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Transformation of regional innovation systems: From old legacies towards new development paths

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Transformation of regional innovation systems: From old legacies to new development paths

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1 Introduction

Over the last 20 years, the innovation system approach has significantly enhanced our understanding of the innovation process, stressing its non-linear, systemic, interactive and evolutionary character. The notion of regional innovation systems (RISs) highlights the regional dimension of new knowledge generation and exploitation and constitutes a powerful concept for explaining regional differences in innovation capacity. RISs can be conceptualised as the set of firms, organisations and institutions which influence the innovative behaviour and economic performance at the regional level (Cooke et al. 2000, 2004; Asheim and Gertler, 2005). They are shaped by existing industry structures and technology paths, the set of knowledge organisations, and the prevailing institutions and networks. As a consequence, they exhibit a high degree of inertia. This may lead to phenomena of path dependency and “lock in” in particular regions and to a certain degree of stability in terms of regional disparities in innovation and economic development.

Regions and their innovation systems, however, are not static entities. In fact, one can observe considerable changes of industry structures, innovation activities and patterns of networking in particular regions in the longer run, often reaching beyond the existing development paths. We find phenomena of innovation-driven catching up processes in lagging regions, restructuring processes in industrial regions leading to new industries and technology paths, as well as sometimes an erosion of innovation capacity and competitiveness in leading regions. Most research on RISs, however, has so far not dealt with such changes. The RIS literature suffers from a key weakness, that is, its static view brought about by a focus on existing structures and relations. As a consequence, the reconstruction of RISs and their evolution over time remains poorly understood. This chapter seeks to advance a dynamic perspective of RISs by suggesting a framework for analysing their transformation. As noted by Simmie and Martin (2010, p. 27) “regional and local economic development is far from a smooth and incremental process but is subject to all sorts of interruptions and disruptions: periodic economic recession, the unpredictable rise of major competitors elsewhere, unexpected plant closures, the challenges arising from technological change and the like”. Moving beyond a static view on RIS and elaborating on a dynamic perspective is thus high in demand.

A dynamic view on RIS requires more room for agency (see, for example, Martin and Sunley, 2010). Analyses of RISs tend to focus on institutional set-ups, subsystems and the links between them, often paying little attention to individual economic agents (managers, workers, entrepreneurs, etc.) and organisations like firms and universities (see also Gertler, 2010). By taking into account key actors of change we link individual agency and RIS structures in analyses of RIS transformation.

The aim of this chapter is to enhance our understanding of how processes of RIS transformation take place. We will identify key actors and drivers of path renewal and new path creation and we seek to find out to which extent such changes are related to the existing economic and institutional structures. Based on a discussion of relevant theories and a critical literature review we will develop a conceptual frame for analysing RIS changes. Besides the RIS approach we will use ideas from evolutionary economic geography (EEG) which provides valuable insights into the long-run regional trajectories and sources of change in regional economies (Boschma and Martin, 2007, 2010). We will also discuss empirical examples of such shifts based on evidence from Austria and other countries.

2 Sources of stability in regional innovation systems

RISs tend to be relatively stable phenomena. Martin and Sunley (2006) identify a set of different sources for regional stability and path dependence, including the existence of natural resources, sunk costs of local assets and infrastructure, regional technological “lock-in”, local external economies of industrial specialisation, economies of agglomeration, region-specific institutions, social forms and cultural traditions and interregional linkages and interdependencies. An explicit focus on the key elements of RISs draws attention to the following factors underpinning their stability.

Although the subsystem of knowledge generation & diffusion (made up of the regional research and educational organisations, intermediaries, etc) is subject to changes (e.g. due to expanding universities, new educational programs, etc.), the set of knowledge organisations and their accumulated competences tend to be rather stable over time. The quality of research organisations can only be changed in the long run through hiring new qualified staff, entering new scientific fields, etc. For this reason we find a relatively high stability of regional patterns of research outputs, patenting and university rankings. The second subsystem of knowledge application & exploitation consists of the set of firms, the industries and dominating clusters of the region. Although individual companies and industries are exposed to market fluctuations and technology changes resulting in an expansion or a reduction of output and employment, the overall economic structure and mix of industries is often rather persistent at least in the short and medium term. This contributes to a certain stability of regional rankings of productivity, per capita income and innovation performance over time.

Furthermore, it is not only the “hard facts” mentioned above but also the “soft” institutions which matter (Hodgson, 1988; Rodriguez-Pose and Storper, 2006). Informal institutions such as common habits of thought, routines, practices, social norms and values are crucial determinants of innovation, influencing the behaviour of actors and the relations among them. A key feature of such institutions is inertia (see, for example, Johnson, 1992). Traditions, routines and old patterns of behaviour and thought tend to be long-lived. Institutional persistency thus has a further stabilising effect on RISs. This does not mean that institutional (un-)learning is impossible. However, the question of how institutions change remains still poorly understood (Maskell and Malmberg, 2007; Gertler, 2010).

Despite a high degree of stability and continuity in general, we may observe dramatic changes in particular RISs in certain periods. Evidence on such processes currently exists for some emerging economies of East Asia or South America. In these world regions we find a number of regional “hotspots” (Singapore, Taiwan, Hongkong, Shanghai, Bangalore, Sao Paolo) where not just economic development but also innovation and technology shifts occur quite rapidly (see Dunford and Yeung, 2011 for China). In Eastern European countries and regions there is evidence of catching up processes which are partly related to endogenous RIS changes but more often due to incoming foreign direct investment. In Western Europe regional changes are usually less dramatic, but also there we observe a dynamic evolution of some peripheral regions, restructuring in old industrial areas, and shifts in the innovation performance of particular metropolitan regions.

How can we conceptualise changes of RISs? In the following we differentiate between various degrees and directions of RIS transformation. Furthermore, we look at different key actors of change and investigate potential modes of the transformation of RISs. We argue that due emphasis should be given to context conditions when dealing with the issues outlined above. The contextual view suggested here recognises the role of the inherited structuring of

the RIS under consideration and the embeddedness in particular forms of production regimes as suggested by the varieties of capitalism approach. These contextual factors have an influence on, but do not determine the directions of change, the group of actors which is likely to take the lead and the key modes of RIS changes.

3 Directions of RIS changes

Despite their inherent inertia RISs evolve continuously. New firms, products and technologies are more or less permanently added to a RIS, whilst old ones vanish (Boschma and Martin, 2007). Consequently, there is a gradual steady change of RISs. More often than not, these small changes are intra-path changes; they do not modify or alter the overall development trajectory of RISs. In certain periods, however, more fundamental changes can be observed, leading to a major transformation of RISs. In this chapter, the focus is on the latter phenomenon.

RIS changes can be of different degrees, ranging from minor (incremental) to major (radical) ones. Importantly, any determination of the radicalness of change depends on the specific level under consideration. An industry or cluster may experience a radical change through, for example, the invention and diffusion of new technologies. This does not automatically imply a radical change of the RIS, however, because such changes do not necessarily alter the region's overall economic structure. In this chapter we look at the level of the whole system when assessing whether changes are radical or incremental. The transformation of a RIS might manifest itself in form of new technologies or innovations. Our specific interest is in changes of regional industry structures and their directions. However, the transformation of the region's industry structure (subsystem of knowledge application) is likely to be associated with a reconfiguration of the knowledge infrastructure, the institutional set-up and the region's network structure in the medium- and long-run.

Recent conceptual work done within EEG on the evolution of regional industries and the mechanisms of regional path dependence, path creation and renewal of paths (Martin, 2010; Martin and Sunley, 2006, 2010) provides valuable insights in this regard. Based on this literature, we distinguish between three basic types of RIS changes:

- Rejuvenation of existing clusters or industries (path renewal)
- Rise of established industries that are, however, new for the region (path formation in established industries)
- Rise of new high-tech and knowledge-intensive industries (path creation in new industries)

Arguably, these three types of change might co-exist within a particular region. A RIS often consists of different industries and clusters, each being at a specific stage of the development path (emerging, growing, declining, renewing). Consequently, this could lead to an overlapping of regional industrial trajectories and different types of change within a RIS.

3.1 Path renewal

Path renewal refers to changes which take place within older industries or clusters which have already existed for a long time in the region. Such changes are about an upgrading and the revitalization of established industries. The transformation of the RIS in this case is modest in nature. Martin and Simmie (2008) identify various reasons that might bring path renewal to

the fore such as the increase of external competition, or the introduction of radical innovations and new technologies within the industry. Furthermore, the loss of innovative dynamism within the regional industry or the relocation of key organisations to other places might urge the rejuvenation of existing regional industries. Arguably, RIS changes based on path renewal modify the existing development trajectory of a region but they do not alter the industry structure. A renewal of existing industry paths does not necessarily lead to the emergence of a new RIS path.

Path renewal of existing industries embraces different forms, ranging from a shift from mass products towards specialities and higher value products as is has been observed in the Styrian metal cluster (Tödting and Trippl 2004, Trippl and Otto, 2009) to the introduction of new technologies and organizational practices as it was seen for example in the automotive cluster in Ontario (Gertler and Wolfe 2004) or the industrial machinery sector in Tampere, Finland (Martin and Sunley, 2006). Importing new technologies or organisational forms from outside the region may also matter. Its success critically depends on the absorptive capacity of the RIS (Martin and Sunley, 2006).

An innovation-based restructuring of ancestral clusters is linked to changes in the region's knowledge infrastructure. These might involve the creation of research and educational bodies that support firms to introduce new technologies and to upgrade their products by providing specialised knowledge and highly qualified labour. The metal cluster in the region of Styria (introduction of laser techniques and new compound materials) and the watch industry in the Swiss Jura Arc (introduction of microelectronics into the former mechanically based watch industry) demonstrate the significance of rejuvenating old industries by building bridges to new technologies (Maillat et al. 1997, Tödting and Trippl 2004). In such cases new technological trajectories may be opened up for traditional industries.

3.2 Path formation in established industries

Path formation in established industries involves more significant RIS changes than path renewal, broadening the economic base of the respective RIS. The emergence of clusters in established industries, that are, however, new for the region is a well known phenomenon. Examples include the emergence of the automotive cluster in the region of Styria (Tödting and Trippl 2004) or the growth of the automobile and electronic industries in Wales (Cooke 2004). The rise of new clusters in such industries can take different routes.

There is the way of exogenously driven development propelled by inward investment. The potential role of foreign companies as key agents of change is highly contingent on the specific nature of their activities. Classical branch plants of multinational companies seldom serve to encourage the birth and growth of innovative clusters in established sectors. Foreign companies, in contrast, that feature high value-added functions and embed themselves in the local economy by creating links to regional actors can give an important impetus to the emergence of a new complex (see the cases of the automotive and electronics clusters in Wales as described by Cooke, 2004). Exogenous-led cluster building, however, is not without danger. The case of the region of Wales is instructive to demonstrate that the withdrawal of foreign companies from the cluster often has negative impacts for the region (Cooke 2004).

The rise of new clusters in established industries can also have endogenous sources. In this case the emergence of a new cluster is based upon sectoral diversification activities of home grown firms that are capable to move into new sectors by redeploying existing assets and

capabilities. Such processes have been described as “related diversification” (Frenken et al, 2007), i.e. path formation builds on competences already present in the region, and can be distinguished from “unrelated diversification” (that is, the development of new clusters which are not related to those already existing in the region). Path formation in traditional industries could also be the outcome of a combination of endogenous and exogenous factors. This is demonstrated by the case of the automotive industry in the region of Styria where the interplay of the attraction of foreign owned companies, diversification strategies of home grown firms (e.g. in the metal industry) and the existence of some traditional roots and competencies in the automotive sector has resulted in the establishment of a new growing cluster (Tödtling and Trippel 2004).

The formation of new clusters in established industries benefits from an accompanying reconfiguration of the regional knowledge infrastructure. The Styrian automotive cluster provides a good illustration for the relevance of institution building in order to encourage the growth of new complexes. The establishment of a technical college for automotive engineering and the creation of various cooperative research centres between universities and firms supported the rise of this new cluster (Tödtling and Trippel 2004). It is also important to note that in the Styrian case the development of the automotive cluster coincided with certain changes and conditions in the international car industry, i.e. the enduring trend to reduce the level of vertical integration and to outsource a variety of activities and functions to qualified firms (1st and 2nd tiers of suppliers) as well as to research organisations (Tödtling and Trippel 2004).

3.3 Path creation in new industries

The most radical form of change is brought about by the emergence and growth of industries based on new technological and organisational trajectories such as knowledge-intensive and high-technology industries, implying a major shift in the development trajectories of regions. How do such new paths come into being? There is a growing recognition that chance, contingent events, serendipity or historical accidents should not be overemphasised in this regard, because new paths often emerge out of previous and existing regional paths (Martin and Sunley, 2006; Boschma, 2007; Martin, 2010) “New paths do not emerge in a vacuum, but always in the context of existing structures and paths of technology, industry and institutional arrangements” (Martin and Simmie, 2008, p. 186). More specifically, path creation in new industries requires the existence of assets, resources or competencies rooted in the area (Martin, 2010). These could include, for example, an excellent scientific base or the availability of a highly skilled labour force. The development of a new high tech agglomeration might also be the result of a strong local demand.

New path creation can result from the branching out of existing industries into new but related technological fields (Martin and Sunley, 2006; Boschma, 2007). The emergence of new high-tech and knowledge-intensive industries hinges strongly on the establishment of new companies and spin-offs (Frenken and Boschma (2007). Existing endogenous firms or foreign direct investment may also play a powerful role in “seeding” a new high tech complex. The rise of the software industry in Ireland, for example, has been triggered by the attraction of foreign companies (O’Malley and O’Gorman 2001) and the IT industry in the Finnish region of Tampere exemplifies the importance of home-grown leading firms such as Nokia in stimulating new path creation by acting as sophisticated customers (O’Gorman and Kautonen 2004). The environment protection industry in the Ruhr area is another good example in this context. It has its origins in the old mining and steel complex (Hilbert et al. 2004). The

leading firms of this cluster and their suppliers were forced by legal restraints and other political measures to reduce pollution and contamination caused by their traditional business by developing internal solutions to the environmental problems. They managed to transfer these competencies and skills situated within the old cluster into new markets, giving rise to the new environment protection industry. Nevertheless, compared to the two other development scenarios discussed here, new firm formation is a crucial element for the emergence of high technology industries (Feldman et al. 2005).

Path creation in new industries preconditions a major transformation of the regional knowledge infrastructure. Taking this road might, indeed, be strongly linked to intensive processes of institution building and institutional change. To create or further develop a relevant scientific knowledge base, to establish excellent research organisations, to upgrade the education and training system, and to establish specialized support structures (science parks, academic spin-off centres, incubators, etc.) are key factors that contribute to developing and sustaining new knowledge-intensive clusters. Often this leads to a neglect of and negative consequences for existing sectors reflecting the downside of Schumpeters “creative destruction”. Under certain conditions, however, in particular in the case of promoting generic fields and technologies (such as ICT, new materials, life sciences, nanotechnologies), new education systems and support structures might benefit both old and new industries.

Having identified three types of change, it is important to emphasize that the transformation of RISs is likely to differ strongly across regions. A large body of work has demonstrated that RISs come in many shapes. Some of them constitute networked systems whilst others are characterized by fragmentation. Furthermore, they can exhibit “thin” or “thick” institutional structures (Tödtling and Trippl, 2005). RISs also differ in terms of economic specialization. The existing structures of a RIS will have an influence on which of the three types of change discussed above is more likely to occur, how changes proceed and which mechanisms of change dominate. In other words: regional transformation is a context-specific phenomenon that varies strongly between different types of RISs. The relevance of pre-existing regional economic and technological structures and competences could be illustrated with a brief example on new path creation based on the rise of biotechnology. Gertler and Vinodrai (2009) investigated life science industries in six Canadian regions and demonstrated that the evolutionary pathways followed by these six regions were far from identical. Differences in local historical, geographical and institutional conditions turned out to shape the pattern or specialisation within the industry and influence the subsequent evolution of life science industries in these places in distinctive ways (see section 4.2).

4 Actors of change and the role of context

The transformation of RISs can be the cumulative outcome of regular and ongoing activities by firms and knowledge organisations, the result of more singular efforts (e.g., in response to crisis situations), or it can be the outcome of more strategic actions by, for example, policy makers. Looking at the literature, it seems that, in fact, crisis situations have often been triggering more fundamental changes in innovation systems. Examples here are old industrial regions such as Ruhr area or Styria in the 1980s, the Boston region in the late 1980s (break down of the computer industry due to Japanese competition), Finnish regions in the early 1990s (loss of the Russian market for Finnish firms) or crises in Italian industrial districts in the 1990s due to competition from China and other emerging economies. The response to such crisis situations, however, often varies. Whereas in old industrial regions crisis situations have often resulted in “restructuring”, implying a severe loss of employment and the closing

of plants, other economies such as Massachusetts in the USA and Finland have progressively invested in R&D and education, thus improving their innovation system.

Driving forces and actors of change can be quite different agents such as charismatic individuals, leading firms or policy actors. One of the key arguments proposed in this chapter is that different business systems and types of RISs have an influence on how likely it is that certain actors and not others play a leading role.

4.1 Varieties of capitalism

The key drivers in the transformation of RISs seem to differ by type of industry organisations and institutional forms (Hall and Soskice, 2001; Cooke et al., 2007). In liberal market economies which prevail in countries such as the United States or the United Kingdom, these are often the firms, such as start-ups and fast growing young firms in new industries that collectively shape the development of particular RISs. Also venture capitalists and large firms in various industries play a key role. Furthermore, in liberal market economies universities are often regarded as influential players, as they often have a stronger focus on the application and exploitation of knowledge than most European universities. This is also reflected in a more prominent role of technology licensing and liaison offices, incubators and the support of start-ups. Policy has an influence on the federal level e.g. through R&D spending, health and military research and at the local level through infrastructure provision.

In coordinated market economies like Germany, Austria and the Nordic European countries we find a stronger role of policy actors and of associative governance (Cooke and Morgan 1998) both at national and regional levels in comparison (Cooke et al. 2000). This includes a broader and more comprehensive set of activities and measures for improving the national and regional innovation systems. Besides investments in (mostly public) universities this includes cluster programmes, RIS strategies, as well as networking activities. In Europe, the governance of innovation has become more complex and multi-level in nature through the EU framework programmes, the Lisbon agenda and efforts to establish a European Research area. This has clearly led to a stronger orientation and earmarking of EU structural funds for enhancing competitiveness, R&D and innovation in the most recent programme period.

The argument advanced here is that different institutional forms of capitalism have an influence on – but do not determine – who is likely to perform as key actor of change. National institutional forms and modes of production regimes form essential context conditions for RIS changes, although significant differences between regions situated within and embedded into the same wider institutional framework might exist.

4.2 Types of RISs

As noted above, the structuring of the RIS shapes regional path renewal and creation in substantial ways. The rise of the biotech industry is a good example in this context. It has followed very different routes and was triggered by different driving forces. The case of the biotech industry in Canadian regions is telling in this respect. Gertler and Vinodrai (2009) identified a variety of critical enabling factors and triggering events in their analysis of six life science regions in Canada. “In some clusters, a pioneering firm sparked latent entrepreneurialism or provided credibility and “inspiration” for actors in the region (Montreal, Vancouver, Halifax, Toronto). In Askatoon and Montreal, cluster emergence was driven by

policy decisions made at the federal level to locate national laboratories in each city. Yet, in Ottawa, while local associative actors and a lead firm were important, it was an exogenous shock that served to raise the profile of life sciences activities” (Gertler and Vinodrai, 2009, p. 252). Consequently, despite being embedded in the same national context, the leading actors and driving forces varied considerably from region to region. Furthermore, existing regional capabilities and resources and the structure of the regional economy had an influence on which type of biotech emerged in the six regions investigated. Saskatoon’s specialisation in agricultural biotechnology emerge from the established agricultural economy in that region, while strengths of Halifax in marine-related activities is reflected in the regions’s strengths in marine-related biotechnology (Gertler and Vinodrai 2009: 246f).

Pre-existing local economic and technological structures and competences matter essentially. Referring once more to the case of biotechnology, recent work suggests that new regional path creation in this field is likely to follow different routes, depending on historically evolved RIS structures (Trippel and Tödtling, 2007). Regions that already host successful high technology industries constitute a favourable environment also for the rise of new knowledge-intensive clusters, even if the newly emerging sectors are different from those developed in the past. Prevezer (2001, p. 18) analysed the emergence of the biotechnology sector in California and showed that the industry “inherited a great deal from the earlier development of computing” in the area. Several of the prominent preconditions for successfully developing high technology companies were there, including excellent research organisations, experienced venture capitalists, a pool of highly skilled mobile labour, and good communication networks. Consequently, “the history of having grown the computing industry in California was relevant to the establishment of biotechnology in the Bay area” (Prevezer 2001, p. 25). Boston with its transitions from electronics, to computers and software, to biotechnology and where generic elements (research universities, venture capital, networks) have supported this transformation is another prime example for a “strong high technology RIS” (Tödtling, 1994). Regions which lack such structures, experiences, and knowledge assets are likely to follow different development paths. The rise and early development of biotech in these areas seems to be less a spontaneous phenomenon and depend much more on the inflow of external knowledge, expertise and market intelligence and a stronger role of policy. In addition, it is inextricably linked to a transformation of the RIS that becomes manifest in the creation of a variety of new organisations, processes of institutional (un)learning and socio-cultural shifts. The evidence provided by Trippel and Tödtling (2007) for three Austrian biotech clusters confirms this view.

5 Modes of change

How do RIS changes occur and in which areas can we observe major transformations? Table 1 provides an overview on different areas of RIS transformation in various subsystems. We distinguish between (1) changes in soft or informal institutions, (2) the creation or disappearance of RIS elements, and (3) the transformation of the network structure. We illustrate the relevance of these areas by providing evidence drawn from our own empirical work on RIS changes in Austria as well as from the literature. It is beyond the scope of this chapter to discuss each area for each subsystem in full detail or to refer to numerous examples. Our aim is to provide a framework and an outlook that might guide future investigations of RIS changes.

The different areas of change are often strongly interrelated. In the academic sector, for example, the rise of a culture of collaboration with industry (change in soft institutions), is a

precondition for and is reproduced by the creation of various university-industry links (change in the network dimension). Nevertheless, for analytical purposes it seems to be important to look at these separately.

Table 1: RIS transformation: Critical dimensions of change and RIS subsystems

| | | RIS SUBSYSTEMS | | |
|------------------------|---|---|--|---|
| | | Knowledge application system | Knowledge generation & supporting system | Policy system |
| AREAS OF CHANGE | New strategies, routines & patterns of behaviour | <p>Focus on new products in traditional fields / niche markets: metal cluster Styria</p> <p>Diversification strategies: automotive cluster Styria</p> | <p>Emergence of a culture of collaboration with industry & a culture of commercialisation of science within academia („rise of academic entrepreneurship“): Austrian biotech clusters</p> | <p>Reoriented focus and new approaches: rise of innovation policies, cluster approaches, promotion of networks (or in more general terms: new modes of state engagement): Styria, Vienna, Upper Austria, Tyrol, national K-initiatives in Austria</p> <p>New policy measures: competition-based policy / picking the winner approach: BioRegio (Germany), innovation policy in Vienna</p> |
| | New RIS elements | <p>Emergence of new industries / clusters: e.g. biotech in Austrian regions</p> <p>Arrival of firms from outside the RIS (as source of new knowledge): automotive clusters Detroit, Ontario; software industry Ireland; automotive cluster Styria; biotech cluster Vienna</p> <p>Inflow of highly-skilled individuals with specialised competences from outside the region: biotech cluster Vienna (inflow of experts with managerial competence)</p> | <p>New research organisations & educational bodies: biotech cluster Vienna; automotive cluster Styria; ICT Saarland</p> <p>New science parks: Software park Hagenberg Upper Austria</p> <p>Implantation of spin-off centres, TLOs, etc: biotech clusters in Austria, Styria (various industries), Upper Austria (various industries)</p> | <p>New funding agencies: Austria regions, particularly Upper Austria, Styria, Tyrol, Vienna</p> <p>New managing units: e.g. cluster management agencies: Styria, Upper Austria</p> |
| | New networks & reorganisation of existing networks | <p>Renewal of business networks: from hierarchical interfirm networks to interactive innovation-oriented ones: metal cluster Styria</p> <p>Emergence of new networks: automotive cluster Styria, metal cluster Styria</p> <p>Extra-regional networks: Old industrial areas (many examples)</p> | <p>Emergence of various forms of UIPs such as competence centres jointly run by companies and universities (long-term institutionalised forms of knowledge exchange): various examples in Austria</p> | <p>Breaking-up old policy networks: Styria</p> <p>New modes of governance (multi-actor-governance, interactive governance involving main regional stakeholders): Styria, Tyrol, Upper Austria</p> |

5.1 Changes of soft institutions: new strategies, routines and patterns of behaviour

RIS changes can manifest themselves in the emergence of new routines and pattern of behaviour as well as the unlearning of existing ones. Arguably, also formal institutions, i.e. laws and regulations (e.g. the Bay-Dole act in the US, environment protection laws, etc.) can trigger RIS changes altering incentive structures and legal framework conditions for innovation activities. Nevertheless, in the following, our focus is on soft institutions.

Behavioural routines of organisations tend to be stable in the short run. Processes of search, learning and imitation, however, can lead to changes of such routines, enabling organisations to adapt to new framework conditions or even strategically manipulate their environment (Essletzbichler and Rigby, 2007) Looking at firms (i.e. the knowledge application system) there is plenty of evidence on the importance of new strategies, routines and pattern of behaviour. The case of large companies in the Styrian metal cluster is telling in this regard. After their privatisation they developed new patterns of behaviour. By re-shifting their focus from mass products to innovative specialities and by developing niche markets, these companies played a key role in the renewal of the old cluster. The adoption of new competitive strategies, thus, was an important element for the transformation of the RIS. Furthermore, the diversification strategies followed by some of these firms were crucial for the growth of a new cluster in the region, i.e. the automotive cluster (Tödtling and Tripl, 2004; Tripl and Otto, 2009).

Changes of incentives and routines are also observable in the academic sector. The emergence of a new culture of academic entrepreneurship and commercialisation of science in many parts of the world is a well-known phenomenon. The rise and growth of the biotech industry in Austria can only be fully understood if previous major changes in the academic sector are taken into consideration (Tripl and Tödtling, 2008). The emergence of new attitudes and pattern of behaviour regarding the commercialisation of scientific findings, and the gradual rise of a culture of academic entrepreneurship and collaboration with business have essentially propelled the evolution of Austrian biotech clusters (Tripl and Tödtling, 2007). Consequently, the opening of the “ivory tower” and the move of Austrian universities towards the market place figures prominently in the development of biotechnology.

The emergence and role of new innovation policy strategies and routines are widely documented and discussed in the literature. Referring once again to the case of Styria we have seen a withdrawal of the state as an owner of the large companies and as provider of industrial subsidies, and its re-emergence as promoter of research-industry interfaces, thus facilitating networking and collective learning activities (Tödtling and Tripl 2004). Like in many other countries and regions, in Styria, for example, a major shift from a firm-centred approach to a system-centred one (promotion of clusters and networks) has occurred. This is often accompanied by moving beyond direct intervention towards indirect facilitation, reflecting a new mode of state engagement and a new role of public actors (Cooke and Morgan, 1998). In Vienna, essential changes of the RIS were brought about by a shift from traditional regional policies towards innovation-oriented ones. Moreover, new policy instruments such as the introduction of competition-based policies favouring a “picking the winner approach” (see the case of BioRegio in Germany) can imply essential RIS changes.

5.2 Changes in RIS elements

RIS elements are defined here as individuals, organisations or more complex units such as industries or clusters. In the following we concentrate on the role of individuals and organisations. Changes at the level of industries and clusters have already been discussed in Sections 3 and 4.

As noted earlier, analyses of RIS transformation should provide room for agency as asserted by key individual agents and organisations. Individual agents can play a critical role in all three RIS subsystems, i.e. in the knowledge application system (entrepreneurs, venture capitalists), policy system (charismatic policy agents) and the knowledge generation & diffusion system. Individuals from the academic sector can be an essential engine of change. One of Germany's first star scientists in the field of computer science, for instance, has played a key role in the rise of the ICT cluster in the old industrial area of Saarland (Trippel and Otto, 2009). The work done by Zucker and her colleagues (Zucker et al., 1998, 2002; Zucker and Darby, 2006) suggests that direct involvement of top researchers in the commercialisation of science was an important factor for the development of biotech in specific places in the United States. Focusing on highly-cited scientists Trippel (2011a) has shown that the attraction of elite researchers is often highly beneficial for the receiving regions. The stars tend to keep close connections to their sending regions, thus providing access to distant knowledge pools for the receiving region and they engage in regional knowledge transfer and diffusion activities.

The emergence or disappearance of new firms, research and supporting organisations and new governance agencies can also trigger the transformation of regional economies. The latter may include the establishment of new funding agencies and cluster management units as it has been observed in many places around the world. In the following we concentrate on changes in the knowledge application (firms) and knowledge generating & diffusion systems. The foundation of new firms or the attraction of companies from outside the region adds new elements to the RIS. Such processes tend to occur on a regular basis but sometimes they can set in motion major changes leading to a transformation of the RIS. Looking again at the case of biotechnology confirms this view. Our own work on the Viennese biotech cluster (Tödting and Trippel, 2007; Trippel and Tödting, 2007) has shown that the establishment of Intercell, one of the first successful academic spin-offs in Austria, was critical for cluster evolution, as it served as a role model for other spin-offs, thus, encouraging and stimulating entrepreneurial activity and cluster growth. The arrival of foreign companies can also play an essential role provided that they possess specific technological or other competences and share them with local actors. Such processes proved to be critical for the growth of the Styrian automotive cluster (Tödting and Trippel, 2004; Trippel and Otto, 2009).

RIS changes can also take place by establishing new organisations in the region's knowledge generation & diffusion system. Establishing new research organisations, educational bodies, science parks or spin-off centres is a well-documented phenomenon in the literature. Our empirical work on three biotechnology clusters in Austria (Trippel and Tödting, 2007) has shown that new path creation in the regions of Vienna, Styria and Tyrol has been accompanied and facilitated by a reconstruction of their RISs brought about by establishing academic spin-off centres and new research institutes.

5.3 Changes of networks

Another important dimension of RIS transformation concerns the region's relational fabric. Changes in the network structure involve the breakup or reconfiguration of existing relations as well as the creation of new ones.

RIS changes can manifest themselves in the creation of networks between hitherto unrelated actors. The case of the Viennese food sector represents an interesting example in this regard. Over the last years Viennese food companies have faced the challenge to adopt innovation-oriented restructuring strategies to cope with increased competition from foreign producers. Switching to an innovation-based path forged the food firms present in Vienna to create links to actors with whom they have never collaborated before, namely the universities located in the region. By so doing, they gained access to new science-based knowledge which underpins their innovation activities particularly when combined with experienced-based knowledge available in-house or acquired from value-chain partners (Trippl, 2011b). The establishment of new networks among firms proved to be an essential factor for the recovery of the metal cluster in the old industrial region of Styria. For a very long time, fierce rivalry among the large companies in this cluster resulted in the absence of market relations and knowledge links. It was only in recent years, partly promoted by policy actors, that these actors started to collaborate intensively, transforming the cluster into a more networked system. Similar evidence is available for the automotive cluster in Styria (Tödtling and Trippl, 2004; Trippl and Otto, 2009), pointing to the gradual emergence of a culture of cooperation in the region.

Not only the establishment of new networks but also the reconstruction of existing ties can drive processes of regional change. The renewal of business networks by the substitution of hierarchical interfirm linkages with innovation-oriented interactions is often crucial in this regard. Finally, changes in the relational dimension also matter in the policy system. This is well documented for old industrial areas. Ties between the state, firms, and trade unions were often too strong, preserving existing structures and institutions. Evidence suggests that dismantling these petrified policy networks was one key factor amongst others triggering the renewal of these areas (see the cases of Styria in Austria and the Saarland and the Ruhr area in Germany as described by Grabher, 1993 and Trippl and Otto, 2009). Furthermore, RIS changes can manifest themselves in the formation of new policy networks in the context of new modes of governance such as multi-actor-settings involving main regional stakeholders in the formulation and implementation of policies. In Austria there is plenty of evidence on the rise of such constellations in traditional industrial regions like Styria and Upper Austria (Tödtling and Trippl 2004) as well as in metropolitan and peripheral areas (Trippl and Tödtling 2007).

Our discussion on changes in the relational assets of regions was centred on the transformation of existing and the creation of new ties between regional actors. This does not mean that extra-regional networks do not play a role in the transformation of RISs. On the contrary, there are strong reasons to assume that the most important sources of variety in knowledge bases can be found abroad (Maskell and Malmberg, 2007). The importance of interregional and international innovation networks and the capacity of RISs to get access to and absorb knowledge from extra-regional sources in order to avoid "entropic death" and parochial lock-in are widely acknowledged in the literature (Camagni 1991, Oinas and Malecki 2002).

6 Summary and outlook

Existing RIS approaches so far have been able to highlight the role of key actors and organisations from science, business and policy, and their interactions, as well as the role of hard and soft institutions for innovation processes. Due to their static nature, however, these approaches fail to address the transformation of RISs in an appropriate way. We have provided a conceptual frame for understanding transformation processes of RISs by looking at the direction of changes, key actors and areas of change.

We argued that RIS changes often take place within existing sectors or clusters in the form of path renewal. This may imply severe changes of products, processes and organisations e.g. through the application of new technologies in existing industries. However, it does not transform the RIS in a broader way. A second route is related to industrial diversification, i.e. the formation of a new regional path in established sectors. This can occur e.g. through the attraction of direct investment in industries new for the region, and respective supply chain development. This might lead to a new cluster in the region and include the development of knowledge bases and technologies not yet existing there. Finally, path creation in new knowledge-based industries implies a more radical change in the RIS both from a structural and a technology perspective. The RIS is getting a stronger role not just in the application of knowledge but also in the generation of knowledge in such industries.

RIS changes are driven by key actors from business, science or policy, sometimes as a planned rational action based on exploration and foresight, or more spontaneously in response to crisis situations. Although there is room for agency, the direction and kind of change is shaped by existing structures and contexts such as the business systems and RIS characteristics. This implies that in particular regional settings we might find quite different outcomes, as a result of combined actions by firms, universities, and policy agencies which are embedded in the contexts of a particular business system and RIS type.

Regarding the areas of RIS transformation, we have identified the change of “soft” institutions (change of routines and attitudes), the change of RIS elements (e.g. the closure or setting up of research organisations and firms), as well as changes of knowledge relations and networks within the region and beyond. Most visible is usually the setting up of new organisations such as a university or research park. Such measures, however, are often not able to transform a RIS more fundamentally if they are not accompanied by institutional change (new behavioural attitudes and routines) the creation of networks within the region and beyond. This implies that new elements should offer possibilities for relating to existing structures and for knowledge interactions in the regional economy. A vertical cluster approach might enhance innovation and competitiveness in particular industries, but it seems to be too narrow to enhance the transformative capacity of the overall RIS since it ignores the potential interrelations between clusters and industrial paths. A broader horizontal and related variety based view provides more opportunities for such knowledge links between clusters and paths, and the development of new paths (Frenken et al. 2007, Boschma and Frenken 2009, Cooke et al. 2010).

In this paper we have dealt with the direction, the actors and modes of RIS transformation. Little has been said, however, about the transformative capacity of such systems. Why are some regions and their innovation systems more able than others to promote path renewal, formation and creation, i.e. to renew and change their industrial structures? Recent insights provided by scholars working in the field of EEG form a valuable basis for thinking about the transformative capacity of RISs (see e.g. Boschma and Martin 2010). A key concept in this

context is that of variety (diversity) in economic structures, institutions and knowledge bases. The transformative capacity of a RIS is positively affected by the degree of sectoral variety (diversity). The same might hold true for the knowledge bases. It is often argued that the broader and more diverse the knowledge bases, the larger the scope for innovation. These findings underline the importance of variety in the knowledge available for innovation as a determinant for the transformative capacity of RISs. Frenken et al. (2007) have proposed a refinement of this idea, arguing that certain types of variety are more conducive to regional growth and innovation than others. They distinguish between related and unrelated variety. Although unrelated variety or diversification (emergence of a new sector which is not related to those already existing in an area) might protect the region better against asymmetric shocks in demand, related diversification may be more beneficial, because in this case the broadening of the economic or knowledge bases builds on competences present in an area, allowing for complementarities to existing industries and knowledge bases. This implies that the long term development of regions depends on their ability to diversify into new applications and new sectors while building on their current knowledge base and competences. Connections to knowledge sources located outside the RIS are acknowledged to be particularly important to ensure variety and new innovation impulses (see, for instance, Maskell and Malmberg, 2007; Martin and Simmie, 2008).

There are still considerable knowledge gaps and open questions regarding the transformative capacity of RIS such as the following:

- Which types of knowledge variety enhance the transformative capacity of a RIS?
- Why are specific paths selected and not others? What is the relative importance of chance, first-mover advantages and strategic decisions in this regard?
- Do RIS transformations differ, depending on whether triggered (a) by externally generated crises or (b) by endogenous processes?
- To what extent are RIS changes based on (a) a top-down and anticipatory transformation or (b) bottom-up and endogenous processes (e.g. a self-organised market-based transformation)?
- How does this relate to the magnitude of change of techno-economic paradigms (minor or major)?
- In which ways are changes in different dimensions in different RIS subsystems related to each other?

Exploring these issues would enhance ones understanding of how RISs transform themselves over time and would shed further light on critical factors and conditions for their change.

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