interests of firms, established product requirements and meanings, intra- and interorganisational relationships [and] government policies' (Kemp et al. 2001, 273).

The creation of novel technologies thus is shaped by the interactions of the micro level of users, firms and households, the meso level of technological regimes and the macro level of sociotechnical landscapes. These levels change simultaneously in a co-

evolutionary process. The value of such a concept is to point to the multi-dimensionality of processes of sociotechnical change, to the multiplicity of actors involved in the process and to the embeddedness of local practices and niches in various contexts with their own specific history and dynamics.

The following picture tries to capture this embeddedness and the co-evolution of sociotechnical elements such as artefacts, practices and meanings at different levels of integration. Many strategies of environmental policy such as regulation and standards are focusing on the regime level – but highly depend, as our picture indicates, on both broader socio-economic structures and on practices, expectations and strategies of actors at the micro-level.



A multi-level model of innovation (cf. Rotmans et al. 2001)

Functions of innovation systems

Closely related to the concept of sociotechnical regime or system, Jacobsson and Bergek speak of technology-specific or sectoral innovation systems, meaning sociotechnical configurations around specific technologies (such as photovoltaics), industry sectors (energy system) or societal demand areas (mobility). For a successful evolution and performance of such systems, several 'functions' have to be fulfilled (Jacobsson and Bergek 2004, 212):

- "Creation and diffusion of 'new' knowledge
- The guidance of the direction of search among users and suppliers of technology […]
- The supply of resources such as capital and competencies
- The creation of positive external economies, both market and non-market mediated

- The formation of markets. Since innovations rarely find ready-made markets, these may need to be stimulated or even created. This process may be affected by governmental actions to clear legislative obstacles and by various organisations' measures to legitimise the technology".

Most of these functions imply scientific, technological or design challenges or financial demands only to a lesser extent; instead, most of them point to organisational challenges to co-ordinate and align various actor groups, shape institutional contexts and facilitate collective learning processes.

More generally, we can distinguish three different types of functions of innovation systems:

- "Structure: Innovation systems shall provide structures for innovation activities and support functions of the IS itself. This can be achieved by the introduction of actors, institutions (rules, norms, etc.), networks or artefacts.
- Orientation: Orientation can be given by means of 'Leitbilder', visions or other 'open methods of coordination', or more concrete as information flows or financial incentives.
- Adaptability: Adaptability is a prerequisite of a system to maintain its other functions over time. One possible way to maintain this function is by means of strategic intelligence, or involvement of users into innovation process" (WEBER et al. 2006).

The second function of orientation is crucial because it opens up the possibility to combine normative arguments about the direction of sociotechnical change within an innovation systems framework. Moreover, the need to orient innovation processes towards specific policy objectives such as sustainable development is rightly put into a prominent place.

Managing the transition of sociotechnical systems

An important challenge for innovation-related policies (be it at regional, national or international level) thus is to support the growth and evolution of specific sociotechnical systems (e.g. renewable energy technologies) or the transformation of existing regimes (e.g. the energy system). Building on our multi-level model of innovations the shift of sociotechnical regimes – and this is what is of special interest for transitions to sustainability – is always the outcome of processes of change within a multi-level context that transforms over time. 'They do not start with a new discovery, but depend for their development on the accumulated experience in other sectors, the presence of a network of actors that was willing to sustain it and the presence of a niche in which it could be used' (KEMP 2002). Radical innovations that may later play a role in regime shifts are first developed in 'technological niches' – 'a specific domain for application of a new technology functioning as a testbed where, under temporary protection from market and other institutional pressures, producers, users, and sometimes government develop it to maturity' (WEBER and HOOGMA 1998, 548). A central issue for the up-scaling of niches is the topic of social learning. Concepts like learning-by-interacting between producers and users (cf. LUNDVALL 1988) or double-loop learning (ARGYRIS 1999), which is reflexive with respect to the context of action and underlying assumptions guiding one's activities, are of special interest for transition processes.

Building on an understanding of innovation processes as described above, the concept of transition management (ROTMANS et al. 2001, ELZEN et al. 2004) aims at developing an exploratory, flexible way of policy making with constant evaluations and adaptation of transition objectives and instruments, which decidedly focuses on long-term changes and changes at system level. At the heart of instruments to shape transition processes are strategies to organise processes of social learning, to set up sociotechnical experiments and allow for an experimental way of policy making, as well as strategies to collectively develop visions of transition goals, e.g. images of possible futures of the energy sector, and develop pathways to get there. The regional level may be of special interest for such learning processes: 'Due to their proximity and flexibility, regional networks provide an ideal platform for carrying out social innovation experiments which are often very complex and involve a great number of actors, needing close interaction between various kinds of firms, consumers and government agents' (SCHIENSTOCK 2005, 108). Policy in such a context mainly takes over a role of coordination and facilitation – also addressed in concepts of policy networks and policy learning (for a more detailed discussion see SCHIENSTOCK 2004).

We have already pointed to the importance of intermediary organisations for the functioning and performance of regional innovation systems. Transition processes towards sustainability certainly share the before mentioned functions and roles of intermediaries (as coordinators, agents of trust, alignment of users and producers, facilitation of knowledge flows etc.). However, intermediation at a systemic and coordination level becomes of special importance in the face of complex tasks such as policy integration (e.g. economic, innovation, technology and environmental policy).

Specific intermediary roles are played by environmental consultancies often mediating between companies and the regulatory level (see e.g. GUGGENHEIM 2005), by environmental agencies often playing a challenging and interesting role as 'boundary organisations' between science and policy (GUSTON 2001), and above all by advocacy groups and NGOs, which are highly active in areas related to the provision of public goods in general and the environmental area in particular (compare e.g. TE'ENI and YOUNG 2003, BACH and STARK 2004). Moreover, the complexity of the task of a transition towards sustainability, the requirement to integrate a variety of actors and policy areas and to reach some agreement about the concrete aims of the transition process (transition targets, transition paths, ways of assessing contributions to sustainability) puts special demands on the quality of intermediation and collective learning in this process.

Long-term and complex changes such as transitions to sustainable development thus also require new types of intermediary organisations which function at system or network level (VAN LENTE et al. 2003) – in the case of energy system transitions, for example, these roles are often taken over by energy agencies at national or regional level. In particular, systemic intermediaries can take over the following functions in system coordination and transformation:

- 'Articulation of options and demand, which includes the stimulation of technological variety and the search for possible applications. It also includes the awareness of possible futures.
- Alignment of actors and possibilities, by initiating and strengthening linkages between the various parts of the innovation system. It includes the building and sustaining of networks and the facilitation of interfaces.
- Support of learning processes, by enhancing feedback mechanism and by stimulating experiments and mutual adaptations' (VAN LENTE et al. 2003, 256).

Strategies of a transition-oriented technology policy thus probably will have to make more conscious and active use of intermediary organisations to facilitate change processes.

An example: Combined heat and power generation at household level (Micro CHP)

Let us illustrate some of the strategies discussed above with a short example. Fuel cells or combinations of Stirling engines with conventional gas or bioenergy based heating systems provide the possibility to co-generate heat and electricity in households. Such a 'radical decentralisation' of electricity generation could become an important feature of the transformation of the electricity system towards sustainability. However, even if technologies and pilot applications already exist, there is still much uncertainty about how these technologies will be integrated into the system ('Will the small-scale production units be centrally controlled by utilities or will there be more autonomy on the side of the user?', 'How will the feed-in into the electricity network be regulated?', 'Which practices will evolve, e. g. new kinds of co-ordination at municipal level, user behaviour and acceptance?'), or what the ecological effects of such technologies will be (cf. KÜNNEKE 2003). Especially if there is the policy aim of a sustainable energy system, the way such technologies (or better: sociotechnical configurations) are introduced should be carefully observed, and the development of more sustainable configurations should be supported. In the light of our discussion of system transitions, 'top-down planning' of the introduction of such a technology does not promise to be very successful, given the high uncertainty of its actual use and the role various stakeholders will play in this process. Under such circumstances, 'experimental approaches' with a focus on learning and on reflecting early experiences with such technologies within pilot areas of application could be much more feasible. Such a niche management strategy could include the following elements:

- Sociotechnical mapping: Who are the relevant actor groups with respect to this technology, and what are their interests and expectations?
- Joint vision building: How could a possible future with micro CHP look like and how could we get there?
- Sociotechnical experiments: Applying micro CHP technology in certain niches (e. g. model communities; ecologically highly motivated users) and learning about practices of using micro CHP (e. g. 'How do users match heat and electricity demand?', 'Which kinds of interactions with utilities do they prefer?', 'Is their energy behaviour in households changing?'). These experiments could be a valuable point of reference for the design of a regulatory framework for the introduction of micro CHP.

The regional dimension of sociotechnical systems

Compared to the national or regional innovation systems approaches discussed in the first section, such questions as how to transform sociotechnical systems towards policy aims such as sustainability offer different perspectives: they focus much more on the orientation of innovation system evolution and transformation (towards environmental

objectives, but also social aims such as inclusivity of information systems); they much more emphasise the local use and implementation of technologies; and they argue for more flexible and adaptive policy strategies, experimenting with sociotechnical niche applications or developing scenarios (interactively with stakeholders and various social groups), and consequently strategies for the transformation of sociotechnical systems.

Geographical and socio-cultural proximity as important features of regional innovation systems may also support closer relations between users and producers (potentially resulting in learning effects about use contexts and product improvements), and also between producers and policy making or public authorities (potentially resulting in the better institutional embedding of new products or technologies). Not least, regional programmes around specific technologies or application fields (sustainability in general – see e.g. GERSTLBERGER 2004, new mobility concepts, new energy technologies, use of information technologies, etc.) may help to integrate a broader range of social groups in the region into the innovation process – for example user groups, advocacy groups and other civil society organisations – and may provide joint guiding visions orienting the expectations and activities of the heterogeneous actors involved. In a similar vein, Schienstock argues that the development of environment beneficial products and processes 'depends to a great extent on the exchange of tacit or sticky knowledge on the basis of trust and social capital. Also, the fact that concerned people and households have to be involved in the creation of a new development path points to the great importance of spatial proximity' (SCHIENSTOCK 2005, 105). Before this background, regional technology-related transition strategies may indeed be a valuable addition to a policy oriented towards the creation of a rather general innovation support infrastructure.

However, the evolution and transformation of sociotechnical systems is not an exclusive issue for regional policies – sociotechnical regimes usually have a much wider scope, and usually would require national and international efforts to be transformed. Nevertheless, regions may be an important stepping stone in establishing and widening technological or market niches. Experiments or new concepts for transport, energy or communication often take place at a municipal or regional level. While regional actors may be important stakeholders in transitions of sociotechnical systems, it is nevertheless important to integrate their efforts in a multi-level governance approach with national and international levels of policy and activity.

3. TRANSITION-ORIENTED REGIONAL INNOVATION POLICIES

Switching from regional innovation systems to sociotechnical systems is more than a mere shift in perspective. The regional innovation systems approach predominantly focuses on the institutional support system for innovations in regions (including 'informal' socio-cultural structures as they are for example addressed by the concepts of social capital or innovative milieu), i.e. the education system, the existence of a qualified workforce, relations between universities in the region and companies, networks between companies and other actors, regional agencies and administrative units and their support for innovative companies and other elements. At the same time RIS are rather neutral with respect to the fields of technological innovation they support. Usually they rather focus on generic fields such as 'high-tech innovations' in general, or they

put emphasis on specific generic technologies, such as information and communication technologies, modern biotechnology or nano-technology. In most cases such technologies are produced for the world market or – less often – play a role in regional supply chains of industry clusters or branches (e.g. regional chip manufacturers supplying the regional car industry with specific microchips).

Sociotechnical systems such as specific technological infrastructures, or sociotechnical configurations such as renewable energy systems, ICT applications such as e-government (KINDER 2002) or 'digital cities' (OUDSHOORN et al. 2004, ROMMES 2005), the mobility system, etc. often have a strong regional focus in their 'application dimension', though they usually build on existing generic technologies or other technological innovations from outside. Nevertheless, various case studies analysing the social shaping of technologies point out the importance of the 'downstream side' of innovations, i.e. their implementation into specific contexts, processes of appropriation and consumption – a phase where innovations often go through an iterative process of mutual adaptation of technological design and institutional/social context (see e.g. the contributions in OUDSHOORN and PINCH 2003 or ROHRACHER 2005). Compared to the regional innovation systems approach, the focus on sociotechnical systems thus is on the one hand narrower, as it is organised around a specific technology or service field, and on the other hand broader, as it not only deals with technological innovations, but also with the socio-cultural contextualisation and use of these technologies. However, regional applications of technologies may in turn have an important impact on innovations, and may consequently strengthen the innovative capabilities and economic competitiveness of regional companies involved in this process.

Although regional policies addressing the transformation of sociotechnical regimes or the implementation of new technology niches do not aim at a general support system for innovative activities, they may contribute to the eventual development of innovative milieus, they may provide important niches for new start-up companies and their products, they may strengthen networks between companies and other regional actor groups linked by shared visions and joint efforts, and they may support the contextualisation and robustness of innovations, thereby contributing to potentially competitive new products and services. Moreover, such strategies of regional innovation policy are better integrated with other policy aims, such as the promotion of renewable energy generation or the accessibility of specific ICT applications for a broader range of social groups.

Juxtaposing these two perspectives, we see that there are a number of possible synergies in combining the two approaches. Strengthening the development of new technologies through a supportive institutional and socio-cultural infrastructure at the regional level certainly may contribute to the economic wellbeing of regions, but it is only one dimension of the support of innovations. Creating specific contexts of application for new technologies, experimenting with new sociotechnical constellations and niches may at least as much contribute to the innovative strength of a region, and may contribute not only to economy, but also to an improved social and environmental quality of regions. While only in some occasions will the two approaches overlap with respect to the technology fields involved (e.g. nano-technology applications in specific regional contexts), there are other possible

synergies that could arise from an approach supporting both, the general conditions for innovation in a region and the practical transformation of sociotechnical systems with a strong regional component:

- A focus on the specific applications and use contexts of technologies in regions – e.g. specific solutions in the field of mobility, energy, environment or ICT applications – may well contribute to the development of innovation networks and social capital in a region, as such regional efforts potentially connect companies, administration, research institutions, intermediary actors, NGOs and interested groups of citizens. Problem-oriented applications of technologies which contribute to politically and socially desirable goals will generally integrate a broader range of regional actors into regional transformation processes, and may help to create some kind of regional identity. A higher level of regional activity and a focus on social learning which goes along with such transformation processes may also provide an environment for innovative companies and industries which innovate for markets and applications of technologies outside the region.
- While RISs tend to favour high-tech companies, multi-national corporations and their ancillary industries, programmes for regional sociotechnical change may also support smaller, low and medium tech companies which may be nurtured in regional technology niches, and eventually produce for export markets. Examples of this kind can be found in Styria in the production of solar thermal collectors or biomass heating systems, which both were developed in a regional context and for regional application, and meanwhile have become increasingly successful on international markets. Both approaches – RIS and regional sociotechnical programmes – may thus have complementary effects, and in the end support a broader range of companies and innovative activities in the region than e.g. a pure focus on a biotech-region.
- In some cases application-oriented regional activities may also strengthen the involvement of otherwise world-market-oriented companies in regional technology projects. A recent example in Styria is a start-up company developing micro cogeneration systems at household level, i.e. providing a unit of a Stirling engine and a generator which can be integrated in pellets heating systems, and simultaneously produce heat and electricity for households. This company not only profits from regional programmes supporting the use of bioenergy and the development of a range of SMEs producing bioenergy heating systems, but also from the existence of the Styrian automotive clusters and the regional availability of competent developers of motor prototypes, which have also been used for the development of Stirling engines in cogeneration systems.

Activities to strengthen regional innovation systems and activities aiming at specific sociotechnical niches and regional sociotechnical transformation processes towards social and environmental goals may interact positively to strengthen the social and economic basis of regions and contribute to a sustainable regional development, not only serving goals of economic competitiveness but also of social wellbeing and environmental quality.

REFERENCES

ARCHIBUGI, D. – MICHIE, J. 1997. Technological Globalisation and National Systems of Innovation: An Introduction. In Archibugi, D. – Michie, J. (eds.): *Technology, Globalisation and Economic Performance*. Cambridge: Cambridge University Press, p. 1–23.

ARGYRIS, C. 1999. *On Organizational Learning*. 2nd edition. Cambridge, MA: Blackwell Publishing.

BACH, J. – STARK, D. 2004. Link, Search, Interact. The Co-Evolution of NGOs and Interactive Technology. *Theory, Culture and Society*, 2001/3: 101–117.

CARLSSON, B. – JACOBSSON, S. – HOLMEN, M. – RICKNE, A. 2002. Innovation Systems: Analytical and Methodological Issues. *Research Policy*, 2002/31: 233–245.

CHARLES, D. – BENNEWORTH, P. 2004. From Regional Innovation Strategies to the Multi-Level Governance of Science, Technology and Innovation. In *Proceedings of the Conference Regionalization of Innovation Policy – Options and Experiences*. Berlin: Deutsches Institut für Wirtschaftsforschung.

COOKE, P. – URANGA, M. G. – ETXEBARRIA, G. 1997. Regional Innovation Systems: Institutional and Organisational Dimensions. *Research Policy*, 1997/26: 475–491.

DOLOREUX, D. 2002. What We Should Know about Regional Systems of Innovation. *Technology in Society*, 2002/24: 243–263.

EDQUIST, C. – HOMMEN, L. 1999. Systems of innovation: theory and policy for the demand side. *Technology in Society*, 1999/ 21: 63–79.

ELZEN, B. – GEELS, F. W. – GREEN, K. (eds.) 2004. *System Innovation and the Transition to Sustainability*. Cheltenham: Edward Elgar.

ETZKOWITZ, H. – LEYDESDORFF, L. 2000. The Dynamics of Innovation: from National Systems and 'Mode 2' to a Triple Helix of University-Industry-Government relations. *Research Policy*, 2000/29: 109–123.

FARRELL, H. – KNIGHT, J. 2003. Trust, Institutions, and Institutional Change: Industrial Districts and the Social Capital Hypothesis. *Politics and Society*, 2003/4: 537–566.

FREEMAN, C. 1995. The 'National System of Innovation' in Historical Perspective. *Cambridge Journal of Economics*, 1995/19: 5–24.

FÜRST, D. – SCHUBERT, H. – RUDOLPH, A. – SPIEKERMANN, H. 2001. Regional Actor Networks between Social Capital and Regional Governance. *Connections*, 2001/1: 42–67.

GEELS, F. W. 2004. From Sectoral Systems of Innovation to Socio-Technical Systems. Insights about Dynamics and Change from Sociology and Institutional Theory. *Research Policy*, 2004/33: 897–920.

GERSTLBERGER, W. 2004. Regional Innovation Systems and Sustainability – Selected Examples of International Discussion. *Technovation*, 2004/24: 749–758.

GUGGENHEIM, M. 2005. Organisierte Umwelt. Umweltdienstleistungsfirmen zwischen Wissenschaft, Wirtschaft und Politik. Bielefeld: Transcript.

GUSTON, D. H. 2001. Boundary Organisations in Environmental Policy and Science: An Introduction. *Science, Technology and Human Values*, 2001/4: 399–408.

HEINTEL, M. 2004. Regionalpolitik in Österreich Retrospektive und Perspektive. *Österreichische Zeitschrift für Politikwissenschaft*. 2004/2: 191–208.

JACOBSSON, S. – BERGEK, A. 2004. Transforming the Energy Sector: the Evolution of Technological Systems in Renewable Energy Technology. In Jacob, K. – Binder, M. – Wieczorek, A. (eds.): *Governance for Industrial Transformation. Proceedings of the 2003 Berlin Conference on the Human Dimensions of Global Environmental Change*. Berlin: Environmental Policy Research Centre, p. 208–236.

JOHNSON, B. 1992. Institutional Learning. In Lundvall, B.–Å. (ed.): *National Systems of innovation. Towards a Theory of Innovation and Interactive Learning*. London and New York: Pinter.

KEMP, R. 2002. Environmental Protection through Technological Regime Shifts. In Jamison, A. – Rohracher, H. (eds.): *Technology Studies and Sustainable Development*. München: Profil, p. 95–126.

KEMP, R. – RIP, A. – SCHOT, J. 2001. Constructing Transition Paths through the Management of Niches. In Garud, R. – Karnre, P. (eds.): *Path Dependence and Creation*. Mahwah, New Jersey/London: Lawrence Erlbaum Associates, p. 269–299.

KINDER, T. 2002. Introducing an Infrastructure for Joined-up-Government in Local Public Administration: a West Lothian Case Study. *Research Policy*, 2001/31: 329–355.

KÜNNEKE, R.W. 2003. *Innovations in Electricity Networks.* In *Proceedings of the Research Symposium European Electricity Markets*. The Hague: ECN, AER and CPB.

LEYDESDORFF, L. – COOKE, P. – OLAZARAN, M. 2002. Technology Transfer in European Regions: Introduction to the Special Issue. *Journal of Technology Transfer*, 2002/27: 5–13.

LUNDVALL, B.–Å. 1988. Innovation as an Interactive Process: from User-Producer Interaction to the National System of Innovation. In Dosi, G. – Freeman, C. – Nelson, R. – Silverberg, G. – Soete, L. (eds.): *Technical*

Change and Economic Theory. London/New York: Pinter, p. 349–369.
LUNDVALL, B.–Å. (ed.) 1992. *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning*. London and New York: Pinter.
LUNDVALL, B.-Å. 1998. Why Study National Systems and National Styles of Innovation? *Technology Analysis & Strategic Management*, 1998/4: 407–421.
MOLINA–MORALES, F. X. – LÓPEZ–NAVARRO, M. Á. – GUIA–JULVE, J. 2002. The Role of Local Institutions as Intermediary Agents in the Industrial District. *European Urban and Regional Studies*, 2002/4: 315–329.
MORGAN, K. 1997. The Learning Region: Institutions, Innovation and Regional Renewal. *Regional Studies,* 1997/5: 491–503.
MULLER, E. – ZENKER, A. 2001. Business Services as Actors of Knowledge Transformation: the Role of KIBS in Regional and National Innovation Systems. *Research Policy*, 2001/30: 1501–1516.
NELSON, R.R. – ROSENBERG, N. 1993. Technical Innovation and National Systems. In Nelson, R. R. (ed.): *National Innovation Systems: A Comparative Analysis*. New York/Oxford: Oxford University Press, p. 3–21.
OUDSHOORN, N. – PINCH, T. (eds.) 2003. *How Users Matter. The Co-Construction of Users and Technologies.* Cambridge, MA: The MIT Press.
OUDSHOORN, N. – ROMMES, E. – STIENSTRA, M. 2004. Configuring the User as Everybody: Gender and Design Cultures in Information and Communication Technologies. *Science, Technology and Human Values*, 2004/1: 30–63.
PORTER, M. 1990. *The Competitive Advantage of Nations*. New York: Free Press.
RIP, A. – KEMP, R. 1998. Technological Change. In Rayner, S. – Malone, E. L. (eds.): *Human Choice and Climate Change: Resources and Technology*. Vol. 2. Columbus, Ohio: Batelle Press, p. 327–399.
ROHRACHER, H. (ed.) 2005. *User Involvement in Innovation Processes. Strategies and Limitations from a Socio-Technical Perspective*. Munich: Profil.
ROMMES, E. 2005. Taming Technology, Shaping Gender. The Domestication of Amsterdam's Digital City. In Rohracher, H. (ed.): *User Involvement in Innovation Processes. Strategies and Limitations from a Socio-Technical Perspective*. München-Wien: Profil, p. 175–203.
ROTMANS, J. – KEMP, R. – VAN ASSELT, M. 2001. More Evolution than Revolution: Transition Management in Public Policy. *Foresight*, 2001/1: 15–31.
SCHIENSTOCK, G. 2004. From Path Dependency to Path Creation: A New Challenge to the Systems of Innovation Approach. In Schienstock, E. (ed.): *Embracing the Knowledge Economy. The Dynamic Transformation of the Finnish Innovation System*. Cheltenham: Edward Elgar, p. 3–27.
SCHIENSTOCK, G. 2005. Sustainable Development and the Regional Dimension of the Innovation System. In Weber, M. – Hemmelskamp, J. (eds.): *Towards Environmental Innovation Systems*. Berlin: Springer, p. 97–113.
SHARIF, N. 2006. Emergence and Development of the National Innovation Systems concept. *Research Policy,* 2006/35: 745–766.
SHARP, M. – PAVITT, K. 1993. Technology Policy in the 1990s: Old Trends and New Realities. *Journal of Common Market Studies*, 1993/2: 129–151.
STORPER, M. 1995a. Regional Technology Coalitions. An Essential Dimension of National Technology Policy. *Research Policy*, 1995/24: 895–911.
STORPER, M. 1995b. The Resurgence of Regional Economies, Ten Years Later: the Region as a Nexus of Untraded Interdependencies. *European Urban and Regional Studies*, 1995/3: 191–221.
TE'ENI, D. – YOUNG, D. R. 2003. The Changing Role of Nonprofits in the Network Economy. *Nonprofit and Voluntary Sector Quarterly*, 2003/3: 397–414.
TRUFFER, B. – DÜRRENBERGER, G. 1997. Outsider Initiatives in the Reconstruction of the Car: the Case of Lightweight Vehicle Milieus in Switzerland. *Science, Technology and Human Values*, 1997/2: 207–234.
VAN LENTE, H. – HEKKERT, N. – SMITS, R. – VAN WAVEREN, B. 2003. Roles of Systemic Intermediaries in Transition Processes. *International Journal of Innovation Management*, 2003/3: 247–279.
WEBER, K.M. – HOOGMA, R. 1998. Beyond National and Technological Styles of Innovation Diffusion: a Dynamic Perspective on Cases from the Energy and Transport Sectors. *Technology Analysis and Strategic Management*, 1998/4: 545–566.
WEBER, K. M. – KUBECZKO, K. – ROHRACHER, H. 2006. System Innovations in Innovation Systems. Experiences with Adaptive Foresight in Austria. In Andersen, M. M. – Tukker, A. (eds.): *Perspectives on Radical Changes to Sustainable Consumption and Production. Proceedings of the Workshop of the Sustainable Consumption Research Exchange (SCORE) Network*. Roskilde: RISOE, p. 479–501.