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THE REGIONAL INNOVATION SYSTEM OF BADEN-WÜRTTEMBERG RECONSIDERED:

PATH DEPENDENCY AND TECHNOLOGICAL LEADERSHIP

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9.1 Introduction

With a view on various macro-economic and social indicators, the federal state of Baden-Württemberg can be characterised as an extremely successful regional economy. One of the main reasons for this lies in the fact that the regional innovation system consists of a multitude of public research institutes (both universities and non-university research centres), a favourable mixture of innovative and technology oriented SMEs as well as numerous large multinational companies, which in their interplay appear to be extremely capable of introducing innovations in very specific segments of the manufacturing sector with a high value added (automotive industry, mechanical and electrical engineering). However, during the last two decades many regional scientists have pointed to inherent hindrances or risks of the regional innovation system in terms of path-dependencies due to extremely stable and network-based developments unable to adapt to technological shifts beyond the established more traditional technological and institutional trajectories (e.g. Cooke and Morgan 1994; Heidenreich and Krauss 2004). One of the key arguments of these critics is the observation that radical innovations and particularly leading-edge technologies are underrepresented and that policy initiatives focusing on these technologies are at risk of failing. This contribution critically assesses these findings of path-dependent regional development in Baden-Württemberg empirically, using recent survey data on technological potentials in the twelve planning regions of Baden-Württemberg, regarding the diffusion of existing and potentially relevant technologies in the future and on the structure and dynamics of scientific research in the federal state.

The structure of this chapter is as follows: firstly, the perceptions of the regional innovation system of Baden-Württemberg in the literature are revised. Secondly, and from a conceptual perspective, this contribution presents Baden-Württemberg as a fairly routinised regional innovation system that is nevertheless able to develop substantial economic momentum despite its rather traditional set-up. The next section is devoted to the formulation of working hypotheses that will guide the empirical analyses in the subsequent section in a direction as to reveal aspects of the regional innovation system of Baden-Württemberg that have been overlooked in earlier analyses and that nevertheless contribute to a better understanding of the region's prolonged economic success. Empirical evidence with regard to the research hypotheses follows in the fifth section. This section begins with the description of the methodological approach, before focussing on aspects like technological profile, inter-organisational networks and intra-regional distribution of competencies. The chapter concludes with a summary which addresses the research hypotheses and presents the main findings.

9.2 The regional innovation system of Baden-Württemberg: a literature overview

In line with the rise of research on innovative milieux, innovation networks, new production concepts, for instance with a view on lean production, and industrial districts in the late 1980s/early 1990s, the concept of regional innovation systems (RIS) was first introduced by Cooke in 1992 and reviewed similarly in the first collection of papers on the subject (Braczyk et al. 1998; Cooke 1998). The RIS approach resumes the various regional concepts and combined them with the research on national innovation systems. According to Cooke et al. (1996, p. 12) regional innovation systems are defined as "[…] geographical distinctive, interlinked organizations supporting innovation and those conducting it, mainly firms". Thus, the concept is based on the fact that the region and the spatial environment play a certain role in the innovation process of companies and other innovation related actors (Koschatzky 2001). A more recent definition of a regional innovation system by Cooke (2004, p. 3) is: "a regional innovation system consists of interacting knowledge generation and exploitation subsystems linked to global, national and other regional systems for commercialising new knowledge". In accordance with this definition, the authors explicitly point to the fact that successful RIS are not only characterised by well functioning regional dynamics in terms of more or less closed networks or knowledge exploitation structures, rather than by both, intraregional and extra-regional linkages, to other knowledge and innovation systems.

As mentioned above, the RIS concept integrates some of the main elements of different theoretical approaches, particularly network-, milieu- and district-related considerations as well as knowledge-based approaches. All of them deal with the significance of spatial proximity within the production and innovation process. Spatial and social proximity between the actors of innovation (and production processes) are considered as essential for the realisation of innovations (Boschma 2005; Torre and Rallet 2005). The spatial concentration of knowledge providers and knowledge-exploiters supports knowledge turnover and the generation of new knowledge relevant for further innovations. Additionally, the RIS concept emphasises the role of regional institutions (Cantwell et al. 2009; Cooke et al. 2004), be it public or private institutions. According to Heidenreich (2005, p. 741), RIS are – in contrast to innovation clusters – integrated by institutions and regional cultures. For Storper and Salais (1997) RIS can be analysed as *social fields* which are institutionalised, for instance environments of organizations, regulations and corresponding regulatory bodies, networks, rules and conventions, etc. Important actors in the social fields of RIS may be single individuals (being in charge of innovation related topics) or on the "meso-level" organisations like universities, public and private research facilities, private companies, organisations of the intermediary system (e.g. consultants, technology transfer agencies, R&D funding organisations, innovation financing institutions). Well-functioning regional innovation systems may have several *potential advantages*, particularly with a view to private companies within the system. First of all, spatial and organisational proximity reduce transaction costs which typically occur in the shape of long lasting cooperation agreements between clients and suppliers in specific branches or with regard to the division of labour within the innovation process, especially when complex, irregular, uncertain, unpredictable and hardly codified tasks emerge. Sydow (1992) points to transaction costs reducing features of networks which constitute one essential element of a regional innovation system. A second advantage of RIS (and regional networks) are the so-called "untraded interdependencies" (Storper 1995), which comprise non-market-based exchange relationships like regional governance structures, the institutional framework, access to specialised technological knowledge, information about new markets, etc. The creation of regional collective goods is often the result of these kind of exchange relationships which stabilise the regional networks and patterns of cooperation between the actors within the RIS (Heidenreich 2005). Major agglomeration advantages and possibilities of an intensified exchange of informal, non-codified, implicit knowledge finally constitute a third advantage, strongly connected to the cognitive dimensions learning and innovation (Asheim and Isaksen 2002).

Research on regional innovation systems has generated various empirical findings of their structural features and innovation dynamics (Braczyk et al. 1998). A typology of regional innovation systems has been put forward by Cooke (1992). Thinking more specifically of modes of regional innovation, Cooke proposed three modalities (grassroots, network, dirigiste), which primarily describe the degree of hierarchies in terms of research, development, innovation support and technology transfer. Two years later Cooke and Morgan (1994) further elaborated the typology by including modes of business inter-relationships and added the dimensions "globalised", "interactive" and "localist". These dimensions reflect the regional structure of the companies as well as their market orientation and interrelationships. On the basis of this typology, the regional innovation system of Baden-Württemberg for instance is assigned to the group of network/interactive regions (cf. Cooke 1998). These kinds of RIS are characterised by a mixture of basic and applied research, large and small companies and a balanced proportion of public and private research institutions.

In line with an increase of research on RIS during the 1990s – mostly from regional science and economic geography – Baden-Württemberg was among the first regions which were investigated as a case of regional economic success and a potential generic and generalizable model (Cooke and Morgan 1990; 1993). Even though the regional success of Baden-Württemberg is still valid today, in the early 1990s questions were raised as to a possible loss of comparative advantages and the remaining locational advantages (Heidenreich and Krauss 2004). The concept of flexible manufacturing of high-quality industrial products (Piore and Sabel 1984) made it possible for regional manufacturing companies to avoid competition primarily affected by the price of goods. In contrast to the post-war period where low-cost mass products primarily contributed to income, wealth and employment, a strategy oriented towards flexible supply and low-cost products and services – supplemented by lean production, development and marketing – undermines the relative and absolute strengths of a region like Baden-Württemberg and other industrial districts (Heidenreich and Krauss 2004).

Within the scientific debate on whether a prosperous regional innovation system like Baden-Württemberg in increasing global competition, especially since the early 1990s, would still be able to adapt its institutions in order to cope with low-cost mass producing countries, authors like Krauss (1999), Krauss and Stahlecker (2003), Heidenreich and Krauss (2004) described and analysed the main characteristics of the Baden-Württemberg RIS. These studies particularly pointed to the highly institutionalized structures and networks which show remarkable stability and continuity. The authors concluded that reinforcing those industrial and institutional patterns that have proved successful in the past may hinder attempts to adapt to new industries and services needed for the renewal of the RIS. The main concern of Heidenreich and Krauss (2004, p. 206) becomes apparent in the conclusion: "[…] this institutional environment has become so firmly rooted that a problem of lock-in is to be expected in the face of new demands".

Within this context, Krauss (1999) and Casper (1999) emphasise that the main strengths of the regional innovation system of Baden-Württemberg lie in process innovation and incremental improvement innovations in experience-based technology paths. The institutional environment or the intermediary system is to a large extent oriented towards supporting these incremental, continuous and routine innovations. In contrast, high-technology fields and radical, science-based innovations are of secondary importance and – despite significant support schemes of the state of Baden-Württemberg geared towards leading-edge technologies and related innovations - encounter major structural hindrances inherent to the system. The regional innovation system is dominated by product and process innovations in the field of complex and highly advanced, i.e. mature technologies (Krauss and Stahlecker 2003). The technological basis of Baden-Württemberg is built on the three main industry clusters automotive, mechanical and electrical engineering which significantly shape the technological profile of the region with distinctive emphasis on transport technologies, mechanical and electrical engineering (as well as process measuring and control technology) (Frietsch et al. 2010).

As for the industrial relations within Baden-Württemberg and between the dominant clusters in particular, Cooke (2001) points to the fact that regional firms maintain various vertical and horizontal, market and non-market, trustful and sceptical relations with each other (heterarchical RIS). Furthermore, relationships of the companies with intermediaries and government departments are stabilizing the regional innovation system. In both dimensions – market and non-market oriented relationships – economic and political power clearly influence the networks and the techno-economic path as a whole. Within this context, large international and technologically-strong companies like Daimler, Bosch, ZF Friedrichshafen AG and other first-tier suppliers for the automotive industry are certainly dominating actors within and beyond the regional networks and therefore are key actors regarding the renewal of a routinised innovation system like Baden-Württemberg.

In line with pointing out that the incremental improvement of routine innovations in experience-based technology-paths rather than leading-edge technological fields appears to be one of the main strengths of Baden-Württemberg, categorising the region as a routinised innovation regime seems justified, in which the existing incumbents have the innovative advantage (Acs and Audretsch 1990) seems to be plausible. According to this rationale, the regional renewal primarily occurs on the basis of the existing companies rather than on firms having the innovative advantage outside of the industry incumbents (entrepreneurial regime). The following section elucidates this specific aspect of the Baden-Württemberg RIS.

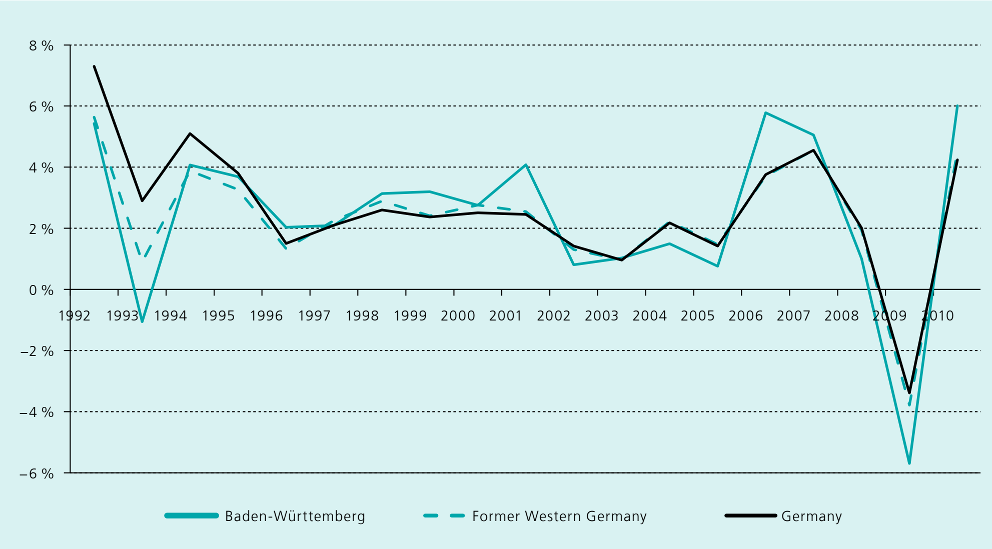
9.3 Baden-Württemberg: a "routinised" innovation system?

As outlined above, the innovativeness and the transformative capacity of Baden-Württemberg's regional innovation system had become subject to substantial debate in the course of the 1990s (Cooke and Morgan 1990; 1993; 1994; Fuchs and Wolf 1999; Heidenreich and Krauss 1998; Krauss 1997), which left at least the academic community with a number of worrying findings that seemed to forebode a further slackening of the region's formally dynamic development trajectory as well as a development of lock-in effects and further rigidities in what was already perceived as a fairly traditional industrial set-up. More than a decade later, it now seems necessary to reconsider these findings in the light of current empirical evidence.

First of all, it seems that the mentioned academic literature has taken stock of the situation at a particularly unfavourable point in time. While it is true that Baden-Württemberg's participation in the post reunification boom (even compared to other German states) was below average, its GDP grew continuously above average throughout the second half of the 1990s until the end of the dot.com boom in 2002 (cf. Figure 9–1).

Following a period of consolidation until 2005, Baden-Württemberg's regional economy improved again in the second half of the 2000s, reaching significantly above

Figure 9–1: GDP growth rates (nominal) in Baden-Württemberg in comparison to Germany



Source: own calculations based on Federal Statistical Office of Germany (destatis)

average growth rates. Moreover, it recovered more dynamically from the 2008–2009 crisis than the rest of the country – even though it had been affected to an above average degree in the course of it. Evidently, the region's economy has not only remained resilient but also at different points regained substantial momentum, and thus clearly refuted earlier predictions of economic decline or structural inertia. Additionally, during the last two decades, the RIS of Baden-Württemberg has seen the rise of new and primarily knowledge-based industries that increasingly contribute to the economic success of the region since knowledge-intensive business services in particular act as accelerators regarding regional knowledge dynamics (Strambach 2002; 2008). The RIS of Baden-Württemberg has undergone a catching-up process in this respect (Krauss 1999). Nonetheless, the falsification of the conclusions alone does not permit to falsify the assumption itself and the question whether Baden-Württemberg remains a "routinised" innovation system remains to be answered. To that end, two main issues had to be addressed.

Firstly, it seemed necessary to question whether the regional economy is actually characterised by industry branches that can be considered "traditional". To clarify this issue, we identified those sectors in Baden-Württemberg that represent at least 1.5 times the share of regional employment than they do at national level. In this respect, we arrive at the quite unambiguous finding that the region's dominant industrial sectors are indeed not to be counted among those typically identified as high-tech sectors. Instead, the machine building and the automotive industry remain the dominant sources of employment, complemented by other sectors which can at least in part

Table 9–1: Dominant industrial sectors in Baden-Württemberg (2010)[1]

	Employment Baden-Württemberg	Employment Germany total	Regional share in national employment	Location quotient
Manufacturing of machinery	254,719	939,209	27.1 %	1.93
Manufacturing of automobiles and parts thereof	189,894	769,588	24.7 %	1.76
Manufacturing of office machinery & optics	88,221	401,271	22.0 %	1.57
Manufacturing of electrical equipment	74,366	333,442	22.3 %	1.59
Manufacturing of pharmaceuticals	33,013	120,432	27.4 %	1.95
Manufacturing of textiles	9,953	39,981	24.9 %	1.77
“Traditionally important sectors”	650,166	2,603,923	25.0 %	–
Total, industrial sector	**1,128,392**	**5,793,328**	**19.5 %**	–
Total	**3,887,750**	**27,710,487**	**14.0 %**	–

Source: own calculations based on Federal Statistical Office of Germany (destatis)

be considered traditional, such as the electrical industry or the production of pharmaceuticals and textiles. In these sectors of traditional importance for the region, the federal state holds a national share of 25.0 %, while its overall share in industrial employment is significantly lower, with about 19.5 % (Table 9–1).

Secondly, earlier research indicated that Baden-Württemberg’s regional economy had an inferior potential to regenerate due to the limited entrepreneurial potential of the local population. More precisely, Stahlecker and Muller (2008) had been able to illustrate that, contrary to the popular conception of Baden-Württemberg as a region of small-scale entrepreneurship, the regional start-up intensity had remained below national average throughout much of the 1990s. At the time, this seemed to corroborate the impression of an inflexible system dominated by large, existing firms in traditional fields.

Consequently, this second aspect needs to be re-evaluated based on novel data. As illustrated by Figure 9–1, the regional economy had lived through multiple crises, so that the propensity to set-up firms might well have changed. Apparently, however, the regional economy has not undergone any such transformation. As Table 9–2 illustrates, the regional relation of enterprise start-ups to overall employment has remained more than 20 % below national average in most recent years.

In summary, the empirical findings continue to support the assumption that Baden-Württemberg is in many ways a fairly “routinised” innovation system, or at

1 The Location Quotient (LQ) is calculated as follows: Share Sector in Total Employment [region]/ Share Sector in Total Employment [nation].

Table 9–2: Enterprise start-ups per 1,000 employment

	2004	2005	2006	2007	2008	2009
Baden-Württemberg	2.37	2.31	2.42	2.01	1.99	2.04
Germany	2.93	2.97	2.89	2.77	2.57	2.74

Source: own calculations based on Creditreform and Federal Statistical Office of Germany

least one in which existing players and established routines play a substantial role. Remarkably, however, earlier conclusions that this made Baden-Württemberg prone to become less successful seem to be fully unwarranted. Apparently, the regional economy has managed to stay resilient and at several times develop substantial momentum despite its, in part, quite traditional set-up.

9.4 Research guiding hypotheses

Research on the production and innovation system of Baden-Württemberg over the last 20 years has generated many insights into the specific structural characteristics, institutional environment and possible future development of a successful regional economy. Given the dominance of the three overlapping clusters, automotive, mechanical-engineering and electrical equipment for the economic sector of Baden-Württemberg, it has been argued that the institutional environment is significantly geared towards the specific needs of these sectors, which are mainly engaged in generating incremental, continuous and routine innovations rather than radical, science based innovations. Given the fact that Baden-Württemberg as a whole shows characteristics of a routinised innovation system and that innovation activities and the underlying technology fields are in a first phase incorporated into regional specific contexts, the first hypothesis can be formulated as follows:

Hypothesis 1: A routinised innovation system like Baden-Württemberg does not allow for the diffusion of technology fields beyond the experience-based paths dominated by the core branches of the regional economy.

In line with a quite stable institutional environment, the strengths of the Baden-Württemberg RIS have been described by analysing the specific inter-organisational relationships and innovation networks. One of the main conclusions of the investigations is that the firms in Baden-Württemberg – large companies as well as SMEs – maintain various relations with each other, be it market-based or on an informal basis. Furthermore, companies' relationships with intermediaries and government departments stabilize the regional innovation system and supplement the trust-based exchanges within the system. Untraded interdependencies and the provision of collective goods are described as the results of normatively stabilised regional networks. However, the question of how a regional innovation system like Baden-Württemberg can renew and further develop the regional capabilities in terms of an update of the institutional and governance system is regarded sceptically. Hence, certain authors concluded that a reinforcement of those industrial and institutional patterns, that have proved successful in the past, may hinder attempts to adapt to new industries and services needed for the renewal of the RIS. This rationale is illustrated in the second research hypothesis:

Hypothesis 2: Due to the dominance of specific branches, the institutional environment and the inter-organisational relationships, the Baden-Württemberg RIS tends towards a lock-in situation with inherent structural and cognitive barriers regarding the integration of extra-regional knowledge potentials.

The spatial structure of Baden-Württemberg shows a decentralized pattern of an urban development pattern with Stuttgart as the capital region and many medium-sized cities like Heidelberg, Karlsruhe, Mannheim, Freiburg, Ulm or Konstanz. All of these "urban functional areas" are characterised by a rather diverse economic sector and technological capabilities. However, due to the sheer size of the metropolitan area of Stuttgart with its large manufacturing cores, the capital region clearly dominates the economic and technological system of Baden-Württemberg as a whole. Nevertheless, the competitiveness of the RIS is not exclusively connected with Stuttgart. Major regional potentials, sometimes forming sub-innovation systems on their own (e.g. the medical devices cluster in Tuttlingen, the software cluster in Karlsruhe or the biotechnology-cluster in Heidelberg), are to be found outside the Stuttgart area. Thus, intra-regional technological and innovation competencies are a distinctive feature of the Baden-Württemberg RIS. Against the background that the different regional sub-systems have adopted their role as essential "elements" within the innovation and production system of Baden-Württemberg, a third hypothesis can be entitled as:

Hypothesis 3: A routinised innovation system like Baden-Württemberg is characterised by intra-regional competencies which enable a flexible adaption to specific market demands and technological change as a whole.

The following section will test the hypotheses empirically. In addition, it will demonstrate that even a routinised innovation system is able to remain resilient and can even develop substantial economic and technological momentum.

9.5 Empirical evidence

The primary goal of this contribution is a general investigation of the regional innovation system of Baden-Württemberg between path-dependency and technological leadership that particularly acknowledges prior findings, past and present economic structures and the system's capacity for renewal. Core characteristics such as the economic and technological profile of the whole region as well as intra-regional distribution of competencies, the importance and range of innovation networks and present approaches to support regional innovation activities need to be addressed. This section will test the three research guiding hypothesis that have been derived in the frame of the regional system of innovation approach with explicit recognition of prior studies and the present economic condition. The empirical evidence is based on data gathered from an enterprise survey carried out by the team of authors, data on the employment situation in knowledge-intensive industries as well as on data concerning patent applications.

9.5.1 Database and methodological approach

Research and technological development is a rather complex phenomenon and can be addressed at various levels. The macro-economic perspective allows an assessment of the past and present general economic structure such as growth dynamics, changes in sectoral composition as well as the founding of new firms. The micro-economic perspective allows an assessment of the behaviour of single enterprises and how they operate internally. Since the regional innovation potential does not only depend on the regional economic structure and internal enterprise characteristics but likewise relies on intra- and inter-regional networks that represent cooperation and interaction opportunities, a third level of analyses is rather important for the study of the regional innovation system: the meso-level. The meso-level is dedicated to network analyses and regional and sectoral modes of cooperation during innovation processes. For testing the hypotheses an intra-regional mode of assessment was employed. Although administrative regions do not necessarily represent functional economic regions, looking at administrative entities is inevitable in order to employ statistical data for analyses. The intra-regional analyses are based on the so-called *Raumordnungsregionen* which are used for spatial planning purposes in Germany. In general, these regions cover several NUTS 3 regions, but are – with a few exceptions – smaller than NUTS 2 regions. Baden-Württemberg comprises 12 of these regions which encompass two to six NUTS 3 regions.

The micro-economic i.e. firm perspective and respective cooperation patterns representing the meso-level were captured by an extensive online enterprise survey among enterprises in Baden-Württemberg from technology oriented sectors (for details compare Table 9–3). The questionnaire was divided into different sections, addressing enterprise characteristics such as sector of economic activity, firm size, R&D spending behaviour and patenting behaviour, but also the actual and future importance of different technologies (details are displayed in Table 9–4 and Table 9–5), as well as specificities of R&D partners and their (regional) provenance.

In order to represent all of the above mentioned twelve sub-regions in Baden-Württemberg, the online survey was designed in form of a regional stratified sample. Altogether 33,600 enterprises were contacted in June 2011. The vast majority of questionnaires were sent to a named member of senior management or otherwise addressed to the managing director. After a follow-up round we received 1,760 duly completed questionnaires by the beginning of August, which corresponds to a response rate of approximately 5.2 %, although response rates vary slightly from sub-region to sub-region. All analyses were performed with SPSS.

Table 9–3: Sectoral composition in Baden-Württemberg

Sectors of economic activity	Share in survey	Share of enterprises liable to taxation (2008)	Share of employees (2008)
Core technology oriented economic sectors			
Mechanical engineering (NACE 28)	11.6 %	3.0 %	14.6 %
Electrical engineering, electronics, IT-hardware and equipment (NACE 26, 27)	11.3 %	1.8 %	6.9 %
Automobile production (NACE 29, 30)	2.9 %	0.6 %	10.0 %
Metal products, surface engineering, jewellery (NACE 25)	5.7 %	5.8 %	8.0 %
New technology oriented economic sectors			
R&D services (e.g. technical KIBS) (NACE 71, 72)	9.7 %	41.4 %	18.9 %
Telecommunications, IT, software (NACE 62, 63)	15.7 %	5.8 %	4.1 %
Measuring and control equipment, optical equipment (NACE 26.5.)	3.4 %		
Medical engineering, orthopaedics* (NACE 26.6.)	1.9 %	1.8 %	5.7 %
Other economic sectors (of interest)			
Glass, ceramics, rocks and soils (NACE 23)	0.6 %	1.1 %	1.2 %
Food products, beverages and tobacco (NACE 10)	1.7 %	3.7 %	4.2 %
Textiles, leather (NACE 13)	2.0 %	0.8 %	0.8 %
Metal fabrication, foundry (NACE 24)	2.1 %	0.8 %	2.0 %
Print industry, paper products (NACE 18)	3.3 %	2.3 %	2.7 %
Wood, paper, furniture (NACE 16, 17, 31)	3.4 %	4.7 %	4.6 %
Construction industry (NACE 41, 42)	5.4 %	24.9 %	9.7 %
Petroleum, plastics, chemicals, pharmaceuticals (NACE 19, 20, 21, 22)	5.8 %	1.5 %	6.5 %
Other remaining sectors	13.6 %	n.a.	n.a.

Sources: Fraunhofer ISI enterprise survey, employment data and enterprise data from the Statistisches Landesamt Baden-Württemberg (the regional statistical office)
*Medical engineering, orthopaedics does not belong to the new core sectors of the knowledge economy, since two branches are integrated at the statistical office, the two sectors could not be separated. Economic branches were truncated according to the classification scheme for economic activities published by the German statistical offices in 2003

Table 9–4: Importance of certain key technologies for enterprise competitiveness today

	New technology oriented economic sectors	Core technology oriented economic sectors	Other economic sectors
Technologies	**important**	**important**	**important**
Information and communication technologies	95 %	89 %	84 %
Optical technologies	31 %	36 %	31 %
Production technologies	38 %	85 %	79 %
Bio-technologies	12 %	7 %	18 %
Nano-technologies	14 %	19 %	23 %
Microsystems technologies	26 %	31 %	15 %
Health and medical technologies	18 %	19 %	28 %
Energy technologies	43 %	66 %	64 %
Environmental technologies	41 %	58 %	68 %
New materials	29 %	69 %	66 %
Surface technologies	20 %	60 %	50 %
Technologies for e-mobility	25 %	35 %	20 %
Other technologies	13 %	22 %	14 %

Source: Fraunhofer ISI enterprise survey

In order to capture differences between traditional economic sectors and new, emergent sectors representing the economic shift towards a knowledge-based economy, four different groups of industries have been defined: (i) core technology oriented sectors (mechanical engineering, electrical engineering, automobile production, metal fabrication and foundry as well as metal products, surface engineering and jewellery), (ii) new and knowledge based technology oriented sectors (R&D services, telecommunications, IT and software industries, measuring and control equipment as well as optical equipment), (iii) other economic sectors that belong neither to the former nor the latter group (glass, ceramics, rocks and soils, food products, beverages and tobacco, textiles and leather, metal fabrication and foundry, print industry, wood, paper and furniture, construction industry as well as petroleum, plastics, chemicals and pharmaceuticals) and (iv) other remaining sectors, which emerged as an artefact from the enterprise survey pooling enterprises that do not fit into one of the former categories.

The sectoral composition of Baden-Württemberg's economy is displayed in Table 9–3. The sectoral shares in Baden-Württemberg vary, according to what is defined

Table 9–5: Importance of key technologies for enterprise competitiveness until 2020

	New technology oriented economic sectors		Core technology oriented economic sectors		Other economic sectors	
Technologies	**incr. importance**	**decr. importance**	**incr. importance**	**decr. importance**	**incr. importance**	**decr. importance**
Information and communication technologies	74 %	0 %	74 %	0 %	69 %	31 %
Optical technologies	28 %	2 %	33 %	1 %	23 %	3 %
Production technologies	28 %	1 %	63 %	1 %	60 %	2 %
Bio-technology	13 %	4 %	11 %	3 %	20 %	4 %
Nano-technology	17 %	3 %	32 %	2 %	30 %	3 %
Microsystems technologies	25 %	2 %	34 %	1 %	17 %	4 %
Health and medical technologies	18 %	3 %	24 %	3 %	26 %	3 %
Energy technologies	45 %	1 %	70 %	2 %	61 %	1 %
Environmental technologies	42 %	1 %	59 %	2 %	63 %	1 %
New materials	21 %	3 %	49 %	1 %	51 %	2 %
Surface technologies	19 %	3 %	44 %	1 %	40 %	3 %
Technologies for e-mobility	33 %	2 %	44 %	2 %	25 %	5 %
Other technologies	10 %	3 %	18 %	4 %	9 %	5 %

Source: Fraunhofer ISI enterprise survey (the category "stays the same" was omitted for the sake of clarity. Taking all three categories together, the sum of the percentage shares equals 100 %)

as the main unit of interest, namely enterprises or number of employees in the region. Since only technology oriented sectors were considered in our analyses, the percentages in each column of Table 9–3 equal 100 %.

9.5.2 Technological profile

This section addresses Hypothesis 1 and assesses empirically whether a routinised RIS like Baden-Württemberg is able to adopt and acknowledge emerging technologies. Two key questions from the enterprise survey allow to capture such features of a RIS. The enterprises were asked to state the importance of certain key technologies for the productive efficiency and their competitiveness today and up to the year 2020. As for today, the enterprises were able to differentiate between important and unimportant, whereas for 2020, the enterprises were able to differentiate between three categories, namely increasingly important, importance will remain the same as today and decreasingly important. The results are displayed in Table 9–4 regarding the importance of certain key technologies as of today and in Table 9–5 regarding the importance of certain key technologies until 2020.

Table 9–4 summarises the results from the enterprise survey, differentiating between the different and relevant formerly mentioned sectors (new technology oriented economic sectors, core technology oriented economic sectors, other economic sectors). It can easily be perceived, in particular by the grey shaded lines, that the importance of the technologies varies greatly and, moreover, is even partly independent from the sectoral affiliation of the enterprises. For example, information and communication technologies are classified as important by 83.7 % to 94.8 % of the enterprises in the different economic sectors. Since information and communication technologies qualify as cross-sectional technologies used by a majority of enterprises, these finding are not surprising. Quite the opposite holds for certain branch technologies such as health and medical technologies, nano-technologies or bio-technology. Consequently, they are perceived by only a minority of enterprises as important for their productive efficiency.

Differences in the importance of certain key technologies between the enterprises from the different sectors were analysed using a Kruskal-Wallis-Test. The test verifies that there are significant differences between the different sectors in their perception of the importance for most of the key technologies. Based on three degrees of freedom, the p-value (asymptotic significance) is equal to 0.000 for most of the technologies (exceptions are optical technologies, nano-technologies, health and medical technologies, as well as the category "others"). Consequently, there is strong evidence to reject the null hypothesis that the importance of these technologies is equal for the different sectors (except for the above mentioned technologies). Good examples for the difference in the importance of certain technologies can be assessed by comparing the answers concerning production technologies or new materials in the respective rows in Table 9–4.

Table 9–5 displays the results from the enterprise survey concerning the importance of key technologies until 2020, differentiating again between the different sectors. The importance of single technologies varies from technology to technology and is also partly independent from the sectoral affiliation of the enterprises. For example, information and communication technologies are classified as increasingly important by 69.1 % to 79.1 % of the enterprises in the different categories. Interestingly, none of these key technologies is expected to be of decreasing importance by more than 5 % of the enterprises of each group. For the vast majority of technologies, the enterprises expect their importance regarding their productive efficiency to remain the same until 2020.

Another Kruskal-Wallis-Test was used to reveal significant differences concerning the importance of certain key technologies until 2020. The test verifies that there are significant differences between the different sectors in their perception of the importance for most of the key technologies. Based on 3 degrees of freedom, the p-value (asymptotic significance) is equal to 0.000 for most of the technologies. There is consequently strong evidence to reject the null hypothesis that the importance of these technologies is equal for the different sectors (exceptions are information and communication technologies, optical technologies, health and medical technologies as well as the category "others"). Good examples for the difference in the importance of certain technologies until 2020 can be assessed by comparing the answers concerning production technologies or new materials in the respective rows in Table 9–5.

A first tentative interpretation of these results comes to the conclusion that a routinised RIS such a Baden-Württemberg is able to adopt and acknowledge emerging technologies, even in core technology oriented sectors of the regional economy.

9.5.3 Innovation and research networks

This section is devoted to empirically testing Hypothesis 2, which states that due to the dominance of specific branches, the institutional environment and the inter-organisational relationships, the RIS of Baden-Württemberg tends towards a lock-in situation with inherent structural and cognitive barriers regarding the integration of extra-regional knowledge potentials. In order to assess existing innovation and research networks, these sections draw on survey data concerning R&D activities of enterprises in Baden-Württemberg. It is of particular interest to see in which of the twelve different technology fields the enterprises from the different economic sectors maintain R&D activities (be they intra-mural and/or with partners) and in which they do not. The following Table 9–6 displays the results, again sectorally and technologically differentiated.

Table 9–6: R&D activities of enterprises

	New technology oriented economic sectors		Core technology oriented economic sectors		Other economic sectors	
Technologies	**in-house R&D**	**with partners**	**in-house R&D**	**with partners**	**in-house R&D**	**with partners**
Information and communication technologies	56 %	12 %	31 %	19 %	14 %	19 %
Optical technologies	8 %	6 %	14 %	12 %	6 %	6 %
Production technologies	15 %	12 %	49 %	20 %	40 %	22 %
Bio-technology	3 %	5 %	1 %	4 %	6 %	7 %
Nano-technology	2 %	6 %	3 %	12 %	8 %	11 %
Microsystems technologies	7 %	8 %	9 %	16 %	3 %	7 %
Health and medical technologies	7 %	6 %	7 %	6 %	17 %	6 %
Energy technologies	11 %	13 %	26 %	20 %	14 %	23 %
Environmental technologies	8 %	11 %	17 %	19 %	19 %	26 %
New materials	5 %	9 %	18 %	30 %	17 %	27 %
Surface technologies	4 %	7 %	14 %	28 %	19 %	15 %
Technologies for e-mobility	6 %	11 %	18 %	14 %	4 %	7 %
Other technologies	11 %	4 %	16 %	7 %	7 %	3 %

Source: Fraunhofer ISI enterprise survey (the category "no R&D" was omitted for the sake of clarity. Taking together all categories, the sum of the percentage shares equal 100 %).

The differentiated perspective regarding the various technological fields reveals some interesting results. First of all, it is interesting to see that the majority of enterprises from the new technology oriented economic sectors maintain in-house R&D activities in the technological field of information and telecommunication technologies. This stands in sharp contrast to all other technological fields. In this group, 73.7 % of enterprises compared to 92.4 % of enterprises declare to have no R&D at all. Secondly, enterprises from core technology oriented economic sectors and enterprises from other technology oriented economic sectors seem to have different foci regarding their R&D activities. Almost 50 % of the enterprises from the core technology oriented economic sectors perform in-house R&D in the field of production technologies. Enterprises from core technology oriented sectors seem to seek R&D partners especially in the fields of new materials and surface technologies. Apparently, R&D partnerships are of certain importance, especially for enterprises from the core technology oriented economic sectors as well as for enterprises from other economic sectors. It can be stated as a first conclusion that in particular enterprises from the core technology oriented economic sectors and enterprises from other economic sectors perform R&D activities in co-operation with partners (in certain technology fields) and thus counter-corroborate the assumption of existing cognitive barriers and a tendency towards a technological lock-in situation.

In order to assess the inter-organisational relationships of enterprises from Baden-Württemberg in greater detail, Figure 9–2 provides an overview of certain characteristics of R&D co-operation partners. In the enterprise survey, the enterprises were asked to enlist their most important R&D partners in different technology fields and to state their origin.

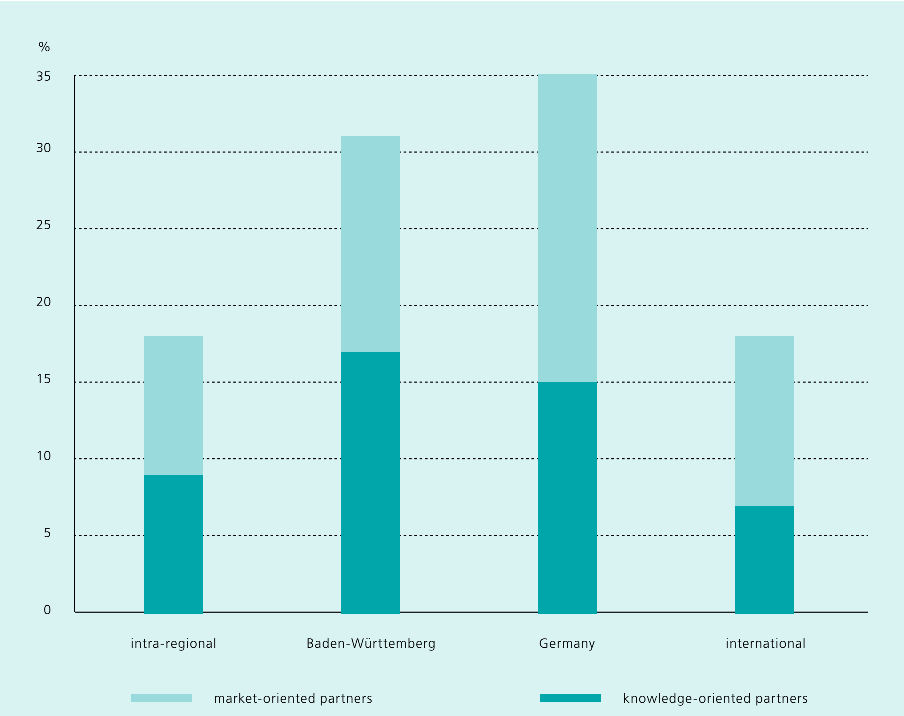
For the sake of clarity, answers for the different technology fields were aggregated and the results are displayed in Figure 9–2. The data show that regional enterprises do cooperate intra-regionally (within their own *Raumordnungsregion*), inter-regionally (with partners from Baden-Württemberg) as well as with partners from outside the regional system (from Germany or even from abroad) and thus actively integrate extra-regional knowledge into the RIS of Baden-Württemberg. Knowledge-oriented R&D partners are predominantly found regionally whereas market-oriented research partners predominantly come from outside the region and are found in the national context or even internationally.

Summarising the findings from this section, it can be concluded that the RIS of Baden-Württemberg does not suffer from lock-in effects, since even enterprises in core technology oriented economic sectors practice their R&D activities in partnerships with partners from within the region but also with partners from outside the region.

9.5.4 Intra-regional distribution of competencies

This section addresses Hypothesis 3 and assesses whether intra-regional competencies enable a routinised innovation system like Baden-Württemberg to adapt flexibly to specific market demands and technological change as a whole. To cover competen-

Figure 9–2: Reach of R&D co-cooperations of enterprises in Baden-Württemberg



Source: Fraunhofer ISI enterprise survey (market-oriented partners: customers, suppliers, other enterprises, knowledge-oriented partners: universities, universities of applied sciences, research institutes and R&D service providers)

cies and technological strengths, the following analysis draws on employment data in knowledge-intensive industries, on the one hand, and on patent applications data on the other.

The following Table 9–7 provides an aggregated overview on employment strengths in knowledge-intensive manufacturing and in knowledge-intensive services. The industries are analysed at 2-digit NACE code level. The classification is based on the list of knowledge and technology products and industries by NIW, Fraunhofer ISI and ZEW (Gehrke 2010). Seven industries are grouped together in knowledge-intensive manufacturing, while knowledge-intensive services are comprised of 19 industries.

As becomes clear, that with regard to knowledge-intensive manufacturing, Baden-Württemberg clearly exceeds the German share. However, within Baden-Württemberg, there are six regions which have particularly high shares. These regions are located around Stuttgart and in southern Baden-Württemberg around Lake Constance and in the south-eastern part of the Black Forest. With regard to strengths in service industries, only three regions around the main cities – Stuttgart, Mannheim and Karlsruhe – are above average.

Table 9–7: Employment shares on total employment 2010 in %

Region Stuttgart	Region Heilbronn-Franken	Region Ostwürttemberg	Region Mittlerer Oberrhein	Region Rhein-Neckar	Region Nordschwarzwald	Region Südlicher Oberrhein	Region Schwarzwald-Baar-Heuberg	Region Hochrhein-Bodensee	Region Neckar-Alb	Region Donau-Iller	Region Bodensee-Oberschwaben	Baden-Württemberg	Germany
Share of knowledge-intensive manufacturing industries													
19.8	19.8	23.3	14.6	14.8	16.4	10.9	18.9	14.7	16.5	20.8	19.9	17.5	10.9
Share of knowledge-intensive service industries													
23.6	15.6	13.1	23.4	25.7	14.2	19.2	13.7	16.2	18.3	17.2	16.5	20.0	20.0
Share of knowledge-intensive manufacturing and service industries													
43.4	35.4	36.4	38.0	40.4	30.6	30.1	32.6	30.9	34.8	38.0	36.3	37.5	30.9

Source: statistical data from Bundesagentur für Arbeit (Federal Employment Agency)

Looking at particular strengths is necessary to improve the understanding of spatial patterns in Baden-Württemberg. Specialisation measures like the location quotient help to reveal relative strengths. In this case, Germany was taken as the reference area. The data indicate that more differentiated spatial patterns emerge when taking a closer look. For example, with regard to the manufacture of chemicals and chemical products, the regions Mittlerer Oberrhein, Rhein-Neckar and Hochrhein-Bodensee show a specialisation. Pharmaceuticals are produced in the regions Ostwürttemberg, Rhein-Neckar, Hochrhein-Bodensee and Donau-Iller. It is interesting to note that the employment shares of manufacture of machinery and equipment are higher than the national average in all but one region (the exception is Mittlerer Oberrhein). But, as the shares are generally high, only in one region the location quotient indicates a specialisation (Bodensee-Oberschwaben). A similar picture emerges with regard to the manufacture of motor vehicles. Although in this industry six regions have employment shares above the national average, it is only the region of Stuttgart that has a high specialisation indicator. In contrast, the manufacture of other transport equipment is concentrated mainly in the regions Donau-Iller and Bodensee-Oberschwaben.

With regard to knowledge-intensive services, the three regions with the biggest cities – the regions Stuttgart, Mittlerer Oberrhein and Rhein-Neckar – dominate. But, in addition, some regions are also specialised in certain service activities. For example, the region Donau-Iller is specialised in telecommunications. Apart from the region Mittlerer-Oberrhein, also Ostwürttemberg is specialised in information

Figure 9–3: Technological specialisation in Baden-Württemberg's regions

Source: own illustration

service activities while computer programming, consultancy and related activities are mainly concentrated in the regions Mittlerer Oberrhein and Rhein-Neckar.

Different patterns of technological capabilities are also reflected in distinct patent application activities. The following map is based on the Fraunhofer ISI patent classification in 19 technological fields covering all patent applications (cf. Figure 9–3). For each region, specialisation indicators were calculated. The map depicts only those technological fields for which the specialisation value is positive and, in addition, greater than the values of Germany and Baden-Württemberg. Among the 19 technological fields within Baden-Württemberg, there are three in which no region is specialised. These are basic chemicals, pharmaceuticals and telecommunication.

Metal products is the technological field in which most regions are specialised. As can be seen, those regions are in addition mostly specialised in general machinery and/or machine-tools as well. Only two regions are specialised in transport, i.e. vehicles. As discussed above, the reason may be that those two regions dominate the average in such a way that no other region reaches the threshold even if absolute values might be high as well. Technological fields like computers, office machinery, audio-visual electronics and optics are only visible in one region at a time.

As becomes clear, Baden-Württemberg has not only several technological strongholds, but rather than being concentrated in one spot or evenly distributed in space, spatial patterns of distinct capabilities emerge. These can be regarded as a form of spatial division of labour building, a form of related variety which facilitates the reshaping of traditional industries.

9.6 Summary and conclusions

To summarise the empirical findings and conclude vis-à-vis the delineation of Baden-Württemberg's emergence in the former literature of regional innovation systems, this section critically assesses the empirical findings along the research guiding hypotheses before reaching an overall conclusion.

Concerning *Hypothesis 1*, we conclude that the innovation system of Baden-Württemberg despite its routinised structures allows the diffusion of technologies beyond the experience-based paths. Hypothesis 1 thus can be falsified according to the empirical evidence. Core technology oriented economic sectors, new technology oriented economic sectors as well as enterprises from other sectors adopt and develop technology besides traditional areas.

Based on the empirical analyses, *Hypothesis 2* can also be falsified. The RIS of Baden-Württemberg does not show particular signs of a lock-in situation, neither in the core technology oriented economic sectors nor in other sectors of the regional economy. However, differences in the adoption of technologies prevail between the different sectors of the regional economy. Intra-regional as well as extra-regional sources of knowledge are used to enlarge the regional knowledge base and to circulate this knowledge within the region.

Finally, we were able to show that the innovation system of Baden-Württemberg is indeed characterised by intra-regional economic and technological competencies.

Such a setting helps enterprises to flexibly adapt to specific market demands and technological change as a whole. It offers intra-regional cooperation potentials when seeking particular economic resources and technological competences. Consequently, *Hypothesis 3* thus could not be falsified.

To summarise the empirical findings and relate them to former descriptions of the RIS of Baden-Württemberg, it can be stated that Baden-Württemberg has maintained its economic success despite the routinised structures of its regional innovations system. Moreover, the region has managed to develop strong, new technology oriented economic sectors that complement the traditional core branches of the regional economy and which are even able to cross-fertilize each other as our empirical analyses show. Thus, the conclusions by Krauss (2009) can be enlarged in such direction that the RIS of Baden-Württemberg has already managed the reorganisation of its traditional economic structure and displays many features of a successful and well-functioning RIS, characterised by functioning regional dynamics, due to intra-regional division of competencies, networks structures apt for knowledge exploitation, and both intraregional and extra-regional linkages to other knowledge and innovation systems.

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