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INNOVATION SYSTEM REVISITED

EXPERIENCES FROM 40 YEARS OF FRAUNHOFER ISI RESEARCH

40

FRAUNHOFER VERLAG

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Imprint

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PREFACE

We are taking the occasion of Fraunhofer ISI's foundation 40 years ago to look back over four decades of successful innovation research and advice to clients from politics and industry. It is one of Fraunhofer ISI's key characteristics that "systems research" is already part of its name, and that it adopted a systemic perspective right from the outset. Innovations only very rarely result from the efforts of one individual; usually they emerge due to the cooperation of many actors from different organisational, social and cultural contexts. The Fraunhofer ISI has contributed to a better understanding of the complexity of innovation processes by applying a systemic perspective in its diverse studies of technologies, sectors, nations and regions and has thus helped to strengthen the theoretical foundations of such processes.

This book addresses academics and political and industrial decision-makers, and aims to offer an overview of current analyses which deal with the systemic research approach from different perspectives or use this as the basis for analysis. On Fraunhofer ISI's 40th anniversary, this book demonstrates the wide diversity of topics on which researchers at the institute have been working in this thematic context. Alongside an introduction to the topic and conceptual and methodological aspects, the different approaches of the innovation system concept are addressed with regard to national, technological, industrial and regional studies, as are questions of public governance. This has resulted in a wide range of contributions which make it clear just how far-reaching Fraunhofer ISI's research spectrum is in this thematic field.

We would like to thank all our clients from politics and industry, our partners and academic colleagues for the major impetus they gave to our research, without which the articles in this book would not have been possible. We also express our thanks to the Innovation System Task Force at the Fraunhofer ISI for helping to prepare the concept for this book, to the authors for their contributions and to everyone involved in compiling this publication.

Prof. Marion A. Weissenberger-Eibl
Director of the Institute

Dr. Harald Hiessl
Deputy Director of the Institute

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FRAUNHOFER ISI'S SYSTEMIC RESEARCH PERSPECTIVE IN THE CONTEXT OF INNOVATION SYSTEMS

KNUT KOSCHATZKY

1.1 Looking back: origins of the systemic perspective

Back in the year 1972, when the Fraunhofer Institute for Systems and Innovation Research ISI (Fraunhofer ISI) was founded, its founding father and first director, Helmar Krupp, published a study entitled "The function of the Fraunhofer Society in the Innovation System of the Federal Republic of Germany". In this study he painted a picture of the research and innovation landscape of Germany by describing the "subjects" individuals, teams, education, industry, public R&D organisations, financial system, public authorities, and international organisations (Krupp 1972, p. 36). With regard to the role of the Fraunhofer Society (FhG) in the West German innovation system he concluded: "Such an innovation system provides the framework within which the exact location of the FhG can be determined. Each objective of the FhG should assume that it contributes to applied research to structure the innovation system in the area between research and society, and show the form in which that could happen. Conversely, the innovation system provides efficiency criteria" (translation of Krupp 1972, p. 36). He expanded this view by stating "this scheme illuminates the diversity and complexity of transfer processes, the communication graphs, which contribute to innovation systems" (ibid., p. 36). It can thus be concluded from his orientation towards a national model of innovation that, since the beginning, Fraunhofer ISI has been following a systemic innovation research perspective.[1] At a time when the concept of national innovation systems had not yet been developed in the way it is understood today, a similar perspective was introduced by Helmar Krupp and applied to the German situation. This is one of the examples of the pioneering work of Fraunhofer ISI and its contributions to the scientific advancement of innovation research and innovation policy research.[2]

Many of the facts which are commonly understood today were either new or had not yet been discovered in the 1960s and early 1970s. In 1966, Jacob Schmookler published his seminal book on "Invention and Economic Growth" (Schmookler 1966). Contrary to the economic mainstream, which built on the work of Joseph Schumpeter as the representative of a supply-driven innovation approach, by using empirical data Schmookler discovered that there is a high correlation between the investments in new products and patent intensity and concluded that innovation activity and demand behaviour are closely related. Increases in investments occur earlier than increases in patenting. While "[…] most economists have traditionally regarded business firms and government as the prime sources of dynamic happenings, […] demand factors may also prove the most common cause of the invention of a radically new product […]" (Schmookler 1966, pp. 179, 204).

Regarding the question whether innovations are supply- or demand-induced, Schmookler's work is often used as a contraposition to Schumpeter (cf. Coombs et al. 1987, p. 96). According to Schmookler, changes in demand strongly influence technological development and the differentiation of economic activities (cf. Grupp 1998, p. 80). The major value of his research is the fact that he understands the process of invention not only as a technical and scientific supply phenomenon, but emphasises on the influence of the demand side (Schmookler 1966, p. 183). The subsequent discussions of both approaches have led to the consensus that both "technology push" and "demand pull" in mutual interaction can be driving forces in the innovation process (cf. Kromphardt and Teschner 1986, p. 237).

This aspect is important as, during the early 1970s, at least as can be seen in the publication by Helmar Krupp, innovative activity was regarded as a mainly technical process where the management of a company could predetermine the areas and directions of innovation. Furthermore, innovations were assumed to be generated

1 In this contribution, innovation as the central constituent of the innovation system approach is defined as an interactive process of the transformation of information, implicit and explicit knowledge into new products, processes, organisational and social behaviours and structures. Innovation processes can be incremental or radical, they have technological, organisational and social character, and they are context specific, because socio-cultural factors significantly influence the ability, kind and intensity of interactions between the different actors in the innovation process and the learning processes between them (Koschatzky 2001, p. 62).

2 Fagerberg and Sapprasert (2011, p. 673) wrote: "Although Freeman was the first to use the term in a publication, he was quick to point out that: 'according to this author's recollections, the first person to use the expression "National Systems of Innovation" was Bengt-Åke Lundvall (Freeman 1995, p. 5)'". It should not be discussed here who was the first to use the term, but there is no doubt that Helmar Krupp was one of the first.

by a chain of mainly rational decisions, and research and development plays a predominant role. This view is reflected by a reference Helmar Krupp made to an OECD publication in 1971 titled "The Conditions for Success in Technological Innovation" (OECD 1971). The OECD publication is a good indication of the understanding of innovation processes at that time and the need to improve both theoretical and empirical knowledge in innovation economics and innovation research.

The first empirical studies analysing innovation characteristics and innovation differences at the industry level were carried out in the late 1960s. One of the most prominent studies was the SAPPHO project, in which 43 pairs of both successful and unsuccessful innovations in the chemical industry and the manufacture of scientific instruments were analysed regarding their success and failure factors (cf. Freeman et al. 1971; Rothwell et al. 1974). It turned out that successful technological development depends on a thorough knowledge of user needs and conditions of use, coordination of the development, production and marketing activities in the company, incorporating external information and advisory services for science and technology, basic research in the company in cooperation with external research institutions (e.g. universities). This shows that, as early as the 1960s and 1970s, it was assumed that innovation cannot be carried out in isolation, but is supported by an interactive environment.

Hence, interactivity and linearity were the main inputs to the first systemic models of the structure and components of (technological) innovation processes. In his study published in 1972, Helmar Krupp not only used the term "innovation system", but also described a model developed by Mottur (1968) which integrates the linear innovation process in an environment formed and influenced by the socio-economic system (e.g. programmes, projects, policies) and the science and engineering educational system (science and engineering knowledge, technological-industrial knowledge). Feedback loops already existed then as well as the use of technological innovations as an important feedback channel (cf. Figure 1–1).

This systems model and its description of the different functions and interactions shows parallels with the chain-linked model published by Kline and Rosenberg in 1986 (Kline and Rosenberg 1986), although this later model is more focused on the innovation process itself, while the Mottur model connects innovation with higher systemic frameworks like the economic or educational system.

1.2 Innovation systems – different perspectives

Nevertheless, the dominant paradigm in both technology transfer and innovation was the linear model. According to this view, the innovation process consists of a sequence of individual stages, ranging from idea generation, research, development, to production and marketing, which usually have little or no overlap and which form discrete and distinguishable units (cf. Kay 1979; 1988). In the understanding of this sequence, marketing an innovation is followed by its diffusion, where the latter can occur either through imitation or adoption (cf. Davies 1979, Metcalfe 1981).

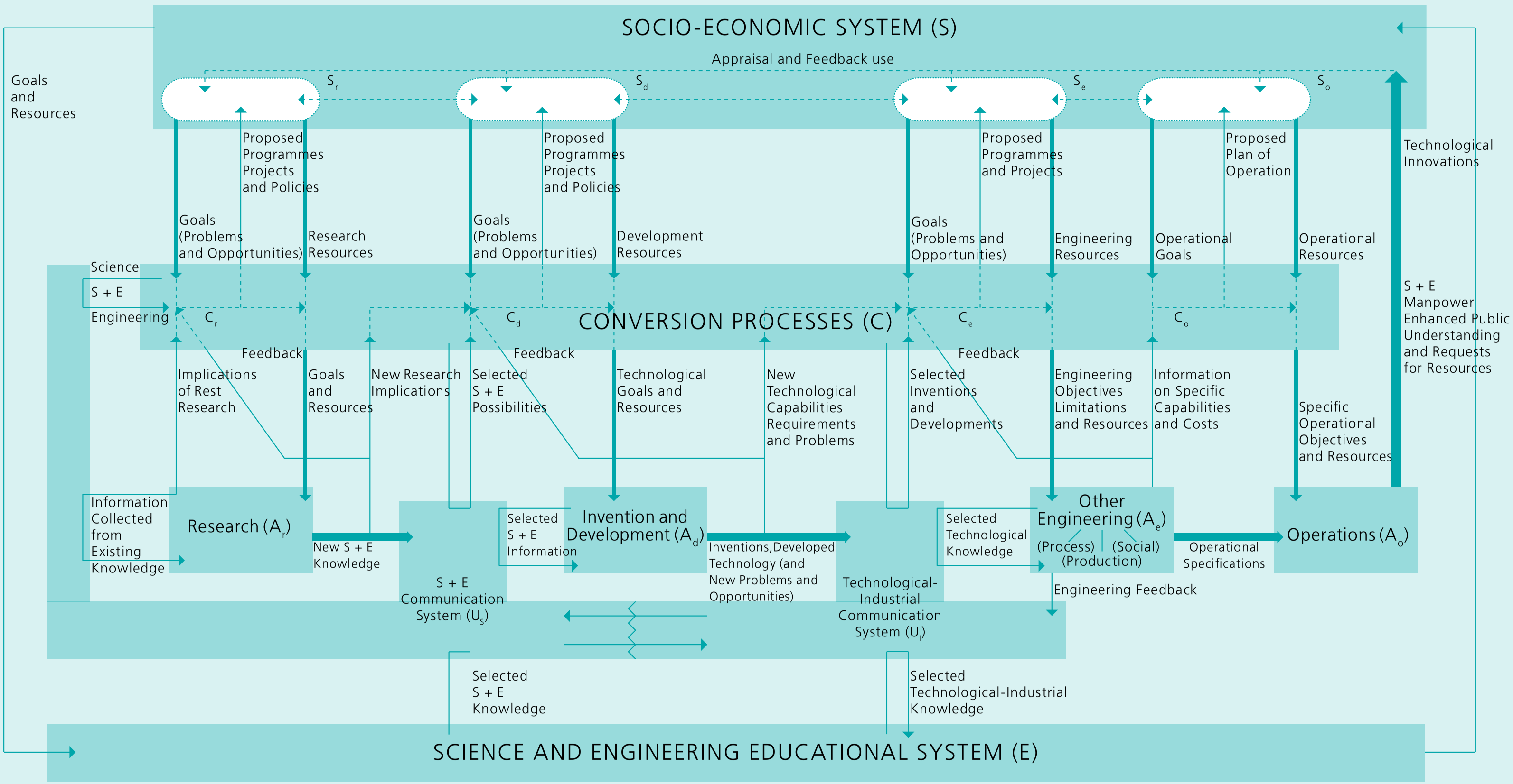
Two generations of linear models can be distinguished (Rothwell 1992; 1993; 1994):
- the "first generation: technology push" models of the 1960s, which emanate from a technology-driven innovation activity and
- the "second generation: need-pull" models of the 1970s (e.g. Utterback 1974), which regard innovation as a result of market and demand-induced R&D activities

Although the first foundations had already been laid in the 1960s, system approaches in innovation research gained considerable importance during the 1970s and 1980s due to clear insights into the economics of innovation (e.g. in terms of the innovation patterns of SMEs, the importance of technological trajectories, the cumulative character of technological change), and the development of new ideas about the complexity and non-linearity of innovation processes (cf. Nelson and Winter 1977; Freeman 1982; Dosi 1982; 1988). Based on the ideas of Friedrich List about the German national transport system and the national system of political economy (List 1838; 1841), which, among other aspects, dealt with the optimisation of production and the development of national infrastructure and institutions, Christopher Freeman developed the concept of a "national system of innovation" (Freeman 1987). He developed List's idea further by considering it necessary that the national government promotes the technological infrastructure of a country.[3] He assumes that short-term strategies (such as wage or exchange rate changes), however, have only limited effects on strengthening the international competitiveness of an economy.

The most important characteristics of systems of innovation are summarised in the definition by Edquist, who wrote that innovation systems are defined by "[…] all important economic, social, political, organisational, institutional, and other factors that influence the development, diffusion, and use of innovation" (Edquist 2005, p. 182). During the late 1980s and especially during the 1990s, complex analyses of the national framework conditions for technology development and diffusion, technical change, and innovation and learning were carried out (e.g. Dosi et al. 1988). Lundvall (1992), for example, made important additional contributions to the theoretical advancement of the concept. The major focus lay on the institutional set-up defined by national boundaries and the interaction processes which influence the innovation actors and which stimulate learning processes. According to him "[…] a system of innovation is constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge and […] encompasses elements and relationships, either located within or rooted inside the borders of a nation state" (Lundvall 1992a, p. 2). Significant subsystems that both influence and include learning, searching and exploring are the production system, the marketing system and the financial system (ibid., p. 12). With regard to learning and innovation, two influencing factors, whose framework is set by the nation-state, play an important

3 Freeman emphasised the role of List by stating that "List's book on 'The National System of Political Economy' might just as well have been entitled 'The National System of Innovation' since he anticipated many of the concerns of this contemporary literature" (Freeman 2002, p. 193).

Figure 1–1: The process of technological innovation



r = research d = invention and development e = other engineering o = operations s = Science and engineering i = Technological-industrial

Source: adapted from Mottur (1968, p. 124) role, namely a common cultural background and the institutional structure. Spatial and cultural proximity promote learning and exchange processes (Schmoch et al. 1996, p. 125). As a matter of fact, social and cultural factors influence the successful implementation of innovation processes. The institutions of a country also reduce innovation- and market-related uncertainties (Lundvall 1992a, p. 10).

Nelson and Rosenberg (1993, pp. 4–5) split the term national innovation system into its three components and define innovation as a process which puts the company in a position to manufacture products and manage production processes that are new to it, to the country or even to the world. System is understood as a set of institutions whose interactions influence the innovation performance of the national companies. The system does not have to have been fully developed, nor do the institutions have to work together in a smooth and coordinated way. Regarding the term "nation", Nelson and Rosenberg point out that even within nations the institutional structures in different technology fields differ significantly from each other and that the common denominator of these institutions is their transnational rather than their national orientation.[4] This raises the question whether the concept of a national innovation system makes any sense at all. The answer is that, despite international technology development and diffusion, institutional and cultural factors have a specific national expression and can significantly influence technological change. These influences are stronger or weaker depending on the size of a country and the globalism of techno-economic systems, and still justify the use of the nation state as the unit of analysis, although transnational innovation systems and their effects on national innovation policies should not be excluded (Nelson and Rosenberg 1993, p. 16).

While this discussion has anticipated the recent debate about the appropriateness and relevance of a national concept in a globalised world (e.g. Freeman 2002; Carlsson 2006), it also stimulated the development of innovation system approaches at two other ends of the spectrum: the sectoral/technological and the regional dimensions. In all of these specific forms of innovation systems, the delimiting factors are sectors, technological fields or spatial entities below the national level. Technological innovation systems are defined "[...] in terms of knowledge/competence flows rather than flows of ordinary goods and services. They consist of dynamic knowledge and competence networks. In the presence of an entrepreneur and sufficient critical mass, such networks can be transformed into development blocks, i.e. synergistic clusters of firms and technologies within an industry or a group of industries" (Carlsson and Stankiewicz 1991, p. 111). A sectoral innovation system is a "group of firms active in developing and making a sector's products and in generating and utilizing a sector's technologies" (Breschi and Malerba 1997, p. 131). Malerba's (2002, p. 250) definition is "a set of new and established products for specific uses and the set of agents carrying

4 "The system of institutions supporting technical innovation in one field, say pharmaceuticals, may have very little overlap with the system of institutions supporting innovations in another field, say aircraft. On the other hand, in many fields of technology, including both pharmaceuticals and aircraft, a number of the institutions are or act transnational" (Nelson and Rosenberg 1993, p. 5).

out market and non-market interactions for the creation, production and sale of these products". According to Malerba (2002, pp. 250–251) the basic elements of sectoral systems are products, agents (firms, universities, financial institutions, central government, local authorities, individuals), knowledge and learning processes (differentiation across sectors, impacts on innovative activities, organisation and the behaviour of firms and other agents), basic technologies, inputs, demand, and the related links and complementarities, mechanisms of interactions both within firms and outside firms, processes of competition and selection, and institutions (such as standards, regulations, labour markets). The sectoral innovation system thus focuses specifically on the framework conditions in a particular industry. It consists of a knowledge base, technologies, inputs, and an existing, emergent and potential demand. The concept emphasises that actors belonging to a certain sector have sector-specific knowledge and use sector-specific technologies, and that market relations, the institutional context, actors' behaviour, etc. are specific to these sectors.

The concept of regional innovation systems, developed by Cooke (1992), is based on the notion of localised knowledge and the specific endowment of regions with institutions, organisations, and networks which influence the generation and diffusion of innovations. A regional innovation system is therefore "[…] typically understood to be a set of interacting private and public interests, formal institutions, and other organizations that function according to organizational and institutional arrangements and relationships conducive to the generation, use, and dissemination of knowledge" (Doloreux and Parto 2005, pp. 134–135). Regional systems respond to different rationales, institutional and governance settings which can be found at the sub-national territorial level and are thus context-specific. It is a distinct element of the concept that a region does not offer all the factors and institutions necessary for innovation, but that it is part of a superior, i.e. national system, and has to cooperate with other regional or national systems in order to merge all the necessary resources in the specific territory (Cooke et al. 2004; Asheim and Gertler 2005).

All these studies are a reflection of an evolutionary innovation perspective, according to which innovation is not a homogeneous process, but exhibits technological and socio-cultural peculiarities which can, in turn, be of a national, regional, and also international nature.[5] Due to the diminishing influence of nation states on multi-national enterprises operating from their territory (Dunning 1988), and the transnational and transcontinental character of new technologies,[6] the specific assets of countries and their potential as competitive scientific-technological locations become the centre of interest (cf. Koschatzky 2001). In this context, it was underlined by Michael Porter that the national environment and the home base of companies is an

5 "Processes of innovation transcend national borders and sometimes they are local rather than national" (Lundvall 1992a, p. 4).

6 "There is good reason to believe that in recent years, just as the idea of national innovation systems has become widely accepted, technological communities have become transnational as never before" (Nelson and Rosenberg 1993, p. 17).

important condition for globalisation processes.[7] On the one hand, national supply conditions of human capital and R&D infrastructure as well as the general location conditions affect the competitiveness of enterprises, while, on the other hand, the home market of at least the major economies is an important test market to improve the product attributes and thus to facilitate the entry into other markets (Porter 1990, pp. 63–64). While a national or a regional innovation system can easily be defined by national or regional geographical boundaries, and more recently, also by the degree of stickiness and the kind of knowledge base and its relation to proximity (Asheim and Gertler 2005, p. 310), the definition of a sectoral innovation system depends on sectoral delimitations which can be applied at different levels of granularity (e.g. the two, three or four digit level of industrial branch classifications). Technological innovation systems are even more difficult to define, because there is no commonly accepted definition of certain technologies. Technological innovation systems are therefore more difficult to grasp. Nevertheless, the advantage of this heuristic concept compared to spatial or sectoral innovation systems is that it contains the inherent aspect of a dynamic component. Technological systems not only incorporate parts of national, sectoral or regional systems, but include the dynamic dimension of technological change. While a major criticism of the innovation system concept, its static character, mainly applies to national, regional and sectoral approaches, the dynamic characteristic of technological systems makes this concept the basis for recent advancements in technological innovation systems (Hekkert et al. 2007). This new line of discussion shows that technological innovation systems follow different rationales compared to their spatial or sectoral counterparts. Some of the new ideas will be discussed later in this chapter.

1.3 Central characteristics and heuristic concepts of innovation systems

Components and relations

Although some definitions of innovation systems have already been presented, the general characteristics of a "system" still need to be discussed. With reference to Ingelstamm, Edquist points out that "a system consists of two kinds of constituents: There are, first, some kinds of components and, second, relations among them". Besides, "the system has a function, i.e. it is performing or achieving something." And, the third aspect is, "it must be possible to discriminate between the system and the rest

7 "The role of the home nation seems to be as strong as or stronger than ever. While globalization of competition might appear to make the nation less important, instead it seems to make it more so. With fewer impediments to trade to shelter uncompetitive domestic firms and industries, the home nation takes on growing significance because it is the source of the skills and technology that underpin competitive advantage" (Porter 1990, p. 19).
Globalisation and regionalisation are not a contradiction, but parallel processes: "[…] regionalisation is a tendency taking place parallel to globalisation. The regionalisation perspective further represents an alternative development model for local industrial development, with clear implications for what are important tools in local level policy" (Isaksen 1998, p. 40).

of the world" (Edquist 2005, p. 187). So the system must be specific and identifiable.

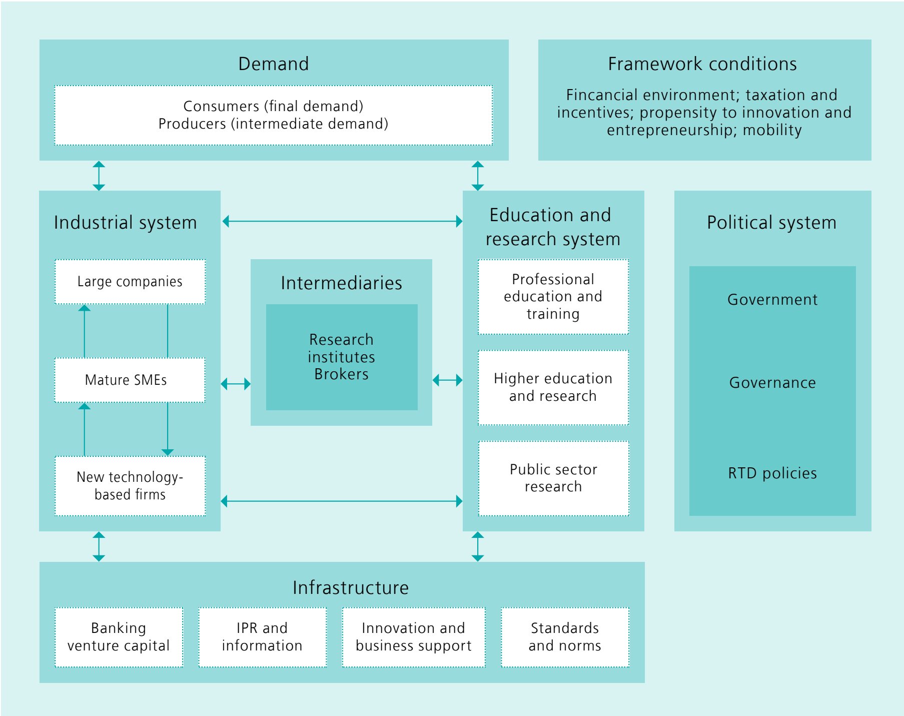
The components consist of a bundle of organisational actors and actor groups and institutional rules defining the "rules of the game". Both actors and rules have a pertinent function for the success of innovative efforts (ibid., p. 186). According to Nelson (1993, pp. 517–520) and Patel and Pavitt (1994), innovation systems are made up of four main elements:

1. The institutional structures of a country, region or sector: they are formed by companies, universities, research and training organisations, norms, routines, networks, financial organisations, and the policy of promoting and regulating technical change.
2. The incentive system of a country, region or sector. This includes, among others, incentive systems for innovation, technology transfer, learning and qualification, business formation and job mobility within and between organisations.
3. The skills and creativity of innovation and economic actors in a country, region or sector. Both between and within countries and between companies in a country there are great differences in the diversity and quality of products and services and opportunities to forge new paths of development.
4. The cultural peculiarities of a country, region or within a sector which are reflected, for example, in the different acceptance and user understanding of technologies.

These central characteristics form the basis of different interpretations of innovation systems and are usually adapted according to specific application needs. In many cases, heuristic models of innovation systems are built around the general institutional structures of countries, regions or sectors. One example of an innovation system model often used and extended in studies by Fraunhofer ISI is that developed by Kuhlmann and Arnold (2001) in their study on the role of the research Council Norway in the Norwegian innovation system (cf. Figure 1–2). This model focuses on the two main sub-systems industry and education/research, and links them through the active role of intermediary organisations. These sub-systems are influenced by and themselves influence the demand system, the framework conditions and the existing infrastructure system, and are shaped by the political system.

As already pointed out, not only the amount, quality and composition of organisational actors matter, but also the content, intensity and quality of their relations. Interactions and networks as a specific form of transactions are additional, important features of an innovation system. Both interactions and networks can take different characteristics and are described in the extensive literature on network economics and innovation networks (for an overview, see Liefner and Schätzl 2012, pp. 135–142; Koschatzky 2001, pp. 133–155). A classical feature is the distinction between strong and weak ties. Strong ties to one or only a few partners are characteristic for production-oriented networks, where larger companies bind suppliers closely to them, or for cooperations in which the number of potential partners is limited a priori. According to Granovetter (1973; 1982), the strength of relationships depends on the effort that is required for their upkeep.

Figure 1–2: Heuristic model of an innovation system



Source: adapted from Kuhlmann and Arnold (2001, p. 2)

The weaker the effort made in the fostering of relations, the weaker is the binding intensity, but the higher the number of possible contacts. In terms of innovation-relevant relationships, "strong ties" limit the number of potential partners and potential diffusion channels for information and innovation. Granovetter argues that "weak ties" bridge social distances more easily and thus allow easier contacts to a larger number of partners than is possible by "strong ties" (an effect called "loose coupling" by Weick 1976). So there is wider access to information and a greater choice of diverse knowledge sources. For innovation networks this means that "weak ties" reduce the risk of dependencies on individual partners, but at the cost of the increased risk of opportunistic behaviour, because, in soft relationships, sanctions for violating the rules of the game are hardly effective because of the variety of available options.

Besides the strength of ties, their purpose and content are also relevant features. Not only information can be transferred via collaborative ties between different actors and organisations, but also knowledge in its different forms (e.g. implicit or tacit and explicit or codified knowledge, knowledge about facts ("know-what"), about natural laws and social principles ("know-why"), about abilities ("know-how"), and knowledge about those who know how to do things ("know-who"), synthetic knowledge related to engineering know-how, or analytical knowledge related to scientific know-why; cf. Nonaka 1994; Foray and Lundvall 1996; Asheim and Coenen 2005). In cases where highly valuable (and competitive) tacit analytical knowledge is exchanged in (parts of) innovation systems and utilised in innovation projects, it can be assumed that the output of the innovation system differs positively from others in which this kind of knowledge is not subject to collaborative ties.

A specific role of "relation" affects the exchange of the political system with the other sub-systems. It is expected that the political system plays an active role in shaping the whole innovation system, in making it coherent and in developing it further. Nevertheless, its politics do not act in isolation, but are simultaneously influenced by the other sub-systems in an interactive way. This role (or function) within an innovation system makes the model so popular in the political field. It not only provides a good overview of the main fields of innovative activity, but attributes an active governance function to the political system. The basic assumption of the innovation system concept is that the growth and competitiveness of a given economic unit (country, region or sector) is determined by the networking and innovative abilities of its companies. These abilities as well as the supporting infrastructure can be influenced by the public administration (political system) by promoting the interaction, networking and learning between the different sub-systems and their actors (Storper and Scott 1995, pp. 513–518). This support (or intervention) does not improve only the intensity of linkages, but also their quality and their output and, in sum, the innovation system itself. In cases of system fragmentation, the inherent message of the innovation system approach is therefore that an intensification of collaboration within and between the sub-systems can mobilise new learning potentials and thus increase creativity and innovative output. Besides this general message, the concept does not provide indepth recommendations for specific policy instruments and programmes. Nevertheless, using the regional innovation system approach as an example, five steps are recommended in order to stimulate network mobilisation (cf. Cooke 1996, p. 168; Koschatzky 2001, p. 179):

1. Identification and involvement of actors ("stakeholders") who are committed to bringing in financial and human resources. These can be individuals or organisations of the innovation infrastructure.
2. Formulation of an innovation strategy based on an analysis of the supply of innovation-supporting services and the implicit and explicit demand of the companies.
3. Setting of standards and promotion of continuous quality improvement, both in production and research.
4. Sectoral focus of the measures in order to achieve largest possible effects with limited resources.
5. Development of skills for the development and management of networks and for innovation support.

These steps are far from being precisely formulated policy measures, but aim to illustrate that the governance dimension is also discussed in the innovation system literature (cf. for example Uyarra 2010 with regard to regional policy). This discussion also addresses the question whether public intervention is justified by either system or market failures (Woolthuis et al. 2005; Dobrinsky 2009). The argument is that, for example, systemic insufficiencies like path dependencies, missing abilities to adapt to new technological paradigms, or deficiencies in regulatory frameworks or social institutions justify the use of innovation policy instruments.

Functions

The analysis and understanding of innovation systems is not only directed towards their organisational actors and the interactions between them, but also towards the functions the actors and the whole system fulfil. The major function of the innovation system itself is to stimulate innovation and increase the innovative output in order to secure and increase employment and social and economic wealth. The literature on innovation systems provides a broad set of functions which a system should accomplish. Edquist (2005, pp. 190–191) lists the following ten functions (which he calls activities): (1) provision of research and development (R&D) and creating new knowledge, (2) competence building like the provision of education and training and human capital creation, (3) formation of new product markets, (4) articulation of quality requirements, (5) creating and changing organisations relevant for innovation, (6) networking including interactive learning, (7) creating and changing institutions that influence innovating organisations and innovation processes, (8) incubating activities, (9) financing of innovation processes and facilitating the commercialisation of knowledge, (10) provision of consultancy services relevant for innovation processes. These activities are not equally important in all innovation systems, but their relevance varies according to the kind of innovation system (national, sectoral etc.) and also over time.

According to Johnson (2001; cited in Hekkert et al. 2007, p. 419), innovation systems should fulfil eight functions: (1) supply incentives for companies to engage in innovative work, (2) supply resources (capital and competence), (3) guide the direction of search (influence the direction in which actors deploy resources), (4) recognise the potential for growth (identifying technological possibilities and economic viability), (5) facilitate the exchange of information and knowledge, (6) stimulate/create markets, (7) reduce social uncertainty (i.e. uncertainty about how others will act and react), (8) counteract the resistance to change that may arise in society when an innovation is introduced (provide legitimacy for the innovation). Hekkert et al. (2007, pp. 421–425) propose seven functions that can be applied to map key activities in innovation systems: (1) entrepreneurial activities, (2) knowledge development, (3) knowledge diffusion through networks, (4) guidance of the search, (5) market formation, (6) resource mobilisation, (7) creation of legitimacy/counteract resistance to change.

While the functions listed by Edquist seem to be closer to the "classical" understanding of the innovation system model (e.g. as described in Figure 1–2), both Johnson and Hekkert et al. have a less organisational view, but their functions are more related to a systemic model in which general characteristics of the innovation process are used to analyse the interactions among the functions and their impact on the economic output of the system, namely on entrepreneurial activities. Hekkert et al. (2007, p. 422) therefore state that "the presence of active entrepreneurs is a first and prime indication of the performance of an innovation system." Besides the entrepreneurial sector, their functions do not originate from the role of the other sub-systems of an innovation system, but are more superior in character. The function "guidance of the search", for example, can be seen as the sum of activities by different system components that "[...] positively affect the visibility and clarity of specific wants among technology users" (Hekkert et al. 2007, p. 423). Although the demand function was already included in the "classical" model, it was not included in the list of activities given by Edquist (2005). It is especially this aspect, together with the more socially/individually based functions of the reduction of social uncertainty and the counteraction of resistance to change that distinguish the understanding of these superior (or system inherent) functions from the general understanding of functions directly related to specific elements of an innovation system.

Besides these differences, this short review of the role of functions in and of innovation systems makes it clear that it is not only necessary to examine the organisational set-up and the linkages between the different organisations, but also to analyse the functions these organisations fulfil together with those functions that emerge from the different inherent features of contemporary innovation processes and the need to organise innovation processes in a competitive and sustainable manner.

Delimitations and openness of innovation systems

While at the national level there is generally no doubt that the organisational set-up and the interactions between the different stakeholders in innovation processes constitute the existence of an innovation system, this is much less clear when it comes to the level of regions (as sub-national entities) or sectors. The merit of the innovation systems approach is that the formulation of an analytical conceptual framework to analyse empirical evidence from individual case studies allows general conclusions to be drawn about the systemic elements of the innovation process. At both the regional and sectoral level, significantly higher diversity can be observed and the system concept is to be questioned far more than on the national level.[8] It therefore depends on empirical tests whether the respective unit of analysis (region, sector) meets the system criteria and whether it is possible to detect the central elements of the system and their interactions. In its general validity objective, the innovation system therefore describes ideal innovation systems and is thus a hypothesis which has to be tested for each individual case (Koschatzky 2001, p. 184). Not every region or sector is therefore an innovation system, and not all of these innovation systems can exist alone and independently of other innovation systems. Many smaller units fulfil either specialised functions in national innovation systems (regions, sectors) or in supranational settings (mainly sectors), without whose existence they would be not operational. This aspect of "landscape" was included in some of the more recent innovation system approaches (cf. Markard and Truffer 2008, p. 597). The openness of the "system" and

8 According to Cooke (1998, p. 17): "[...] very few regions have all the attributes of a RIS (regional innovation system) [...]". For the political implications cf. Tödtling and Trippl (2005).

its interrelations with other systems is of course not only a requirement for smaller units; nations and supra-national entities do not operate in isolation either (Carlsson 2006). Interfaces to other systems are therefore a fundamental requisite and have to be included in empirical analyses. The growing "leakiness" of innovation systems and their dependence on international developments has therefore become an important characteristic over the last few decades (ibid., p. 65).[9]

Synthesis of the elements of innovation systems

Taking the heuristic approach of innovation systems and their major constituents as a conceptual framework of analysis (Edquist 2005; Malerba 2002), Table 1–1 summarises all the elements which are classically considered to be important or constitutive for any innovation system and which can thus be subject to both spatial (national and regional) and sectoral/technological factors of influence (cf. Koschatzky et al. 2009).

While some aspects, such as the form of competition, are sectoral- or technological-specific, they can, of course, also be the result of the national or regional business culture. The impact of relevant policy measures, on the other hand, which is considered a spatial (national/regional) characteristic in many studies, is increasingly complemented by the influence of transnational, sector- or technology-specific policy frameworks, e.g. the Joint Programming Initiatives at the European level. While policies are designed from both sectorally focused and cross-sectoral perspectives, it depends to a high degree on the specific national/regional environment whether sectoral or cross-sectoral policies play a more decisive role on at the level of policy-making (transnational, national, regional) at which they are designed. For many other constitutive elements, such as agents and organisations, interactions, knowledge base, human capital, and institutions, the double and interrelated importance of sectoral and spatial specificities becomes even more evident from the examples given in Table 1–1. Even for the impact of technological trends, which is often given as a key argument for the high(er) importance of the sectoral approach, the multi-level framework concept of "niches" and the influence of regimes and the landscape show that technological developments can also be related to the "environmental" setting from which they emerge.

1.4 Reflections and critique

The criticisms regarding different aspects of the innovation system concept can be summarised as follows (cf. Bokelmann et al. 2012, pp. 32–33):

- The innovation system concept is a (normative) hypothesis. It describes how structures and interactive relationships are embodied in the ideal case. Whether the investigated case has all the attributes of an innovation system cannot be determined ex ante, but will be the result of the study itself.
- The systemic nature of innovation (which is however not universally given) is an essential feature of the concept, but a relation to value added chains within innovation systems is not postulated. Value added chains will have to evolve as a

9 The interdependencies of national, regional and international systems of innovation are discussed by Fromhold-Eisebith (2007).

Table 1–1: A sectoral-territorial approach to the analysis of innovation systems

Innovation System			
Elements	**Territorial dimension**		**Sectoral dimension**
	regional	**national**	**sector/technology field**
Agents and organisations	regional governance bodies, regional education institutions	national governance bodies, national education institutions, national IPR administration	MNEs, international standardisation bodies, international IPR administration, (international) branch associations
Interactions	local cross-sectoral networks	national cross-sectoral networks	international intra-MNE interactions, communities of practice
Knowledge base	localised tacit knowledge (specific, application-related, cross-sectoral)	codified knowledge (general, basic research related, cross-sectoral)	codified knowledge, tacit knowledge in intra-MNE networks, tacit knowledge communities of practice
Human capital	regional labour pool	national labour pool, mobility of labour force	specialised labour market, cross-sectoral mobility of labour force
Institutions	regional laws, regional governance	national laws and regulations, national governance	international treaties, international norms and standards
Policies	regional innovation policies, education policies	innovation policy, education policy	transnational ICT sector oriented policies and policies aiming at IT skills
Technologies and demand	regional laws on technology, regional acceptance of technology, regional buying power, regional demand caused by industry structure	national laws on technology, acceptance of technology in society, position to lead markets	factual trends in leading edge technology development
Competition and selection	regional economic characteristics: presence of competitors in the field, spirit of competition, entrepreneurial spirit, foundation aptitude	national economic characteristics: anti-trust legislation, bankruptcy legislation	sectoral specificities, firm size, position in product/service life cycle, mobility of product/service, degree of specialisation

Source: Koschatzky et al. (2009, pp. 8–9) based on Edquist (2005) and Malerba (2002) result of innovation processes, but are not related to the organisation of innovation processes (which are in the invention phase initially not value added oriented).

- Although the focus is on innovation, R&D is seen as a necessary requirement for the generation of innovations. The concept does not include a specific focus on or explanation of how innovations can be generated without inputs from the research sector, i.e. without formal R&D.
- Since no quantifiable thresholds exist from which interactive relationships sum up to an innovation system, there is wide scope for interpretation with respect to whether the object of study is an innovation system or not.
- Although the innovation system concept is based on theoretical and empirical evidence, it is in itself not a closed theory. It is a heuristic framework for the structural analysis and description of different innovation systems.
- A theoretical framework for the characteristics of different innovation systems does not exist. While the scientific basis is formed by the concept of national innovation systems, regional, sectoral or technological innovation systems are enhancements within the same conceptual framework. The assumptions that the casespecific environment influences the innovation patterns and that the innovation output can be improved by an intensification of the collaborative ties between the subsystems of an innovation system are essential for all facets of innovation systems.
- This aspect also describes the importance of public governance. According to the innovation system concept, it is the task of policy to create innovation-friendly conditions and the respective infrastructures, and to encourage networking between the different innovation actors (such as research collaborations, transfer bridges) so that diverse and successful interactions within and between the subsystems can develop which, in turn, increase the innovation output.
- Since the majority of analyses deal with territorial innovation systems at the national or regional level, models are quite similar regarding the institutional and organisational conditions in these territorial systems (cf. Figure 1–1). Different subsystems are identified, but only roughly outlined on the model level. It is up to empirical studies to fill these subsystems with content. Appropriate subsystems are borrowed for the analysis of sectoral innovation systems, but not explicitly offered.
- The concept allows static structural analyses and intertemporal comparison, as well as conclusions about the dynamics of the system. The concept itself is not dynamic. It represents a supply-oriented framework in which demand and user orientation play a certain, but not dominant role. Socio-cultural aspects are implicitly included, but only become visible by comparing different innovation systems. The concept also does not provide evidence regarding effectiveness in an innovation system. Interdependencies can only be determined by interpretation, but are themselves not included in the concept.
- Overall, the concept remains vague with regard to the specific conditions in each of the analysed cases. There is no detailed description of the required system components, especially regarding the different subsystems necessary. There is also no mandatory methodology for measuring the systemic characteristics of an

innovation system. Interactions are seen as a necessary condition, but how they should be designed and how they can be measured is not part of the concept.

– The concept of innovation systems as described above therefore provides only a rough orientation for empirical studies. The most relevant aspects, design of features and their measurement, are open questions which have to be answered by specific analyses. This fuzziness is a great weakness of the approach, but also makes it possible to flexibly adjust studies to the specific conditions of the object of analysis. The approach is therefore still popular and is also used in studies by Fraunhofer ISI as the different contributions in this book will show.

1.5 Recent interpretations of the innovation system approach

In recent years, not only the sustainability of an approach which highlights the role of nations in a globalised world has been questioned, but also its static character and the non-consideration of socio-cultural aspects and user demands in an environment in which these aspects are becoming more and more important. In recent contributions to this scientific debate, attempts have been made to develop multi-level conceptual frameworks for the comprehensive analysis of sectoral and technological innovation and for bridging the different territorial scales in innovation policies.

Major impulses arose primarily from the articles by Geels (2004), Hekkert et al. (2007) and Bergek et al. (2008). Important new elements are the multi-level perspective (MLP) defined by landscape, regimes and niches and the extension of sectoral innovation system approaches by integrating of a socio-technical system, the mission- and demand-oriented perspective as formulated by Geels (2004), the functional perspective of Hekkert et al. (2007) and Hekkert and Negro (2009) and the application of the functional approach in the context of technological innovation systems by Bergek et al. (2008).[10] As an attempt to merge the socio-cultural multi-level approach and the function-based technological system approach, the paper by Markard and Truffer (2008) argues that technological innovation systems must be complemented by the multi-level perspective with landscape, regimes and niches (see also Chapter 2 for a thorough discussion of this approach).

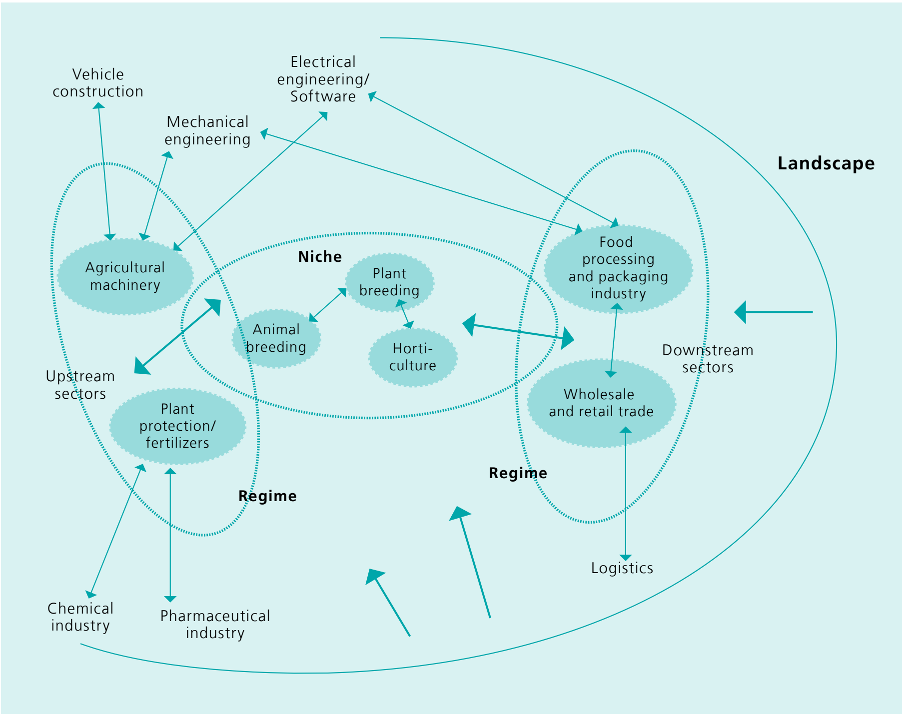
The landscape as the macro level "[…] includes a set of factors that influence innovation or transition processes but are hardly (or only in the long run) affected by themselves" (Markard and Truffer 2008, p. 603). A (socio-technical) regime is "[…] a coherent, highly interrelated and stable structure at the meso-level characterized by established products and technologies, stocks of knowledge, user practices, expectations, norms, regulations, etc. From the evolutionary perspective, a regime represents the selection environment for technological development in a certain field or sector, thus exerting a significant barrier for radical innovations to diffuse" (ibid., p. 603). The local level of innovation processes is defined by niches. They are "[…] commonly

10 Regarding the mission-orientation and the related demand perspective, e.g. by focusing on specific problems and user needs in the context of global challenges like demographic changes, poverty, energy consumption and environmental protection, reference can be made to the identification of the relevance of demand factors as impulses for innovations by Schmookler (1966).

referred to as protected spaces or incubation rooms, in which new technologies or socio-technical practices emerge and develop isolated from the selection pressures of 'normal' markets or regimes" (ibid., p. 605). Systemic change may occur through tensions in the socio-technical system, e.g. by changes in the landscape, and create windows of opportunities for inventions and innovations which subsequently create new regimes and foster the change of the system (cf. Geels 2004).

The multi-level perspective of innovation systems can be illustrated by applying this approach to the German agricultural socio-technical innovation system (cf. Figure 1–3).

Figure 1–3: Agricultural innovation in a multi-level perspective



Source: own draft according to Markard and Truffer (2008, p. 612)

The focal technological innovation system is composed of the three core elements of agriculture, namely plant breeding, animal breeding and horticulture, which are in themselves distinct niches with specific technologies and socio-technical practices (Bokelmann et al. 2012). Technological links exist, especially between plant breeding and horticulture, as well as between the two niches dealing with breeding technologies. Two dominant regimes exist on both the upstream and downstream side which strongly influence innovative activity and the use and diffusion of innovations in the agricultural core field. Two niches play the major role here: agricultural machinery and plant protection/fertilizers. They are not linked to each other but are closely linked to other sectors like vehicle construction, mechanical engineering and electrical engineering/software for machinery and the chemical and pharmaceutical industry for plant protection and fertilizers. Most of the agricultural technology is supplied by this upstream regime and innovation as such in agriculture is more oriented towards adaptation and efficiency improvements of these input technologies and less towards inventive activities. On the downstream side, weaker innovation impulses are generated by the food and the trade sector, because their focus is on further processing and product design rather than on input technologies for agricultural production (Menrad 2001). Overall linkages exist between mechanical and electrical engineering and the two upstream and downstream regimes via agricultural machinery and food processing and packaging machinery. The landscape can be defined by the demand for safe and cheap food, by agricultural and especially subsidy policies and by environmental and energy policies which have not only increased in importance over the last few years but which also reflect conflicts of interest in the use of farm land for food production, environmental protection and the production of biofuels.

These interdependencies between the different regimes and niches would not be as apparent if the classical sectoral innovation system model were used. The multi-level perspective allows conclusions to be drawn about dominant socio-technical regimes influencing innovation in the focal technological innovation system, in this case agriculture, and supports the empirical evidence that most of the new technologies and processes in agriculture are provided by the machinery and chemical industry. Systemic changes will therefore mainly be based on changes on the input side, on changes in the landscape and to a lesser extent on activities on the output processing side, and have to be responded to by the core agricultural production activities (cf. Bokelmann et al. 2012).

Besides these advantages, the multi-level perspective approach – at least at this level of analysis – includes functions and their interactions in order to understand technological change and innovation (Hekkert et. al 2007, p. 427), but does not provide insights into the organisational and institutional structures underlying and influencing niches, regimes and the landscape. These must be analytically determined for each case and cannot be built on a theoretical concept already incorporated into the multi-level innovation system perspective. This approach is therefore well suited to the analysis of individual technologies, but does not capture higher-level (policy) contexts. Due to the selective focus and complexity of multi-level structures, the results from this kind of analysis can be generalised only to a limited extent and are politically difficult to communicate.

1.6 Conclusions for innovation system analyses at Fraunhofer ISI

As explained in Section 1.1, Fraunhofer ISI was one of the first institutes to apply the systemic perspective in innovation research. During the last 40 years, many contributions have been made to advancements both in innovation economics theory and in empirical innovation research. The backbone of many studies was and still is the concept of innovation systems at the national, regional, sectoral and technological level. Advantages and disadvantages of the "classical" approach have been described in different parts of this chapter. A few years ago we started to discuss whether it is necessary to enhance the heuristic model we have been using for a long time and to create a new Fraunhofer ISI innovation system approach. After an intense debate we came to the conclusion that this is not necessary, because the different existing approaches provide a sufficient analytical basis and have to be used in a flexible and adapted manner.

One aspect in this respect is the combination of the classical approach with the new multi-level perspective when analytically necessary, depending on the objectives of the analysis. If institutions and organisations at different levels (national, regional, sectoral, technological) are the focus of a (comparative) analysis for which a common framework is necessary, and if an overall political context is to be identified and analysed, then the classical model is a worthwhile choice. If, however, the understanding of socio-technical frameworks, functions, interrelations and dynamics in a specific sector or technology is at the centre of analysis, then the new multi-level perspective approach can provide deep insights into the systemic structures of these sectors or technologies by using systemic modelling techniques. In a more static perspective, landscape, regime and niche can be organisationally described using the different systemic elements of the classical approach. It therefore depends on the research objectives, available data and policy orientation of the analysis whether the classical or the multi-level approach or a combination of the two is an appropriate choice. In the context of the research spectrum of Fraunhofer ISI, both approaches are valuable starting points for innovation system analyses and the application of different qualitative methods and qualitative econometric models and the modelling of dynamic processes in complex systems.

Besides these more general conclusions, research regarding the innovation system concept at Fraunhofer ISI is centred on the following aspects:

– *Theoretical foundation and further development*: Research topics include the simulation of transition management or the implications resulting from the dynamics of technology (different maturity levels of technologies) for the requirements and interactions with innovation systems, e.g. with regard to interactions. Other studies address the question of measurement at different spatial levels and the necessary indicator models in relation with data availability. The public governance of innovation and theoretical considerations about instruments that can be designed to implement mission-oriented approaches are other research fields in this respect.
– *Indicators*: The focus here is on bibliometrics, patent indicators, the use of other innovation indicators, benchmarking, mapping, scenarios and foresight, as well as qualitative surveys. The analysis of interactions usually refers to research-led interactions (co-patents, co-publications, network-analysis) as well as financial and product flows (foreign trade) between countries.
– *Modelling*: This aspect is partly connected to the theoretical foundations. Research is done in the context of system dynamics models. One aspect is

modelling the effects of policy measures in order to identify starting points for the evaluation of specific policy instruments in specific technology areas. Modelling an innovation system would be an ideal case (but probably only partially realisable) in order to identify various levers for the optimisation of an output by a given input (or vice versa).
– *Actors*: The innovation system concept as well as many studies conducted by Fraunhofer ISI are R&D-driven. Further development is needed regarding the implications of innovations with little or no formal R&D for the innovation system concept and interactions in the system. Additionally, a differentiation between research and development would be analytically useful. The innovation system concept is industry-oriented and needs to be extended to include innovation in the service sector.
– *Governance*: As a consequence of the given structures in the innovation system heuristics, the policy recommendations do not differ widely. Improvements are needed, for example, in linking innovation and industrial policy (and their instruments). One approach might be to look at the logic of action of actor groups whose cooperative behaviour can be influenced by industrial policy instruments in order to meet specific innovation policy objectives.

In this respect, different approaches and perspectives in innovation system studies by Fraunhofer ISI are presented in the following chapters. *Conceptual and methodological issues* are addressed in the contribution by Jonathan Köhler, Michaela Gigli, Antje Bierwisch and Arne Lüllmann about "New Directions in Numerical Modelling of innovation: Applying agent-based methods and complexity to sustainability transitions" and by Oliver Som in "Innovation systems without formal R&D". The *national perspective* is taken by Rainer Frietsch and Torben Schubert in their contribution "Public research in Germany – Continuity and change" and by Kerstin Cuhls, who looks at Japan 25 years after the study by Chris Freeman in the chapter "The Japanese innovation system 2011 revisited". Other perspectives are analysed in the rest of the contributions. The *technological perspective* is addressed in the contribution by Carsten Gandenberger and Christian Sartorius about "Decentral wastewater infrastructure – Characterisation and overcoming path dependencies based on a technical innovation system analysis" and in the contribution by Antje Bierwisch, Ralph Seitz and Stephan Grandt highlighting "The innovation system of security – A new quality in the relationship between political, economic and social actors". In an *industrial perspective* Emmanuel Muller, Andrea Zenker and Elisabeth Baier focus on the service sector in their contribution about "Knowledge Angels or how creative people foster innovation in the service industry – emerging concepts and international observations". Two contributions highlight the *regional perspective* of innovation. Elisabeth Baier, Henning Kroll, Esther Schricke and Thomas Stahlecker address the discussion about Baden-Württemberg as a production and innovation regime from the 1990s and early 2000s and ask whether the innovation system here is still characterised by path dependency and technological leadership. The cluster concept is integrated in the innovation system debate by the contribution by Thomas Stahlecker, who deals with "Regional clusters and disruptive technologies – The example of the Baden-Württemberg automotive cluster in transition towards e-mobility". Four contributions discuss different aspects of *public governance* in innovation systems: "Challenge-oriented policy-making and innovation systems theory: reconsidering systemic instruments" is the topic of the contribution by Stephanie Daimer, Miriam Hufnagl and Philine Warnke. Timo Leimbach and Sven Wydra raise the question "Friendly or hostile takeover?" and look at the growing entanglement of industry and innovation policies and instruments. A technology policy focus can be found in the contribution by Hans Marth and Barbara Breitschopf titled "Impacts of policy measures on the development and diffusion of micro CHP technology in Germany". The final contribution in this series by Ralf Lindner discusses the "Cross-sectoral coordination of STI-policies: Governance principles to bridge policy-fragmentation".

These contributions constitute a selection of recent research by Fraunhofer ISI and are intended to illustrate that the systemic perspective in innovation research and the use of the innovation system approach, in both the classical and new interpretation, are as alive as they were in 1972 when the Institute was founded.

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2

NEW DIRECTIONS IN MODELLING INNOVATION: APPLYING AGENT-BASED METHODS TO SOCIO-TECHNOLOGICAL TRANSITIONS

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2.1 Introduction

The objective of this contribution is to propose some directions for research into the simulation modelling of structural change in socio-technical systems. As the other contributions in this volume show, there is a rich literature in the study of technological change using the ideas of systems of innovation. Most of this literature takes the underlying social and technological structures as given. However, there are some innovations that arise from entirely new technologies (e.g. digital computers) that offer new products or services and give rise to new social and economic structures. There are also social and political issues, of which global warming is a clear example, where there is a scientific consensus that far-reaching technological changes are necessary (e.g. the transition away from the fossil fuel motor car and a transition to housing that actually generates energy). Such drastic changes in technology also involve changes in culture, markets, institutions and in behaviour (Freeman and Louçã 2001; Grin et al. 2010).

There are two literatures that address these radical changes: Kondratiev waves (or long waves) and transitions studies. Both of these address the dynamic processes of change and use the idea of co-evolution of sub-systems of society as a framework for analysis (Köhler 2012). However, simulation modelling of the co-evolutionary processes in these literatures is limited.

Formal modelling has some particular advantages over other research methodologies in this context of radical changes. It can accurately address complexity of system dynamics and transitions, which are the result of multiple interactive mechanisms, dynamics, feedback and synergy. This is important for counterfactual policy analysis and forward looking studies, notably when these involve radical, structural changes. Theoretical model analysis can generate testable hypotheses or “confront” theoretical explanations of historical phenomena with historical data, to examine whether the theory indicates relevant variables and processes.

Köhler (2003) proposed a model structure for the analysis of Kondratiev waves, but this only uses economic variables and does not explain changes in the structure of demand. The transitions literature has relatively little modelling analysis (cf. Safarzynska et al. 2011). An important direction is the use of evolutionary economics, but these models do not address the complex social structures proposed by the theories. They also do not address how the behaviour of people as consumers and firms as producers change their behaviour in response to radically different technologies or pressures from the general environment such as climate change. Therefore, models which can simulate the development of such structures might provide new insights.

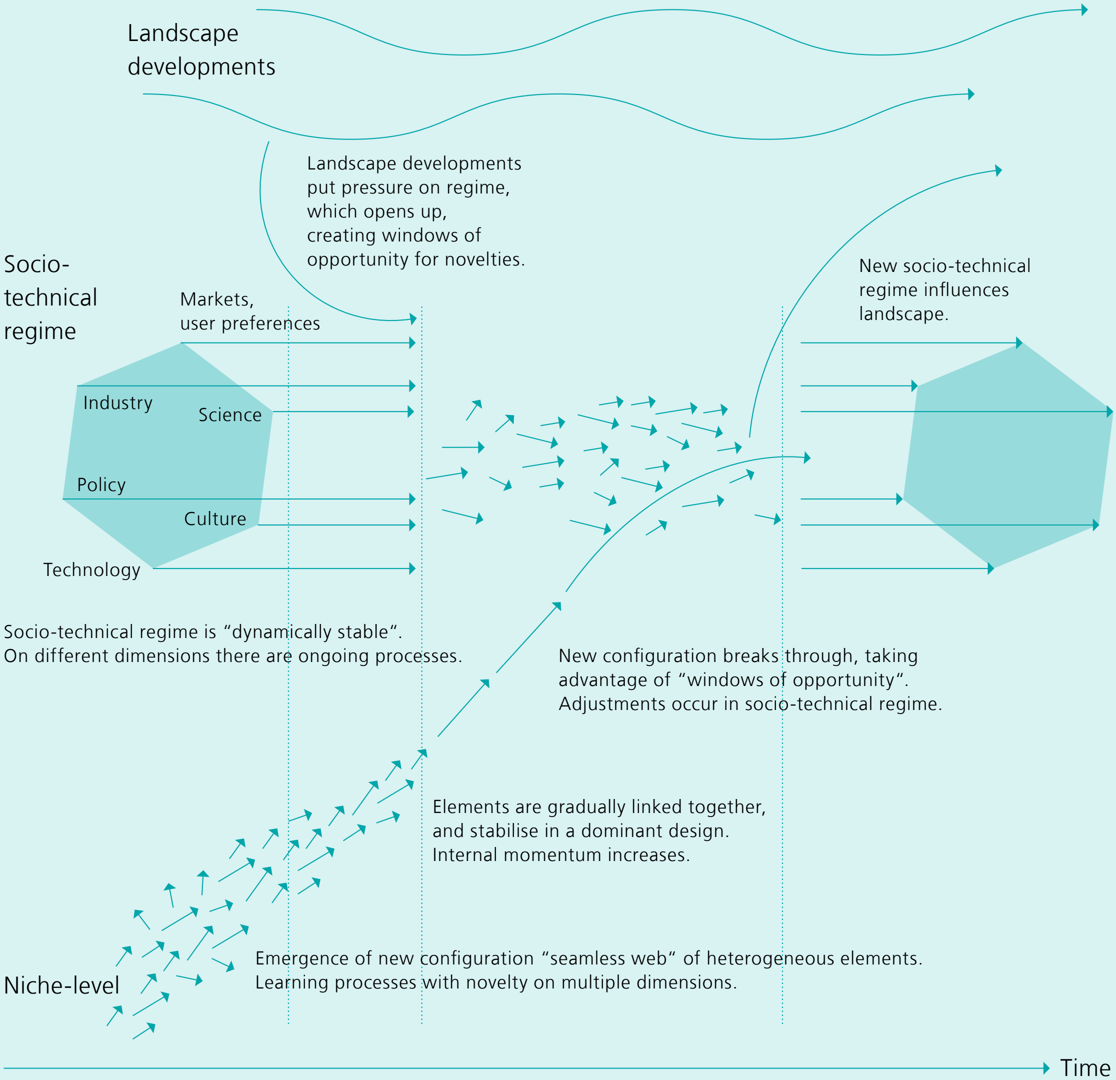
The next section introduces the theoretical structure proposed by transitions theory, the “Multi-level perspective” (MLP) and identifies research questions to be addressed by modelling developments. Köhler et al. (2009) is one of the few attempts to try and represent the social structure proposed by transitions theory in a numerical model. This structure is introduced and used as a starting point for the discussion of possible modelling developments. Since the modelling of behaviours is limited in the current simulation literatures, the possible application in models of psychological understanding of consumer choice and sustainable consumption is considered. Ideas for the representation of niche and regime structures from social network theory analysis and the firm strategies’ literature are then discussed. Mathematical methods that might be applied are identified. The contribution concludes by indicating possible directions for the modelling of sustainability transitions into the future.

2.2 Transition theory

Transition theory is a rapidly growing literature (cf. Grin et al. 2010 for a comprehensive survey, EIST 2011 (first issue) for a series of articles on the current literature and issues). Transitions are a process of radical change in society, in response to either issues in society (climate change, health provision in an aging population, water management in rapidly growing regions with limited supply are examples that are addressed) or new technological developments.

In order to analyse such changes, the “Multi-level perspective” (MLP) was developed (Kemp 1994; Kemp et al. 1998; Rip and Kemp 1998). This identifies a landscape of general social and cultural factors, a regime which is the current technology and societal institutions and also niches – individual technologies and actors outside or peripheral to the regime. The regime has a well-developed and complex social structure. These societal systems comprise inter-locking economic, social, cultural, infrastructural and regulative subsystems, which are associated with a range of social groups. The stability and cohesion of societal systems is established and reinforced through cognitive, normative and regulative institutions (Geels 2005). A regime can

Figure 2–1: A dynamic multi-level perspective on system innovation



Source: adapted from Geels (2002, p. 1263) be understood as a particular set of practices, rules and shared assumptions, which dominate the system and its actors (Rotmans et al. 2001). Regimes typically focus on system optimisation rather than system innovation, because habits, existing competencies, past investment, regulation, prevailing norms, worldviews etc. act to lock in patterns of behaviour and result in path dependencies for technological and social development (Smith et al. 2005; Geels 2005).

Niches are the loci for radical innovation (Geels 2005; Rotmans et al. 2001; Smith et al. 2005). The regime may be threatened from the niche level, or from changes at the broader landscape level of economic, ecological and cultural trends, or from internal misalignment amongst regime actors (Geels 2005). Once a threat is recognised, regime actors will mobilise resources from within the regime, and in some cases from within niches, to respond to it (Geels and Schot 2007; Smith et al. 2005). Geels (2002) has a useful depiction of this multi-level perspective, shown at Figure 2–1.

This identifies the different levels through time, with increasing levels of social and economic activity on the vertical axis. Geels (2005) identifies four phases of a transition: Emergence of novelty, development in market niches, breakthrough of the new technology and gradual replacement of the regime. The approximate boundaries in time between these phases are indicated by the vertical dashed lines in Figure 2–1.

A transition occurs either when a regime is transformed or through regime change. In a transformation the regime responds to the systemic and landscape changes by changing some of its practices and rules, and possibly replacing some institutions and actors. On the other hand, when a regime is unable to weather the changes, it collapses or is overthrown, and is (eventually) replaced by a new regime better suited to the new conditions, constituting regime change. Geels and Schot (2007) develop a typology of pathways of transitions through time. This descriptive, historical analysis has also been applied to analyses of current issues and policymaking, e.g. energy policy and water management, so-called "transition management" (Rotmans et al. 2001; see also parts II and III of Grin et al. 2010).

The fundamental insight of transition studies is that radical change comes from niches and that transitions are manifest though niche growth and interactions between the regime and niches. Therefore, the research question to be addressed is: how can the creation of niches and their growth be modelled in order to understand pathways to new socio-technical structures?

2.3 An agent-based model of transitions

The state of the art in modelling such questions is that of a research area that is only just beginning, with very few examples of numerical modelling of transitions (Safarzynska et al. 2012). Bergman et al. (2008) is the only attempt that we are aware of to model the MLP explicitly. The conceptual structure of the model is described in detail in Haxeltine et al. (2008), and Köhler et al. (2009) describes the application of this model structure to sustainable transport. The modelling approach combines agent-based modelling techniques with a system structure. It is original in that there are two types of agent. There are a small number of complex agents (the regime and niches), which have an internal structure and are therefore sub-systems within society, and a larger number of simple agents (consumers).

The model uses the concept of practices as the metric through which agents position themselves in society and over which behaviour is defined. Practices of both the complex and simple agents are each represented as point values along different axes, constituting a multi-dimensional practices space. Figure 2–2 schematically shows a two-dimensional practices space, which might be e.g. P_x CO_2 emissions and P_y cost of transport. The complex agents (regime and niches) and the consumer agents are shown separately for clarity, but actually occupy positions along the same P_x and P_y practices axes. Consumer agents are points in the space, while in the figure the size of the regime and niche ovals is proportional to their relative support (e.g. the proportion of consumers that buy a conventional motor car vs. electric car vs. public transport). In the model, the consumer agents support the complex agent that is closest to them and therefore the positions of the regime and niches are based on clusters of support i.e. like-minded consumers. The positions of the consumer agents in the practices space change depending on landscape signals, so the regime and niches have to move i.e. change their practices, not only to grow but often just to maintain their support.

Figure 2–2: Two illustrations of a two-dimensional practices space

Practice axes P_X and P_Y. Left: regime and niches, which can move in the space and interact with each other. Right: the consumer agents showing supporters scattered in the practices space, coloured by the agent they support, ● = regime (R), ● = niche 1 (N1), ● = niche 2 (N2).

Source: own illustration

The model is stochastic in that the simple agents are initially randomly assigned over the practice space, with an even distribution.

There are two ways a transition can be represented in the model. The first is regime change, which occurs when an incumbent regime loses support and strength and a niche with different practices takes its place, gaining strength to transform into the new regime. Unless the replacement is immediate, there will be a period without a regime in between. The second way a transition occurs in the model is through regime transformation, which occurs when the regime significantly changes its practices through adaptation and/or absorption of niches, moving to a significantly different location in the practices space.

A limitation of this model is that the internal structures of the niches and regime are not based on an empirical analysis of these social structures. This depends on the development of a theory of these structures which is lacking in the literature (Köhler et al. 2012). A further limitation of the model is that the support of the simple agents for a niche or the regime is based on a simple mathematical distance calculation in preference space. There is no explicit consideration of the decision process through which the structure of behaviours might change, there is just a linear connection to an exogenous weighting of the parameters in practice space. We therefore proceed to consider how these limitations might be addressed.

2.4 Psychology of behavioural change

An important feature of agent based models is that they are structured to enable a wide range of behaviours to be represented. These behaviours can range from simple heuristics such as "buy the car that your neighbour bought" (keeping up with the Jones') through homo economicus (maximising utility over the alternatives, subject to a budget constraint) to empirical observations in choice experiments, questionnaires and first-hand in-depth qualitative insights from case studies. Since the modelling of behaviours is limited in the current transition theory literature, the possible application of models of psychological understanding of consumer choice and sustainable consumption is considered.

As mentioned above, we know that the structure of behaviours of simple agents (consumers) can change; however, transition theory does not take account of the underlying decision process. Explanatory approaches from other disciplines (e.g. behavioural economics, ecological economics, marketing or consumer behaviour studies) often assume economically motivated choices as the main or even sole cause of behavioural change. Hence, in order to elicit sustainable consumer choices, financial incentives are judged to be the method of choice without supporting measures. Unfortunately, the behavioural changes that they initiate are usually not of a sustainable nature. Due to the lack of intrinsic motivation, they cease to exist when the financial incentives are removed. Also, they are not transferred to other situations, i.e. they exhibit no "situative consistency" (Lantermann and Linneweber 2006, p. 846). For this reason, environmental psychological models try to draw a holistic picture of human decision making by including an interdisciplinary approach to explain pro-environmental or innovative behaviour, trying to take all relevant determinants into account. Therefore, they have an advantage when compared to the "homo oeconomicus" paradigm.

Psychological theories and methods can serve to understand the complexities of the causes and conditions of human apperception and behaviour. The goal of setting up behavioural models in psychology is to make the emergence of specific behaviours and their interdependency with personality traits, cognitions and emotions, and external factors, better to grasp. Obviously, these models simplify reality to some extent, but on the other hand this serves as a precondition to infer correlational and causal relationships between psycho-social variables. Thus, these variables and their interdependencies are thought to be predictors, determinants or moderating variables of the specific behavioural outcome in question. They are usually mapped to a flow-chart diagram displaying their correlative and/or causal relations. Just like theories and models from the empirical social sciences in general, the methodological steps of phrasing hypotheses, empirically testing (not necessarily in this order; depending on the approach being either deductive or inductive) and validating these hypotheses can always be observed while formally investigating processes of human decision making.

Before proceeding to more detailed examples of how environmental psychological theories and empirical research can make a valuable contribution to modelling socio-technological transitions, a short overview of the most powerful models explaining human actions in diverse contexts is provided. One can mention the Norm Activation Model (NAM) and the Theory of Planned Behaviour (TPB). Both action theories try to explain the transformation of (environmental) related attitudes into manifested behaviour.

The Norm Activation Model (NAM) (Schwartz 1977) states that pro-environmental behaviour, in this model being part of pro-social behaviour, results from the activation of *personal norms*, which are conceived as a set of personal values and moral obligations. Personal norms will be activated when an environmental problem is perceived and the individual ascribes responsibility for negative consequences to herself (*ascription of responsibility; awareness of consequences*). In interaction with the awareness of such consequences – i.e. not acting would lead to a negative outcome – the pro-environmental behaviour will occur.

Greater influence is often assigned to the Theory of Reasoned Action (Fishbein and Ajzen 1975) – and notably its extension – the Theory of Planned Behaviour, TPB (Ajzen 1991; 2002). The latter assumes that a behavioural *intention* can lead to a specific *behavioural reaction*, but the intention itself depends on *attitudes* towards the behaviour. This describes the degree to which performance of the behaviour is positively or negatively valued. Specifically, the evaluation of each outcome contributes to the attitude in direct proportion to the person's subjective estimation of the probability that the behaviour produces the outcome in question. A barrier exists, when there is a low subjective estimation that the behaviour will produce a given outcome. The model also includes *normative beliefs* as a product of perceived social pressure towards the execution of the behaviour, and a personal motivation to act upon it. Moreover, the theory includes the construct of *perceived behavioural control* thus acknowledging that behaviour does not necessarily take place, even when a strong intention exists.

Even if objectively a behaviour could be performed, the perception that factors may impede that performance in a given situation, can lead to its not taking place. There are also syntheses of these theories (e.g. Matthies 2005). For example, Bamberg and Möser (2008) in a meta-analysis of 57 empirical studies investigating the psycho-social determinants of pro-environmental behaviour confirmed the statistical relationship between eight factors, most of them mentioned above.

Many authors have made use of one of those theories in the area of energy saving behaviour in the built environment (e.g. Black et al. 1985; Abrahamse and Steg 2009), or have focused on more sustainable transport choices (e.g. Becker 2000, Steg et al. 2001). There are various other theories explaining sustainable consumer choices, characterised by emphasis on certain sets of variables (i.e. either norms, values, ascription of responsibility etc.).

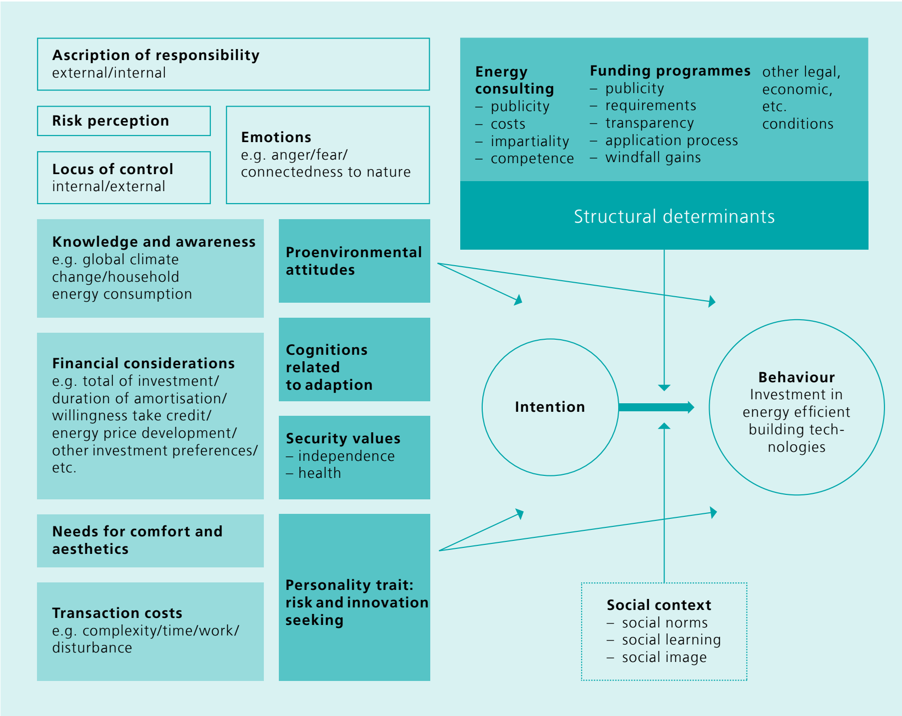
In the following we will examine examples of how single parameters for modelling could be obtained, and as a consequence the strength of their influence on behavioural reactions measured. As exemplary research areas, we focus on consumers' decision making towards sustainable housing and transport choices.

First, examples from the domestic building sector demonstrate how elements of the two above mentioned models, and in particular another powerful environmental psychological model (the responsibility- and norm-relevant action theory of pro-environmental behaviour by Kals and Montada (Kals 1996; Montada and Kals 1995), have been used by Sauerborn (2005) to explain the determinants of private house builders' motives and behavioural determinants for ecological and socially innovative actions in the house construction domain. This model integrates, along with attitudinal, value-related and moral determinants, a number of factors specifically related to the action field of ecological constructing. It therefore draws emphasis on cognitions related to the perceptions of personal responsibility towards the environment (including locus of control/self-efficacy, ascription of responsibility, and risk perception), knowledge-related factors (including knowledge about cost-effectiveness), environment-related emotions (such as anger with non-environmental actions, or connectedness to nature) and innovative personalities, as well as structural and social contextual factors. The model has been empirically tested and the measurement instrument[1] validated. The theory has also been used by one of the authors as a basis for the development of a heuristic model via an inductive empirical process (Gigli 2008), which collected and categorized factors influencing the decision-making of homeowners when investing in certain energy-efficient building technologies.

The main influences integrated into the heuristic model (see Figure 2–3) are being further statistically tested for interaction and (causal) explanatory strength of single factors. For this purpose, a questionnaire has been developed (Prochnow et al. 2012). The latter, aside from being a statistical instrument, can serve as a means to assist municipal activities to motivate citizens' uptake of financially sane climate change mitigation measures in the housing stock (Gigli et al. 2012).

1 A questionnaire, by which the hypotheses stated in the model were operationalized into scales and items.

Figure 2–3: Heuristic framework model for testing determinants of investment in energy-efficient building technologies



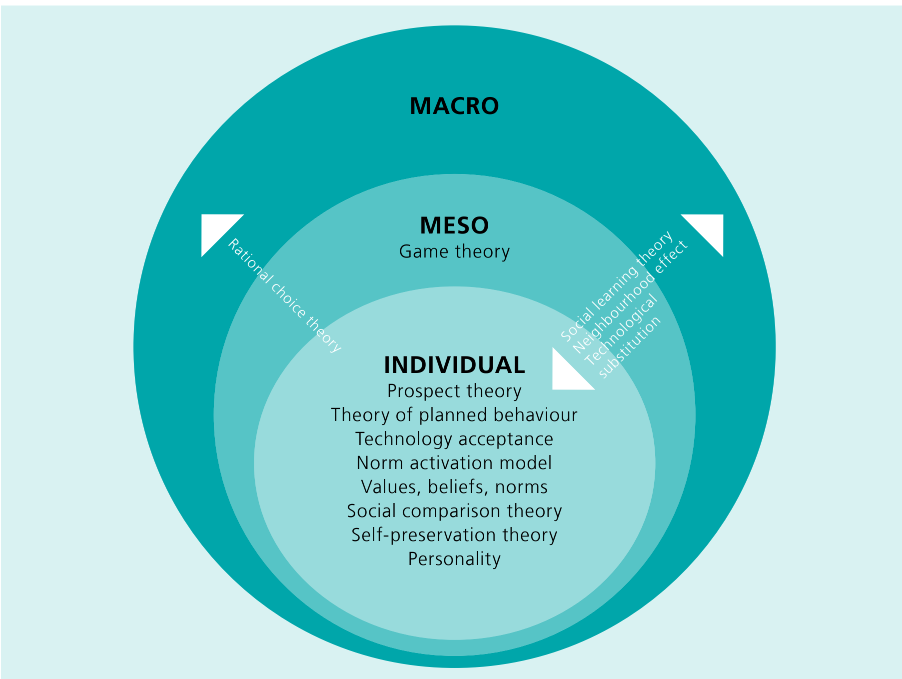
Source: adapted from Prochnow et al. (2012)

The heuristic model displays a large diversity of cognitive, emotional, normative as well as socio-demographic and contextual factors influencing the decision in favour or against the uptake of domestic energy efficiency measures. Obviously, financial considerations play a major role, however, there are multiple cognitions at play and some have a stronger influence than others, e.g. the awareness of the high sum of the total investment has a stronger influence on the actual behaviour than the expectation of financial assets after amortisation and/or through low operating costs. In this vein, other factors are correlated, e.g. reluctance to take a loan (even with extremely low interest rates). Another major barrier is the lack of knowledge on different energy-related topics and not only about the why and how of domestic energy saving. For example, there are also low levels of knowledge regarding the existence of energy-saving counsels (some are for free; for more professional ones a state subsidy is granted) or in general on the existence of state funding programmes. In addition to a technological interest and ability, as well as an innovative personality, an important factor concerning the purchase of renewable energy technology is the intention of homeowners to be independent of energy providers and thus of rising energy prices in the future. Risk perception and perceived self-efficacy, as well as the adoption of responsibility to solve climatic problems seem to have an influence as well. Other important factors that hinder or motivate domestic measures are transaction costs (like perceived stress, the objection to dirt and chaos in the house or long-term presence of workmen) and thoughts about aesthetics and comfort (concerns that the building will not look attractive anymore, e.g. through an insulation of the walls or fitting of solar panels on the roof). Influences by the social environment of the homeowners and strong correlations with socio-economic characteristics are evident in various aspects. If modelling, in this example of energy efficient technology choices, takes into account behavioural determinants it might produce more reliable and realistic results.

In general, the more specific the behaviour explained by a model (e.g. investment in a bundle of energy-efficient building technologies by homeowners vs. reducing energy use at home) the greater predictive power it will have.

Second, there is an extensive literature on the psychology of decision making in sustainable transport. Anable et al. (2011) provides a comprehensive overview of theories and models targeted at the explanation of factors affecting consumers' choices with regards to (innovative) car technologies. Peters et al. (2011) consider the psychological determinants of fuel consumption in vehicles. The theories applied are illustrated in Figure 2–4.

Figure 2–4: Levels and theories of behaviour change applied in the literature to electric vehicle adoption



Source: adapted from Anable et al. (2011, p. 1017)

Ernst (2009; 2010) advocates computer based Social Modelling (or agent-based modelling, ABM), that he points out as coping better with the challenges of social scientific investigation of environmental change, especially in relation to classical social scientific methods of theory building. This method explicitly tries to picture the determining socio-psychological factors of human or institutional decision making. It has been applied in different environmental contexts (Janssen and Ostrom 2006; Schwarz and Ernst 2009). Those models let simulated agents act and move in a simulated environment by bringing possible influencing factors (e.g. social and bio-geophysical) into the equation (Ernst 2010). One has to bear in mind, however, that social simulation always implies a radical simplification of human decision making, and that even if an underlying model can rigorously be tested this model has to be quite parsimonious. Thus, social modelling serves to identify the strongest predictors of the core model and as with conventional models, cannot incorporate all the determinants that exist. Qualitative social scientific research, like interview- and case-studies, serves to overcome this gap by being combined with strictly quantitative methods.

To sum up, it has become evident that along with technological, financial and economic factors, psychological determinants play a major role in ecological and economical viable decisions, for instance in the domain of domestic energy-efficiency or mobility. The current modelling approaches ascribe rather simple characteristics to the decision making of human beings, such as maximising of utility, the reaction on restrictions, the existence of fixed preferences and the availability of perfect information (Franz 2004). In reality, however, manifold and complex determinants of environmentally relevant behaviour are at play, and scientific methods exist to “capture” them. In order to account for the transition processes arising through agents and/or networks (see the following section), and avoiding a “black box” point of view (where the process between stimulus and behavioural outcome is neglected); the modelling of behaviours could be expanded in current transition theory research.

2.5 Niches and regimes: agents, networks, strategies

A further set of issues when modelling transitions is that of definition of entities. The two central concepts in transition theory are the niche and the regime. These are not single agents, but are variously defined by different authors. Markard and Truffer (2008) discuss the different views of regimes as sets of institutions – rules, standards, regulations, norms or as societal sub-systems with actor networks – firms, consumers, political actors. Geels (2005) has niches as market niches or niches of users (or practices).

If a regime is a set of institutions, this is then a set of rules for interaction between agents. In the context of an ABM, these rules could be interpreted as heuristics for agent behaviour, adopted by a subset of agents. However, if niches and a regime are markets or societal systems, the question then arises as to whether niches and regimes should be modelled as separate agents explicitly as in Bergman et al. (2008), or whether they should be allowed to emerge from a complex system of agents that form the elements of social systems e.g. firms and consumers. This would require the modelling of the dynamics of interactions between agents.

If the approach of modelling the niches and regime directly is taken, then there is the question of how to represent the structure of a niche or regime. One possibility is to consider these as networks. Then, the methods of network theory and graph theory can be used to provide indicators to characterise the niche and regime entities. Network analysis is an instrument that can address social resources or social capital (Jansen 2006, p. 26). If social capital is understood as an aspect of social structure, wider possibilities for individual or corporate actors are opened up, so that opportunities for corporate profits or strategies for collective action are created (Jansen 2006, p. 26). Caniëls and Romijn (2008) provide an example of the use of network analysis to analyse bio fuel niche development. In a network structure, the institutions could be used to identify connections between the agents or network nodes. The dynamics of such networks might then be identified as changes in network actors and connections through time.

The idea of niches in socio-economic analysis has come from the concept of niche markets. This idea has been developed in the management literature through ideas of management strategies. From the market-based viewpoint, it is assumed that the profitability of a company is determined not by the companies themselves, but by the industry and the technology. Among other things, competition strategies of the market which characterize their behaviour are assumed to be a determinant of market success. Starting from the same situation, differing behaviours, such as the choice of a company for internal generation of innovations or an innovation cooperation strategy, lead to differing outcomes (Welge and Al-Laham 2008, p. 80).

These kinds of strategy are intended to support the advantageous positioning of the company in the market. Their selection or focus is derived from the market and industry structure. Consequently, this analytical approach can be used to support the strategic plans of companies for generation of competitive advantages based on the environment and constraints. One of the generic strategy approaches is to establish a niche strategy.

In a niche strategy, the company concentrates its activities on meeting the needs of a specific group of customers, a regional market or a limited product line (Porter 2000, pp. 40f., 217ff.; Porter 2004, pp. 28ff.) Example of this are the product niche, regional niche, branding niche, niche cooperation, speed niche, etc. (cf. Welge and Al-Laham 2008, pp. 529f.). As part of strategic management, such a focus is then viewed as useful if the segment has a profitable size, but small enough so that larger competitors with their larger fixed costs can not enter efficiently enough and if a disproportional growth and creation of customer loyalty can be demonstrated (Camphausen 2007, p. 92). The niche strategy is also used for experiments to serve as a precursor to mass-production (Bea and Haas 2005, p. 188).

Low substitutability, highly specialized customers with high interdependence and intense relationships between actors are characteristics of niche markets. These characteristics may influence promoting or inhibiting factors in the development of a niche and hence also the strategic planning of a company, as a player embedded in a network. In addition, the findings may contribute to the strategic management of competitive strategies on the dynamics and also the expansion of a niche into a regime in which the process of changing strategies and their features are included. In addition, it is conceivable that network analysis in niche markets could be used to identify "hidden" or "non-expected" value chains, which have led to new technologies and products that go beyond the established industries and technology groups. In particular, the identification of linkages between sectors or fields other than business and networks outside established value chains are key findings (e.g. passive house – cooperation between glass manufacturers, manufacturers of seals and measurement, control systems, etc.). These studies may provide starting points for analyses that go beyond the linear innovation chain approach.

Based on these ideas, pointers for the establishment and development of new ideas and technology fields might be identified, which go beyond existing approaches to innovation policy. These analyses could identify relations that are outside the usual or expected structures in value chains.

Challenges for implementation in a model are the definition of the extent of a network and the actors and network levels involved. Also, the generalizability of statements in strategic management related to the implementation of focused competitive strategies is a challenge, particularly the discussion in the current literature of "hybrid competitive strategies", in which the typologies of Porter are linked (e.g. Camphausen 2007, pp. 95ff.; Welge and Al-Laham 2008, p. 534).

This should be distinguished from the Strategic Niche Management approach (SNM), as an analytical technique designed to facilitate the introduction and diffusion of radically new sustainable technologies through societal experiments.

Entrepreneurship

Innovation management studies in the field of entrepreneurship research can also offer interesting points in the context of networking (as Schumpeter 1934 pointed out, the recognition and exploitation of new business opportunities requires entrepreneurs to combine previously separate ideas and knowledge to exploit their complementarities). Through networking entrepreneurs identify available resources and find new and better ways to combine them with their own resources and knowledge (Anderson et al. 1994; Arenius and DeClercq 2005). Network relationships enable firms to develop new know-how which in turn assists them to carve out a stronger position in their industry (i.e. Anderson et al. 1994; Hagedoorn 1995; Ahuja 2000; Karamanos 2012). Social network connections, through interpersonal relationships and interest groups, can help entrepreneurs mobilize the resources to start their new business and gain access to suppliers, customers and inventors. This kind of interaction should provide social capital that entrepreneurs can use to obtain resources they need to start a new business, such as to be more innovative or information about financing/funding and the market (Danis et al. 2011, p. 396; Dakhli and De Clercq 2004; Acs and Stough 2008). In addition, social networks and the associated relationships offer reputation and signalling effects so that knowledge and resource exchange can be increased. To understand the relationship between social networks and new business activity the institutional setting is taken into account (because network relationships operate within a broader institutional context). Specialised intermediaries, the regulatory system, contract-enforcing mechanisms are examples for an institutional infrastructure. The identification of such relevant elements for the establishment of a new business can potentially be transferred to the development of niches.

Here there could be an interesting question of how social ties or relationships, particularly in new fields of technology or innovation in which the institutional infrastructure may be less pronounced, are more important than in existing technology fields. The institutional environment consists of regulatory, cognitive and normative dimensions (Scott 2001). A further set of issues for research is the application of these ideas to new business activity in emerging or developing economies.

Innovation diffusion research

Another related area is provided by several studies in the context of innovation diffusion research that apply an agent-based simulation approach in different perspectives. The majority of the studies focused on the structure of the social network that determines the interaction between agents. Moreover, some studies have simulated the interplay between producers and consumers by incorporating product characteristics and modifiable product designs or investigate the impact of different marketing strategies on the diffusion process (Ma and Nakamori 2005; Günther et al. 2011, p. 13; Jager 2007). These studies have the aim of reflecting the individual characteristics and behaviour of agents, their individual preferences and the embeddedness in a social network. Analysis of the integration of product characteristics (product quality, price etc.) and consumer-related characteristics are central results, which can be used to specify the elements of a niche. Another research topic/point of contact in this field is to analyse the impact of network dynamics such as a creation of new edges during the runs as a result of both firm activities like interorganisational cooperation, marketing and communication and changes in the environment based on M&A or bankruptcy/insolvency and so on.

2.6 Possible modelling methods

The conventional approach in an ABM is to model a large number of individual decision making entities such as consumers or firms. A criticism of ABM is then that there are too many parameters to enable a parameterisation to be realistically calibrated against empirical data. This problem can be addressed by considering the "inverse" solution problem. The conventional simulation approach of developing a model, estimating the parameters as well as the data, permits and simulating forward through time produces scenarios as results, which vary according to the parameterisation and the structure of the model. In the inverse problem, the overall phenomenon is identified – a transition that has already occurred such as the transition from steam power to internal combustion engines in transport or the adoption of the internet for communications. Then, plausible parameter ranges for all the parameters in the model are identified. From an initial set of parameter values, the model is run many times to identify the set of parameter values that optimises the performance of the model, by minimising the discrepancy from the empirical data set for the overall transition phenomenon. This tuned set of parameter values could then be used for forward looking scenario analysis. Such parameter sets could also be used to identify plausible ranges of values for new cases.

A further idea is to use game theory, where agents take their predictions of other agents' behaviour into account, with the Nash equilibrium solution concept to define possibility space of outcomes. There will be no closed form solution for large numbers of interacting agents, but it might be possible to use genetic algorithms[2] to explore a solution space. This could also link to the strategic behaviours of firms discussed above.

A further possibility is to treat the regime and niches as neural nets, with decision nodes and a structure that enables a learning process. Neural nets consist of input signals, an internal structure of nodes or neurons, which individually have a binary output dependent on a weighted combination of inputs and outputs that are dependent on the inputs and the node structure. They are programmed to learn appropriate outputs for different inputs and then apply these rules for pattern recognition of inputs to generate outputs (cf. Russell and Norvig 2010, ch. 18 for a recent survey). This approach would enable the niches to be set goals (such as activity growth) and then simulate the learning behaviour in response to a socio-economic environment and responses to changes in the environment. The nodes of the network could be the various actors active in the niche and the outputs could be changes in practices in the niche or the adoption of particular institutions.

2.7 What is to be done?

As Lenin once said, a new direction is required. We have shown that along with technological, financial and economic factors, psychological determinants play a major role in ecological and economic decisions to address sustainability and scientific methods exist to "capture" them. The structure and growth processes of niches and consequent regimes' responses have a fundamental role in sustainability transitions; strategic management and social network analysis suggest methodologies for analysis of these processes, complementing the SNM policy approach from the transitions literature.

Our research question is therefore: how to develop an ABM of sustainability transitions that can investigate how niches arise and grow and under what conditions they lead to a transition to a new socio-technical regime.

As the summary in Section 2.3 shows, the current literature on numerical modelling of radical socio-technological change does not address these issues of behavioural changes towards sustainability and niche growth processes. Even in the wider environmental modelling literature, ABMs do not incorporate the sophisticated theories of consumers' and firms' behaviours outlined here. Therefore, the application of psychological theories and models for specifying behavioural structures for agents

2 In numerical simulation, a search heuristic that mimics biological evolutionary processes.

(consumers) could be extended in transitions research. There is also a need to address the social structures of niches and regimes, possibly through the application of ideas from social network analysis. The application of ideas from strategic management theory as well as SNM from transition theory show promise for the specification of firms' behaviours and the dynamics of niche structures on the supply side.

Several fields of application suggest themselves: IT technology competition, propulsion systems in ships, propulsion systems in cars, building technologies (passive houses, positive energy houses, recycled/organic houses [Seyfang 2010]). Sectors with transitions in the past (e.g. to skyscrapers using steel frames and concrete in construction and from the horse to the motor car or from conventional to high speed rail in transport) offer data for model calibration over completed, successful transitions and are among the most important areas of current social and policy concern for greenhouse gas mitigation.

A further set of issues for research is the application of these ideas to new business activity in emerging or developing economies. In terms of climate change mitigation, the rapid growth conditions in the NICs offer both possibilities of rapid large scale investment and barriers of "conventional" policy thinking.

Finally, there are also challenges in modelling methodology: the calibration of the large parameter spaces of ABMs requires methods for identifying ranges of informative simulations and methods from artificial intelligence might be used to implement learning and hence growth processes in niches.

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3

INNOVATION SYSTEMS WITHOUT R&D?

A RETROSPECTIVE VIEW OF FIVE YEARS OF "LOW-TECH" INNOVATION RESEARCH AT FRAUNHOFER ISI

OLIVER SOM

3.1 Introduction

For the past decades, research and development (R&D) activities have become the most substantial pillar of innovation research in the attempt to explain the innovation ability and competiveness of enterprises sectors and economies (Rammer et al. 2009; Santamaría et al. 2009; Raymond and St-Pierre 2010). Subsequently, the terms "innovativeness" and "R&D intensity" of firms or economies have been increasingly equated by mainstream innovation literature in the past. "There is ample empirical evidence supporting the hypothesis that R&D expenditures are a sine-qua-non for the firm's level of innovation activities" (Shefer and Frenkel 2005, p. 25).

However, empirical studies have shown early on that a significant number of manufacturing firms does not invest in own R&D (Cohen et al. 1987; Bound et al. 1984; Galende and Suarez 1999). Not long ago, Arundel et al. (2008) found out that just over half of all innovative firms in Europe do not perform R&D. Most recently, Rammer et al. (2011) as well as Som et al. (2010) supported this finding for the German manufacturing industry. Their analyses revealed that about 44 % of all innovative firms did not perform internal R&D. Most surprisingly, existing empirical studies could neither identify any significant differences in the economic performance, the economic outcome nor the mortality between non-R&D-performing innovators and their R&D-performing counterparts (Som 2012; Rammer et al. 2011; Som et al. 2010; Arundel et al. 2008; Kirner et al. 2009a).

But these insights have hardly been translated into empirical innovation systems approaches. To date, empirical research on innovation systems technological or innovation performance still is more or less implicitly based on the assumption that the relevant stock of knowledge needed for the successful development of innovations is primarily accumulated through basic and applied research in the public research sector (e.g. universities, non-profit research organisations) and is then refined and transferred into marketable innovative solutions by the research and development (R&D) activities of private enterprises (Arundel 2007, p. 50; Becheikh et al. 2006, pp. 655f.). But if only R&D indicators are used to measure innovation capability, non-R&D-performing firms will not be captured adequately, and consequently will be classified as non-innovative or even be excluded from innovation studies a priori. But given their confirmed level of innovativeness and competitive performance, innovation systems research that is solely focussed on R&D-based modes of innovation might overlook substantial innovation mechanisms and activities beyond mere R&D that highly influence the innovation performance and competiveness of innovation systems (Robertson et al. 2009).

During the past 10 years, innovation researchers have become increasingly aware of the economic relevance of non-R&D-intensive industries and firms. Their contributions have enhanced the scientific, managerial and political awareness of competitive and innovation strategies beyond R&D. Building on the fruitful findings from previous, mostly qualitative and case-study based studies (e.g. Robertson and Smith 2008; Hirsch-Kreinsen 2007; von Tunzelmann and Acha 2005) and sector- or industry-based approaches (Bender 2004; 2006; Hirsch-Kreinsen et al. 2003; Alfranca et al. 2004; Bender and Laestadius 2007) of the earlier years, researchers of Fraunhofer ISI were among the first to supplement these findings on the basis of quantitative firm-level data about the innovation and competitive strategies of non-R&D-intensive firms in the manufacturing industry (Kirner et al. 2007). Meanwhile, there is a growing number of quantitative studies based on broad, quantitative firm level surveys (e.g. Arundel et al. 2008; Heidenreich 2009; Mendonça 2009; Santamaría et al. 2009; Barge-Gil et al. 2008), among them a considerable number of studies conducted by or with the participation of Fraunhofer researchers (Kirner et al. 2008; 2009a; 2009b; Som et al. 2010; 2011a; 2011b; Som and Zanker 2011; Rammer et al. 2011; Som and Kinkel 2012; Som 2012).

This contribution to the 40th anniversary volume thus takes the opportunity to review the past five years of "low-tech" research at the Fraunhofer ISI. To this end, this contribution summarises the main empirical findings about non-R&D-intensive firms' innovation behaviour and competitive strategies. Moreover, it aims to highlight several dimensions which turned out to be specific characteristics of non-R&D-intensive innovation. Starting with these peculiarities, the contribution closes by touching on the question whether one can genuinely speak of a specific sectoral "innovation system without R&D" or whether non-R&D-intensive innovation rather emphasise different modes of knowledge creation and innovation processes that are already incorporated in existing innovation systems approaches.

Most of the presented findings are based on the *European Manufacturing Survey (EMS)*, respectively its German subsample. The EMS survey has been organised by a consortium of research institutes and universities from and across Europe since 2001. The objective of this regular, questionnaire-based postal survey is to systematically monitor European manufacturing industries. It targets firms with 20 or more employees from all manufacturing sectors (NACE 15–37) and is addressed to their general management, plant or manufacturing manager. The German part of this survey called *German Manufacturing Survey (GMS)* is conducted by the Fraunhofer ISI and usually includes firm-level data of approximately 1,500 enterprises of the German manufacturing industry. As yet, data from four survey rounds (2001, 2003, 2006, and 2009) is available. The preparation of the European Manufacturing Survey 2012 is currently under way.[1]

The studies referred to in this overview are mainly based on the 2006 (Kirner et al. 2007; 2008; 2009a; 2009b) and the 2009 (Som et al. 2010; Som et al. 2011a, 2011b; Som 2012) rounds of the German survey. Additionally, findings are also included from in-depth computer-aided telephone interviews (CATI) with non-R&D-intensive manufacturing firms in Germany (Som et al. 2010, 2012; Som and Kinkel 2012) and qualitative case studies with non-R&D-intensive enterprises (Som and Zanker 2011).

3.2 "Low-tech" industries vs. non-R&D-intensive firms

At the industry or sector level of the debate, the differentiation between R&D-intensive and non-R&D-intensive industries follows the classification of manufacturing industries into high-tech, medium-tech and low-tech sectors introduced by the OECD (1994) or its recent modification (Legler and Frietsch 2007). Based on the average share of private sector R&D expenditure (BERD) in the total turnover of a branch, a rough differentiation can be made between R&D-intensive (so-called "high-tech") and non-R&D-intensive (so-called "low-tech") industrial sectors. Depending on the classification used, the group of non-R&D-intensive or so called "low-tech" sectors consists of branches in which the average share of R&D expenditures amounts to less than 3 % (OECD 1994), respectively 2.5 % (Legler and Frietsch 2007). Based on these classifications, industries such as aero-space, computers, semiconductors, telecommunications, pharmaceuticals and instruments are commonly classified as "high-tech", while "medium- tech" typically include electrical and non-electrical machinery, transport equipment and parts of the chemical industries. The remaining "low-tech" category with low R&D intensity then comprises for example industries such as textiles, clothing, leather products, furniture, metal products and so on.

Comparisons of OECD and European economies' manufacturing industries showed that growth performance across countries is not correlated with shares of high-tech in manufacturing. Non-R&D-intensive sectors still account for the largest part of manufacturing output and employment in OECD and European economies,

1 For detailed information see: http://www.isi.fraunhofer.de/isi-en/i/projekte/fems.php.

and their preponderance is decreasing very slowly. For instance, non-R&D-intensive industries in Germany still employ about half of the total work-force and account for an average of 41 % of industrial value-added (Som et al. 2010). These shares are even higher in other European countries (EU–14, EU–10) as well as in the United States and Japan. Last but not least, in case of an additional demand-side stimulus of one billion euros, model-based potential analysis shows that non-R&D-intensive sectors cause higher direct and indirect employment and productivity effects than R&D-intensive sectors, due to their high interrelation with inward partners along industrial value chains (Som et al. 2010).

This is also reflected in the finding that non-R&D-performing firms can be found in all categories of sectoral R&D intensity. Although low-tech sectors – as expected – comprise the biggest share of non-R&D-performing firms (58 %), 27 % of the firms in medium-tech sectors, and nearly 17 % in high-tech sectors are firms without any R&D expenditures. This intra-sectoral heterogeneity continues in the distribution of non-R&D-performing firms within the manufacturing industry. Remarkably, even high-tech (e.g. medical, precision and optical instruments) and R&D-intensive sectors (e.g. machinery and equipment) comprise a significant share of non-R&D-performers (17–28 %). Thus, non-R&D-performing firms are obviously managing to survive even in "high-tech" environments.

Consequently, it has to be stated that, although the classification of industries according to their R&D-intensity is widespread in current innovation research, it is completely unsuitable for a more accurate description of the specific conditions and mechanisms of the innovation processes which are taking place. The division of industry into sectors of low, medium and high technology according to R&D-intensity can only distinguish a more or less valid entity of firms with different levels of R&D in terms of statistical data or economic research. But it certainly does not reflect the actual empirical reality. In reality, there are no "true" non-R&D-intensive sectors. Instead, what can be observed, is a significant share of non-R&D-intensive or non-R&D-performing firms which permeate to varying degrees into sectors with high or very high R&D (cf. Table 3–1).

Hence, as the sector level may not be the appropriate level at which to start an analysis of non-R&D-performing firms' innovation behaviour, we decided to adhere to the firm-level in our studies in order to take care of the substantial inter-sectoral heterogeneity of non-R&D-intensive firms (Kirner et al. 2009a; Som 2012).

The studies considered here thus have either defined non-R&D-intensive firms as firms with a less than 2.5 % share of R&D expenditures of their total sales (labelled "non-R&D-intensive", e.g. by Kirner et al. 2007; 2008; 2009a, 2009b; Som et al. 2010) or firms which completely lack internal and external R&D expenditures (labelled "non-R&D-performing", e.g. by Rammer et al. 2011; Som 2012). Vice versa, firms with R&D expenditures in the surveyed period are defined as "R&D-performing" firms, while firms with more than a 2.5 % share of their R&D expenditures are regarded as "R&D-intensive firms".

Table 3–1: Sector affiliation and firm size of R&D- and non-R&D-performing firms

	R&D-performing firms (> 0 % R&D expenditure)	Non-R&D-performing firms (0 % R&D expenditure)	Total	
Sectoral affiliation (LEGLER/FRIETSCH 2007)* **	Share of firms (%)			
Low-tech sectors (< 2.5 % R&D expenditure)	41.9	58.1	100.0	(n = 948)
Medium-tech sectors (2.5–7 % R&D expenditure)	73.0	27.0	100.0	(n = 363)
High-tech sectors (> 7 % R&D expenditure)	83.2	16.8	100.0	(n = 155)
	(n = 791)	(n = 675)		(n = 1466)
Sectoral affiliation within manufacturing industry (NACE 2-digit)* **	Share of firms (%)			
15 – Manuf. of food products and beverages	27.0	73.0	100.0	(n = 122)
16 – Manuf. of tobacco products	100.0	0.0	100.0	(n = 1)
17 – Manuf. of textiles	48.3	51.7	100.0	(n = 29)
18 – Manuf. of wearing apparel; dressing etc.	42.9	57.1	100.0	(n = 7)
19 – Tanning and dressing of leather etc.	50.0	50.0	100.0	(n = 8)
20 – Manuf. of wood and of products of wood etc.	6.3	93.8	100.0	(n = 32)
21 – Manuf. of pulp, paper and paper products	42.9	57.1	100.0	(n = 28)
22 – Publishing, printing, reproduction of recorded media	8.2	91.8	100.0	(n = 49)
23 – Manuf. of coke, refined petroleum products and nuclear fuel	100.0	0.0	100.0	(n = 2)
24 – Manuf. of chemicals and chemical products	76.4	23.6	100.0	(n = 72)
25 – Manuf. of rubber and plastic products	49.2	50.8	100.0	(n = 128)
26 – Manuf. of other non-metallic mineral products	53.8	46.3	100.0	(n = 80)
27 – Manuf. of basic metals	53.3	46.7	100.0	(n = 45)
28 – Manuf. of fabricated metal products	36.9	63.1	100.0	(n = 255)
29 – Manuf. of machinery and equipment n.e.c.	72.2	27.8	100.0	(n = 281)
30 – Manuf. of office machinery and computers	100.0	0.0	100.0	(n = 5)
31 – Manuf. of electrical machinery and apparatus n.e.c.	68.6	31.4	100.0	(n = 70)
32 – Manuf. of communication equipment and apparatus	87.2	12.8	100.0	(n = 39)
33 – Manuf. of medical, precision and optical instruments etc.	83.0	17.0	100.0	(n = 106)
34 – Manuf. of motor vehicles etc.	70.5	29.5	100.0	(n = 44)
35 – Manuf. of other transport equipment	62.5	37.5	100.0	(n = 8)
36 – Manuf. of furniture, jewellery, sports equipment	43.4	56.6	100.0	(n = 53)
37 – Recycling	0.0	100.0	100.0	(n = 2)
	(n = 791)	(n = 675)		(n = 1466)
Firm size* **	Share of firms (%)			
up to 49 employees	37.9	62.1	100.0	(n = 533)
50–249 employees	56.6	43.4	100.0	(n = 707)
250 and more employees	83.6	16.4	100.0	(n = 226)
	(n = 791)	(n = 675)		(n = 1466)

Affiliation to low-, medium-, high-tech sectors calculated on basis of NACE 3-digit level
Sector affiliation within manufacturing industry on NACE 2-digit level (WZ 2003 Rev 1.1)
Significance levels: *** = p < 0.000 / ** = p < 0.005 / * = p < 0.01 / + = p < 0.1
Source: Som (2012)
In contrast to Som (2012) who focused on firms without any R&D activities, Kirner et al. (2009a) analyzed the distribution of non-R&D-intensive firms (with less than 2.5 % R&D expenditures) across manufacturing industries. But the findings are comparable and support each other.

3.3 Innovation and competitive strategies of non-R&D-intensive firms

With regard to firm size, non-R&D-performing firms are most likely to be found in the category of small and medium-sized firms (Kirner et al. 2009a; 2009b; Som et al. 2010; Som 2012). This finding underlines that non-R&D-performing firms are often SMEs which refrain from R&D activities due to their restricted financial and personal resources. As R&D projects often require a certain minimum size, barriers to R&D include high fixed costs, high financial commitments, or high risk to firm survival in the case of R&D failure. However, as Rammer et al. (2011) showed, the decision of firms to refrain from performing R&D activities is not determined by a lack of financial resources. Instead, the abandonment of R&D expenditures represents an intentional strategic decision of non-R&D-performing firms. Hence, the findings also suggest that almost one in five larger firms with 250 and more employees did not undertake any R&D in the surveyed period. Against this backdrop, the following sections like to highlight important findings from Fraunhofer research about how non-R&D-performing firms nevertheless manage to succeed in innovation and obtain a competitive advantage.

3.3.1 Market environment and competitive strategy

Comprehensive insight into the specific market environment and competitive strategies of non-R&D-intensive firms is provided by the work of Som et al. (2010) and Som (2012). Based on a telephone survey of 220 non-R&D-intensive firms in the German manufacturing industry, Som et al. (2010) revealed that more than half of all interviewed firms locate their most important customers within national boundaries; a quarter even stated that their key customer is located in their regional (< 50 km) periphery. This accounts particularly for smaller non-R&D-performers, while larger enterprises with more than 250 employees are more likely to have their key customers either in countries within the EU, and, to a lesser extent, in other international countries. The strong inward orientation of non-R&D-intensive firms is also reflected in their competitive structures. Hence, the majority of them report that their major competitors are also located within national or regional boundaries.

Nevertheless, compared to R&D-intensive firms the market environment of non-R&D-intensive firms seems to be tougher because they are more frequently active in saturated, stagnating or even decreasing markets than R&D-intensive firms. Due to their tendentially lower product complexity, their products face higher risks of being substituted by rival products. To succeed in cut-throat competition, non-R&D-intensive firms have to outperform their competitors by superior performance.

Looking at the most important competitive factor of non-R&D-performing firms, growth theory assumes that firms without R&D rely primarily on cost competition, as they systematically lack the opportunity to shift their production to higher levels of productivity using R&D and technological knowledge. However, our findings reject this assumption. It is true that about 23 % of firms without R&D report that product price is their unique selling proposition, a figure which is about 10 % higher than that of R&D-performing firms. However, half of all non-R&D-performers also state that product quality is the most important competitive factor used to distinguish themselves from their competitors. Other relevant factors mentioned by non-R&D-performers are customisation of products and adherence to delivery times (Som 2012). Obviously, non-R&D-intensive firms manage to survive in market niches which could be quite attractive in a high-wage country like Germany: the manufacturing of highly customer-specific products with superior quality at partially upscale prices, for example, like functional textiles, quality food, or lightweight and low-wear metal and plastic parts (Som and Kinkel 2012).

On the one hand, given the strong correlation between the R&D intensity of firms and their product innovativeness (Becheikh et al. 2006; Raymond and St-Pierre 2010), and, on the other hand, the strong process orientation which shines out in their relevant competitive factors, narrowing down the definition of innovation to encompass only the R&D-driven area of product innovations appears problematic to analyse non-R&D-intensive or non-R&D-performing firms. Instead, it is much more appropriate to apply a broader, systemic concept of innovation as outlined early on by Schumpeter (1912) and, most prominently, by the 3rd edition of the OSLO-Manual (OECD 2005) that differentiates between product, service, and technical as well as non-technical (organisational) process innovations. Moreover, as such fields of innovation are not necessarily bound to R&D-based knowledge in their origin, this broader concept of innovation also leaves room for other types of knowledge and information sources.

3.3.2 Product innovation

According to other studies (e.g. Huang et al. 2009; Arundel et al. 2008; Heidenreich 2009), our findings confirm that enterprises with higher R&D intensity are more likely to develop new products, which stand out because of their degree of novelty, increased scope of functionality and higher technological level against competitors with lower R&D intensity, and thus achieve correspondingly higher shares of sales. Non-R&D-intensive industrial enterprises introduce product and market innovations less frequently than their research-intensive counterparts and thus achieve lower turnover shares (Kirner et al. 2009a; 2009b; Som et al. 2010; Som 2012). This does not mean that non-R&D-intensive firms are generally not able to produce new products or even market innovations (Som 2012). Depending on their size, many of these companies report the successful development of new products (50–78 %) and even of market novelties (25–33 %) (Kirner et al. 2009b). But the results show that this share is significantly higher in R&D-intensive enterprises, particularly with a view to the share of market innovations. Product innovations in non-R&D-intensive firms often take place in the form of extensions or improvements to existing product portfolios and are therefore more likely to be characterized by a lower level of novelty (Rammer et al. 2011).

3.3.3 Technical and organisational process innovation

Virtually all findings of the studies in question considered the particular importance of process innovation for non-R&D-intensive firms' innovation strategies (Kirner et al. 2007; 2009a; Som et al. 2010; Rammer et al. 2011; Som 2012). Accordingly, the study of Rammer et al. (2011) corroborates this finding by pointing to the much greater importance of technical process innovation for non-R&D-performing firms than for R&D-performers. In consequence, non-R&D-intensive firms use innovative process technologies to the same degree as firms with high R&D-intensity. This similarly high level of process innovation activities in non-R&D-intensive firms is certainly noteworthy, because some of the literature ultimately pointed out that R&D capabilities are an important key to the development of successful, technical process innovations (e.g. Graves and Langowitz 1996; Keizer et al. 2002).

Hence, missing or significantly impeded access to new technological solutions in the production process due to a lack of R&D intensity cannot be determined in our studies. This remarkably good position of non-R&D-intensive companies in the area of technical process innovation can be explained, on the one hand, by the fact that non-R&D-intensive firms often occupy niche markets, in which the success of their products is not so much due to the revolutionary degree of innovation of the products themselves than the special quality, flexibility or the ability to adapt the products to individual customer specifications (Som et al. 2010). These firms have often evolved from simple suppliers to innovative problem-solvers who in the role of "process specialists" (Som 2012) design and implement the manufacturing of products which have frequently been pre-developed by the customers. Here non-R&D-intensive firms often utilize the most modern production technologies, which they either obtain tailor-made from research-intensive machinery and equipment manufacturers or by transferring and customizing already existing technical solutions to the specific requirements of their firm themselves.

On the other hand, non-R&D-performing firms do not (over) compensate their lack of R&D intensity by the overuse of innovative process technology. This might be also due to the fact that these firms are very often found in the group of small and medium-sized enterprises and are therefore subject to the known size-related resource constraints. They are obliged to keep the fixed cost burden in the area of their production technology within reasonable limits. Many non-R&D-intensive firms often tend to abstain deliberately from using innovative process technology, or limit its use to the bare minimum (Kirner 2009b). Possible reasons could lie in the increased risk associated with the degree of novelty of innovative technology. Furthermore, investment in new process technology is frequently not profitable for small enterprises because of the small number of units manufactured; respectively, the technology will be introduced at a later time, when it is offered at a lower price due to subsequent technology generations/technology follow-up improvements (Som et al. 2010; Rammer et al. 2011). In a "low budget" production strategy, these companies rely rather on established, mature and reliable manufacturing technologies which guarantee a high degree of reliability with simultaneously low fixed costs, thus making for adequate profit margins also in strongly competitive, more price-oriented markets.

With regard to organisational process innovation, the empirical results are somewhat surprising, because some authors (e.g. Rammer et al. 2009; Hirsch-Kreinsen 2008) have already shown that innovative organisation and management concepts, for example in the field of work organisation or personnel management, can enable non-R&D-intensive firms in particular to achieve similar innovation successes to especially research-intensive companies. However, our results could not affirm these suggestions. In all fields of organisational process innovation, the share of users is significantly larger for firms performing R&D (Som 2012; Som et al. 2010; Kirner et al. 2009b). This also holds for almost all firm size categories. One possible explanation could be that research-intensive companies tend to manufacture more complex products and thereby use more complex processes which require "more organisation" and more innovative concepts. A second explanatory factor could be the lower export intensity and stronger local market orientation of research-intensive companies (Rammer et al. 2011), which particularly in the inter-company and cross-enterprise area of network organisation requires less advanced organisation forms. Finally, an explanation could lie in the differing employee qualification structures, with a higher share of lower qualified staff in non-R&D-intensive firms (Kirner et al. 2009b). This could mean that in particular the introduction of innovative, participative approaches of reorganisation would seldom be regarded as a suitable concept. Hence, unlike previous findings, neither a compensatory function nor utilization at eye level to innovative, organisational concepts on the part of non-R&D-intensive firms can be found on the basis of our data.

The process expertise of non-R&D-intensive firms, however, is not fully revealed until the analysis of the corresponding output dimensions has been completed. Compared to (intensive) R&D-performing firms, they show superior process performance almost throughout all output dimensions. This even holds when controlled for different firm sizes and different complexity of products (Som 2012; Kirner et al. 2007; 2009a). Hence, non-R&D-intensive firms are able to organise their production processes at least as efficiently as R&D-intensive firms, resulting in comparable productivity, high quality and superior process speed and flexibility. This fits into the picture of their dominant competitive factors to place higher emphasis on the quality of their production processes, enabling them to differentiate themselves from their global competitors via excellent product quality and reasonable costs.

3.3.4 Service innovation

With regard to service innovativeness of non-R&D-intensive firms, our studies provide an ambivalent picture. Firstly, Kirner et al. (2008; 2009b) found out that non-R&D-intensive firms show weaker performance in the field of product-related services compared to R&D-intensive firms. On the one hand, this can be explained by the circumstance that R&D-intensive firms tend to produce products with higher complexity, offering more opportunities for product-related services. On the other hand, non-R&D-intensive firms as such show fewer activities in product development. But as new products and accompanying services are often developed simultaneously, this might also result in fewer activities in this field.

Secondly, however, the strategic service orientation of non-R&D-performing firms, measured by the share of directly invoiced services[2], seems to be slightly higher than for their R&D-performing counterparts (Som 2012). In case of non-R&D-performing firms, the average share of services is higher than that of firms with R&D. This holds across all firm size categories although, especially small and medium-sized non-R&D-performing firms seem to be able to profit from new services. Even when controlling for product complexity, non-R&D-performing firms obtain higher innovation output with product-related services than R&D-performers. However, none of the differences between R&D- and non-R&D-performers are statistically significant. It can be stated, however, that undoubtedly non-R&D-performing firms generally obtain higher innovation output with new services than with new products (Som 2012).

Thirdly, the findings of Som et al. (2010) based on data resulting from a telephone survey among non-R&D-intensive manufacturing firms, affirmed their generally lower performance in the field of service innovation. However, in the field of service innovation that has been introduced in the past three years, non-R&D-intensive firms in turn obtain a significant higher share of sales with product-related services than R&D-intensive enterprises, regardless of the level of product complexity. Hence, it seems that the possibility to offer product-related services is not predominantly defined by a high R&D intensity. Instead, it can be concluded that the geographical proximity and the close interrelationship between their customers and them favours the development of such services. As a result, the field of product-related services probably represents an important strategic opportunity to non-R&D-intensive firms to differentiate them against their competitors by taking advantage of their traditional strengths (Som et al. 2010).

3.3.5 Knowledge basis, network embeddedness and technology management

Besides the mere innovation performance, other important aspects of firms' innovation behaviour, especially in the context of systemic innovation research, lie in their network embeddedness and interrelation with other players, their specific knowledge basis as well as their information sources, which will be addressed in the following sections.

Internal and external sources of innovation knowledge

Because non-R&D-performing firms lack the internal innovation resource of formal R&D, it has frequently been argued that these firms compensate this by cooperating more intensively with external partners in innovation projects (e.g. Bender et al. 2005;

2 The higher the share of directly invoiced product-related services, the more advanced is the transformation from a mere "producer of goods" to the new type of "producing service provider" (Gebauer 2004, pp. 5ff.).

Bender 2006, Hirsch-Kreinsen 2008; Santamaría et al. 2009). However, there are opposing findings based on empirical data showing that firms without R&D participate in innovation cooperation to a much lesser extent than R&D-intensive ones (e.g. Arundel et al. 2008; Tsai and Wang 2009).

Firstly, looking at the internal knowledge base of non-R&D-performing firms (Som 2012) shows that the majority of employees in non-R&D-performing firms fall into the group of skilled tradesmen and skilled workers, similar to firms with R&D. Most interestingly, next in size is the group of low- and unskilled employees with an average share of almost one third. Particularly when compared to this group's share in R&D-performing firms (approx. one fifth), the high share of low- and unskilled employees does seem to be a dominant characteristic of non-R&D-performing firms. In addition, detailed analysis confirms the assumption that many of these firms' low or medium complexity products are manufactured in simple tasks which are likely to be performed by this group of employees. Som (2012) found that most of the low- or unskilled employees are indeed deployed in simple, labour-intensive tasks in production.

In turn, the share of graduate or highly skilled employees is on average half as high in non-R&D-performing firms than in their R&D-performing counterparts. Surprisingly, despite the fact that their share of highly skilled employees is relatively low, non-R&D-performing firms report equal shares of employees at the level of masters or technicians. This may be an indicator of a higher relevance of practical, experience-based knowledge rather than explicit knowledge. Surprisingly, the own employees as knowledge source within the enterprise do not play a superordinated role for innovation in non-R&D-performing firms (Som 2012). This relativises the suggestion which is sometimes made that practice-oriented, tacit or implicit elements of employees' knowledge play a dominant role for non-R&D innovation (Arundel et al. 2008; Bender 2006; Hirsch-Kreinsen 2008).

Secondly, with regard to the most relevant external sources of non-R&D-performing firms' innovation knowledge (Som 2012; Kirner et al. 2009b), customers, suppliers and competitors are the most relevant information sources when it comes to product innovation and new product-related services. For R&D-performing firms, customers as knowledge source play an important role as well, but their own R&D department is of course by far the most important source of product innovation knowledge compared to non-R&D-performers. Moreover, as expected, there is also a big difference in the importance of external R&D organisations as a knowledge source between both firm groups, which is higher for R&D-performers. But it is interesting to see that these differences are not as marked as in the case of innovation cooperation. This could mean that for R&D-performers, R&D knowledge is more likely to be generated internally, while cooperation with external R&D organisations is needed to realise concrete innovation projects. In contrast, the share of non-R&D-performers that mentioned external R&D organisations as a relevant knowledge source is almost equal to the share of these firms which cooperate with external R&D organisations. Obviously, in this case the exchange of knowledge is mostly embedded in collaborative activities.

The comparison further reveals that non-R&D-performing firms consider conferences and trade fairs to be the most relevant source of innovation knowledge in the fields of technical and organisational process innovation. This could mean that non-R&D-performing firms tend to be less embedded in specific knowledge arenas and expert networks, which makes it harder for them to access relevant knowledge in these innovation fields. Hence, conferences, trade fairs and other events offer them the possibility to access new innovation knowledge at relatively low costs.

Thirdly, the analysis of non-R&D-performing firms' network relations the findings of Kirner et al. (2009b), Som et al. (2010) and Som (2012) confirm that R&D-performing firms are much more likely to participate in innovation cooperations than non-R&D-performers regardless of their firm size. Moreover, the group of non-R&D-performing firms additionally shows a much stronger relation between firm size and the propensity to participate in innovation collaborations, which suggests that personnel constraints play an important role in non-R&D-performing firms when it comes to making the decision whether to collaborate or not. Besides R&D-performers' higher general propensity to participate in innovation cooperation, the average number of innovation collaborations is actually similar to that of non-R&D-performers. Again, the majority (both in total and within size categories) undertakes between three and five innovation co-operations. This means that the main difference between R&D- and non-R&D-performing firms lies in the decision whether to participate in innovation collaboration at all and not in the number of their network connections.

Looking at the external partners with which non-R&D-performing firms collaborate in different innovation fields, on the other hand, reveals some interesting results. For the more technology-driven fields of new products and advanced manufacturing technology, suppliers and customers (the latter particularly for new products) are by far the most important cooperation partners for non-R&D-performing firms. Comparing non-R&D-performing firms and R&D-performers, the most striking difference is the relevance of external R&D organisations as cooperation partners. Throughout all fields of innovation, R&D-performing firms collaborate to a greater extent with R&D organisations. This supports the assumption of complementarity between the existence of formal R&D and cooperation with external R&D organisations.

But this is not to say that firms without formal R&D may not benefit from innovation cooperation with external R&D organisations such as universities or research laboratories. More than one out of ten non-R&D-performing firms even stated that they also cooperate with R&D organisations in order to access specialised knowledge. This aspect is also supported by the findings that innovation collaborations between partners with high and low R&D intensity contain a high synergy potential for both partners. Non-R&D-performing firms frequently appear as clients or users of innovative manufacturing and production technologies, which are produced by R&D-intensive enterprises and which enable them to increase the efficiency and quality of their production processes further. In turn, based on their process expertise and great experience in the practical usage of technologies, non-R&D-performing firms are even able to stimulate and support the development of high-tech products in R&D-intensive firms (Kirner et al. 2009b; Som et al. 2010; Som and Zanker 2011; Som and Kinkel 2012).

The second difference is not all that obvious but nonetheless very interesting. The comparison shows that non-R&D-performing firms collaborate more frequently with their competitors, especially in the fields of technical and organisational process innovation, and in the field of product-related services. One explanation could be that both partners cooperate to develop the basic solution to a problem before each of them then adapts this solution individually to its own firm-specific situation. As this only makes sense as long as no fundamental technological assets or core businesses are involved, it could be assumed that such innovation cooperations with competitors tends to take place in peripheral business areas. Other possible explanations could be that, in their role as suppliers, non-R&D-performers are either more frequently forced by their main customers to collaborate with their competitors, or that they try to increase their bargaining power over customers by collaborating in certain fields.

While some authors (Pavitt 1984; Heidenreich 2009) have suggested that most innovations of non-R&D-performing firms stem from suppliers of equipment and materials, this could not be supported by the present findings. There are no significant differences between firms with and without R&D concerning innovation cooperations with suppliers in any field of innovation. Instead, the results show that non-R&D-performing firms – depending on the field of innovation – make use of the whole range of potential partners for innovation cooperations, even external R&D organisations to a minor extent.

Technology management and absorptive capacity

The acquisition and purchase of innovative machinery and equipment or intermediate goods from external sources with little or no further work required is often seen as another important source of innovation for non-R&D-intensive firms (e.g. Tsai and Wang 2009; Heidenreich 2009). This could mean that they are thereby relatively more dependent on the diffusion of external knowledge than R&D-performing firms, particularly through knowledge embodied in acquired products and processes (Arundel et al. 2008).

Empirical analysis shows different strategies of technology management. Nearly half of all interviewed non-R&D-intensive firms either develop new technological solutions on their own or purchase existing technologies from outside the firm which are adapted and integrated according to their specific requirements and manufacturing processes (Som et al. 2010). This includes also the transformation of existing technological solutions into new contexts of operation (Som and Zanker 2011). Only a minority of non-R&D-intensive firms can be labelled as pure technology purchasers that focus on ready-to-use process technologies. This underlines that non-R&D-intensive and non-R&D-performing firms have access to and make broad use of advanced technologies, and, even more important as “process-specialists” have the technological competences to develop them further, transform them into different operational contexts, or adapt them to their own needs (Som 2012). To complete this picture, it has, however, also to be stated that the share of firms with technological in-house development is, as expected, significantly higher for R&D-intensive firms.

This raises the question about the absorptive capacity of non-R&D-intensive firms. In their seminal contribution, Cohen and Levinthal (1989; 1990) described the "absorptive capacity" of firms as the ability to recognize the value of new, external information, assimilate it and apply it to commercial ends. The absorptive capacity of a firm can be distinguished by two interdependent dimensions: a) the capability to search and acquire new, external information about technological trends, and b) the capability to adapt internal processes and resource configurations in such a way that their competitive potential is fully exploited (Cassiman and Veugelers 2006; Arbussa and Coenders 2007). Usually, absorptive capacity is argued to be a cumulative result of internal R&D activities, suggesting that internal R&D capacity and practices of external knowledge sourcing complement each other (Ebersberger and Herstad 2010).

However, the results presented by Som et al. (2010, 2012) show that there is surprisingly little difference in the level of absorptive capacity between R&D-intensive and non-R&D-intensive firms – if the firm's specific relevance of such external impulses is taken into consideration. Both R&D-intensive and non-R&D-intensive firms are equally able to recognize and also successfully implement new technological trends, if this matches their competitive strategy and is therefore considered relevant. Given that not all firms (be it R&D- or non-R&D-intensive firms) compete on the basis of a first-mover strategy, there are significant differences to be found between firms as regards the individually perceived importance of the early adoption of new technological trends. On the one hand, a relevant share of R&D-intensive firms does not perceive a high necessity to monitor and implement newest technological developments. On the other hand, quite a number of non-R&D-intensive firms do consider the recognition and implementation of the latest technological trends to be relevant for their business and therefore engage in practices that allow for the successful absorption of these trends.

This is a surprising finding in so far, as it indicates that R&D intensity might not be a limiting factor for firms' ability to recognize and implement new technological trends per se. By introducing an additional differentiation – the firm's individual prioritisation of the relevance of external trends and developments – these results indicate that absorptive capacity is mainly linked to the perceived necessity to adopt new technological trends. These findings apply also to the non-technological side of absorptive capacity. No significant difference is to be found between R&D-intensive and non-R&D-intensive firms as regards their ability to perceive and implement new market demands and customer requirements, once these are perceived to be highly relevant for the firm's overall business strategy.

3.4 Is there an "innovation system without R&D"?

In the light of the previously presented findings from five years of Fraunhofer research on non-R&D-intensive industries and enterprises, the question arises whether there is a need to consider a specific sectoral "innovation system without R&D" in contrast to "common" R&D-based innovation systems, or whether the phenomenon of non-R&D-based innovation just emphasises certain aspects which are already laid out in innovation systems approaches. Of course, this question is subject to further research and cannot be answered conclusively in the context of this contribution. In the following, some points in favour of both perspectives will be raised.

Starting from Malerba (2005, p. 17), sectoral systems of innovation can be identified by a set of main building blocks:

- a specific knowledge and technology base
- specific patterns of interaction with economic and non-economic network partners for the exchange and generation of knowledge
- a specific institutional setting, which means both the embeddedness of firms into these institutional setting as well as the specific linkages to their institutional environment

Firstly, to address the aspects of a *specific knowledge and technological base*, the depicted findings provide some aspects which could be interpreted in such a way. Compared to R&D-intensive firms, non-R&D-performing firms are characterised by a more distributed knowledge base which is not primarily fed by a linear flow from basic research generated in the science sector to the R&D departments of private sector firms. Instead, non-R&D-intensive firms derive their innovation knowledge from a dispersed variety of sources within and beyond their value chain. Given the characteristics of their internal and external knowledge basis, it can be assumed that non-R&D firms put forth less formalised paths of knowledge generation and accumulation than science-based modes of expert knowledge (Arundel et al. 2008; Hirsch-Kreinsen 2008; Som and Zanker 2011), resulting in pragmatic ways of "doing and using" and a strong orientation towards practical application (von Tunzelmann and Acha 2005, p. 417). This is also reflected in the ability to adapt and further develop existing technological solutions to specific requirements in terms of process integration, design, layout, engineering and construction, and technical problem solving abilities, either for the own enterprise or customers (Som and Zanker 2011; Som et al. 2010). Accordingly, to achieve superior process performance, non-R&D-performing firms are neither necessarily deploying cutting-edge technology nor do they try to compensate their lack of R&D activities by an over-intensive use. Instead, their use of technology rather follows the criteria of feasibility and pragmatism.

Secondly, as pointed out in the empirical findings, the *network relations* of non-R&D-intensive firms are particularly focused on local and regional niche markets and network partners (customers, suppliers and competitors). This geographic proximity and the tight coupling to these partners enable them to accumulate stocks of knowledge about the specific needs and requirements of their clients, resulting for instance in a better performance regarding product-related services. In addition to these services frequently based on process competences, they also offer complete problem-solving packages of client-specific service solutions from one source (one-stop shop). With regard to the supply side, non-R&D-intensive firms contribute to the rapid diffusion of new product ideas and production concepts by adopting the innovations of others and using them in particular for own process innovations. They thus assume an important role as "diffuser" in the innovation system and through their adoption of new technologies continuously increase the efficiency of goods production (Rammer et al. 2011). Corresponding to the less formalised nature of their relevant knowledge, also their network relations beyond the value chain are also less formalised. Specific knowledge arenas and expert networks only play a subordinate role for them. Accordingly, their interactions with R&D organisations like universities and research laboratories are of less relevance compared to R&D-intensive firms.

Thirdly, starting from some of the characteristics of non-R&D-performing firms it can be suggested that they also affect their *institutional embeddedness*. Certainly and most obviously, because the largest share of innovation and technology policy instruments focuses on the stimulation and increase of firm-level R&D-activities (Hirsch-Kreinsen 2008), only a minority of non-R&D-performing firms is likely to participate in such policy measures at the national and European level (Cox et al. 2002; Arundel et al. 2008). In consequence, they can be assumed to be less coupled to the political subsystem than R&D-intensive firms which are directly addressed by policy measures. Moreover, given their significantly higher share of low and unskilled employees which has emerged in the empirical analyses, non-R&D-performing firms are probably less dependent on the availability of highly skilled experts and engineers with tertiary education on the labour market than R&D-intensive firms. In consequence, it can be assumed that they are also less dependent on the educational system in terms of highly skilled employees. While non-R&D-intensive firms are probably not affected by a shortage of a skilled workforce to the same extent as R&D-intensive ones, they rather face the future challenge to secure and develop their internal stocks of practical knowledge in terms of an adequate measure of vocational training and qualification programmes. However, due to their strong interrelations with local and regional partners along their value chains (Som et al. 2010; Som and Zanker 2011), the embeddedness of non-R&D-firms into such regional and national markets and industry structures might be considerably higher than for R&D-performers who are more likely to export abroad.

As outlined by this brief discussion, the innovation behaviour of non-R&D-intensive firms is characterised by certain features that could serve as guiding lines or corner stones in favour of the necessity to erect a specific type of "innovation system without R&D". However, the question about the boundaries of such an innovation system conceptualisation remains open. As the empirical findings show, an innovation system is not very likely to follow the statistical differentiation of sectors and industries, due to their inter-sectoral heterogeneity (Kirner et al. 2009a; Som 2012).

Moreover, as the study of Som (2012) reveals, even on the level of non-R&D-performing firms, one should not expect a homogeneous innovation pattern. Based on quantitative data from the German manufacturing industry, he identified five different innovation patterns among non-R&D-performing firms by performing statistic cluster analysis. These innovation patterns cover the whole range of firms' innovation intensity. On the one hand, there is a group of knowledge-intensive, highly innovative firms showing a "science-based mode of innovation", for instance by the importance of expert knowledge, a high share of highly skilled employees, and the production of high-tech products, which are usually more likely to be found in R&D-performing firms or R&D-intensive sectors. On the other hand, there is a group of firms that closely corresponds to the ideal type of a low-innovative, "low-tech" firm.

Against this background, it can be questioned if the innovation behaviour of non-R&D-intensive firms actually constitutes a distinct innovation system with fundamentally different characteristics than R&D-based innovation systems, or if non-R&D-based modes of innovation just emphasise particular elements and processes of knowledge generation that are already included in existing system approaches and which are frequently overlooked in the R&D focus of empirical analyses and political discussions.

In innovation system theory (David 1996; Foray 1998; Lundvall and Johnson 1994; Edquist and Texier 1998), the decline of the R&D focus was mainly driven by a shift of the analytical focus towards innovation-related activities that go beyond the scope of formal R&D, and, on the other hand, by a changing understanding of the nature of the innovation process itself. The main developments were:

- A broader understanding of firms' internal innovation resources expressed by the terms of "routines", "capabilities" or "competences" (Nelson and Winter 1982; Teece and Pisano 1994; Prahalad and Hamel 1990; Grant 1991), by generally referring to "knowledge" as the most important predictor of innovation (e.g. Grant 1996; Spender and Grant 1996).
- The increased appreciation of engineering, design, production and distribution activities (Freeman and Soete 1997; Hansen and Serin 1997; Koschatzky et al. 2001) as well as investment in capital equipment related to innovation are further determinants of successful innovation (e.g. Evangelista et al. 1998; Evangelista 1999).
- The awareness that the firm's ability to exploit systematically the effects produced by new combinations and uses of components and practices in the existing stock of knowledge may be another crucial enabler for successful innovation (David and Foray 1995; Kline and Rosenberg 1986); for example frequently labelled as "architectural innovation" (Henderson and Clark 1990, p. 12) or "innovation without research" (Cowan and Van De Paal 2000, p. 3). As Kline and Rosenberg (1986) argue, when firms are faced with having to innovate they first look into their existing stock of knowledge, and if the answer cannot be found there, they then consider whether it makes sense to spend on R&D or not.
- The increasing recognition that firms are embedded in social systems of innovation (e.g. Lundvall 1992; Edquist 1997; Nelson 1993). This highlights the systemic nature of innovation processes, emphasizing that firms do not normally innovate in isolation, but in collaboration and interdependence with other organisations (e.g. suppliers, customers, competitors, etc.), non-profit entities

(e.g. universities, schools, government ministries), institutions (e.g. laws, rules, norms), and other social entities (e.g. local residents, consumers). Moreover, firms intentionally may actively make use of their surrounding external sources in terms of collaboration (e.g. Dyer and Singh 1998; Nooteboom 1999), user-driven innovation (e.g. Lundvall 1985; von Hippel 2004), or "open innovation" (e.g. Chesbrough 2003).

In parallel, the understanding of innovation processes has shifted from the linear, sequential and thus predictable nature towards complex and self-referential cycle models (Kline and Rosenberg 1986; Rothwell 2003; Dodgson 2000; Tidd and Bessant 2009) which account for multiple recursive feedback loops and other sources of innovation knowledge. Consequently, innovations are not just the results of scientific work in a laboratory-like environment. They are arrived at in networks where actors from different backgrounds are involved in the process setting new demand for innovativeness. As a result, the innovation process is understood as complex and variable. Against the background of modern, knowledge-based economies, the use of R&D as a proxy or surrogate measure for a wider range of innovation appears no longer adequate (Freeman 1994; Arundel et al. 2008; Raymond and St-Pierre 2010) and the theoretical focus needs to shift "from R&D to learning processes" as all knowledge produced within a firm cannot be attributed to formal research activities (Foray 2006, p. 7; Lundvall and Johnson 1994). Thus, formal R&D remains only one among many other inputs and sources of innovation within the firm (Smith 2005; Arundel 1997; Freeman 1994; Nelson 2000).

Thus, looking at these features of the existing innovation system concept, there are also good reasons to reject the development an additional, non-R&D-based innovation system approach. Instead, R&D-performing and non-R&D-performing firms just seem to follow different but complementary paths of innovation generation, which do not exclude or contradict each other. On the contrary, as some of the presented findings showed, the innovation strategies of R&D- and non-R&D-intensive firms have many things in common and both types of firms make use of the whole bandwidth of strategic options in their innovation behaviour.

3.5 Conclusion

It was the aim of this review to highlight some findings about non-R&D-intensive firms' innovation strategies, which were revealed within the past five years of non-R&D innovation research by the Fraunhofer ISI, and which should be reflected in the light of the innovation system concept. The fact that non-R&D-intensive companies remain important for industrial value-added and employment as well as the results presented for the innovation performance of these firms highlight the necessity for both empirical innovation system research and innovation policy to pay more attention to the specific innovation modes and strengths of this group of enterprises. Regardless of how the question about the existence of a specific "innovation system without R&D" is answered from the individual perspective of the volume, adhering to a sole focus on R&D modes of innovation causes the risk of underestimating the innovation and competitive performance of innovation systems as a whole.

For innovation policy, the results mean that the focus should be directed from a primary orientation on the R&D intensity of enterprises and branches towards a much broader understanding of the innovation capacity of enterprises interaction with other actors. This requires a broader view of innovations and firms' innovation processes, in which, for example, facets such as the internal diffusion, adoption and commercialization of new technologies are also taken into account. One concrete approach here could be to take the identified strengths of non-R&D-intensive firms in the area of process innovations as the starting point and integrating them at an early stage as users of the developed technologies in pre-competitive collaborative projects, together with research-intensive actors. By opening up suitable existing programmes, it could be possible to reduce the specific transaction costs of such collaborations with research institutions and stimulate the up to now rather cautious willingness of non-R&D-intensive firms to cooperate with scientific institutions in appropriate networks (Rammer et al. 2011; Som et al. 2010).

Against this background, present day innovation indicators are not yet accurate enough to be able to provide an adequate explanation of the success factors of non-R&D-intensive firms. On the one hand, this relates to a meaningful, further differentiation of the indicator innovation expenditures in factors such as e.g. expenditures on the design or customer-oriented (re-)construction of the services, which could lead to in-depth knowledge about the innovation successes of non-R&D-intensive enterprises. A further area concerns indicators to measure the absorptive capability of enterprises with regard to technological innovations, in particular with the target of improving their manufacturing and performance processes. In innovation research, R&D expenditures or the share of highly qualified employees are often taken as estimators. The good position of the non-R&D-intensive firms with regard to process innovations, despite the low share of highly qualified personnel and especially expenditures on R&D, underlines the need to design and test further parameters here to model absorptive capacity.

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4

PUBLIC RESEARCH IN GERMANY:

CONTINUITY AND CHANGE

RAINER FRIETSCH, TORBEN SCHUBERT

4.1 Introduction

The German research landscape is in constant flux. This is not a unique development in the world, but commonplace: if you do not go forwards, you go backwards. However, enforced application orientation, shrinking budgets, increasing shares of project funding, international benchmarks, the quest for excellence, the demand for highly qualified personnel, as well as demographics, are forcing the actors in the German research system to adapt and change. Quarrels about responsibility, influence and financial obligations among the federal states and at the national level exert future pressure on the system.

This means that there is more movement in the system than the usual adaptation to a changing environment. Incidents show that new structures and new policies have a considerable impact on the layout of the German research system. A particularly interesting observation is that there are strong arguments in favour of an increased mission orientation and profile development among the actors of the research system in Germany. At the same time, differentiation in terms of missions has been criticised because of the foregoing of collaboration potentials (Heinze and Kuhlmann 2007). In line with this criticism, it can be observed that universities were constantly pushed in the direction of knowledge and technology transfer as well as to establish science-industry linkages. Thus the two policy paradigms that have emerged could be characterised as differentiation and collaboration.

At the same time, we ask whether the mission orientation and the collaborative activities (the latter especially with respect to industry) in the German public research system could be increased. To this end, this chapter describes some of the new forces that are at play in the German research landscape and that have caused several of the actors to reposition themselves. Here we pay particular attention to direct policy initiatives that have influenced the innovation system as such, as well as changes in the financing structures that have become relevant in particular for the public research organisations.

The remainder of this contribution is organised as follows. In the following section the contribution briefly describes the layout of the German research landscape and the missions and role of the most relevant players therein. In Section 4.3 we describe the major innovation policy initiatives, where we pay particular attention to the question, to what extent they have impacted on the mission orientation. In Section 4.4 we discuss the major actors of the German public science sector in more depth alongside their missions and how changes in the financing modes that occurred over the past years have affected their priority setting. In Section 4.5 we furnish our conclusions.

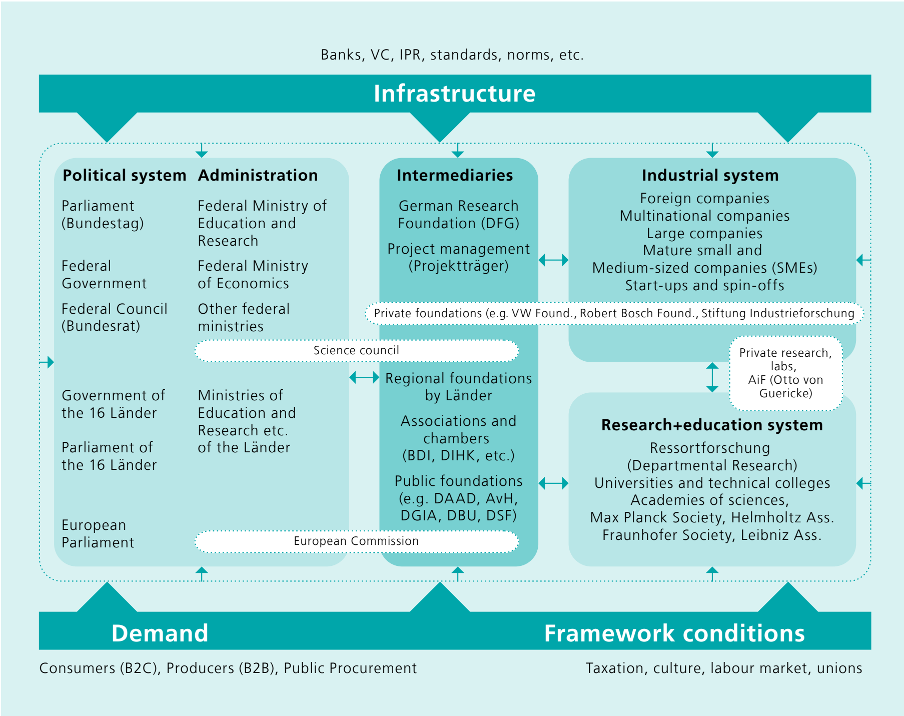
4.2 Germany's innovation system – a theoretical overview and a brief introduction

Nowadays innovation is influenced by a number of factors. Since Schumpeter wrote his work on innovation and the innovative entrepreneur (Schumpeter 1911), the role of and the perspective on innovation have changed considerably. While in Schumpeter's view the owner of a company was the decisive actor in the innovation process, uniting the legal, economic as well as the scientific responsibilities, the complexity of the processes, the division of labour and responsibilities as well as the structuring and target-orientation of research and development changed the layout of innovation at the micro and the macro level. According to Sundbo (1991; 1995; 2001), Schumpeter's era can be called the entrepreneurship paradigm, which characterises the time up to the first quarter or even first half of the 20th century. This was followed by an economic paradigm, where research and development (R&D) processes and the generation of technology and technological solutions became the main driver of the innovation processes. Nowadays, we live in the era of the strategic paradigm, which is still characterised by the strong role of formal R&D activities. However, as innovation is the successful implementation of new products or new processes (OECD and Eurostat 2005), R&D alone is no longer sufficient (cf. Chapter 3 in this volume). Due to the increased complexity of technologies (Kash and Rycroft 2002; Kash and Kingston 2001), the growing importance of knowledge (Berg Jensen et al. 2007; Foray 2004; Lundvall and Foray 1996; Nonaka and Takeuchi 1995; Teece 2003) – especially tacit knowledge – the internationalisation of markets and the internationalisation of knowledge production (Belitz et al. 2006; Patel and Vega 1999; UNCTAD 2005), networking and linkages, as well as the relevance of marketing and image cultivation, strategic aspects have gained importance in the innovation process.

The heuristic of national innovation systems (Edquist 1997; Freeman 1988; Kuhlmann and Arnold 2001; Lundvall 1992; Nelson 1993) takes the multiplicity of actors and institutions into account, which have a direct or indirect effect on the innovation output. It adopts a specific national, regional or sectoral perspective (cf. Chapter 1 in this volume). It is also tailored to reflect the influence of innovation policy, of intermediary institutions like facilitators or funding agencies. In addition, framework conditions, the market side, or finance and taxation might also be a focus of innovation analysis. The systems perspective also allows a differentiated analysis, as not all systems need to have the same layout and the same components. This heuristic is first of all a model of the actors and their relations. Innovations take place embedded in the political, social, organisational and economic sub-systems, constituted by the institutions and organisations that form them. This approach challenges the traditional modernisation theory that assumes one single development path for each national economy (Grupp 1998). Underlying this heuristic is a non-linear or recursive model of innovation processes, which allows the complexity of the process to be better taken into account than the rather simple linear innovation models that were more appropriate in the context of the second paradigm described by Sundbo (Schmoch et al. 2000). At the core of this approach are the industrial system and especially its R&D activities and its directed and target-oriented innovation endeavours. Besides, the public research system is of crucial importance for the success of any innovation system. Innovation policy on the part of government and public administration impacts the innovation activities, either by setting framework conditions and regulations or by directly funding public research as well as private research projects in companies. The education and qualification system which educates and qualifies the necessary, even mandatory human resources, is meanwhile one of the most important preconditions that shape performance. In addition, more on the periphery, but still a relevant sub-system, is society – including culture, risk aversion, or demand in the context of innovation and innovation performance. Furthermore, the financial system supplying the financial resources to invest in R&D and innovation is another relevant sub-system. Taxation and general regulation, including the legal system, which then also includes the intellectual property rights and the effective implementation and use of the legal system, also has an impact. Figure 4–1 depicts a rough description of the German innovation system and its layout.

While the innovation systems approach is meanwhile a well established concept in innovation policy and macro-economic analysis, its implementation in effective policies is less frequent in reality. Even if governments, ministries or agencies claim to have a systemic perspective, the effective real-world, every-day business is still fragmented and characterised by an organisation along technological responsibilities between and within ministries. We can hardly claim here that this situation has been overcome in Germany. However, the new High-tech Strategy 2020 is one important step in this direction. There are still quarrels about responsibilities and competences as well as an organisation that follows traditional paths of technological and functional differentiations.

Figure 4–1: The German innovation system at a glance



Source: Frietsch and Kroll (2010)

The complexity of the innovation process requires that this complexity should also be reflected in innovation policy. The new High-tech Strategy of the federal government takes the systems perspective into account and tries to reflect the complexity of the innovation processes. This is mainly done by moving away from the sectoral or purely technological perspective towards a mission-oriented perspective. The new Strategy starts from the global or big challenges that need to be addressed, and that can be addressed by science and technology. These big challenges are: energy production and provision, mobility, communication, health, and security and safety, which form the five columns of the new High-tech Strategy, and are called demand areas (*Bedarfsfelder*). Derived from these, the missions aim to solve the problems and to tackle the challenges. In addition to the five demand areas, some enabling or key technologies are also mentioned which play a relevant role in several of these demand areas. However, the task is no longer to offer isolated technological solutions, but to move their application and implementation into the focus of the policies. We explain this by citing an example: there is no direct radio frequency identification (RFID) policy or RFID funding programme. RFID may be relevant in the demand area "communication", but also for mobility, health or security and it will be funded by innovation policies based on concrete projects and requirements. This approach becomes even clearer and more understandable when the future projects are taken into account, which form the level below the demand areas. A set of future projects were introduced, among them future cities (more precisely, this is called the CO_2- neutral, energy-efficient and climate adapted city), sustainable mobility, or individualised medicine. It is obvious that a number of technologies are relevant in each of these future projects.

The German innovation system has a multi-level governance structure, both in horizontal and in vertical terms. In terms of science and innovation, essentially two ministries are responsible at the federal level, as well as a set of ministries that focus on certain topics and within which innovation usually plays a subordinate role, while a multitude of ministries and agencies also tackle this topic at the federal state level (*Bundesländer*). Besides, a set of state and para-governmental authorities and agencies are in play at all levels (Frietsch and Kroll 2010).

While the universities are administratively and legally managed at the federal state level, the large public research organisations are either mainly funded by the federal government in Berlin – in the case of Max Planck, Fraunhofer and Helmholtz – or partially funded by the federal government and the federal state where the institute is located – in the case of the Leibniz Association. The German Research Foundation (DFG) – as an intermediary organisation that mainly funds basic research, primarily in universities – is financed by both the federal government and the Bundesländer in equal shares. Universities are legally, administratively, and financially located at the level of the federal states. Following the recent reforms concerning the interaction between the Bundesländer and the central government, they are also almost exclusively financed by the former. However, the central government may co-finance university buildings, in the context of the excellence clusters as one funding scheme of the Excellence Initiative.

The public funding for science and research is aligned along the two dimensions project and institutional funding. The major share of public research funding is allocated as institutional funding, which may however be contingent on performance indicators. At the same time, an increasing share of funding needs to be acquired as project funding by several research performers, especially from national – including DFG – or regional and also European sources (BMBF 2007; BMBF and BMWA 2003; BMF 2009). The goals of project funding especially allocated under different programmes is to steer and channel the research in the public research sector, in universities, but also in companies. Programme funding targets certain policy goals. In the recent years, science-industry collaboration, increased application orientation, SME support, and certain new technologies were among them. Next to the missions of the research organisations and the universities, this is the way to reach certain policy goals.

The German research landscape is also characterised by a huge number of intermediary organisations that help to foster the performance of the system. Among them are the project management institutions, to which the ministries delegate some of the administrative tasks (BMBF 2007). There is also a clear mission orientation in the role of these intermediaries. The already mentioned German Research Foundation (DFG) mainly finances basic research in universities (and some non-university research organisations). There are several other foundations supporting science, research or technology transfer at the regional level. For example, the Steinbeis Foundation is successful as a mediator between science and industry, especially for SMEs and mid-tier companies, on the one hand, and universities and universities of applied sciences on the other hand. Another intermediary body is the German Council of Science and Humanities (*Wissenschaftsrat*), whose task is to advise the federal government and the federal states' governments on the present and future tasks and layout of the higher education system and the research system. The German Federation of Industrial Cooperative Research Associations (AiF/IGF) Otto von Guericke conducts contract research and development for industry (AiF 2008). Recently, technology transfer offices have gained visibility and are seen as relevant institutions by policymakers to move the system towards more application orientation.

Science, technology and innovation performers are manifold and the largest among them have been following a strict mission over decades, targeting certain tasks and scientific areas. The Max Planck Society (MPG) and also the currently 18 institutes of the Helmholtz Association can be located in the area of basic science. The former has a broad spectrum of technologies and research fields ranging from physics, chemistry or biotechnology to social sciences and demography. The latter mainly deals with large-scale research like energy or medicine and biology. They claim to pursue "long-term research goals on behalf of the state and society"[1]. The Fraunhofer Society, on the other hand, is the most important provider of applied research in Germany, thereby also striving to close the gap between science and industry. The members of the Leibniz Association which emerged from the "Blue List" institutes in the 1970s, came into being in 1990, fulfil different tasks, ranging from long-term research to services for other research institutes.

In general, one of the strengths of the German innovation system is the strong and clear division of labour between research associations and societies and also between public and private actors, as well as a strong functional specialisation, which can also be called "mission orientation". The mission of the universities is teaching, basic science, while technology transfer has also been emphasised by policy. At the same time, the performance dimension against which the universities are evaluated is still by and large their ability to produce world class (basic) research. The universities – as a matter of fact – cover the full spectrum of sciences, arts and humanities. Universities are administered and financed by the federal states' governments. Institutional reforms of recent years have changed the governance, the autonomy and in particular the financing structures of the universities. More will be explained in the next section. However, over decades all universities were seen as equal with respect to quality. No such idea as qualitative differentiation existed in Germany. Differences between the universities were ideologically conceptualised as irrelevant or marginal. This has changed in recent years, especially as a result of the Excellence Initiative

1 http://www.helmholtz.de/en/about_us/.

that provides considerable financial resources for concepts that aim for and claim worldwide outstanding research. The concepts that have won this competition so far were clearly boundary-spanning, so not only universities, but also other institutions have been included. They were also interdisciplinary, internationally oriented and especially with explicit science and technology transfer perspectives. Out of this initiative, the Karlsruhe Institute of Technology (KIT) emerged, which is a revolution in the German science system, given the fact that the former university – a regional institution of the state of Baden-Württemberg – and a research centre of the Helmholtz Association – financed by the federal government – merged.

In consequence, new forces have emerged that have pushed the actors in different directions. In particular, the change of the financing patterns has had an immense influence. The shares of institutional funding, especially for universities and the Fraunhofer Society, were reduced in relation to the share of third party funds, meaning these organisations had to reposition themselves.

While the mission orientation was introduced into innovation policy and the national innovation strategy, the clear mission orientation was softened in the research landscape. The questions are why, if this is a strategic move, and if this will have a positive impact on the overall performance of the German innovation system.

4.3 Innovation and research policies in Germany

German innovation policy of recent years or even decades was – among others – focussed on facilitating and fostering the collaboration between science and industry. This intention was essentially driven by two perceptions. On the one hand, the massive investments in the public research system produce a magnitude of relevant and potentially commercially exploitable results. Ultimately, next to general scientific curiosity and the overall enhancement of knowledge, this is what justifies investing taxpayers' money in the science system. On the other hand, the collaboration and interaction, especially with regard to the concrete exploitation and commercialisation of public research results offers a potential for additional – non-public – funding for the budgets of the universities and research organisations, thereby also steering their endeavours towards applicable and commercializable research.

Fostering university-industry collaboration is not a unique idea (Algieri et al. 2011; Schmoch et al. 2000) and many policymakers and governments all around the world have identified the potentials that lie in this collaboration between science and industry. However, the German innovation policymakers have taken this idea seriously and have introduced a bundle of policy measures and instruments dedicated to work towards this goal. The research premium for public research institutes, certain columns within the ZIM programme, a proof of technology funding, or the cluster policies are recent examples of this endeavour (BMBF 2006).

The High-tech Strategy launched in 2006 was a milestone in German national innovation policy. What was new, was the coordination of the innovation policy of several administrative bodies, mainly the Ministry of Education and Research (BMBF), the Ministry of Economics and Technology (BMWi), and several more like the

Ministries of Defence, Transport, or Environment. The core conceptual aims were to increase public expenditures on research – also to reach the 3 % objective of the EU that was adopted in the national policies at that time –, to promote collaboration between public research and industry, and finally to increase the orientation on applied research and the commercialisation of research results (BMBF 2006).

The basic approach of the HTS is based on continuing established and successful policy measures, while improving their coordination and supplementing them with new, target-oriented instruments. New measures were introduced such as the "Cutting-edge Cluster Competition" or the "Research Bonus".

The High-tech Strategy of the federal German government included several means and instruments – not all of them were newly introduced into German science and innovation policy at that time – to support and foster the collaboration of science and industry. For example, the Leading-edge Cluster Competition was a milestone in Germany's science policy with respect to science-industry linkage. The basic principle is to financially support the coordination and collaboration of thematically specialised clusters that were suggested and organised bottom-up. Facilitating regional or local exchange – this is also one of the basic insights from the scientific literature (Koschatzky 2012; Schmoch et al. 2000; Stahlecker 2006) – is the key to a successful policy to link the science and the industry community in certain technological fields. This initiative, that has been in effect since 2007, is organised as a competition, where the partners in a cluster must submit a joint application by the partners, followed by an evaluation by experts. Finally, five clusters per round will be selected, which are funded for 5 years with up to 200 million euros. It is expected that at least the matching amount of funding is invested by the business sector and private investors as well. The goal is the exchange between different actors of the innovation system. Science, industry and further actors in one region shall offer a joint concept that increases their innovativeness. It transpired that the application alone already helps to structure the regional/local activities and connects the actors. A so-called research bonus was introduced in early 2007. It was meant to motivate universities and public research institutes to intensify their collaboration with small and medium-sized enterprises (SMEs). The universities or public research institutes are paid a premium for each contract research project with SMEs.

In the revision and further development of the High-tech Strategy that was launched in 2010 under the title High-tech Strategy 2020, the German government's commitment to supporting the science-industry linkage is continued. A new focus is now laid on the application of the IPR of universities, public research, but also of SMEs. In addition, new campus models aiming to link up universities, public research institutions and industry are to be developed (BMBF 2010).

An equally prominent policy initiative directed to the public research system, in particular, but not exclusively to the universities, was the Excellence Initiative (*Exzellenzinitiative*) which started in 2005/2006. In the context of this programme the German universities had the opportunity to apply for funds from the DFG pertaining to the establishment of graduate schools, the creation of excellence clusters as well as future concepts. While in particular with respect to the future concepts – the above mentioned establishment of the KIT is one result of the Excellence Initiative – have definitely aspects of collaboration-increasing incentives, one must still conclude that the main focus of this programme was from the beginning to advance at least some of the German universities towards the worldwide scientific frontier. So, in general, the Excellence Initiative primarily aimed to create research environments that benefit basic research rather than fostering science-industry collaboration. This is particularly true with respect to science-industry linkages that play, if at all, only a marginal role. The first and second round of this programme (2006/2007) distributed roughly 1.9 billion euros to the German universities, while the third round which runs until 2017 will offer another 2.7 billion euros. The immense sums that were and are at stake led to a wide participation that has strongly influenced the activities and the self-perceptions of the universities.

Thus, in summary, while the High-tech Strategy 2020 tries to strengthen collaborative aspects as well as increase mission orientation, the Excellence Initiative created strong incentives for the universities to increase their basic research tasks. As this might create tensions between the aim of increasing industry-science collaboration and the call for international excellence, we will show in the next section that the pendulum, at least in the universities, has definitely swung to the former.

4.4 The public research system

As already highlighted, the German public science system is a differentiated system both institutionally as well as regards its tasks. Besides the higher education institutions, which themselves can be divided between the universities and the universities of applied sciences (*Fachhochschule*), there are a large number of semi-public non-university research institutes. The majority of the latter belongs to one of the four big research organisations Max Planck Society, Fraunhofer Society, Helmholtz Association, and the Leibniz Association.

In terms of personnel, these four institutes accounted for roughly one quarter of the public science sector in 2009 and thus form a considerable part of the German public science landscape. In more concrete terms, the universities including the universities of applied sciences had roughly 181,000 full-time equivalent (FTE) personnel, among them about 85,000 researchers (BMBF 2012, p. 486), while the number was about 61,000 (36,000 researchers) in the four organisations taken together. Of these 12,000 (6,500) were located in the Max Planck Society, 24,000 (14,000) in the Helmholtz Association, 13,000 (9,000) in the Fraunhofer Society and 12,000 (6,500) in the Leibniz Association (BMBF 2012, p. 489).

Also located in the non-university public research sector are a number of individual research institutes often directly affiliated with the federal states or the central government (*Bund-Länder Institute*). Furthermore, we find a large number of research institutes that are affiliated with the universities via cooperation contracts but are not primarily financed by them (*An-Institute*). While both taken together accounted for roughly 1.3 billion euros of the total budget over the past years (as a reference point, the universities had a budget of 20 billion euros in 2008, see Table 4–1), they constitute highly heterogeneous groups of institutes, which are hardly connected by any common mission or objective (Koschatzky et al. 2008). We will not further discuss these institutes within this contribution.

4.4.1 The higher education institutions

The universities and the universities of applied sciences differ from the big non-university research organisations primarily because only the universities and universities of applied sciences have institutionalised teaching obligations. The non-university institutes, on the contrary, offer teaching only inasmuch as their personnel are also affiliated with the universities.

By 2011 there were 110 universities (including the technical universities) and 231 universities of applied sciences. Additionally, there are 73 "other universities" which have a much narrower thematic focus on special topics. Among them are the pedagogic, theological or sports colleges. In terms of personnel, however, the universities account for 80 %, while the universities of applied sciences account for 17 %. The 73 "other universities" are usually very small and make up the remaining 3 % in terms of staff (Brandt et al. 2011).

While both universities and the universities of applied sciences have the teaching task in common, there are also important differences between them. From a legal perspective, the decisive distinction is that the universities of applied sciences are not allowed to grant doctoral degrees. That implies that the universities of applied sciences focus their teaching tasks on undergraduate teaching up to at most Master's level, while the universities also engage in higher tertiary teaching.

In order to understand the reasons for this 2-class higher education system, it should be noted that the universities of applied sciences in their current form are a relatively new institutional element, which came into existence in the years after 1969. The major reason for the creation of the universities of applied sciences as an additional player was the implementation of the higher education expansion, i.e. the politically fostered increase in access to higher education. While traditionally higher education was the preserve of a small elite and a point of immense social status, today higher education possibilities have been opened up for much larger parts of society. This can also be observed in the statistics: while in 1969 less than 600,000 students were matriculated in a university, this number had reached about 1,800,000 in 1997 (Sternberg 2001).

The major objective in creating the universities of applied sciences was therefore to provide suitable capacities that could sustain the expansion of higher education. Correspondingly, the original aim of the universities of applied sciences was not to increase the research capacities. This explains why also today the universities of applied sciences are focussed on teaching and only engage in research to a limited degree. If they do so, the research is usually of a more applied nature than the basic research conducted at the universities. Furthermore, the universities of applied sciences usually build up strong networks of collaborative research with local companies, many of them small and medium-sized, in order to increase knowledge and technology diffusion as well as offer networking advantages to their students and graduates.

In accordance with this image, Brandt et al. (2011) report that more than 70 % of the university professors report giving highest priority to basic research, while only 22 % of the professors at the universities of applied sciences do so. The latter give, however, the highest priority to applied research (55 %; university professors between 34–39 %). Teaching, on the contrary, is much more important for the universities of applied sciences (60 %, university professors 38–39 %). Furthermore, technology transfer is of lesser importance for university professors. While 22 % of the professors at the universities of applied sciences report high priority for this field of action, at the universities only 5–8 % do so.

4.4.2 The non-university public research institutes

As already mentioned, the non-university institutes, most of which belong to the Big Four (Max Planck, Fraunhofer, Helmholtz, Leibniz), do not have official teaching obligations. Instead, they focus on research. However, the research focus differs strongly. While some are oriented towards basic research, others are focused more on applied research and technology transfer. Like the universities of applied sciences, the non-university research organisations are also a relatively new element in the German public research landscape, having been mainly founded in the middle of the 20th century.

Emerging from the Kaiser-Wilhelm-Gesellschaft which was founded as early as 1911, the Max Planck Society came to existence in 1948. The Max Planck Society with its 80 institutes (most of them from natural science but some also from social sciences and economics) focuses on "world-class" basic research.

The Fraunhofer Society, on the contrary, founded in 1949, was set up as an organisation that is focussed on applied research being conducted with or for actors from the private enterprise sector. Thus the Fraunhofer institutes have a role spanning the boundaries between public science and the private economy. This differentiation is institutionalised in the so-called "domain consensus" (*Domänenkonsens*) which posits that the Fraunhofer Society should be basically responsible for filling the gap between basic research (usually attributed to the universities and the Max Planck Society), applied research and market commercialisation. Today the Fraunhofer Society consists of 80 research centres of which 60 are full institutes, almost all of them from engineering and natural sciences.

Emerging from the Forschungszentren Karlsruhe und Jülich the *Arbeitsausschuss für Verwaltungs- und Betriebsfragen der deutschen Reaktorsicherheit* was established in 1958, which was the original start of the Helmholtz Association[2]. Today the Helmholtz Association has 17 large scale institutes and is by far the largest among the non-university research organisations. Its original mission is defined as to contribute to solving urgent, large-scale societal problems. Traditionally the Helmholtz Association focused on nuclear research. However, due to the increasing societal resistance to this technology which resulted in the final decision to shut down all nuclear reactors in Germany by 2021, the portfolio naturally shifted away from this. Today important topics are among others cancer research, molecular medicine, polar and marine research or health and environment.

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2 This name actually dates back only to 1995.

The youngest of the research organisations is the Leibniz Association which is not a tightly managed research organisation, but a conglomerate of many individual research institutes that are equally active in natural, engineering and social sciences. Initially it emerged from the 46 so-called "Blue List" institutes in 1970, and today comprises 86 institutes.

It is probably right to say that while the Max Planck Society focuses on internationally competitive basic research, the Fraunhofer Society deals with applied research and its diffusion to private actors, and Helmholtz works on large-scale societal problems. The Leibniz Association is probably the organisation whose profile or mission is least clear cut.

In summary, the system of actors and tasks which characterise the German public research landscape that evolved from an initially homogeneous university-dominated system is today highly differentiated. These differences in missions have traditionally been sustained by the financing structures, which we will describe below. However, we will also see that, during the past decade, these structures have experienced changes, which has forced some of the players to adjust their missions.

Because some authors have argued that one hampering factor in the German science landscape which inhibited interorganisational collaboration was the strong segregation (*Versäulung*) (Heinze and Kuhlmann 2007), an important question is whether the current changes in the financing structures are likely to reinforce or weaken this traditional differentiation.

4.4.3 Changing financing structures and implications for the institutional missions

Over the past years, a remarkable increase in overall resource expenditures was observed in the public science sector. This is equally true for universities and universities of applied sciences, Max Planck, Fraunhofer, and Helmholtz, as well as Leibniz. As Tables 4–1 and 4–2 exemplify, the total university expenditures rose from 13.6 billion euros in 2001 (including expenditures for teaching) to about 20.6 billion euros in 2008. This corresponds to a yearly average growth rate of 5.3 %. Similar trends can be observed for the four big non-university organisations. Here, the total expenditures increased between 2006 and 2009 from roughly 3.8 billion euros to 4.5 billion euros, which corresponds to an annual growth rate of about 5.8 %. In accordance with the Pact for Research and Innovation (*Pakt für Forschung und Innovation*), the four research organisations received a budget guarantee and a budget increase of 5 % annually until 2015. The intention was to offer planning scope and a growth strategy. In exchange, they have to report their activities and progress in an annual report – the PFI monitoring report.

The universities and the universities of applied sciences

However, while at first sight this might suggest a situation of financial abundance for public research, this is only part of the truth. In particular, when the universities are looked at in more detail, Table 4–1 reveals that the increases in expenditure were largely financed via third party funds.

Over the period from 2001 to 2008, the state basic funds which are largely granted on an unconditional, non-competitive basis, rose by an annual growth rate of only 2.8 %, while third party funding leapt upwards with a growth rate of 12.8 % p.a. Correspondingly, the share of expenditures financed by state basic funds decreased from 85 % in 2001 to approximately 71 % in 2008.

Table 4–1: The university budgets

	2001	2002	2003	2004	2005	2006	2007	2008
Total expenditures in m Euro	13,696	14,896	16,393	16,604	16,798	17,505	19,162	20,661
Administration income in m Euro	320	403	634	730	889	1,655	1,923	1,945
Third party funds in m Euro	1,627	2,139	2,523	2,646	2,823	3,186	3,640	4,033
State basic funds in m Euro	11,749	12,353	13,235	13,228	13,085	12,663	13,599	14,684
Share of state funding in %	85.79	82.93	80.74	79.67	77.90	72.34	70.97	71.07

Source: Statistisches Bundesamt, own calculations

Thus the strong tendency is to shift resources away from unconditional funding towards competitive finance sources – an observation made already by Schubert and Schmoch (2008). Table 4–2 highlights that this tendency is indeed due to a deliberate state shifting of resources away from basic funds towards the financers of public research, in particular the German Research Foundation (DFG), which offers funds for basic research that must be acquired within a comeptitive application procedure. The share of DFG funds as a fraction of all third party funding increased between 2006 and 2009 from 28.8 % to 34.8 %. Similarly, we can observe an increase of third party funds directly offered by the central government (in particular the Ministry of Education and Research). Here the share increased from 19.5 % to 21.2 %. The biggest losers on the contrary were the private enterprises, whose share fell from 26.2 % to 22.9 %. In other words: More money is being invested in the system by federal sources, but so far the policy goal of "more application orientation" in general has not been reached.

Table 4–2: Third party funding in the universities by source

	Central state	Länder and cities	Other public funds	DFG	European Union	International organisations	Foundations	Enterprises
2006	19.5	3.0	3.0	28.8	9.6	0.8	9.0	26.2
2007	20.2	3.2	1.8	32.1	8.1	0.9	8.0	25.8
2008	19.9	2.8	2.0	33.7	8.9	0.4	7.5	24.8
2009	21.2	3.0	1.7	34.8	9.0	0.5	7.0	22.9

Source: Statistisches Bundesamt, own calculations

So, with respect to the universities, several important changes in the financing structures were observed that are likely to impact on the universities' position in the research landscape. First, the overall resources have been greatly increased. Second, this increase was primarily due to increases in third party funding, which again was a result of the state decisions to redirect previously unconditional funds to the DFG that grants research money within an application-based procedure, as well as the resources provided in the context of the Excellence Initiative. Third, funds from enterprises greatly decreased in importance.

In summary, we indeed find strong increases in the resources available for research tasks, while relatively less seems to be available for industry-science research collaboration. While this corresponds to the expressed desire to bring universities back to the research frontier, also in an international perspective, it is at the same time true that the aim to support and sustain knowledge diffusion through the industrial financing of research has lost impetus.

The non-university research sector

Interestingly, this trend to finance the additional research capabilities only via competitive third party funds cannot be observed for all non-university science organisations (cf. Table 4–3). While all four big non-university research institutions were able to drastically increase their budget between 2006 and 2008, only the Fraunhofer Society experienced a steady decline in its share of institutional base funding, while for the remaining institutes it remained stable (Leibniz and Helmholtz) and even went up by 2.5 % for the Max Planck Society.

Table 4–3: Expenditures of the big non-university institutes

	R&D expenditures in million Euro				Share of state funding in %			
	Max Planck	Fraunhofer	Helmholtz	Leibniz	Max Planck	Fraunhofer	Helmholtz	Leibniz
2006	1,303	1,206	2,578	1,069	79.34	37.92	61.92	68.90
2007	1,290	1,319	2,740	1,107	81.60	35.41	62.15	68.50
2008	1,560	1,401	2,992	1,162	82.78	33.90	62.00	68.92
2009	1,533	1,562	3,112	1,299	78.00	32.00	63.89	65.63

Source: Statistisches Bundesamt, own calculation

In consequence, the political dynamics that apply to the universities led to shifts in expenditure from unconditional funding towards competitive third-party funds does not generally find its counterpart within the non-university public research sector. In fact, only the Fraunhofer Society suffered comparable decreases in the amount of basic funding as a share of total expenditures. With regard to the latter, it can be hypothesised that this will push Fraunhofer towards a much more applied focus, because it has access to DFG funds only in exceptional cases. Thus, the increase of total expenditures in the Fraunhofer Society is quite likely to be primarily due to funds relating to applied and diffusion-oriented research. It should be mentioned that the Fraunhofer Society has grown considerably over the past 10 years, almost doubling the number of its personnel. In consequence, the increased application orientation of the system, introduced by policy-makers, is mainly delivered via the Fraunhofer Society and, to some degree, by the universities although we observed that the relative importance of industrial funds for the universities has been constantly deteriorating.

This implies in particular for the institutes of the Max Planck (basic research) and the Fraunhofer Society (applied and transfer-oriented research) that the original missions seem to be strengthened rather than weakened.

4.4.4 Output profiles in flux

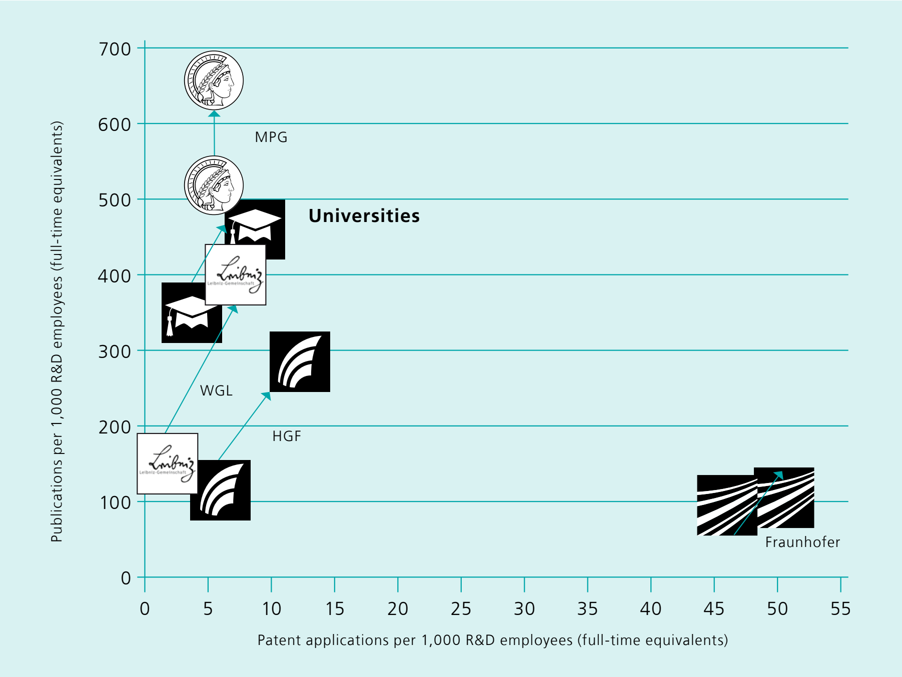
While acknowledging that all major actors in the German public science system experienced an increase in available resources, we also see that for some actors the financial mix strongly shifted in the direction of third party funds. This is true for the universities as well as Fraunhofer. However, while the former basically profited from the increased importance of the third party funds provided by the basic-research oriented DFG, Fraunhofer increased its overall resources through more application-oriented third party funds.

Following this shift in resource orientation, this suggests that the universities are moving much more in the direction of basic research tasks, while putting less emphasis on applied or university-industry collaborative research. The Fraunhofer Society, on the contrary, is likely to strengthen its position in applied research, and linked to that in technology development and transfer.

Indeed, when looking at Figure 4–2 which depicts the evolution of publication intensity (y-axis) and the patent intensity (x-axis) by organisation actor, we can observe that between 1994 and 2008, the universities shifted their output profile strongly in the direction of scientific publications. Over the same period, Fraunhofer retained its high patenting-oriented profile. Likewise, its publication intensity has remained at the same relatively low level since the mid 1990s. The Helmholtz and the Leibniz Societies increased both their publication and their patenting intensity. However, both experienced definitely stronger increases with respect to publishing activities. The Max Planck Society, despite some fluctuations between 1994 and 2008, did not change its position markedly, remaining with its relatively low patenting and relatively high publishing intensities at the other end of the spectrum from Fraunhofer.

In summary, the changes in financing structures are likely to favour re-orientations within the science system that increase the basic research capabilities of the universities, while technology transfer as well as the collaborative industry-public science research collaborations have lost importance. These are likely to be increasingly performed by the Fraunhofer Society (and to a certain degree by the universities of applied sciences). In this light, a dedifferentiation is unlikely to be a dominant feature of the future German science system.

Figure 4–2: Patent and publication intensity (per 1,000 employees) for universities and the four large German research organisations (1994, 2008)



Source: PATSTAT, Web of Science, Statistisches Bundesamt, calculations: ZEW and Fraunhofer ISI

So what we see is that the mission orientation, especially of the two counter poles Max Plank Society and Fraunhofer Society, appears to be strengthened. Furthermore, the universities and to some degree the other two large players are heading towards a greater basic-research orientation. This leads us to conclude that the policy aim of a greater mission orientation is indeed being successfully reached. However, the collaboration among the different players in the innovation system – in particular the establishment of science-industry linkages – appears to have lost importance. This latter conclusion holds, with the exception of the Fraunhofer Society and to some degree the universities of applied sciences.

4.5 Summarising conclusions

The German innovation system is in constant flux, but there seems to be more than the usual change in the system. The innovation systems approach – as the reflection of the innovation actors and their linkages – was taken seriously by German policymakers in recent years. However, the high functional differentiation and division of labour between core actors – this was one of the central characteristics of the German innovation system in general, and of the public research sub-system in particular, for many years – seems to be softened by new incentives and directives that can be summarised under the title "New Public Management" (Schmoch and Schubert 2009; Schmoch and Schubert 2010; Schubert 2008), but also influenced by shrinking relative budgets and demographic trends.

Nowadays innovation is not successfully implemented based on R&D alone. The increasing complexity of technologies, the internationalisation of markets and of knowledge streams, as well as growing competition, move further parts of the innovation process like collaboration and marketing into the centre of discussion. The innovation system, including innovation policy-making, needs to react to these external changes.

The High-tech Strategy and the High-tech Strategy 2020 both aim – among others – to improve the collaboration and linkage between science and industry, mainly to foster the application and commercialisation of public research knowledge and technologies. While the contribution of the first version of the High-tech Strategy was to formulate a coherent strategy and to increase the coordination between departments in the federal government, the latter mainly moved away from technology-oriented policy-making and introduced a mission-oriented innovation policy.

A mission orientation was and still is the basic feature of the German research landscape. A strong division of labour, structural differentiation, and functional specialisation characterise the system. However, the German research landscape was forced to change recently, mainly by changes in the funding and financing structure. Policy-makers offered incentives and changed some of the framework conditions in order to introduce their policies, among them the increased application orientation. Several instruments were introduced, such as cluster policies, certain columns within the ZIM programme or also less successful instruments, like the research bonus. One of the most striking policy changes was introduced by the Excellence Initiative. Before 2007, when this programme was launched, all universities were declared to be equal with respect to quality of research and teaching. With this new initiative, it is accepted that some of the universities are "more equal" than others. This was driven by the insight that in order to perform world-class research and education, some of the universities need to stand out and catch up with world-leading research institutions.

In effect, the whole German research landscape receives more funding in general, and more third-party funding in particular. So the new policies were mainly transformed into reality, not by increasing the institutional funding (to the same extent), but by increasing third party funding, where competition is the main allocation factor. Empirical evidence suggests that the new policies even enhanced the strong differentiation and functional specialisation. The Max Planck Society with its basic research mission and the Fraunhofer Society with its application mission seem to focus even more on their main tasks. The Leibniz and the Helmholtz Associations are obviously affected more by the external changes and are still located in between basic and applied research. The immense state investments that followed the Excellency Initiative have consistently moved the universities in a basic research direction and, despite policy initiatives such as the High-tech Strategy 2020, have experienced a constant erosion of industrial funding.

This leads us to conclude that, with the exception of Fraunhofer, the increased funds in the system have not strengthened the industry-science linkages. So, while the policy aim of greater mission orientation seems to have been fulfilled, the parallel aim of increasing collaboration appears to have been weakened, in particular with respect to the universities.

4.6 References

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5

THE JAPANESE INNOVATION SYSTEM 2011 REVISITED

KERSTIN CUHLS

5.1 Introduction

Due to re-arrangements in the governmental organisation, the year 2001 was a milestone in the Japanese innovation system. Other changes had to follow – they are described in Cuhls and Wieczorek (2010). This chapter reflects the history of the Japanese Innovation System (JIS) from external discussions on the national innovation system approach to the system in Japan itself. In previous discussions of the current JIS, it has become obvious that the models we use to describe such systems are insufficient: it was difficult to fit all actors into the right place, the interaction in the system could not be included and the framework conditions were regarded as "external factors". In Japan, for example, particular difficulties were faced when arguing for the Japanese Agency's or institutions like the AIST (National Institute of Advanced Science and Technology) with their hybrid functions in the innovation system or the specifities of the JIS. Therefore, the second part describes the Japanese Innovation system with the existing model before and after the reforms in 2001.

In 2011, Japan was not only confronted with disasters but had already started to re-orient and reconsider the efficiency of this new innovation system. Revisiting this new system by taking stock of historic and the recent changes, the objective of this contribution is to discuss a potential outlook on further changes.

5.2 History of the national innovation system approach – why was the Japanese innovation system so important in the debate?

The development of the National Systems of Innovation approaches occurred at a time when nations were regarded as the entity to be looked at and compared with respect to their competitiveness. International competitiveness was measured by export data and the success of certain countries was analysed in order to lead markets or to stay in the markets (Freeman 2008, pp. 8ff.; 1988, pp. 31ff.; 1987). The questions behind this were: Why are certain national features better than others? What are the institutions underpinning these and what is the interplay between the institutions? How can the science system and the generation of knowledge be described? The general history of the NIS approach is described in Chapter 1 of this volume. Here we are looking at the background of a country which is often described as "culturally special": Japan. It is open to discussion whether Japan is really special or whether different countries have only different cultural specifities – this contribution does not address this question.

Japan was the first industrial country in Asia and its success story was very much admired because it developed in a very short period of time. During the Tokugawa period (1603 to 1868), the country was completely closed off (*sakoku*, 1633–1853). Trade was only possible with a few countries (China, Netherlands, Taiwan, Korea, Ryûkyû – which is now Okinawa and a Japanese prefecture). Information, especially about science and technology, was filtered into the country via a small island (Deshima) only by the Dutch, the so-called *rangaku*. Nevertheless, even during this time of closure, the country started to flourish, to trade within the country, to develop cultural traits, to establish learning possibilities for everyone, and to build up a new infrastructure, especially as a necessity of the so-called *sankinkôtai* system, which forced every daimyô (noble) of the country to have a residence in Tôkyô as well as in his prefecture and to travel frequently (descriptions can be found e.g. in Hall 1968; Hauser 1997, p. 506.).

After the Meiji restoration in 1867, the structure of the country changed completely in respect to education but also in terms of production and the development of useful things like machines. Japanese engineers were sent to foreign countries to study and very soon Japan changed from a country that was threatened by colonisation into a country that was colonising others. In 1895, Japan won the first war with China and in 1905 the Russian-Japanese war was decided in favour of Japan. The major reason was that Japanese ships and other military equipment were technically much better than Russia's (Inoue 2003).

Japan lost the Second World War but the policy of the US towards Japan was the same as towards Germany: Instead of completely destroying the country, it was rebuilt – both countries were in strategic locations and both were regarded as potential future partners. Again, the country rose economically in a very short period of time (Hentschel 1986; Nakamura 1995) and many of the networks, companies and conglomerations that were established during the war were re-activated or at least provided the backbone for a fresh start (Odagiri and Goto 1993).

Japan's major achievement was its production system. The state supported all purchases of new technology which were needed for export. On the other hand, Japan became even more dependent on exports because it has no natural resources and therefore human resources and their education turned out to be Japan's major capital. Triadisation rather than globalisation could be observed during the 60es to the 80es of the 20th century. The term Triade was coined by Ohmae (1985; 1991), a Japanese-American consultant, to describe the fact that the major exporters and dominating countries in competition with each other were the USA, Germany and Japan. When comparing Japan to the US or Germany (or Europe) – Japan dominated. The innovation system is often used to explain the success factors in these countries.

During the years leading up to the Asian crisis, the debate was dominated by the "threat of the Japanese" (not yet the Chinese), because after the Second World War many Westerners were surprised to see Japan rising to become the first industrialised country in Asia. However, when looking back at history (Hall 1968; Inoue 2003; Linhart and Pilz 1999; Odagiri and Goto 1993), that is not surprising at all. The basis of the success goes back to the Meiji period and even earlier (Sugimoto and Swain 1989). Therefore, the reason for Japan's success is often sought in the innovation system – and this is the reason why many of the first researchers of the National System of Innovation used Japan as an example (Freeman 1987; 1988; 2008; Nelson 1993; Odagiri and Goto 1993; Sigurdson 1995 with his first edition as early as 1984; later: Edquist 1997; Lundvall et al. 2006; Odagiri 2006).

5.3 The Japanese innovation system after World War II

World War II marked a change in the Japanese (Innovation) System that had been in effect under war economy rules from 1938 (with the General Mobilization Law, cf. Nakamura 1995, p. 8) to 1945. For more details about the time until 1945 see Odagiri and Goto (1993). The next changing point in the Japanese Innovation System is marked by the year 2001. There were many other crucial times and crossroads before the 20th century (Sugimoto and Swain 1989). In this contribution, we are looking at the concept of the NIS since the 20th century as the concept as such has not existed that long.

It has often been assumed that a kind of "Corporate Japan" or "Japan Inc" was developed after (and already during) World War II. Japan Inc was the synonym for the interplay of the different stakeholders in the system: A very long-term strategic cooperation between the government and industry, guided by an "invisible hand" (means guided by an unknown coordinator, for a summary see Sigurdson 1995) was assumed. Industrial policy supported these direct links and the financing of such a joint way forward was provided by the famous Ministry for Industrial Trade and Industry (MITI). In fact, this was just an assumption from the outside world. The power of MITI as described in Johnson (1982) was never as strong as assumed and waned with the independence of Japanese companies from export credit signs from the Ministry, the liberalization of markets (Odagiri and Goto 1993) – and of course later on with the introduction of the internet, so that the Ministry's information monopoly was diminished.

The Japanese Innovation System (JIS) developed quickly after 1945 and joined internal forces in an efficient way (Freeman 1987, p. 32). New companies were founded and became the core of the Japanese Innovation System. It was clear that the companies were responsible for innovation and most of the developments took place in the new (e.g. Sony) and old firms (Mitsui, Mitsubishi, Toyota etc.), mainly the larger ones. On the side of the ministries, it was not as transparent: Innovation was mainly the responsibility of MITI (Johnson 1982), because innovations are close to the market and MITI is responsible for "trade and industry", as the name already indicates. For science and technology, the Science and Technology Agency, a quasi ministry under the auspices of the Prime Minister's Office directly, was responsible as well as other ministries (see below).

The ministries acted as moderators in this system. Their extensive knowledge about the companies and instruments forced the companies to adopt the desired policies. But there have always been interesting constellations, in which the companies did not adopt the intended policies or even refused to comply with direct orders, e.g. the famous case of Honda, a motorbike company, which wanted to enter the automobile market and was not allowed to do so by MITI (Sakiya 1987).

The institutions changed after the war – but some remained under new names and the interaction between them that had developed also remained the same. For example, the old conglomerates (*zaibatsu*) that developed in the first half of the 20th century and supported the war economy very efficiently were destroyed officially – but reoccurred as *keiretsu*. Keiretsu are networks of companies, especially large trading companies handling a huge diversity of products, combined with a bank. They are formally interconnected because one company holds the other's stocks and vice versa so that they all have an interest in joining forces. Keiretsu played an important role even in the innovation system of Japan – less as an institution per se but more as the "network" with its flow of information and mutual support. In the institutional model of the Japanese innovation system, they are normally integrated into the category of "industry" (institutional viewpoint), in fact, they represent more than just industry.

The education sector in Japan has always been very strong: people do not intend to enter an academic career so much as to climb up the social ladder by education and to enter a famous company, this was and is still the goal of many people. The selection criteria in this system were and are severe. A huge percentage of Japanese people possess a university degree and regard themselves as "middle class". In Japan, higher education takes place at the national and private universities (for further details see e.g. MEXT 2006). In all cases, tuition fees have to be paid and make up a huge amount of the cost of education for parents.

Science and research were not the task of universities, but were performed in National Laboratories and other research organisations. The laboratories were all under the auspices of a ministry or the Science and Technology Agency (STA, see Sigurdson 1995, p. 41) until 2001. The STA had, as the Environmental Agency, no rank as a ministry, only as an "agency", and was established in 1959, responsible for nuclear energy and energy supply, space research and marine research. In addition, the STA is responsible for the general research overview and basic research.

Six important Councils worked directly under the Prime Minister (Sigurdson 1995, pp. 36ff.). This was first of all the (former) Council for Science and Technology (CST) with the Prime Minister himself, the Minister for Science and Technology (who was the head of the STA), the Minister of Education, Science and Culture (Mombushô), the Minister of Finance, the Minister for Economic Planning and the President of the Science Council plus five experts from science and industry. The CST commented on basic directions in science and research, see e.g. the "Comprehensive and Basic Science and Technology Policy toward the New Century" in 1992.

Separately linked to the office of the Prime Minister was (and still is) the Science Council of Japan, with its 180 so-called "Liaison Committees" (with about 2,370 members) and about 640,000 registered academic scientists. The Science Council is dedicated to the Humanities, Social Sciences and Natural Sciences and is supposed to deal with all research disciplines. Other Councils are the Atomic Energy Commission, the Nuclear Safety Commission, the Space Activities Commission and the Council for Ocean Development.

For pre-formulation and recommendations concerning technology policy and (technology) forecasting (later: Foresight), a very specific National Institute was founded: the National Institute for Science and Technology Policy (NISTEP) which was until 2001 directly integrated into the STA. It was established in 1986 as the reaction to a report of the "Provisional Councils for Promotion of Administrative Reform [...] which pointed out the importance of strengthening and enriching policy research as part of the efforts to strengthen the functions of the Council for Science and Technology (CST)" (NISTEP 1996). The major tasks for NISTEP are advice in technology policy, foresight, human resources, technology transfer, global questions and scientific impact research.

MITI was and is responsible for industrial research, innovation and energy (as application field). The Industrial Technology Council belonged to MITI and worked out the directions for the technology policy of industry. The Industrial Technology Council was involved in the formulation of the famous MITI "visions". The Patent Agency, the Agency of Natural Resources and Energies, which was responsible for the New Energy and Industrial Technology Development Organization (NEDO) belonged to MITI. For the development of new technologies, the Agency of Industrial Science and Technology (AIST) with its 16 national research institutions was, and still is, a very important part of the system (JRDC 1992).

For NEDO and also for AIST, there were research programmes and projects which dealt with future technologies and indirectly implemented the results of the national forecasting activities (AIST 1995). As early as 1977, there was an ad hoc advisory board for the director general of AIST (Working Party for the Formulation of a Long-term Plan for the Development of Industrial Technology) which consisted of university professors, representatives from research organisations, a journalist and people from industry (The Technical Change Centre 1983, p. 8).

Another important Agency for the innovation system was the Economic Planning Agency (EPA), which was responsible for the statistics and the five-year-plans for the economy. One has to bear in mind that these five-year-plans are not static as in most socialist countries, but most of them are changed during the five years. It is a characteristic feature of these plans that they are not fixed plans but provide orientation. If the targets are not achieved, the plan is adapted to reality (and not reality to the plan). EPA also provided lists of new technologies and expected market figures for orientation. Many similarities exist between the content of their lists and the forecasting/foresight studies of NISTEP (especially the Delphi surveys) – and the members of the commissions who formulate the plans were often also members of the Delphi committees.

As already mentioned, most of the research in Japan was and is privately financed. Companies were conducting research and developing their products independently or in co-operations. They "used the factory as a laboratory", and they were able to integrate "between research and development, production management and marketing as a major source of failure, the integrative effect of learning by creative reverse engineering conferred a major competitive advantage on many Japanese firms" (Freeman 1987, pp. 42f.). Many of these co-operations were necessary because the national programmes forced companies to co-operate. Companies participated in a lot of MITI projects (e.g. the 5th generation computer project) in order not to miss any information or to be left behind technologically (Callon 1995). There are obviously projects, in which companies participated voluntarily (The Technical Change Centre 1983, p. 30). In these cases, MITI provided the technical infrastructure and equipment and researchers from industry were sent to this new institute for a certain period of time. This was only possible for specific projects and at the pre-competitive stage. Later on, the (mainly large) companies become competitors again. Therefore, industry in Japan has higher R&D expenditures than industry in other countries but the direct expenditures of the state for industry are rather low (Eto 1984, p. 140, cf. also Odagiri and Goto 1993, p. 103). "MITI's aim is not to reduce competition among Japanese firms but to create the strongest possible companies with the greatest competitive potential" (Freeman 1987, p. 49).

Looking at the functions of institutions, one has to consider that the instruments of MITI and other ministries were and are less "power" or money, but the targeted application of information, which means information generation, analysis, distribution and the function of a "facilitator" for companies in the system (Itoh et al. 1988, pp. 240f.; Hilpert 1993). The high level of trust through formal contacts and the information gathering instruments ("[…] Japanese officials are much better informed, not only about Japanese companies but often about American companies […]") are identified as major success factors by Freeman (1987, p. 36).

In 1996, the government decided a huge enhancement of the budgets for basic science, because Japan was often accused of being a "free-rider" on basic research of other countries (Handelsblatt 1996). This marked a shift from the pure application-oriented research that was necessary in a country that was catching-up and attempted to play in the first league of science. The reason was that in many fields, Japan was already the leading country in research – and therefore needed its own input instead of relying on the basics of other countries.

In these times and contexts, even foresight (at that time "technological forecasting", *gijutsu yosoku*) played a role in coordinating the activities of the different players in the innovation system. Delphi surveys (Kuwahara et al. 2008; Cuhls 1998; 2005) asked about their estimations of future statements, technologies that were regarded as feasible but not yet realised. The results of the surveys that were provided by NISTEP and the Institute of Future Technologies, IFTECH, were widely used by companies as well as by research institutions or the ministries (Cuhls 1998). Also MITI had its own foresight activities and did not only use the above mentioned surveys. There are lists of critical technologies by MITI (Kodama 1991, p. 134) and the famous "visions". They demonstrate guiding principles for the country and were formulated very broadly. They provided rather "informal guidance" (Ehrke 1994, p. 64) for the self-organisation of companies and institutes. The more concrete formulation could be found in the five-year plans of the EPA (for lists of these plans see McMillan 1996, pp. 89ff.).

During the 1950s, the visions were mainly concerned with heavy and chemical industry, during the 60s more with trade liberalisation. In 1963, there was even a very concrete "Long-term vision for the industrial structure" (Freeman 1987, pp. 37ff.) with a shift to "knowledge-intensive" sectors (like electronics) in order to save oil and resources, which seemed to be necessary after the oil shocks. The direct interventions of MITI were rather seen as additions (Ehrke 1994, pp. 62–70; Freeman 1987, pp. 37 ff.; 1988). Table 5–1 and Table 5–2 show an overview of the directions during the 1980s and 1990s. From an MITI point of view, these guidelines and visions contributed mainly to limit fear and the uncertainty about the future (Fuji 1994, p. 150).

Table 5–1: The MITI visions of the 1980s and guidelines for the 1990s

March 1986: General Guidelines for Science and Technology
(Science & Technology Council > Cabinet Approval)
1. Promotion of creative science & technology
2. Balanced development of science & technology in harmony with social progress
3. Development of science & technology from a broad international point of view

September 1988: White Paper on Industrial Technology: Trends and Future Tasks in Japanese Industrial Technology (MITI)
1. More aggressive approach to basic and creative technology
2. Greater international contribution through the R&D process, its outcome and its ripple effect

July 1990: MITI's Visions for the 1990s
(Industrial Structure Council)
1. Strengthening basic and creative R&D
2. Promoting international R&D efforts
3. Developing science & technology in harmony with man and nature
4. Developing technology for regional vitalization

April 1992: General Guidelines for Science & Technology
(Science & Technology Council > Cabinet Approval)
1. Contribute to maintaining mankind's coexistence with Earth
2. Increase of technological knowledge stock
3. Contribute to constructing a society with a safe and enjoyable life

Source: summary of Watanabe (1994, annex p. 8) and Watanabe (1995, p. 39)

Table 5–2: MITI visions for the 1990s

Advancement of techno globalism from a global viewpoint (global activation of science and technology creativity as well as spread and change)
Advancement of research and development with balanced science and technology (advancement of basic, creative research and development)
Advancement of research and development in order to realise a comfortable, prosperous life for the citizens (advancement of excellent research and development for man and nature, advancement of research and development in order to realise a vital regional society)
Basic regulation for the development of science and technology

Source: Tsûshôsangyôshô (1990, p. 8), own translation

The innovation system of Japan is also influenced by the leading industry associations, especially the *Keidanren* or the *Keizai Doyukai*, which have broader actions like the call "Making Japan a Leading Technological Innovator" (Keizai Doyukai 1996, pp. 50–56).

Looking back at the 20th century, Japan developed a new role in the world. Globalisation occurred and the Japanese National System of Innovation was regarded as very efficient and as one of the leading systems in the world. The outside world, however, was not aware of its deficiencies and the Japanese inner world did not want to know. It is obvious that during the 1980s the whole innovation system of Japan worked very well and was admired all over the world. "Japan served as a role model during the 1970s and 1980s. However, it lost its attraction during the so-called "lost decade" of the 1990s, when commentators observed a lack of adaptation and a mismatch with the changing environment." (Storz and Schäfer 2011, p. 34). But when the bubble burst and new rules were introduced into the game of innovation procedures and institutions, when globalisation was realised more and more, the interplay in the Japanese system needed to be adapted and reforms became necessary. Some were made, others are still awaited. The threat that was described in best sellers by authors like van Wolferen (1989) was never that huge.

5.4 The Japanese innovation system after 2001

The year 2001 was a milestone in the changes of the Japanese innovation system. Looking back, in the first decade of the 21st century, the changes and impacts of these changes were severe – but often not acknowledged: Starting with a re-organisation of ministries, a phase of re-orientation of the whole innovation system began. Many of the organisations and institutes started to be more strategically focussed. Some developments in the innovation system bring about greater centralization towards national institutions and government, others tend to have the opposite effect, especially where research institutions are established on a regional basis. This section describes some of these changes and the interplay of the actors involved in the innovation system.

The Japanese innovation system remains highly centralized. Nevertheless, the prefectures and regions have become stronger actors in the system (Fukugawa 2008,

p. 160). The major actors in Japan were and still are the large companies, some of them already multinationals. The government acted more as a mediator than a leader. In many of the future science and technology fields, Japan is among the leading countries worldwide. The expenditures for R&D are still the largest in the world: 3.4 % of the Japanese GDP was already achieved in the year 2004 (MEXT 2006 and earlier White Papers), the general expenditures for science and technology in Fiscal Year 2009 were 3.564 trillion Yen (MEXT 2010, pp. 141f.). The largest share still comes from companies, about 20 % from universities and colleges, less than 10 % from private research institutions (MEXT 2010 and earlier White Papers). The number of researchers in industry as well as in institutions has increased, whereas the number of institutions was consolidated and differed in numbers over time (Table 5–3).

Table 5–3: Number of R&D performing institutions and researchers by kind of organisation

FY	Total		Business enterprises		Non-profit institution & public organisation		University & college	
	Institutions	Researchers	Institutions	Researchers	Institutions	Researchers	Institutions	Researchers
2001	27,061	728,215	22,789	421,363	1,245	47,093	3,027	259,759
2002	22,056	756,336	17,903	430,688	1,138	44,938	3,015	280,710
2003	18,468	757,339	14,258	431,190	1,119	44,845	3,091	281,304
2004	29,663	787,264	25,440	458,845	1,103	44,089	3,120	284,330
2005	28,608	790,932	24,290	455,868	1,089	43,917	3,229	291,147
2006	22,201	819,931	17,764	481,496	1,109	42,959	3,328	295,476
2007	23,204	826,565	18,737	483,339	1,057	42,033	3,410	301,193
2008	26,908	827,291	22,370	483,728	1,040	41,071	3,498	302,492
2009	21,558	838,974	17,029	492,805	1,008	40,322	3,521	305,847

Figures are as of 31 March
Source: MEXT, http://www.mext.go.jp/english/statistics/index.htm (accessed 29 March 2012)

At the beginning of the 21st century, the government ministries were restructured, in particular the ones responsible for science and technology: the Science and Technology Agency (STA), which formerly belonged to the Prime Minister's Office, was integrated into the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and a small section into the Ministry of Trade and Industry (MITI) which was then transformed into the Ministry of Economy, Trade and Industry (METI). The Council of Science and Technology Policy (CSTP) under the leadership of the Cabinet Office was newly established as the major coordinating organ to formulate science and technology policy.

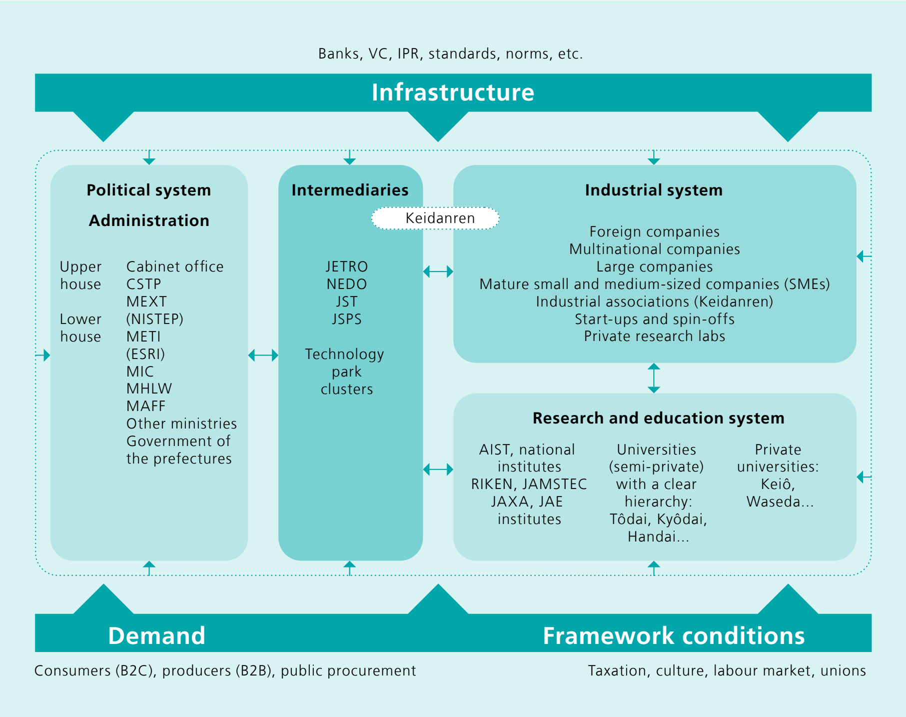
The second large reform concerns the intermediaries. The intermediaries have always played an important role, but now their role has become even stronger. The national laboratories (especially in Tsukuba Science City and other locations) have been integrated under the aegis of the newly structured National Institute of Advanced Industrial Science and Technology (AIST). In a strategic process, they are being re-organized with the purpose of strengthening the ties between public and private research and achieving better knowledge transfer.

The third reform has taken place in the education sector. Since the 1990s, the pace of the reforms in the education sector has accelerated (Eades et al. 2005), which is particularly true for tertiary education. Some of the key words of the reforms taking place are (see e.g. Wieczorek 2001, p. 178): decentralization and deregulation; diversification and flexibility; individualization and internationalization. Moreover, in 2004, the public universities were semi-privatized when they were transformed into so-called "Independent Administrative Institutions" (IAI). This change aims at increased competitiveness in research and education, enhanced accountability together with the introduction of competition, evaluation, and strategic and functional management of national universities (Yonezawa 2008).

A new player in the innovation system is the Intellectual Property High Court. Its introduction in 2006 is a sign that protecting intellectual property rights is regarded as having an important function in the innovation system. IPR questions and strategies are also addressed by the new IPR headquarters at the universities.

The main actors in the Japanese innovation system remain the large Japanese companies, now acting in global markets, but often still doing research at their home base. Some of them have traditionally weak links with political and administrative institutions; others are closely related to ministries. Universities and colleges, political and administrative institutions with their large laboratories are other important actors. A picture of the innovation system is shown in Figure 5–1.

Figure 5–1: Japanese innovation system



Source: Cuhls and Wieczorek (2010), own compilation

New actor: Council for Science and Technology Policy (CSTP)

Meanwhile, the Council for Science and Technology Policy (CSTP; for details see CSTP 2006a) has become a new and strong player in the innovation system. Before the reform of the ministries, Monbushô and MITI both had their own advisory council. In 2001, the CSTP – as well as the Council on Economic and Fiscal Policy or the IT Strategic Headquarter – was established within the Cabinet Office as one of the 73 government top councils based on the "Law for Establishing the Cabinet Office". The CSTP consists of 14 members and the Prime Minister himself, who chairs the council. Six cabinet members are heads of ministries closely related to S&T policy. The CSTP itself represents parts of the innovation system. It has a secretariat with a regular staff of almost 100, most of whom have been seconded from various ministries, from research organisations or companies.

Science Council of Japan (SCJ)

The purpose of the SCJ is to promote the advancement and development of science and its mission is reflected and spread in administration, industry and national life. The SCJ was established as a "special organization" under the jurisdiction of the Prime Minister in January 1949. It is now organized by 210 members representing about 790,000 scientists in Japan. It independently conducts activities to deliberate and implement important matters concerning science, and to promote liaisons between research and science, and to improve efficiency. In April 2004, the "Law to Amend Part of the Science Council of Japan" was enacted. The SCJ was then placed under the authority of the Cabinet Office in April 2005 and its new organisation was inaugurated after implementing operational reforms. In order to contribute to the promotion of Japanese science and technology, in close cooperation with the CSTP, the new SCJ is promoting activities with emphasis on policy recommendations, the coordination of scientists, international scientific exchanges, promotion of public acceptance of science and promotion of scientific capabilities of young people.

The ministries

Nowadays, the ministries have no strong direct power, if indeed they ever have had. After the reform of the ministries and the abolition of some agencies in the year 2000 (discussion see Cuhls 2008), we see a new organisational chart in the administration of science, technology and innovation in Japan (see also CSTP 2006a): the former Environmental Agency has become the MoE; the STA was integrated into MEXT, which is responsible for the national universities and laboratories. The National Institute of Science and Technology Policy (NISTEP) is now also integrated into MEXT. NISTEP is an important actor in the innovation system because it generates indicators for the government, is active in science and technology foresight activities, for which it has an internal center (STFC), and is linked to innovation policy-making. NISTEP is often in charge of informing the CSTP, thus preparing and providing relevant information for the highest science and technology council in Japan. Foresight in NISTEP, which is performed every five years to inform the stakeholders of the innovation system about future occurrences, has even been intensified.

MEXT supervises also other public IAI, such as the Institute of Physical and Chemical Research (RIKEN), or the Japanese Agency of Marine Science and Technology (JAMSTEC).

The second ministry which has always played an important role in innovation, mainly in applied research (but also basic research in selected fields like energy, e.g. for solar energy) is the former MITI. It has been reformed and is now called Ministry of Economy, Trade and Industry (METI). METI is still responsible for the national research institutions headed by the National Institute of Advanced Industrial Science and Technology (AIST) which integrates the large national research facilities under one roof, and for the New Energy and Industrial Technology Development Organization (NEDO), which is the intermediate organisation for energy issues.

METI still plays an important role in the innovation system via the intermediaries, but it has lost its "information monopoly" (assumed e.g. by Freeman 1987, p. 36) and the control over financial institutions such as the Japan Development Bank or the Fiscal Investment and Loan Plan. The large companies only partly care about the policy of METI. They act independently (mainly in global markets) and most of them accept the policy of METI as a framework. Nevertheless, there are still strong interconnections between METI and the companies, often expressed as exchanges on a personal level, which means direct communication or the exchange of personnel for a certain period of time. METI is also responsible for small and medium-sized company policy and provides strategic papers for them (see www.meti.go.jp).

The former Economic Planning Agency (EPA), in earlier times famous for its prognostic studies as preparation for the five-year plans, was integrated into the Cabinet Office and expanded its functions. Parts of the EPA became an institute in the Cabinet Office, the Economic and Social Research Institute (ESRI). As the Cabinet Office's think tank, ESRI links theory with policy.

Even the Japanese External Trade Organization (JETRO) which belongs to METI has to be mentioned as part of the Japanese innovation system. It was founded nearly 50 years ago in order to support Japanese companies when entering foreign markets and to give them access to related information. Therefore, JETRO has often been called the "Japanese spies" who are well informed about foreign innovation plans. In Figure 5–1, they are included in the section of the intermediaries. JETRO has 38 offices throughout Japan which provide information and advice on potential trading partners as well as regional investment environments. JETRO's regional offices work with METI Bureau and prefectural governments on inward investment promotion. JETRO has been reformed and (among different new programmes) JETRO Invest Japan Business Support Centers (IBSC) were established in 2003. The IBSCs are often frequented and it is assumed that this has already led to direct investments in Japan. JETRO is not directly involved in fostering the development of science and technology, but it helps to acquire knowledge from other countries, which is also supposed to lead to innovation. Moreover, they foster cooperation and help to bring innovations to the (export) markets.

International scientific exchange organisations

The Science Council Japan (SCJ) represents Japan through its affiliation with 48 international scientific organisations, including the International Council for Science (ICSU) and the International Academy Council (IAC). It has been striving for cooperation with various countries by actively participating in six international academic cooperative projects, including the International Geosphere-Biosphere Programme (IGBP). The OECD, APEC, ASEAN, IEEE, ISO, etc. are certainly also important regarding internationality. The Science Council of Asia (SCA), an international scientific organisation which aims at promoting collaboration and cooperation among Asian countries in scientific research, convenes annually on the topic of sustainable development in Asia.

Intermediaries

While they have always served to bridge the gap between public and private research, the importance of intermediaries in the Japanese innovation system has increased in recent years. In Figure 5–1 it is rather difficult to represent them because some of them have double functions, for example those institutions which are now "intermediaries" and have already existed for a long time (like the National Institute of Advanced Industrial Science and Technology), but in a different setting. At first, they were organized similar to the headquarters of the national institutes, as pure funding institutions, or even as the network which holds the institutes together. Nowadays, they have headquarters which define visions, missions and strategies in all these cases. On the other hand, these headquarters act as the link and transfer organisation from the ministries to the institutions, sometimes even to industry.

As part of the administrative reform in 2001, the legal status of most national research institutes was changed to Independent Administrative Agencies (IAA). This greatly increases their flexibility in terms of personnel and financial management. Regular evaluations are carried out by the ministries. Some funding agencies as well as some R&D performing organisations have been called Special Public Corporations; in 2003 most of them were also transformed into IAA.

The Japan Society for the Promotion of Science (JSPS, *gakushin*) is an IAA, and was founded in 1932 as a non-profit foundation through an endowment granted by Emperor Shôwa to contribute to the advancement of science in all fields of natural and social sciences and the humanities. It became a quasi-governmental organisation in 1967 under the auspices of the Monbushô, and since 2001 under MEXT.

The Japan Science and Technology Agency (JST, not to be confused with the former Science and Technology Agency before 2001) is an IAA with direct links to and financed by MEXT. Predecessors of this organisation were the Japan Information Center of Science and Technology (JICST) which existed from 1957 to 1996 and which was fused with the Research Development Corporation of Japan (JRDC). It existed from 1961 to 1996, and until 2003 it formed the Japan Science and Technology Corporation. In 2003, it was formed into an "agency". JST also manages a Research Institute of Science and Technology for Society (RISTEX) which aims to promote research and development starting from the needs perspective.

The New Energy and Industrial Technology Development Organization (NEDO) was established by the Japanese government in 1980 to develop new oil-alternative energy technologies. In 1988, NEDO's activities were expanded to include industrial technology research and development, and in 1990, environmental technology research and development. Activities to promote new energy and energy conservation technologies were subsequently added in 1993. Following its reorganisation as an incorporated administrative agency in October 2003, NEDO is now also responsible for R&D project planning and formation, project management and post-project technology evaluation functions. The activities of NEDO are concentrated on different technologies and themes, e.g. in the industrial sector nanotechnology and materials development, biotechnology development, electronics, information and communications technologies development, industrial technology development (machinery, manufacturing and processes, aerospace, etc.), projects related to medical, welfare and ergonomics technology, global environment industrial technology research and development projects, chemicals and others.

In 2003, the Institute of Space and Astronautical Science (ISAS), the National Aerospace Laboratory of Japan (NAL) and the National Space Development Agency of Japan (NASDA) were merged into one IAA: the Japan Aerospace Exploration Agency (JAXA). This agency therefore not only acts as an intermediary but also performs research itself. While space development and utilization, aviation research and development are the measures to achieve the nation's policy objectives, JAXA's contribution is to promote a mission and to develop a vision in space science and technology. As a core organisation for aerospace technology, JAXA will promote consistent activities, from basic research to technology development and utilization.

Research and education system

The Japanese university system consisted of private and public universities. Students had to pay tuition fees at every university, however private universities were and are much more expensive. Compared to Germany, education in Japan is very expensive and people often need a loan in order to be able to afford to send their children to university. The Japanese education system is often called meritocratic (*gakureki shakai*).

Expanding the independence of management in the areas of budget, organisation and personnel affairs, national universities (which account for less than 20 % of the students in higher education, but 80 % of the national budget) and inter-university research institutes were incorporated under the National University Corporation Law in April 2004 and were turned into Independent Administrative Institutions (IAIs). In the mid-term, even the financing of the national universities will change and the government has also sent clear signals indicating that it would like to see the number of national universities decrease in future (e.g. with a centres of excellence program). This has already resulted in some mergers between national universities.

Another major point of the 2004 reforms was the development of a rigorous assessment system. The new reforms were designed to reduce the difficulties in obtaining the external accreditation needed to establish new departments and courses and to replace it with much stringent ex-post-facto assessments. All national universities have been required to produce six-year plans and targets against which their performance will be judged and which will determine their subsequent funding (Goodman 2008). Third-party evaluation agencies, accredited by MEXT, have been set up in order to undertake the evaluation of institutions' teaching and research. A final point in the current reform process has been a greater emphasis on transparency and accountability (Goodman 2008).

In 1995, the Ministry of Education started a special program for Centres of Excellence (COE), which aimed at selectively improving university research environments to world-class level. Annually, around half a dozen new centres were selected and awarded a five-year grant. In 2002, a new COE program was started, the "Center of Excellence Program for the 21st Century". Its focus is to improve doctoral programmes at universities (develop graduate schools in different fields). The aim is to establish 30 centres of excellence nationwide (in 2005, there were more than 600 universities in Japan) (European Commission 2005, p. 82). The background of the new program is a perceived need to concentrate research resources at those universities which have the potential to achieve world-class level in their research. Two-thirds of all grants were divided among 14 universities, which were awarded four or more COEs (e.g. the University of Tôkyô, Kyôto University).

Universities, even after the reforms, are not the major player in transferring knowledge to the market, although their ties to industry are strengthened and there are more and more direct cooperations (Kondo 2005). Especially the huge increase of national funds for basic research during the last 20 years encouraged them to enter the research market. But most of the universities concentrate more on education and less on research. This might be changing in the mid-term future because of their changed status as IAI since 2004.

Academic research in Japan is conducted in undergraduate departments, graduate courses, research laboratories and research facilities at universities, as well as at joint-use inter-university research institutes, which are not tied to a specific university. Research laboratories devoted to research in designated specialized fields have also been established at universities. At the end of FY 2005, a total of 59 research laboratories had been established at national universities, including 20 research institutions for the joint use of the nation's universities (MEXT 2006, p. 294).

Research projects such as neutrino research conducted by the Institute for Cosmic Ray Research (ICRR) of the University of Tôkyô have produced research results of the highest international standards (MEXT 2006, p. 294). Sixteen existing institutes were reorganized into four organisations (National Institutes for the Humanities, National Institutes of Natural Sciences, High Energy Accelerator Research Organization, and Research Organization of Information and Systems) with the corporatization of national universities in 2004. Nevertheless, the inter-university research institutes continue to make significant contributions to research advances in a variety of fields by acting as centres for promoting joint research between researchers employed in universities nationwide, and by providing a place for joint use of facilities, equipment, and materials which are unique or large in scale. Projects such as the B-Factory project of the High Energy Accelerator Research Organization (KEK) and SUBARU, an optical-infrared telescope, a project of the National Astronomical Observatory of Japan (NAOJ) also promote cutting-edge international research. In addition, each organisation is making efforts to create new sectors beyond the framework of existing organisations and sectors by establishing collaborative organisations and facilitating exchanges of researchers in different sectors.

Public and private research institutions

There are many public and private research institutions in Japan. Their programmes, contribute to basic research as well as to innovation. In the following, only those institutions are mentioned which play a large role in the innovation system.

The National Institute of Advanced Industrial Science and Technology (AIST) is not a governmental institution, although it is to a large extent funded by the Japanese government. A large part of the research performed at AIST has direct relevance for industry, but has so far received relatively little financial support from industry. AIST was established in 2001, however, AIST and its ancestors have been active in "contributing to society through continuous advancement in technologies and support to Japanese industries" since 1876. AIST is meanwhile the head of the national laboratories and has started a consolidation process in basic research and the national institutes linked to it, see above. In many cases, AIST acts as an intermediary (cf. Figure 5–1).

The mission of the *Institute of Physical and Chemical Research (RIKEN)* is to conduct comprehensive research in science and technology (excluding the humanities and social sciences) as provided for under the "RIKEN Law", and to publicly disseminate the results of its scientific research and technological developments. RIKEN carries out high level experimental and research work in a wide range of fields, including physics, chemistry, medical science, biology, and engineering, covering the entire range from basic research to practical application. RIKEN was first organized in 1917 as a private research foundation, and re-organized in 2003 as an IAI under the auspices of MEXT.

Under MEXT, there is the Japanese Agency of Marine Science and Technology (JAMSTEC). The title of this agency sounds like that of an intermediary, but like AIST, its status can be seen as an in-between intermediary and research institution. JAMSTEC is more of a research organisation as it hosts different research institutions. The major one is the Marine Technology Center (MARITEC), which has been involved in the development of various leading-edge technologies, aimed at driving forward research and studies which are already underway at JAMSTEC.

There are many independent institutes or university institutes on the research market, e.g. the Kyûshu Institute of Technology (KIT), the Tôkyô Institute of Science and Technology or the Japan Advanced Institute of Science and Technology (JAIST), to name but a few.

The industrial sector

Multinational corporations (incl. R&D centres) remain the main actors in the Japanese innovation system. Their share of R&D expenditures in the country is more than two-thirds. Nearly half of the R&D expenses in the private sector are spent by the top 10 large companies. They have their own research laboratories, where they perform basic research and product development. The central research institutes of large companies have few links with university and public research institutes. In the meanwhile, some of them are no longer domestic companies, but global actors (like Sony, Canon, Fujitsu) with R&D centres all over the world, which still do most of their research at the home base. This turns out to be a disadvantage in times of globalisation. On the other hand, many international companies are also present on the Japanese market, some of which have relocated their R&D facilities to Japan in order to be close to customers and knowledge. And increasingly, the suppliers are following, e.g. the large automobile suppliers (Bosch etc.) are all present in Japan. Some of the companies look carefully at the governmental policy for innovation, science and technology. But most of them are strong enough just to regard this as a framework condition.

The globally competitive multinational corporations coexist with a large number of small and medium-sized enterprises (SMEs), where 70 % of Japanese workers are employed. But these SMEs are currently highly dependant on the Japanese market. In recent years they have been trying to cooperate with companies abroad.

In Japan banks are the main providers of venture capital – and that means start-ups find it difficult to get funding. Previously, Japanese-German foresight surveys often stated that funding was one of the major obstacles in high-technology sectors in Japan (Cuhls et al. 1995; Cuhls and Kuwahara 1994). Since 2000, when it became possible for professors at national universities to simultaneously hold positions in private sector businesses, the number of university-based venture companies in Japan has increased noticeably (from 128 in 2000 to more than 1,000 in 2005), but this is still low by international standards (MEXT 2006, p. 70).

Industrial Associations play a large role in promoting and fostering science, technology and innovation in Japan. One of the very large players is the Japan Federation of Economic Organizations (*Nihon Keidanren*). Nihon Keidanren was established in 2002 by fusing Keidanren and Nikkeiren. Additionally, associations can be found in every large innovation field, from nanotechnology to robots. A few examples are the Japan Robot Association, the Healthcare Engineering Association of Japan, the Japanese Association of Healthcare Information System Industry (JAHIS) or the Support Center for Advanced Telecommunications Technology Research.

Scientific societies also promote science and technology in the innovation system. Some of the well-known examples are the Robotics Society of Japan (RSJ), Japan Society of Mechanical Engineers (JSME), the Japan Society for Precision Engineering (JSPE) or the Information Processing Society of Japan (IPSJ). They also represent the strong thematic fields of Japanese science and technology.

Collaboration between the public and private sectors

Science and technology parks as well as industrial clusters have developed strongly in Japan in recent years. Tsukuba Science City is the best known and well-established science and technology park. A new science park is Kansai Science City between Osaka, Nara and Kyôto. Not all of these technology parks have been that successful in bringing together people from universities, national laboratories and industry. Especially parks that were out of reach were not attractive for researchers (Hokkaidô etc.) at first, but meanwhile it has been possible to establish industrial clusters even in these locations. Cluster issues are: Automobile and Transport Equipment, Pharmaceuticals and Healthcare, ICT (Information and Communication Technology), Semiconductors, Biotechnology, Electronic Components and Devices, Precision Machinery (Robotics, Optics, Precision Instruments, etc.), Life Science etc.

There are also regional incentives for investments: some regions define cluster-like thematic areas and offer incentives for national and international investments to attract foreign firms. These clusters are not only intended to foster production, but also to conduct research and innovation. Some of the science parks have only regional sponsors and some of them even host big science facilities. It is a little known fact that the big synchrotron radiation facility SPRING 8 which is located in Hyôgo prefecture is to a large extent regionally financed (run by the Japan Synchrotron Radiation Research Institute).

In Japan's regions integrated innovation support systems can be found. One of the most traditional innovation support agencies for SMEs in Japan are the so-called kôsetsushi centres. They have been set up and financed by prefectural governments. These centres form a dense network of 172 centres in Japan.

In 2005, a new organisation occurred: 41 institutions were either authorized or accredited as technology licensing offices (TLOs) under the Law for Promoting University-Industry Technology Transfer (1998). In addition, JSPS (supported by METI and MEXT) has sponsored transfer support centres which provide advice on patenting, feasibility studies on technologies as well as financial support for applications for overseas patents. The number of university-based start-up companies totalled 531 as of the end of 2003, steadily approaching the goal of 1,000 such companies set by METI.

5.5 Is the Japanese innovation system at a crossroads?

The JIS is specific, in fact, every country is specific in its NIS because the system does not exist in a vacuum but is embedded in culture, literature, history, economic and the social framework of the country. Especially "history matters" and "institutions matter" (Storz and Schäfer 2011) and therefore, there is a permanent change in any innovation system. The question is rather whether there are evolutions or whether there is a radical shift.

Lee (2006, p. 73) sees Japan in a paradigmatic crisis since the 1990s: In the beliefs held by many Japanese people about their own political-economic system, there is no consensus or underlying common understanding as often assumed by authors of the nihonjinron. Lee defines nihonjinron as a "broadly based ideological stance for Japan's nationalism" between "unqualified ethnocentrism, extolling Japan's cultural genius" and "depressed soul-searching". There are ups and downs in this debate of Japanese uniqueness, more or less nihonjinron. Interestingly, Lee assumes a connection between institutional reforms and nihonjinron: "If institutional reforms in Japan take place only during a period of strong negative Nihonjinron, there will have to be a change from positive Nihonjinron to a negative one before they are undertaken". This means that first of all, a change in the national identity has to take place and after that reforms are possible. This is an interesting thought in relation to the nationalism debate in Japan, which however needs further examination.

Perez suggested that "depressions represent periods of mismatch between an emerging new paradigm and the old institutional framework. Big boom periods of expansion occur when there is a 'good match' between a new techno-economic 'paradigm' or 'style' and the socio-institutional climate" (citation of Perez 1983 in Freeman 1987, p. 76). Currently, Japan seems to be at such a mismatch-point.

Obviously, the perpetual catch-up syndrome that was observed especially between the 1950s and the 1980s with its permanent hunger and restlessness to become no. 1 and gain knowledge came to an end at the end of the century (see e.g. Lee 2006; Odagiri and Goto 1993). In many research fields, Japan is now among the leading countries and the strategies that were successful at a time when the country was catching-up do no longer apply.

Neglecting the debate about the Japaneseness, one can state that the year 2011 with its natural and man-made disasters is a new demarcation line that puts the Japanese Innovation System once more at a crossroads. Especially the sectoral innovation systems (energy, environment) are under pressure and are in question because the events of "March 11" demonstrate the vulnerability in parts of this sector. Even some of the actors in this system are under suspicion. The question is rather *how long it will take* to change such a national and sectoral system – the question is not *whether* it will change.

5.6 Outlook

There are a lot of challenges in Japan – as in other countries. As already stated in Cuhls and Wieczorek (2010) more and more attention is being paid to Human Resources. The high level of education should also enable the Japanese to be more flexible and therefore meet the challenges of the coming decades. Nevertheless, career paths and working environments still need to become more flexible. Reforms in recent years are targeting more creativity and individual empowerment. This is necessary because Japan is facing a huge demographic change which will challenge the availability of well-educated persons.

Mobility and internationality are major challenges for industry as well as for the Japanese education system (see MEXT 2006). Most importantly, the lingua franca English has to become more widespread in Japan.

The high standard of education is one of the reasons for the continuing high quality inside the Japanese innovation system. But Japan's isolation from the outside world is becoming more and more a problem in terms of its research. Scientific publications by Japanese authors are cited internationally only half as often as those by their American or Swiss colleagues. Japanese do not publish in international journals as often as American or European researchers, and hardly ever apply for a patent jointly with a foreign partner. Recent data do not show signs that this situation is improving. Moreover, the percentage of foreign researchers among highly skilled workers is extremely low in Japan compared to international levels. Without opening their innovation system to foreign researchers (or to put it in other words: without attracting foreign researchers), Japan will face a shortage of researchers in the future (foresight figures can be found in e.g. MEXT 2003, see also MEXT 2006 or 2010).

The infrastructure in Japan is very good. General infrastructure for traffic (highways, trains, airports and harbours) is very dense and convenient. IT networks and mobile communication are very well developed – the only challenge here is their maintenance and update.

The Japanese market is over-regulated and fenced in against international competition by barriers for market entry. For example, the licensing procedure for a new business takes an average of 23 days – in France a mere seven. Some sectors are regarded as especially inefficient in Japan, these are: construction, trade, and services.

The Japanese system for venture capital is rather bank-oriented. This is why the whole economy was hit so badly by the bank crises and it remains vulnerable. Also, innovations are more financed by banks than by the real venture capital market (Nabor 2007; Storz and Schäfer 2011).

There are many new laws and regulations in Japan, which all deal with innovation, and transfer of science and technology into the market. They seem to be rather successful in playing a role in coordinating the different actors of the innovation system. The most important one is the Science and Technology Basic Law (since 1995, Legislation No. 130), which is unique. Based on this law, Science and Technology Basic Plans are developed to give a clear framework and fill the law with life, i.e. budgets. Currently the Fourth Basic Plan for the years 2011 to 2016 is in effect. An innovation strategy, further developed from a paper called "Innovation 25" (CSTP 2006b) supports the strategic priority-setting and coordination of actors in the system. Further ideas can be found in Hirasawa (2010).

The major current challenge is to overcome a kind of "depression" that is noticeable in the country since it was hit by the three disasters. The first reaction was to do "business as usual" – that is why Japan was admired for keeping so calm. But there are different possibilities of impacts on the innovation system in years to come:

- The first one is that Japan stays "depressed", the system is not running smoothly and the actors are losing more and more motivation.
- The second one is the opposite: A new euphoria, driven by the disasters similar to the new establishments of institutions after World War II might occur. In this case, the motivation is gained by the necessity of "getting up" and "re-starting" once more, to rise like a phoenix from the ashes.
- In fact, the future reality will be somewhere in-between: The first depression seems to be waning now. Many people are re-motivated and one can even notice a new societal feeling of mutual help and care, at least in some regions of the country. Some economists currently argue that Japan will prosper economically once more – the first signs and signals can already be figured out and measured (see the discussion of the National Bureau of Asian Research, NBR Forum, http://www.nbr.org/, during February and March 2012).

This contribution was written in March 2012, exactly one year after the disasters. The expected sudden changes in the innovation system have not occurred until now – reforms and major changes take their time, especially in Japan and under the circumstances of rather weak political guidance (change of Prime Minister etc.). But looking back at the last 10 years and what in hindsight has already changed, one can be sure that Japan will recover and remain on international markets with its stable innovation system as a backbone – with some cultural specifities, its history and the people who were not only shocked but are used to changes induced by natural disasters (earthquakes, typhoons, floods, heavy rains…). At least, these people will not give up – and remain a huge factor in the globalised world of the future.

The second lesson is that even if everybody is complaining about missing structural reforms, the case of Japan demonstrates how dynamic NIS are in the long run, and that they are steadily changing although this change is not visible at first sight but only when looking back and reconsidering the framework conditions and historical circumstances. Therefore, history matters, circumstances matter, culture matters and systems as well as education and institutions in general matter. This is the reason why we still have a problem to really draw a comprehensive model of the National System of Innovation with its different dimensions, be it in Japan or elsewhere.

As long as we do not have this comprehensive model, we can at least update what we know. Revisiting a changing system at certain points in time is therefore not only worthwhile doing. It is even necessary as time goes by. Only the change itself is permanent – this old saying is inherent in the timescale problem – and remains unsolved in the descriptions of the National System of Innovation in the current static models. Therefore, historic updates – revisits – are crucial.

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6

DECENTRAL WASTEWATER INFRASTRUCTURE:

CHARACTERISATION AND OVERCOMING PATH DEPENDENCIES BASED ON A TECHNICAL INNOVATION SYSTEM ANALYSIS

CARSTEN GANDENBERGER, CHRISTIAN SARTORIUS

6.1 Introduction

The centrally organised disposal of wastewater in Germany is a strongly regulated field for several reasons: because it is a public service, on the one hand, and because of its monopolistic character on the other. Innovations here are triggered and pushed by different actors, some of whom belong to the regulating authorities, some to the private sector. This applies to research as well as to the development and diffusion of the relevant technologies. The existing wastewater infrastructure has proven to be very innovative over the past decades with respect to various challenges, but the limits of its adaptability are reached if the underlying structure of the system is at stake, as is the case with demographic or climate change. Elements of a decentral infrastructure which could improve adaptability in the face of these major challenges and decrease uncertainty are only diffusing very slowly. This is valid in a technical-scientific sense, but also with regard to the actors and the framework conditions.

Based on the concept of a technical innovation system, we describe the factors which support or hinder innovations in the field of decentral wastewater infrastructure. In doing so, we refer especially to the innovation system functions listed by Bergek et al. (2008) and Hekkert et al. (2007). In addition to this, we draw particular attention to the characteristic feature of radical innovations, which deviate from already established technology paths and therefore may be subject to lock-out effects which hinder their further diffusion in spite of their principal suitability (Sartorius and Zundel 2005).

After describing typical actors and the specific framework conditions of wastewater disposal in general and of decentral wastewater disposal in particular (in Section 6.2), we show (in Sections 6.3 and 6.4) how path dependency and lock-in effects arise at the expense of decentral infrastructure alternatives and (in Section 6.5) how at least one of the obstacles can be overcome by re-organising property and utilisation rights and how this is accompanied by changes in the innovation system. The conclusions (in Section 6.6) round off this contribution.

6.2 Background

The original purpose of a centrally structured sewer system is to collect feces and wastewater of all kinds and to transport these away from residential areas. In addition to this, in order to avoid damages to the environment, the system is fitted with (central) sewage treatment plants which treat the wastewater, removing unwanted organic substances, nutrients and trace substances before discharging it into water bodies. The system of sewers not only represents the largest part of the required investments. Its planning and design also have to take into account all the eventualities of future developments because of its expected service life of more than 50 years. These include, among other things, demographic developments in the population being served and changes in water consumption and the profile of pollutants to be transported. In combined wastewater and storm water sewers, this also involves the changed frequency and intensity of heavy rainfall and storms due to climate change and the associated limits to their performance capacity (Koziol et al. 2006). Substantial adaptation costs or sunk costs may arise in the case of larger deviations from the originally planned concept. This cost drawback on the part of the central sewer system is offset by positive economies of scale effects at the sewage treatment plants, which allow more advanced treatment processes to be implemented at a given specific cost in larger plants.[1] The high capital cost of sewers is relativised from the viewpoint of the individual user if they are used to dispose of the wastewater of a large number of people in more densely populated areas. Another advantage from the viewpoint of the operators of the wastewater infrastructure is that it is easy to check whether the system is functioning correctly because this can be done centrally. The latter is less an economic and more of a political argument that has to do with the public welfare function of the state in the context of environmental protection and sustainability in general and the treatment of waste and wastewater in particular.

Unlike central wastewater infrastructure, the decentral alternative manages to collect the wastewater without a broad network of sewers. Instead, the wastewater from individual houses or small groups of houses is treated on-site with the help of small-scale wastewater treatment plants (SWTP) and subsequently discharged into a water body or allowed to seep away. The purification performance of these plants corresponds in principle to that of small central sewage treatment plants; the stricter standards of larger treatment plants, especially with regard to nutrient elimination,

1 This advantage is used by the legislator to set higher requirements for larger plants.

can also be met if advanced upgrading measures are applied. Small-scale wastewater treatment plants have therefore been recognised as equivalent to central treatment plants in line with Annex 1 of the German Wastewater Ordinance (AbwV) since 2002. Due to their very nature, SWTP are obviously not able to realise economies of scale to any significant extent, so that they are initially more expensive than central plants for the same level of performance. Up to a certain degree, they can make up for this drawback via increased numbers and the lack of sewers, so that at least in sparsely populated rural areas, decentral sewage treatment plants are more economical than their central counterparts. SWTP also have advantages if additional wastewater disposal capacities would have to be constructed in more densely populated areas because the existing infrastructure has reached its limits, or because it is becoming too expensive to operate a central infrastructure in regions with a shrinking population.

Table 6–1: Regional distribution of the population connected to small-scale wastewater treatment plants in Germany in the years 2001, 2004 and 2007

	2001		2004		2007	
Federal state	**1000 p.e.**	**%**	**1000 p.e.**	**%**	**1000 p.e.**	**%**
Baden-Württemberg	69	0.7	62	0.6	53	0.5
Bavaria	561	4.5	470	3.8	407	3.3
Berlin	2	0.1	2	0.1	–	–
Brandenburg	132	5.1	93	3.6	88	3.5
Bremen	0	0	0	0	0	0
Hamburg	–	–	6	0.3	5	0.3
Hesse	18	0.3	16	0.3	14	0.2
Mecklenburg-West Pomerania	270	15.3	241	14.0	205	12.2
Lower Saxony	516	6.5	482	6.0	454	5.7
North Rhine-Westphalia	480	2.7	426	2.4	364	2.0
Rhineland-Palatinate	28	0.7	20	0.5	14	0.3
Saarland	7	0.7	7	0.7	4	0.4
Saxony	493	11.2	369	8.6	334	7.9
Saxony-Anhalt	337	13.1	233	9.3	166	6.8
Schleswig-Holstein	171	6.1	159	5.6	147	5.2
Thuringia	216	9.0	184	7.8	179	7.8
Germany	3301	4.0	2769	3.4	2435	3.0

Note: p.e. = person equivalent
Source: StaBuA (2003; 2006; 2009)

In this respect, there are no reasons why both alternatives should not coexist in accordance with their relative merits. However, if a more detailed analysis is made of the figures listed in Table 6–1 showing the number of persons connected to SWTP, it is evident that there has been a steady decline in every German federal state since 2001. The question has to be asked whether the economically viable use of SWTP is actually limited to a share in the range of single-digit percentages which is where the figures are headed at the moment. That economic aspects are possibly not solely decisive is indicated by the fact that in some – but not all – non-city states shares of well below 1 % are reached, even though larger shares of the population here live in areas in which a central connection is much more expensive than the decentral option.

6.3 Lock-in effect due to sunk costs

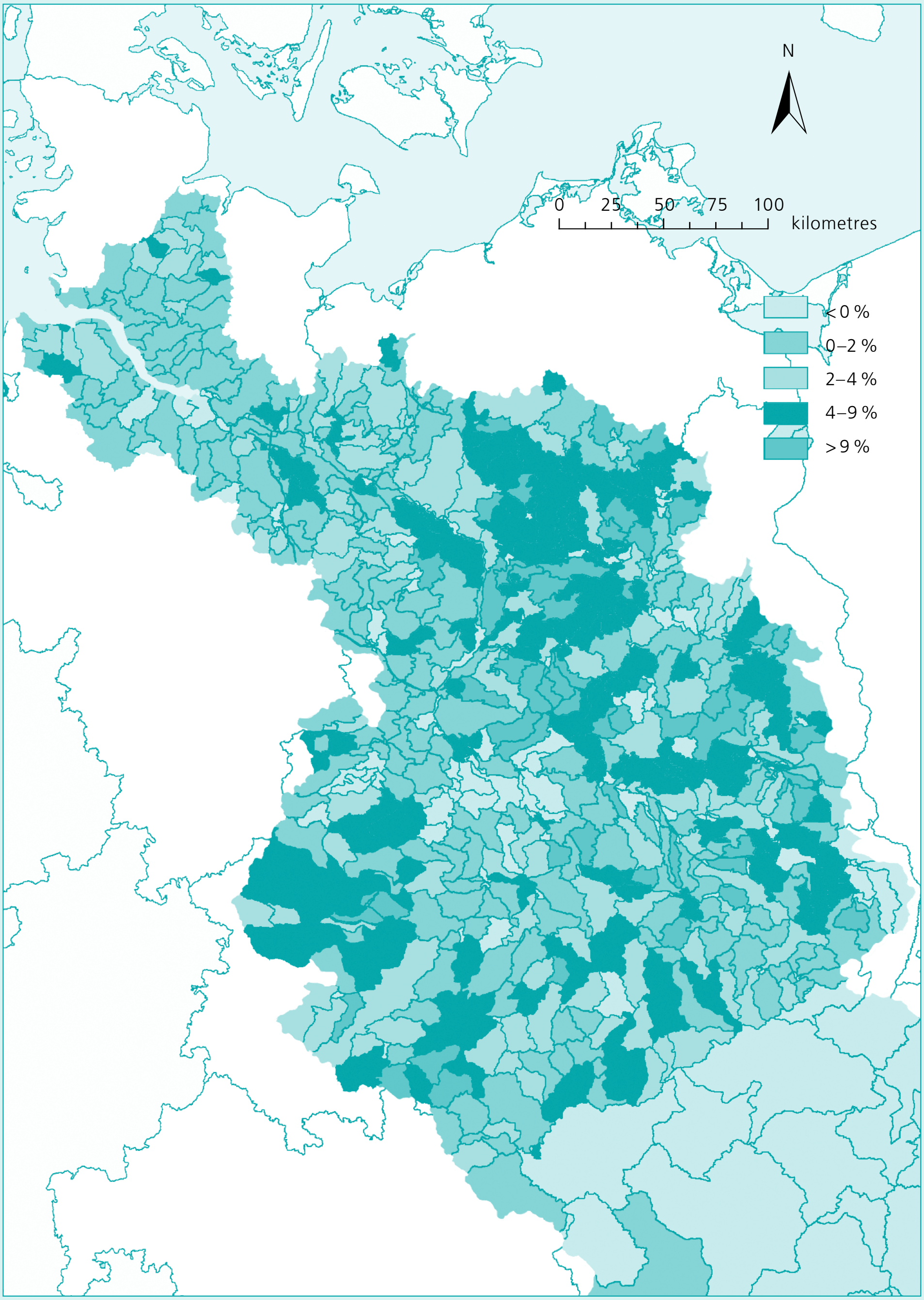
According to the comments made in Section 6.2, central wastewater treatment and SWTP are basically substitutes from a technical point of view. There are also no technical-economic reasons for a lock-in effect, i.e. the wider use of one of the two alternatives does not systematically preclude the other (Arthur 1988; David 1985). SWTP are neither dependent on additional (network) infrastructure which still has to be constructed, nor are there any technical incompatibilities between the decentral and the established central variants (Zundel et al. 2005). In order to confirm (or refute) the existence of a possible lock-in effect in favour of central wastewater disposal, it is shown first how SWTP would spread geographically if their use were based predominantly on technical and economic criteria. The INNUWIM (Innovation in Urban Water Infrastructure and Management) model is used for this purpose. This model was applied by Sartorius et al. (2011) to extrapolate the development of the wastewater infrastructure and its impact on nutrient emissions in the Elbe river basin up to the year 2020. As Figure 6–1 shows, the expansion of SWTP is mainly concentrated on Brandenburg. Other regions with significant but more moderate growth exist in parts of Thuringia, Saxony and Mecklenburg-West Pomerania. The average growth rates of the federal states concerned, which are presented in Table 6–2 up to the year 2020, confirm this impression.

Table 6–2: Comparing the stock of SWTP in the non-city states of the Elbe river basin with the increase predicted until 2020 using the model

	Stock (%)[2]			Growth (%)[2]
Federal state[1]	**2001**	**2004**	**2007**	**2004–2020**
Brandenburg	5.1	3.6	3.5	4.1
Mecklenburg-West Pomerania	15.3	14.0	12.2	1.7
Lower Saxony	6.5	6.0	5.7	1.1
Saxony	11.2	8.6	7.9	1.6
Saxony-Anhalt	13.1	9.3	6.8	0.7
Schleswig-Holstein	6.1	5.6	5.2	0.7
Thuringia	9.0	7.8	7.8	3.1

SoaBuA (2003; 2006; 2009); own calculations
1 Excluding the city states of Berlin and Hamburg
2 Ratio of the number of (additional) population connected to SWTP to total population

Figure 6–1: Ratio of the increase in persons connected to SWTP to the total population in the period 2004 to 2020 in the German part of the Elbe river basin



Sources: StaBuA (2003; 2006; 2009); own calculations

If mainly economic-technical criteria were decisive for the construction of SWTP, then there should be a large stock of them in federal states with high growth potential, whereas low potential should be accompanied by small stock figures. If the stock of SWTP in a particular state is higher than expected based on the potential, in the new federal states (i.e. states of the former GDR), this might also be related to the fact that decentral wastewater disposal was much more widespread in the former GDR, including the acceptance for certain malfunctions, than was the case in the FRG at the same time. This appears to be particularly the case for Saxony-Anhalt, since the stock here was comparatively high, particularly in 2001, in spite of the low potential. This relatively high stock, however, had dropped by almost half, by 2007, which indicates that, wherever possible, preferably the most up-to-date figures should be compared with the potential. Against this background, the state of Brandenburg particularly stands out, as the lowest numbers in terms of stock are set against the highest potential. There seems to be the tendency in Brandenburg to keep the stock of SWTP lower than seems plausible from a technical-economic perspective in other German federal states.

One reason for this could be the desire to achieve the highest possible capacity use of the central sewage treatment plants in view of the large investments made after reunification in expanding and upgrading the wastewater infrastructure. Operating central sewage plants with an extensive network of sewers which supply the wastewater is associated with a fixed cost share of up to 75 % (BDEW 2008). Every resident, disposing of wastewater using a SWTP instead of connecting to the existing central wastewater disposal system, would reduce the revenues of the waste disposal company in proportion to the amount of wastewater no longer treated centrally. The costs for the company, in contrast, would only be reduced by one quarter which would result in a considerable shortfall in their budget. In order to prevent residents withdrawing from using public wastewater disposal facilities, a mandatory connection and usage policy is practiced in Germany. Accordingly, wastewater producers who can be connected to public wastewater infrastructure at reasonable cost in fact have to connect and dispose of their wastewater there. In Brandenburg, this mandatory connection and usage policy is enforced with particular stringency because oversized sewage works were authorised and constructed after reunification, which are now underutilised and generating high costs. The enforcement goes so far that houses which are already connected to a SWTP and whose inhabitants refuse to comply with the mandatory connection to the central system are forced to do so by order of the police (NN 2008).

Even if mandatory connection and usage and its especially strict enforcement seem to be primarily responsible in Brandenburg for the contradiction between the high growth potential and the low actual stock of SWTP, this still does not necessarily indicate a lock-in effect. Different forms of one institution in different federal states are more likely to indicate only the competition of two technologies under different framework conditions. If the conditions for competition change, then the result changes too. At this point, therefore, it cannot be assumed that there is really a systematic basis in favour of the established technology as described by David (1985). However, if the reasons for the different forms of the connection compulsion are investigated, it can be concluded that the investments in excess capacities of municipal (central) sewage plants represent sunk costs to a large extent, mainly on account of these plants' long service lives of usually more than 50 years, which the operators of the infrastructure then try to reduce to the greatest extent possible. Sunk costs therefore represent the real cause of the contradiction and may very well be the reason for a lock-in effect (Zundel et al. 2005).

6.4 Lock-in effect due to institutional obstacles

Unlike the eastern federal states, sunk costs cannot be the reason for the low share of SWTP in the non-city states of Baden-Württemberg, Hesse, Rhineland-Palatinate and Saarland. Neither is any other economic-technical cause immediately apparent. It can therefore be suspected that features in the actor structure or the framework conditions are responsible for the low diffusion of SWTP. To investigate this in a more detailed analysis, we use the technical innovation system approach (TIS) of Bergek et al. (2008) and Hekkert et al. (2007). This approach is based on the idea that technical change in general and innovations in particular are influenced by many actors and framework conditions, especially institutions. These can – depending on how they or their characteristics are affected – influence the innovation process either positively or negatively. Furthermore, it has to be considered that the actors can even influence how framework conditions are shaped, depending on their own interests and influence. Depending on the type and extent of the possible impediments to an innovation, usually a path dependency, but frequently also a lock-in effect can be determined. The latter is particularly likely if a whole new technical approach is being pursued which does not build on existing components of the established system. In contrast to the *incremental* changes along established technology trajectories (in the case in point: central wastewater disposal), we then talk about *radical* innovations (Dosi 1982, p. 158f.). In the following, we apply the TIS approach to wastewater infrastructure and specifically to the introduction of SWTP. The TIS approach of Hekkert et al. (2007, pp. 421ff.) covers the following seven functions which are viewed as essential for the formation and diffusion of innovations:

(1) Entrepreneurial activities form the core of the innovation process. The entrepreneur recognises the opportunity for an innovation, collects resources to develop it further and decides at various points (under high uncertainty) whether it makes sense to continue or not. In the case of decentral wastewater treatment, considerable progress has been made in the development of SWTP and the treatment processes implemented in them. So far, the risk involved has been limited, since most parts were able to draw on existing components and the investments in the plants are relatively low. There was a greater need for adaptation concerning the variability of wastewater volume and the resulting higher demands with regard to robustness. In the future, it will be important to be able to conduct (remote) checks that SWTP are functioning correctly and simultaneously to improve their economic efficiency. This will require

the production and, where necessary, operation of larger numbers of SWTP which will probably lead to an increased risk.

(2) Knowledge development, i.e. learning, forms the basis of the innovation process and represents its most essential resource. Its institutionalised form is known as research and development (R&D), which itself requires investments in material, human and eventually financial resources. In the case of SWTP, the more basic part of this knowledge has already been developed in private enterprises and public research institutes, like the *Prüfinstitut für Abwassertechnik* (Testing Institute for Waste Water Technology, PIA) and at several university institutes. The same types of enterprises and institutes, albeit in somewhat different research areas, are involved in developing remote control capability for SWTP. As far as innovative ways of operating (a larger number of) SWTP is concerned, a very different type of non-technical knowledge needs to be acquired, whose development will probably involve quite different actors. We will go into more detail later.

(3) Knowledge diffusion in networks is essential in so far as, except during the early phases of some inventions, knowledge creation involves the collection and recombination of the ideas and experiences of various actors who are somehow related to the innovation considered. Beyond the companies and institutes directly involved in the development and operation of SWTP (see last point), this includes institutes concerned with standardisation and testing like PIA and the *Deutsches Institut für Bautechnik* (German Institute for Construction Technology, DIBt), which measure and compare performance according to commonly agreed, unified standards and thus enable the comparative evaluation of different technical approaches. Another important multiplier for knowledge concerning SWTP is the *Bildungs- und Demonstrationszentrum für dezentrale Abwasserbehandlung* (Training and Demonstration Centre for Decentralized Sewage Treatment, BDZ), which compares the performance and operating experiences with different types of SWTP and helps to disseminate the knowledge gained among the manufacturers (giving them the opportunity for improvements) as well as the users. Knowledge diffusion is, however, not limited to manufacturers and users. It includes both legislators and administrators (i.e. the wastewater authorities), which set the rules and monitor and control the facilities once they are installed and in operation.

(4) Guidance of the search refers to the direction in which R&D ought to proceed and needs to be supported accordingly. This is especially true in the context of environmental innovations where the legislator sets compulsory rules, which can only be met by employing specific technologies. For SWTP the respective basic requirements are given in Annex 1 of the Wastewater Ordinance, which states the maximum allowed emission limits for BOD, the nutrients N and P, and for the sterility of the runoff under various conditions. It should be noted in this context that these limits are not simply set top-down by the authorities, but that they are developed in an exchange of opinions between stakeholders as to what should be done with regard to safeguarding human health and protecting the environment and what can be done from the technical and economic perspective (see knowledge network function, above). Less

basic innovations related to SWTP which include the extension of their basic functions by remote monitoring and control are not guided directly by the above mentioned legislation, but by the attempt to comply with it as economically as possible.

(5) Market formation is a basic aspect of innovation as it includes the entire progression of a new product from its invention to appearance on the market. Entering the market requires much more than acquiring knowledge and solving technical problems. Building and expanding manufacturing capacities requires substantial financial resources and human capital needs to be restructured in order to market the large quantity of production output. As a market for SWTP already exists, its basic formation appears to have taken place already. However, although its actual market share is rather small, it seems to be declining rather than increasing (cf. Table 6–1). From this perspective, the questions arise whether the market is indeed really so small and which parameters could be changed in order to expand it. This paraphrases the basic question tackled in this contribution, which we will look at in more detail later. Another argument usefully discussed at this point is the need to design a market formation strategy. All more or less radical innovations which are not directly related to the established technology paradigm tend to be more costly, especially when they first enter the market, because they have not yet been able to benefit from economies of scale and learning-based cost degression. In order to still gain a foothold in the market, it is advantageous to identify market niches where at least a limited number of customers are willing to pay an initially higher price for the innovative product (Kemp et al. 1998). For SWTP, this is the case in remote regions where households can be connected to the central sewage system only at very high costs. In some (relatively well-off) federal states like Baden-Württemberg, the authorities are willing to pay the higher price for the central sewage connection in rural regions, whereas in less wealthy states, like Saxony, they are not. Accordingly, the remote regions of Saxony do indeed represent a market niche for SWTP. However, while the existence of a market niche strongly supports the diffusion of an innovation, this condition is not sufficient on its own.

(6) Resource mobilisation as a requirement for the development and diffusion of (environmental) innovation has already been emphasised in various contexts: material, financial and human resources. As SWTP are not high-tech, their material needs are not sophisticated and the mobilisation of the respective resources is not a problem. Financial resources are also not limiting, because SWTP facilities are not very expensive and the costs are met directly by the users. This latter issue might change if a large number of devices were bought and operated by a single company and offered as a service to the customers. In this case, this company would face a large upfront investment with only long-term (and thus risky) returns. We will see later how this situation may be overcome.

(7) Creation of legitimacy is a very important aspect in the context of SWTP employment, although this may not seem so relevant at first. Legitimacy basically refers to the motivation to employ a technology. In most cases, innovations cause benefits and, at least for some stakeholders, costs. The benefits are often uncertain as is the

overall success of the innovation. From this perspective, it is legitimate to ask whether an innovation should be supported at all by the government. With respect to SWTP, legitimacy appears to be less of a problem, since the need for wastewater treatment is established in the *Wasserhaushaltsgesetz* (Water Management Act, WHG) and the related Wastewater Ordinance. Moreover, SWTP have been around for quite a while now and used to be even more widespread in the past. Beyond these basic arguments, however, the acceptance of SWTP is ambiguous from different perspectives. While SWTP in their current form may be acceptable to users, water authorities consider them problematic unless specific safety measures are implemented. Since these measures are costly, their application decreases user acceptance of SWTP. One way to resolve this conflict could be a substantial change in how SWTP are operated, but this also involves certain challenges which we will discuss in the following.

The legislator makes the basic assumption that the run-off discharged by SWTP meets the stipulations of the German Wastewater Ordinance, and that SWTP operators i.e. the households are complying with them as long as the plant has a general permit and is maintained properly. However, this turns out to be an invalid assumption because of weak control and the low level of professionalism when operating the plants. Therefore the political reservations have less to do with the SWTP technology itself and are directed more at its incorrect operation by private households (cf. e.g. BaWü 2002). The existing studies on this topic seem to substantiate this: Based on studies of several thousand SWTP as well as surveys of water authorities and the manufacturers of SWTP, Otto (2000) found that, in 1996, the 9.5 % of the population not yet connected to the central system produced up to a maximum of 44 % of the total resident-related COD emissions from wastewater treatment plants. A study in Bavaria by Schleypen (2001) found that 7 % of the population discharged 70 % of the organic waste. According to estimates of Baden-Württemberg's Ministry for the Environment and Transport, the actual purification performance of SWTP is lower than central facilities by a factor of 8 to 10, in spite of the fact that they are fundamentally equivalent in technological terms as stated above. A study by Eggert (2007) based on data from maintenance companies confirms this suspicion: In 2004, only 62 % and in 2007 only 68 % of the SWTP checked met the requirements of the German Wastewater Ordinance. As a result, the federal states Baden-Württemberg, Hesse, Rhineland-Palatinate and Saarland have decided that they will do without SWTP as much as possible, in spite of their status of non-city states and the associated additional costs2 (cf. Table 6–1).

2 The Environmental Ministry of Baden-Württemberg regards 25,000 euros as reasonable costs for those obliged to be connected to the sewer system (BaWü 2002). In addition to this, the state provides a subsidy of approx. 4,000 euros per connected person (BBU 2006). The total costs of being connected to the central sewer system for a 4-person household, therefore, amount to roughly 40,000 euros, which are considered to be acceptable. These are set against the costs of approx. 6,000 euros for a small-scale wastewater treatment plant with a 4-person capacity (investment costs including installation), although financial support of small-scale treatment plants is not planned. Obviously, Baden-Württemberg is prepared to spend quite a lot on central wastewater disposal and for its citizens to do the same.

In the other non-city states, the authorities have no reservations about the use of SWTP if the connection to the central sewage network is more expensive. Saxony, Thuringia and Mecklenburg-West Pomerania even support their construction under these conditions (SMUL 2007; MUMV 2007). And North Rhine-Westphalia was especially active in the research and further development of SWTP from the 1990s up to the middle of this decade. And yet the share of the population connected to SWTP still dropped continuously and significantly even in these federal states from 2001 through 2004 up to 2007, as can be seen in Table 6–1. This cannot be due to the basic performance of SWTP. It could mean, however, that SWTP are less attractive today compared to municipal wastewater disposal for other reasons. This must take into account the fact that SWTP were rarely serviced in the past and therefore were hardly able to function properly 10 to 20 years after their installation, but at the same time did not cause any costs. Today, in contrast, the operators, i.e. usually the users themselves, are obliged to enter into a maintenance contract and the SWTP have to undergo to two to three service and maintenance checks each year, depending on the type. This upkeep on its own is usually just as expensive as, or even more expensive than, the sewage rates which would have to be paid for a connection to the municipal wastewater disposal system – even without including the other operating costs and other inconveniences. This argument also indicates that the decrease in SWTP is not due to a lock-in effect, but rather to a decrease in their attractiveness.

The obvious question here is whether these expensive inspections two to three times a year are the only way to maintain the performance capacity of SWTP, which are much more efficient today than they were 10 or 20 years ago? Other regulations are also conceivable which would be less costly and/or more user-friendly and which could increase the attractiveness and thus the diffusion of SWTP. In this context, it should be asked what potentials new business models can offer to overcome the path dependency diagnosed above.

6.5 The potential of new business models

In order to answer this question, a study was conducted, together with the Abwasserzweckverband (AZV) Leisnig (local wastewater treatment authority), to examine the impacts of a business model for operating SWTP (AZV Leisnig 2010). Some parts of this model have already been realised and others are still in the process of being implemented. The region administered by the AZV is in Central Saxony and covers an area of 95 km^2 with 48 districts. With the exception of the town of Leisnig, the region has a rural structure.

The main impetus for the AZV to become involved with new concepts for operating SWTP was given by the forthcoming European Water Framework Directive, which is due to be implemented by 2015, and by the state of Saxony's support in the form of the relevant funding programmes. Because it was not possible to expand the central wastewater treatment as required by the WRRL, on account of the high cost of constructing sewers in the rurally structured region of the AZV, it was decided to first check the performance of the existing SWTP in order to determine how far away they are from the state of the art in this field.

To this end, the AZV Leisnig first offered maintenance contracts for SWTP. During the course of these service inspections, it quickly became clear that many SWTP are in a poor condition, which can be traced back to errors made during installation, operation and servicing. Because of the insufficient expertise of the private households and the lack of advice, the SWTP types selected frequently did not comply with the daily operating requirements. On top of this, the decision about wastewater disposal is dictated by price rather than quality considerations in many households and, on the part of the manufacturers or operating partners, successful sales seem to be the main driver rather than the suitability of the installation to solving the respective wastewater problem.

6.5.1 Improving the available information and acceptance

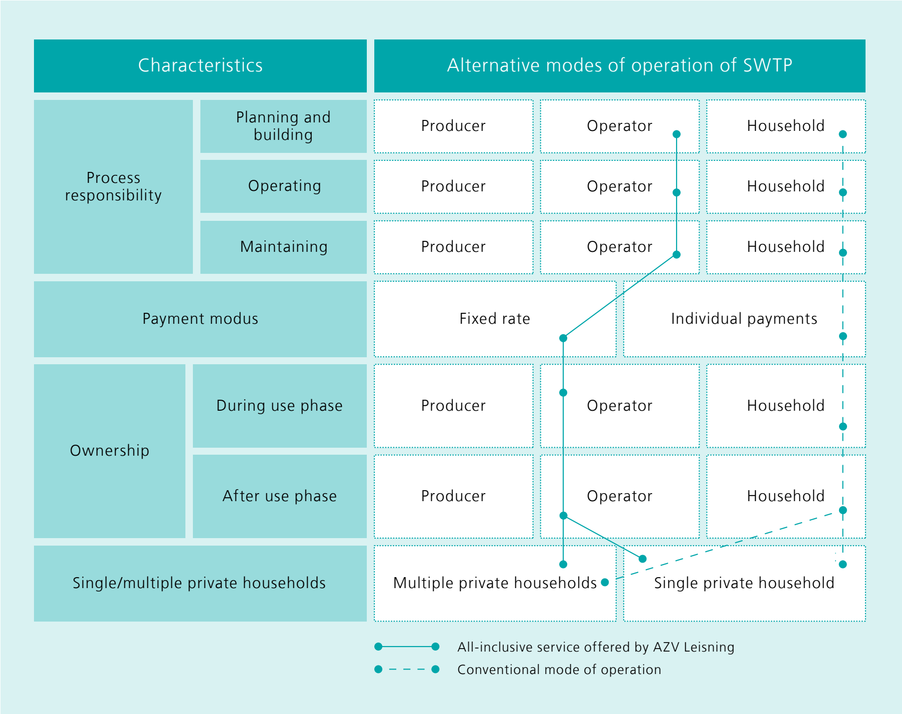
This is why the AZV set itself the goal of gaining direct access to the SWTP by offering the operating scheme which also gives them greater control of the installations' condition. Another goal is the stronger integration of SWTP manufacturers. Direct access and individual control of the SWTP is also important in the context of complying with the threshold limits for the run-off from SWTP, because it is impossible to localise the cause of increased measurement values at sewer level without knowing the condition of each discharging SWTP. Since the AZV has to answer to the water authority for complying with effluent standards, this is another reason for the strong interest in having direct access to the SWTP. Another argument for developing a new business model is the high investments for modernising the stock of plants: a 4-person household has to reckon with between 5,000 and 10,000 euros to build a new SWTP; retrofitting an existing 3-chamber septic tank with a biological stage costs about 3,000 to 4,500 euros (Sachsen-Anhalt 2002). Especially in a structurally weak region with high unemployment like that administered by the AZV, many property owners cannot afford such an outlay – in spite of the state's funding programme. Therefore the wider population is also increasingly concerned with the problem of wastewater disposal and called upon the AZV to help develop suitable solutions.

The basic features of the business model offered by the AZV are listed in Figure 6–2 and compared with conventional SWTP operation.

6.5.2 Adapting use and property rights

As can be seen in Figure 6–2, the so-called "All-inclusive service" package endows the AZV Leisnig with the responsibility for planning, building, operating and servicing the SWTP and entering into a private law waste disposal contract with the owner of the property to this end for an indefinite period. The AZV is paid a fee by the property owner for these services. The SWTP remains the property of the AZV during and after the end of the contract period. Two variations of the business model can be distinguished, using the criterion "exclusivity of use". These can be regarded as the

Figure 6–2: Comparison of the conventional model for operating SWTP with the "All-inclusive service" offered by AZV Leisnig



Source: Lay et al. (2003)

main components of the total concept for adapting wastewater disposal to the new legal framework conditions: group solutions and individual solutions.

Implementing group solutions (with 12, 40, 60 or 80 residents) assumes that several buildings in a village are connected to a decentralised group treatment facility. Since the SWTP are built on a publicly owned plot of land, the AZV can access them at any time (e.g. for maintenance and inspections). After initial reservations, these group solutions have since become highly accepted by the population, largely because they are not operated as separate public installations, but are integrated into the central wastewater system. This has the decisive advantage for the users that they are placed on an equal footing with households connected to the central system in terms of the fees paid.

If the costs for connecting a property to the central wastewater system or a decentralised group solution exceed a certain threshold, the AZV wants to offer individual solutions. In contrast to group solutions, in which the plant is constructed on a neighbouring piece of public land, in an individual solution the SWTP is built directly on the property of the wastewater producer. This means that the AZV has to be allowed regular access to the property in order to build, operate and service the installation.

Since this requires the property owner's consent, individual solutions – as opposed to a group solution – cannot be imposed via the connection and use obligation, but only through private law contracts. When drawing up these contracts, the property's specific conditions have to be considered, on the one hand, and, on the other hand, there is great uncertainty so far about the main influencing and cost factors such as, e.g. how liable the installations are to malfunction. In spite of this uncertainty, the contract conditions have to be attractive enough to motivate the property's owner to switch to the new business model.

Because the new business model of the AZV is still in an early phase of implementation, only a few reliable insights have been gained so far. Nevertheless, plausible indications can be found at this point with regard to the likely impacts on the innovation system of decentral wastewater disposal which are discussed below, based on the seven functions of the TIS approach used by Hekkert et al. (2007).

6.5.3 Impacts of the new business model on the innovation system

(1) Entrepreneurial activities: The AZV does not conduct any technology development itself and as a public institution works on a non-profit basis. This is why care must be exercised in using the term "entrepreneur" in this context. Nevertheless, within the strongly regulated field of wastewater disposal, the AZV still has a role to play which corresponds to the functional character of an entrepreneur in the sense of the TIS approach. Considerable pressure to change is exerted by the reforms in the regulative setting and the specific adaptation problems of the Association (rural region, structural unemployment), to which the AZV has reacted by designing its operating scheme. This is primarily an organisational innovation but brings technical adjustments in its wake. The AZV was able to follow up experiences from the pilot project "Dahler Feld" of the Lippeverband in North Rhine-Westphalia, where a similar model was realised as part of the AKWA research project for several households (Hiessl et al. 2007). Unlike this spatially highly limited and publicly funded pilot project, the AZV is taking on much higher economic and political risks by aiming to introduce the operating scheme throughout the entire administrative district.

(2) Knowledge development: The gradual implementation of the business model in the area administered by the AZV Leisnig results in learning processes taking place at different points in the TIS: In technology terms, new functional requirements of the installations are relevant, because the operator is attempting to operate a large number of installations at lowest possible costs and, among other things, wants to use remote monitoring to do so. In organisational terms, there is continued uncertainty regarding the concrete contract terms of the operating scheme. This uncertainty will only be able to be reduced over time as experiences are gathered with the actual operation of the installations ("learning by doing"). As Figure 6–2 clearly shows, in principle, there are alternative conceivable designs of the business model, e.g. by more strongly involving the SWTP manufacturers.

(3) Knowledge diffusion in networks: Diffusion processes take place both within the administrative district and within the network of decentral wastewater disposal

in Germany. Within the administrative district, the operating scheme of the AZV is regularly presented and discussed at public meetings, at which it is increasingly possible to refer to the experiences of pioneering users and early adopters. Within the network of decentral wastewater disposal, the knowledge generated by the AZV Leisnig will be passed on to the manufacturers of SWTP. Horizontal diffusion processes also take place at administrative level, because other wastewater associations will orient themselves on the approach taken by AZV Leisnig.

(4) Guidance of the search: The AZV Leisnig has positioned itself more centrally within the technical innovation system of SWTP by implementing the business model. By documenting, analysing and processing experiences made with the daily operation of several hundred SWTP, concrete technical requirements can be derived for the SWTP manufacturers, for example with regard to robustness, maintenance friendliness, modularity and remote monitoring and control, and the further development of SWTP technology can be pushed in terms of an association created for this specific purpose. The AZV is already actively influencing the manufacturers of SWTP and those producing remote electronic monitoring systems so that these are better matched and adapted to the operators' needs. The AZV uses public tenders as the primary means of implementing these requirements.

(5) Market formation: There is an associated shift in the responsibilities for procuring SWTP when switching to the operating scheme of the AZV Leisnig which results in a fundamental change in the market structure and the procurement process. While SWTP manufacturers have been used to selling their systems directly to the households or via agents, the AZV Leisnig now takes over the central procurement of the systems. Because it can be assumed that the AZV Leisnig has much higher expertise than the average private household, this results in a professionalisation of the procurement process which should impact the corresponding innovation processes. This development is favoured by the information asymmetries between vendors and buyers having less effect due to the changed setting, and by more specific requirements of SWTP performance being formulated by the buyer and demanded in public tenders.

(6) Resource mobilisation: Alongside private households, the German federal states also play a major role in mobilising financial resources. From the perspective of the federal states, operating schemes can contribute to more efficient use of the funds available for the construction of SWTP. According to the Förderrichtlinie Siedlungswasserwirtschaft (Guideline Municipal Water Management) (RL SWW/2009), the Free State of Saxony provides a basic grant of 1,500 euros (4 p.e.) for constructing a new SWTP with a biological purification stage and a basic grant of 1,000 euros (4 p.e.) for retrofitting an existing plant. If, for example, it is assumed that at present 458,000 residents are not connected to the central wastewater network in Saxony and that 80 % of these systems need modernising, then at least 91.5 million euros are required solely in the form of basic grants. The business model is able to achieve a much more efficient use of public funds because private households frequently invest in systems which do not meet their actual daily operating requirements, due to their lack of specialist knowledge.

Concerning the resource of knowledge, the new business model has the major advantage that AZV Leisnig is at home in the wastewater management sector and is able to draw on existing experiences in many regards (e.g. the treatment of wastewater in general and dealing with authorities and associations), which means that the optimisation of the business model can be expected in a relatively short time.

(7) Creation of legitimacy: From the perspective of the households, the first point to be made is that AZV Leisnig's offer has created an alternative to operating the system themselves. However, how each customer evaluates these two alternatives depends on many different factors. Because the business model of the AZV Leisnig means that all the work associated with operating the SWTP has now been shifted into the commercial sector, the benefits each household associates with such an offer depend heavily on the costs involved. AZV Leisnig has some leeway here as to whether it charges the households the total costs or only a fraction of them, especially where the individual solution is concerned. In the latter case, the rest would have to be borne by the community as a whole, meaning a general increase in the rates as a result. Because the additional costs are inevitable, it is likely that the early involvement of the citizens, e.g. in public meetings, will be a decisive factor in how the operating scheme is accepted.

6.6 Conclusions

This example of the decentral wastewater disposal of the AZV Leisnig clearly illustrates what David (1985) and Dosi (1982) understand as path dependency or technological paradigms. According to David (1985), path dependency describes a series of events in which the possible result is influenced by prior events. This means the longer a path has already been trodden, the lower the number of paths which could still be taken. Transferred to the actor network of wastewater disposal, this means that the actors' freedom of action becomes smaller, the more connections they have with other actors in the network. With technological paradigms, Dosi (1982) also alludes to the close link between innovations and the actors who develop, manufacture, operate, use or regulate them. In order to avoid a lock-in effect, everyone would have to change their actions in a coordinated manner, which is not very likely.

Two causes of a lock-in effect in wastewater disposal could be identified on the part of the central technology based on networks of sewers and large sewage plants and at the expense of small-scale wastewater treatment plants. One results from the long useful life of central sewage systems and sewage plants in combination with obvious oversizing and declining wastewater volumes, above all in eastern Germany. High sunk costs result in the case of switching to an alternative technology such as SWTP, which the operators try to avoid. The situation is made even worse by the fact that the upkeep of the central wastewater infrastructure is also associated with high overheads which further increase the sunk costs. This problem is now becoming very apparent in Brandenburg and the water supply companies here are attempting to limit their damages by strictly enforcing the connection and use obligation wherever possible. An escape from this lock-in situation is currently only foreseeable in locations where it is doubtful whether the central wastewater disposal is still able to function properly as a whole or in parts, for example, due to a further decline in the population and their specific consumption volumes. The sunk costs are then accepted here and parts of the central infrastructure are deconstructed and the wastewater of the remaining residents disposed of using SWTP (Koziol et al. 2006).

The other cause is related to the reliability of decentralised wastewater disposal, the associated costs and the level of acceptance resulting from these two issues. For SWTP to be able to hold their own against the established, central technology, it is not enough for them to be cheaper. They also have to be just as reliable, among other things, and should not be harder for their users to manage than the conventional technology. Several demands are being made here at the same time which would have to be coordinated and implemented by those very actors who are currently predominantly working with the central infrastructure. This presupposes a learning process which culminates in new business models, for example, like the “All-inclusive service” package offered by AZV Leisnig. In line with the strategic niche approach of Kemp et al. (1998), SWTP would become more and more attractive, due to learning effects on the part of providers, users and regulators and, as a result of this process, continually expand their niches. Over the course of this development, decentralised wastewater management would not completely replace its central counterpart but, in the long term, it would become a major, widely established component of the total system of wastewater disposal.

The deficiencies associated with private households operating SWTP and the regulative pressure exerted by the upcoming implementation of the European Water Framework Directive have resulted in the emergence of new business models for operating SWTP, which could accelerate this development. This is not only because political acceptance of decentral wastewater treatment is increasing, due to the resulting professionalisation, but also because the role of the actors and their links in the innovation system are changing substantially, due to the altered arrangement of property rights.

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7

THE INNOVATION SYSTEM OF SECURITY:

A NEW QUALITY IN THE RELATIONSHIP BETWEEN POLITICAL, ECONOMIC AND SOCIAL ACTORS

ANTJE BIERWISCH, RALPH SEITZ, STEPHAN GRANDT

7.1 Introduction

The attacks on New York and Washington 2001 (9/11), Madrid 2004 (3/11) and London 2005 (7/7) made the threats which western societies are facing from terrorists much more visible than before. In order to cause as many fatalities as possible and disrupt economic and social life, these attacks aimed at a totally new catastrophic level. Far worse scenarios, like the use of radiological or biological substances for attacks, are also conceivable. Even small terrorist or criminally motivated groups can achieve huge impacts and cause substantial damage, facilitated by global mobility and the interconnectedness of global networks. Even minor interference can bring about the collapse of complete supply networks, despite the existence of robust technologies. At this point in time, it is apparent that security risks are changing. Furthermore, natural disasters or technical accidents can also trigger severe damage in such a densely networked world. Existing security measures focus on protecting the central nervous system of society. Society's dependence on flawlessly functioning supply systems like energy and transport networks, internet and communication, food and water and health care is obvious. As a result, security measures must aim to restrict the consequences of natural disasters, accidents and terrorist attacks.

Treating security as a system is increasingly becoming the focus of security-related affairs, as is its perceived bridging function. The understanding of security changed after the end of the Cold War. At the content level, there has been an increase in the variety and depth of topics. Not only technological aspects but especially humanitarian aspects, such as the change in how security is perceived, or political and legal aspects, such as the maintenance of internal security or the protection of fundamental rights, are increasingly the subject of research efforts in the field of civil security. These substantive qualitative and quantitative changes are closely connected with comprehensive changes at the level of the involved actors. No longer just the military, but also private actors, companies, research institutions, individuals and associations of different kinds are involved in the topic of security. This gives rise to even more new challenges for security research, which needs to significantly expand its range of approaches. This change can be observed at both a quantitative and qualitative level with regard to content and actor orientation.

This chapter aims to bring in the security issue as an interesting and challenging object of study of the innovation system. It suggests that security could be considered as a field of innovation system research because of the involvement of diverse topics and actors and their interactions. Based on the specific characteristics and dimensions of security, this contribution outlines the particular need for a systemic understanding of security in the context of innovation research. Additionally, it derives potential fields of future research, and identifies open questions as well as unresolved issues in the context of security as part of an innovation system approach. Only the application of a systemic approach makes it possible to understand the logic behind the individual elements and their dynamics and to demonstrate the interactions of systems. This is necessary to combat the emerging challenges and can be applied in a targeted and successful manner in future research and innovation policies.

This contribution starts by outlining the changing concept of security. Fraunhofer ISI's activities in security research will then be briefly described and demonstrated, based on current research policies at national level (Germany) and supranational level (EU). The third section is devoted to considering two security challenges in a system-oriented approach. Based on this, future research needs are derived in the field of security in innovation system research. The contribution ends with a summary of the key messages.

7.2 The concept of security and existing policy instruments

The following section offers a brief outline of the concept of security and how this has changed over time. Security as a social construct is exposed to changes in society, so that the understanding of security is subject to constant change. Security is no longer understood as the mere absence of threat, but rather as the successful management of risks and uncertainties. The second part of this section briefly discusses existing policy instruments in the field of security at a national and European policy level.

7.2.1 The changing concept of security

Today, security is a multifaceted and complex issue. It has been studied within several research streams, e.g. criminology (Armitage and Pease 2007), sociology (Cameron and McCormick 1954; Zedner 2003), psychology (De Witte 1999), international political studies (Baldwin 1997; Waever 1993; 1998), economics (economic security –

Nesadurai 2005; security economic – Brück et al. 2008) and technological studies (Rouhiainen 2009).

After the end of the Cold War, military threats to the survival of the state no longer seemed to constitute the main security risk. Other more multifaceted threats emerged which were likely to have impacts on security, and which the state appeared unable to face alone (Webber et al. 2004, pp. 5–6). Therefore, there was a broadening of both the understanding of security and the potential levels of analysis to include individuals, groups, humanity and even the whole planet (Christou et al. 2010, p. 343; Buzan and Waever 2009). According to Daase (2011), the extension of the concept of security and therefore the change of security culture can be illustrated using four dimensions: references, subjects, space and hazards.[1]

– With respect to the *dimension of reference*, it should be noted that the concept of security has evolved from the state through society and down to the individual. In the 1950s and 1960s security meant especially the security of the state and the defence of its sovereignty (Mandelbaum 1988; Daase 2011, p. 143). Then, in the early 1970s, liberal theorists came up with the concept of "societal security", which aims at a situation where citizens can live together in peace and freedom and where productivity and prosperity are possible (Waever 1993; Keohaene and Nye 1977; Daase 2011, p. 143). The concept of "human security", which has been discussed since the 1990s, represents a further step. This concept focuses on the human individual as an object of reference (Beitz 1979; Douyle 1983; Pogge 2001).
– On the *dimension of subjects*, a change can be observed in the policy areas in which hazards are identified and security should be ensured. Military attacks and the loss of political self-determination were considered to be the biggest threats to a state, so that security was usually approached from a military perspective (Herz 1950). The concept of security was extended to include economic vulnerability in the 1970s and the ecological perspective in the 1980s (Nye 1982; Maull 1984; Tuchman 1989; Myers 1989; Homer-Dixon 1991). The concept of "humanitarian security" after the end of the Cold War resulted in a further expansion of the concept of security (Woodward 2001; Holzgrefe 2003). Because of these developments, the current concept of security covers domestic and foreign policy, defence policy, economic policy, environmental policy, health policy and human rights policy (Daase 2011, p. 145; Paleri 2008, pp. 64ff.).
– The extension of the concept of security must also be observed from a *spatial dimension*. Traditionally, security focuses on the national territory of a state (Waltz 1979). This territory-oriented concept has been extended by the concept of international security that goes beyond these borders and is related to intergovernmental cooperation efforts targeting international stability (Daase 2011, p. 146). The focus is not only on maximising national security, but also on establishing an international environment in which all states enjoy a reasonable

1 For more details, see Daase (2011).

degree of security (Oye 1986; Müller 1993; Haftendorn et al. 1999). The concept of "global security" goes one step further and refers to humanity as a whole, and the prospect of a global world society of free individuals (Buzan 2004).
– With respect to the *dimension of hazards* and the conceptualisation of uncertainty, the focus of the security debate has recently shifted from the strengths of the opponent to one's own perceived weaknesses (Daase 2011, p. 147). Risks or threats relate not only to territories or the vulnerability of collective goods, but also to the natural and social relationships in which each individual is existentially bound. Addressing these risks will require a proactive policy of identifying the risks before threats can arise.

This expanded understanding of the concept of security demonstrates the changes in security culture and the complexity clearly defining security. The definition of security is a continuing challenge, since security is a "social phenomenon", is always "relative" and "everywhere" (Waever 1993, p. 23; Fischer and Masala 2011, p. 114; Christou et al. 2010, p. 341). Buzan argued in the 1980s that "security" can be seen in a broader perspective, affecting thinking in social, economic, environmental and political spheres, as well as in military ones.

"[...] security is a generic term that has a distinct meaning but varies in form. Security means survival in the face of existential threats, but what constitutes an existential threat is not the same across different sectors [military, political, economic, societal and environmental – amendment by the author]." (Buzan et al. 1998, p. 27).

As a result, security cannot be considered as a singular concept, as its definition depends on the applied context (Brooks 2009).

The definition of the term security, its roles and actors is the most fundamental challenge for research on security. The historical background of an organisation and its cooperation with different policy and/or economic actors plays a crucial role in defining and interpreting the concept of security. In addition, it has been shown that the technology-oriented and more humanities-oriented organisations vary in their approaches and perspectives regarding the security discourse. One type of organisation addresses the technological potential and feasibility, and the other type takes into account topics such as security awareness, cultures, risk, costs and benefits, as well as the application in existing infrastructures. Not only does the term security have different meanings in different languages and disciplines (cf. Beyerer et al. 2010, pp. 49f.); there are also conceptual differences (cf. Gerhold 2011, p. 29). On the one hand, researchers refer to the conceptualisation of security as "coping with uncertainty and risk" where security is understood as a "wicked problem" (Conklin 2005, pp. 7f.). In this context, security is an indefinable, complex, and nonlinear problem, which is extremely difficult to solve. This view is found particularly in social science approaches, in which security is interpreted as learning to deal with unavoidable, indefinable or unpredictable uncertainties (cf. Bonß 1995; Bechmann 1993). On the other hand, the term security is understood as "maximising security and safety". Here, the presence of security is understood as the objective absence of risks and danger (Gerhold 2011, p. 30; Thoma et al. 2010) and emphasises security as a public policy framework problem (cf. Bonß 1996, pp. 169f.). From a policy and research-based perspective, these different approaches result in different actions and thought patterns. For R&D programmes or funding schemes it is important to be aware of and handle these extended dimensions, different meanings and approaches.

In summary, the concept of security has gradually been expanded and societal security needs now take precedence over the needs of the state. At the same time, the changes in the dimensions bring changes and extensions in the security-related actors and ultimately also in innovation fields (research and development issues). This change impacts security policy; the old Cold War "community of threat" has been replaced by the so-called "world risk society" (Beck 2007; 1996). The demands made of security policy have also changed under the aspects listed so far, from a reactive security policy to a proactive security policy (Daase and Friesendorf 2010). Changes can be observed in how individuals perceive security and hazards, at the level of social norms and social practices as well as the international and transnational level of ideas and norms. Security understood as a social construction is evolving continuously in the context of a changing society. Security is seen as a social phenomenon, which implies that security can mean different things to different groups in different places, and at different times. The complexity of security threats, the actors, the instruments and the security practices for their regulation have gradually come to be interpreted as problems of "governance" (Christou et al. 2010, p. 343).[2]

Therefore a key challenge in the context of a systemic analysis is to create a basic understanding of security. This contribution focuses on civil security rather than military security and tackles specific issues.[3] Civil security as defined here essentially concerns the protection against threats from terrorism, serious and organised crime, natural disasters, pandemics and major technical accidents and includes intentional interference and exogenous security risks (security), and also accidental damages and endogenous security risks (safety) (BMWI 2010; Haverkamp et al. 2011, p. 9).

7.2.2 Existing research programmes addressing security at national and European levels

At the core of civil security is the vulnerability of modern society to a variety of hazards, whether these are caused by terrorist or criminal threats, large-scale accidents or natural disasters (Haverkamp et al. 2011, p. 9). Today civil security is a central topic in security policy programmes and for domestic strategies. The term civil security marks a profound transformation that characterises the orientation of thinking, institutional settings and political objectives in the security fields (Haverkamp

2 Security governance is an "intentional system of rule that involves the coordination, management and regulation of issues by multiple and separate authorities, interventions by both public and private actors, formal and informal arrangements and purposefully directed towards particular policy outcomes" (Kirchner and Sperling 2007, p. 3).

3 This is due to the fact that military research is often not published for confidentiality reasons. The authors are aware that a clear distinction between military and civil security with regard to technological innovations is not possible, but choose to focus here on civil security and civil applications.

et al. 2011, p. 9; BMBF 2012; European Commission 2011). Civil security today is an essential aspect of security policy, since hazards, threats and risks of heterogeneous origin are transferred into the same risk context. The following discussion briefly summarises the existing policy instruments in "civil" security at both national and European level.

The national level – Germany

The security research programme in Germany is firmly embedded in the federal government's "High-tech Strategy for Germany" (BMBF 2010). As part of the development and continuation of this strategy, security is identified as a priority alongside climate/energy, health/nutrition, mobility and communication. This strategy is increasingly focused on promoting innovation in emerging industries. The set priorities reflect the strong position of German industry and research areas with high potential. Since 2007, the BMBF has provided over 250 million euros for the security of citizens in the first national framework programme for civil security. The initiated research programmes are on target to increase the security and resilience of society with the help of innovative high-tech solutions and organisational concepts and strategies (BMBF 2007; 2012). Interdisciplinary, broadly based agenda processes with relevant stakeholders such as research organisations, government agencies, associations and end-users in the private sector were used to identify the research objectives and contents and contributed to focusing research. To facilitate knowledge transfer, interdisciplinary and collaborative projects are being funded, i.e. cooperations between research and industry as well as between rescue and security forces and the operators of infrastructure facilities. SMEs are addressed as potential suppliers of security technologies. In addition, the research programmes are geared towards close cooperation with EU Member States as well as towards strategic alliances with non-European countries.

Research on the social dimensions of innovative solutions constitutes an integral part of the first national research programme. The social dimensions of civil security are strongly interrelated with the technological developments over the entire research process via "technology networks" and "scenario-oriented research".[4] The humanities and social science research should make a significant contribution to problem-solving in the context of specific development processes and applications, and also examine basic questions concerning security culture and architecture (e.g. security expectations, perception, assessment, acceptability). The focus is on the following four dimensions: culture, architecture, organisation and technology.[5] The guiding principle here is to conduct research on appropriate security concepts and technology developments and not merely to foster acceptance of existing technologies. Fraunhofer ISI

4 For detailed information, see: http://www.bmbf.de/en/11773.php.

5 Moreover, the dialogue between the various actors in society is an essential part of the security research programme and is also part of the expert dialogue which will be coordinated by Fraunhofer ISI. http://www.bmbf.de/de/12655.php.

is currently involved in various research projects that are dedicated to the social dimensions of security research. Projects focus on issues such as security awareness and perception, mechanisation, the economic aspects of security and social environment effects on the evaluation of security measures.[6]

In January 2012, the new framework programme "Research for Civil Security" was adopted by the federal government as the continuation of the 2007 Security Research Programme. The new programme will run until 2017. The BMBF has provided this programme with a budget of about 222 million euros. Research funding will be assigned according to the global challenges of civil security: security of critical infrastructure, economic security, security in cyberspace and security of citizens. A holistic, integrated approach to research will be pursued, involving the entire innovation chain from research to application and focusing on the needs of end-users, such as government agencies and organisations responsible for security and operators of critical infrastructure. The question is how research and new security solutions can contribute towards increasing public security without adversely affecting citizens' fundamental values, such as freedom and self-determination (BMBF 2012, p. 3). Funding priorities are the societal aspects of civil security research, urban security, security of infrastructure and business, protection and rescue solutions, and protection from hazardous substances, epidemics and pandemics (BMBF 2012). Through the involvement of various ministries and policy fields, a broader context is provided for research and also legislation, standardisation, procurement and international cooperation in the field of security. The need for policy cross-cutting activities in the field of civil security is also strengthened by more detailed strategies, such as cyber-strategy or the strategy for modern civil protection (BMI 2009; 2011). Funding research is intended to exploit the economic opportunities offered by civil security research and to establish Germany as a leading provider of security technologies.

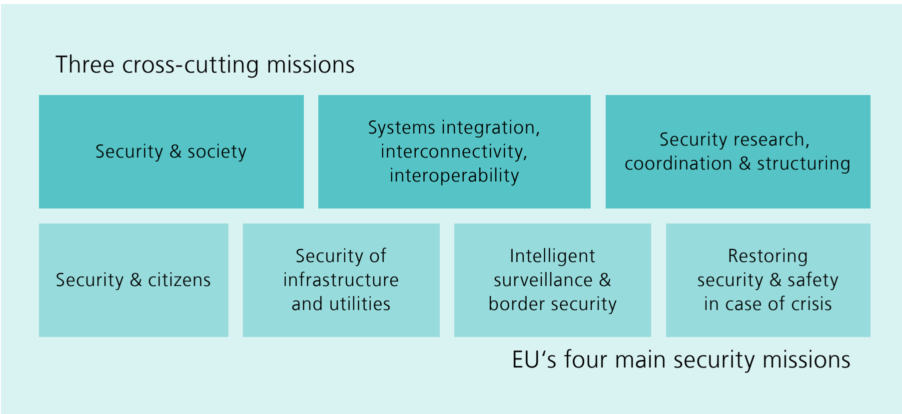
The European level

Due to the increasingly complex, interlinked structures of modern industrial society which extend beyond national borders, the European Union has developed a comprehensive strategy for European security research. At EU level, there is a broad and integrated concept of security in the new Internal Security Strategy, which was presented by the Commission on 22 November 2010 (European Commission 2010). This strategy reflects the widely used notion of "comprehensive security", which covers criminal and terrorist acts and the protection of citizens, businesses and society against cybercrime as well as natural and man-made disasters. In the context of EU security research, conceptualising security started with a Group of Personalities (GoP) in 2003 and 2004, initiated by the European Security Strategy (ESS) (European Commission 2003). As an outcome of the Group's work, the European Security Research Advisory Board (ESRAB) was created to substantively develop the planned European

6 For detailed information, see the BMBF funded research projects: SIRA: http://www.sira-security.de/en. BaSiD: http://basid.mpicc.de/basid/de/pub/basid_home.htm.

security research programme and to promote a market for security and defence-related products (European Communities 2004). This board laid the foundations of what is now the security theme of the 7th Framework Programme in 2007–2013.[7] The 7th EU Research Framework Programme is the first to include civil security research as a separate subject area and a total of 1.4 billion euros were provided to fund research. The aim of the European security research programme is to develop new technologies and suitable accompanying measures to more effectively protect Europe and its citizens from threats such as terrorism, organised crime, natural disasters and industrial accidents, while at the same time strengthening the competitiveness of European companies that make significant contributions to these objectives. Basic principles like respecting the privacy of individuals and protecting civil liberties underlie the implementation of any planned activities. The overall structure of the security theme is summarised in four security missions and three cross-cutting missions (cf. Figure 7–1).

Figure 7–1: The EU's security missions[8]



The four security missions form the basis of the Security Research Programme and each of these is supported by cross-cutting research projects which are either multidisciplinary in nature or promote cross-border R&D coordination and networking activities. The resulting technologies apply both "hard security" functions (border management, critical infrastructure protection etc.) and service-oriented ones, such as first-responder capabilities, public transport security, civil disaster planning, crisis

7 Initial efforts to establish a European security research community had already been made with the "Preparatory Action on Security Research" (PASR) in 2004–2006.

8 For detailed information, see: Decision No 1982/2006/EC of the European Parliament and of the Council of 18 December 2006 concerning to the Seventh Framework Programme of the European Community for research, technology development and demonstration activities (2007–2013); e.g. Cooperation Work Programme 2007, Theme 10: Security, European Commission C(2007)560 of 26.02.07, http://ec.europa.eu/enterprise/policies/security/missions/index_en.htm.

management and emergency communication.[9] At the European level, in addition to the analysis of new threats and technological opportunities, current projects will also be devoted to the comprehensive analyses of security-related needs, in order to define the main functions needed to address the fluctuating security landscape. Fraunhofer ISI is involved in several projects dealing with issues such as privacy, emerging and critical technologies and their drivers/influencing factors, and trends, threats, societal needs and opportunities and futures research in the context of security.[10] Research in this field of "security as an evolving concept" should improve the understanding of new threats as well as the associated technological opportunities and emerging security-related ethical, cultural and organisational challenges. These research concepts should help the authorities to assess investment alternatives for prevention, early warning or preparedness and to make choices when addressing threats to public security that achieve social cohesion and fully respect citizens' fundamental rights.

From 2007 to 2009 an even larger programme, the European Security Research and Innovation Forum (ESRIF), devised a medium- to long-term strategy for European security research (ESRIF 2009).[11] Given the need for long-term orientation, it compiled a set of context scenarios with a 2030 time horizon to outline how current trends might combine to create alternative future "scenarios". These scenarios covered a range of risks, from natural to man-made incidents, and were used to test and identify how short- and medium-term risks and challenges could evolve into long-term ones (ESRIF 2009, p. 9). The result was a European Security Research and Innovation Agenda (ESRIA) for the next 20 years. The next European Framework Programme for Research and Innovation – HORIZON 2020 – will run from 2014 to 2020. The topic of security plays an important role in the main area concerning "social challenges" (European Commission 2011).

Market and system failures are distinguished as two main areas in which government intervention in research and innovation can be justified. These principles also apply to RTI policy in the security field, but due to the strong role of government as a user of research and innovation, it also has a prominent role to play in shaping research and innovation trajectories through its procurement activities. In other words, security is a model case for demand-side innovation policy that is currently being debated in European and national innovation policy. Previous studies in the field

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9 More information: http://ec.europa.eu/enterprise/policies/security/missions/index_en.htm.

10 For detailed information, see e.g. ETTIS – European security trends and threats in society: http://www.cordis.europa.eu; ETCETERA – Evaluation of critical and emerging technologies for the elaboration of a security research agenda http://www.etcetera-project.eu/; PRISMS – The PRIvacy and Security MirrorS: Towards a European framework for integrated decision: http://www.isi.fraunhofer.de/isi-de/t/projekte/fri-prisms.php; SAPIENT – Supporting fundamental rights, Privacy and Ethics in surveillance Technologies: http://www.sapientproject.eu/.

11 ESRIF – European Security Research and Innovation Forum – convened by the European Commission in September 2007 and composed of nationally designated representatives of the Member and Associated States.

of security tended to analyse rather isolated, clearly defined topics focusing on individual elements or sub-elements with the goal of finding out more about their logic of action, nature and development paths. Interactions between the elements and the resulting changes due to dynamic aspects, however, were not adequately considered. The systemic view of security, whether from a supranational, national or sectoral perspective, was neglected. As a result, it should be noted that there are ongoing parallel efforts in different disciplines to address security. For instance, on the one hand, market studies centre on the economic potentials of the security industry and mostly ignore, for example, interaction with the political system and the demand side. On the other hand, political science studies have mostly focused on the interactions between political and social actors, the dynamics of technological change have not been considered in previous studies.

The interactions of sociological, economic, cultural, environmental, political and ethical aspects have rarely been considered from an overall system perspective. Only very recently have research projects been carried out which take interdisciplinary or trans-disciplinary perspectives in security-related research into account (Gerhold 2011). This is surprising, since the security theme seems an especially relevant object of study while, at the same time, representing a challenge to system research approaches. It is essential to include society's needs, because technological security measures may be rejected by society despite their technical feasibility. A systemic approach which includes demand and social aspects, political and framework conditions, industrial systems and infrastructures, the education and research system and the dynamics of these elements could be an important step within the context of the "evolving concept of security" and preventive security policy.

7.3 Security as a multidimensional challenge

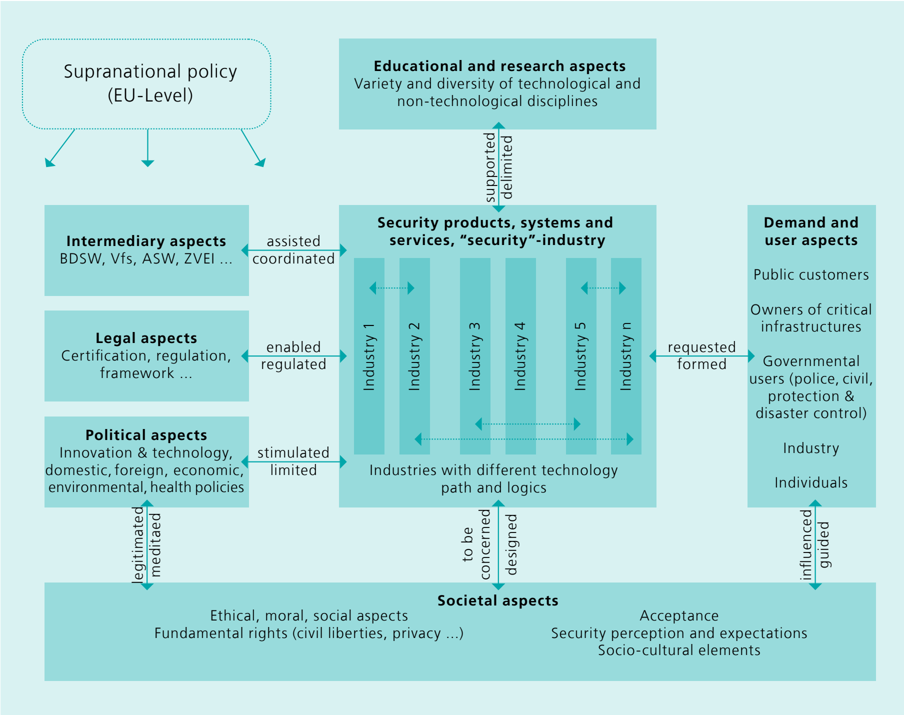
This section deals with the implications of the observed changes in the understanding of security in relation to key elements of innovation system research (cf. Chapter 1). The heuristics of the innovation system approach (Edquist 1997; Kuhlmann and Arnold 2001; Lundvall 1992; Nelson 1993; Malerba 2004; 2005) are considered as a framework for the analysis of security for two reasons. First, a set of multiple actors and institutions have a direct or indirect impact on the outcome and performance of an innovation system. Second, there are influencing factors and interdependencies between these elements which can support but also hinder innovation. The systemic aspect is seen here as crucial for the analysis of civil security.

In summary, the complexity of the security concept is reflected in the following points (cf. Figure 7–2):

- security as an aspect in different policy areas (e.g. foreign and domestic policy, defence policy, innovation and research policy, economic policy, environmental policy, transportation security, energy security, health system)
- security as an aspect in different industrial sectors (e.g. automobile, electronic, mechanical engineering, services in different fields)
- security as an aspect in different research fields: humanities (e.g. economics,

politics, history, religion, cultural, social sciences; natural sciences – e.g. physics, chemistry, biology, medicine)
- security as an aspect in different funding schemes (e.g. regional, national, supranational)
- security as a social construct underlining social change (security as an evolving concept, security perception and assessment, acceptability, influence of socio-cultural factors, security as a public good)
- security as an aspect in different user and stakeholder groups (e.g. industry, individual, society, political, state and public institutions)

Figure 7–2: Security and key elements



Source: own illustration

The innovation system research done so far has rarely been devoted to the topic of security. A study of the existing literature only identified papers dealing with the influence of military research and development activities on national or technological innovation systems (Vekstein 1999; Mowery 2009; James 2009). There are some market studies on various fields of technology, but they use different definitions and methodological approaches (e.g. VDI/VDE 2008; Berenberg Bank and HWWI 2008; ECORYS et al. 2009). In addition, no national, sectoral or regional innovation system studies could be found that specifically analyse civil security and its potential for innovation.

Because of space limitations, we focus on the following two aspects which are highly relevant in the context of innovation system research: challenges due to the heterogeneous subsystems and challenges due to the impact of societal aspects and the role of ethical aspects. Because the relative performance of innovation systems is determined in particular by the differentiation of subsystems and their institutional interactions (Edquist 1997, pp. 16–20), these two topics are key starting points and are simultaneously viewed as challenges to a systemic analysis by the authors.

7.3.1 Challenge I: Heterogeneous subsystems

With the changing concept of security, qualitative and quantitative changes at the level of the market and at the level of scientific topics can be observed. Security systems as well as their bridges and cross-cutting functions are more frequently at the forefront of analysis. The energy and transport networks, internet and communications, food and water supply, and health care are viewed as a system's "lifeblood". The market for security technologies and their basic products and services is seen as having sustainable growth prospects for German and European industry (VDI/VDE 2008; Berenberg Bank and HWWI 2008; ECORYS et al. 2009). For the year 2015, the estimated total volume of the security market in Germany is roughly 31 billion euros (VDI/VDE 2008, p. 9).[12] Opportunities are seen especially in the high system capability, but also in the use of leading-edge technologies.

At the same time, a universal definition of the security market is missing, as are reliable statistics on the market and market trends in individual sectors or regions.

> "The security industry is highly complex, with technological inputs that can either be specific to the security market, or be dual with defence market applications, or increasingly come from a variety of other fields such as health, consumer goods, transport, information and communications, etc. Consequently, the concept of the 'security industry' is somewhat amorphous and does not correspond to any specific industrial classification of activities." (ECORYS et al. 2009, p. 4)

The security industry does not have a universally recognised definition (Staccato 2007; VDI/VDE 2008; Berenberg Bank and HWWI 2008). Security does not appear as an industry in official statistics such as the NACE classification because of the huge problems associated with its definition. It seems impossible to decide where to assign police activities or secret services, or robots equipped with infrared cameras and the ability to detect biometric features (Berenberg Bank 2008 and HWWI, pp. 47f.). Security technologies are characterised by their cross-cutting nature. Potential products, systems and services are produced with the help of basic technologies such as information and communication technologies, microelectro-mechanical systems

12 For detailed information, see: VDI/VDE (2008).

(MEMS), nanotechnology, optical technologies, sensors and biotechnology. This shows that the security industry is a complex object of investigation, which competes with various product and service groups from other economic sectors. This complexity is also reflected at the actor level. Thus, a non-specific search in a company database[13] disclosed more than 9,500 companies dedicated to “security”. The use of information and communication technologies for security is important across all sectors and can be regarded as a “cross-cutting enabler”. For example, the use of automatic “intelligent image processing technologies” is far-reaching and these technologies are found in very different industrial applications, e.g. medical engineering, automotive industry, security engineering but also in public and critical infrastructures. This variety of security technologies, systems, services and applications means that a multitude of actors are involved in the innovation process. There is a large diversified market demand, which is characterised by sectors such as engineering, automotive, banking and insurance, but also by public facilities such as airports, railway stations or sports facilities and by individuals. Analysing diverse market and technology studies shows that, in particular, the technologies, systems and services shown in Figure 7–3 are counted as the “security industry” and its “application fields”. This diagram shows the cross-cutting functions of security technologies and the differentiation and classification of problems associated with the security market.

In addition to the demarcation problems, there are more specific problems in the security market which can only be briefly summarised here. The customer structure of the security market is characterised by the fact that a significant share of the demand for security solutions is required by government institutions and public policymakers (“pre-public technology procurement”). Consequently, the purchasing behaviour of the state has a direct influence on the development of the security market and therefore on innovation performance. This is related to the aspect of public technology procurement as a demand-side innovation policy instrument (cf. Rolfstam 2005; Edquist et al. 2000). In addition, the demand for security technologies is often only established by legislative requirements (BMWi 2010). Corporate security management and the regulations controlling liquids at airports and the proposed repeal for 2013 are examples of this.[14] Cross-institutional decision-making processes and the involvement of different actors are some challenges in this market. In the case of the security of a critical infrastructure such as an airport, various levels of security are concerned (Hartmann et al. 2008, pp. 25f.). These various levels, in turn, are the responsibility of different actors (firefighters, security and service personnel, state police and federal police). Security technologies have to be coordinated across the different security levels and integrated into a holistic security concept. Standardisation efforts

13 Markus database: German, Austrian and Luxembourg company information and business intelligence. For detailed information, see: http://www.bvdinfo.com.

14 This is based on the EU Regulation (EC) 300/2008 in conjunction with the EU Regulation (EC) 185/2010. The regulation was introduced in 2006 after terrorists had tried in vain to use liquid explosives to destroy several passenger jets at Heathrow airport.

in the security field are only just beginning. The DIN's "Coordination Office for Civil Security" was set up at the end of 2010 for standardisation in Germany.[15] At the European level, the actors have also started working on standardisation in the area of security and the establishment of a "European Security Label" (ESRIF 2009). These activities should ensure the transparency and comparability of the high quality and safety of products and services and thus serve as a potential market opening for the security industry in the future.

Open questions and starting points for further research

The issues listed provide numerous starting points for further research regarding the systemic analysis of civil security. A fundamental aspect here is the differentiation of the subsystems which is essential for the relative success of an innovation system approach. Without a comprehensive knowledge of the market structure and the interdependencies within it and with other elements, targeted economic and technology policies are not possible. Existing studies are therefore unable to provide information about future markets or about differentiated growth potentials (VDI/VDE 2008; Berenberg Bank and HWWI 2008).

Regarding the demarcation challenge, it can be observed that current studies of future market conditions and market developments in the security sector exclusively use qualitative methods (e.g. content analysis and expert judgement). Established parameters and indicators are not applied to the security sector. An appropriate analysis should identify the "innovation chain(s)" and the resulting economic activities and would cover the input into the innovation processes, the results of research and development processes and the successes in the national and international markets. The analysis of patent and publication data, R&D expenditures, foreign trade contribution, export balance and of the exploration, development and adoption of processes, products and services (e.g. substitution and compensation potential) of the security industry was not considered in previous studies. The authors believe that a scenario-based approach is needed to analyse the security sector due to the high dynamics and complexity of the issues involved, but that this should be quantitatively supported. Only by combining quantitative and qualitative approaches can an analysis be made of such a dynamic and elusive sector as the security sector. Additionally, system dynamics models are also suited to analysing the multiple feedback loops in the innovation process, the interactions between subsystems and the impact of changes in the actor, regulatory and institutional constellations on the other elements. Such an approach could generate a deeper, systemic understanding of the market, which could further contribute towards a harmonised and qualified analysis of the economic subsystem in security technologies, systems and services. This would enable a comprehensive picture to be built up of the security industry and its innovation potential. Based on this, targeted innovation and industrial policy measures could then be undertaken.

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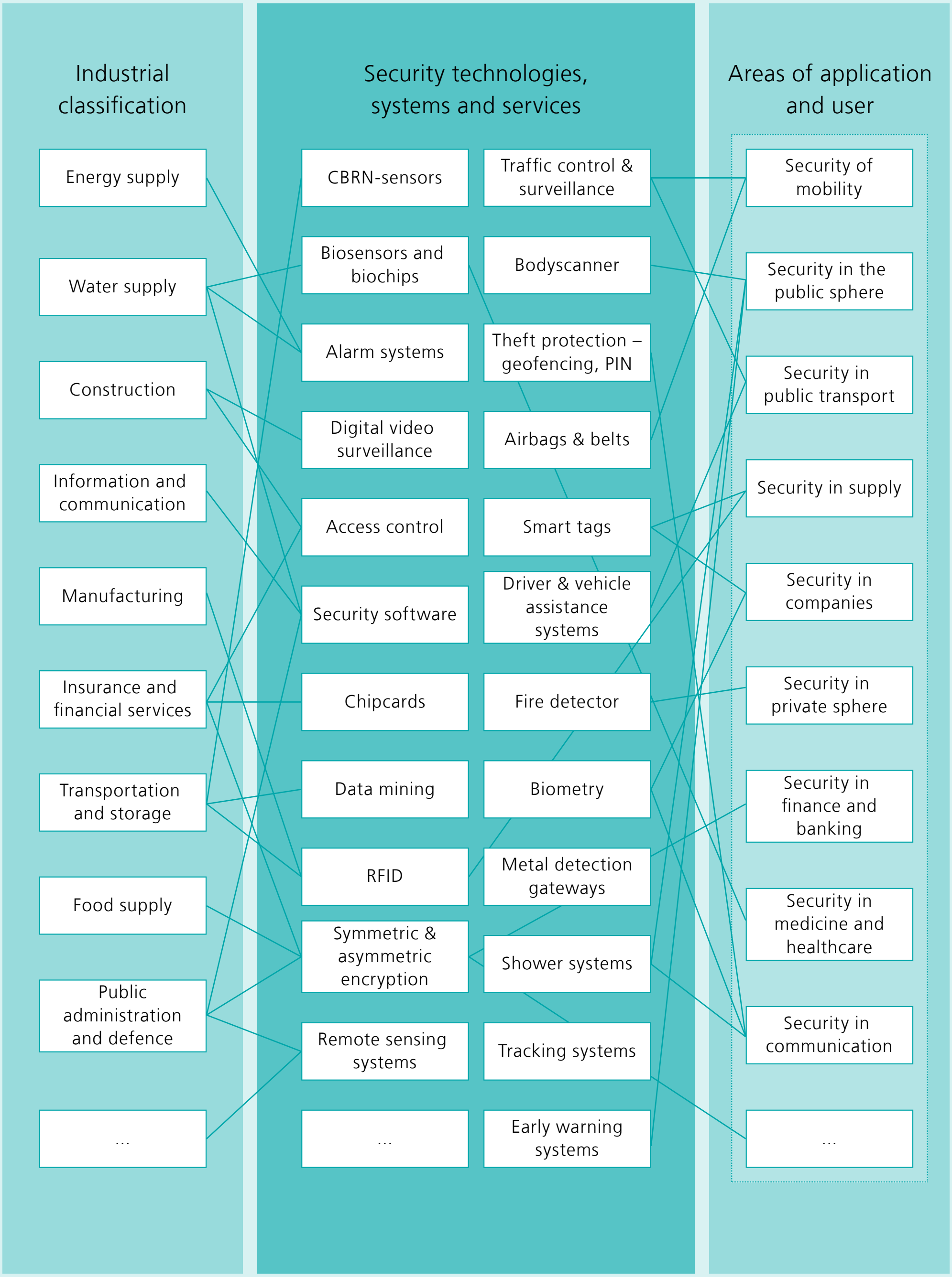
15 More information: http://www.sicherheitswirtschaft.din.de/cmd?level=tpl-home&contextid=sicher heitswirtschaft.

Figure 7–3: Security in the context of industrial classification and areas of applications



Source: own illustration

Another aspect also has analytical potential, the analysis of the interaction with the science system and the necessary transfer activities, which are currently being criticised in Germany and need to be improved (VDI/VDE 2008). The actors and variety of safety research subjects are also reflected at the scientific research level. A publication analysis of security-related topics in the last five years clearly demonstrates this. These appear in engineering, chemistry, biotechnology, computer science, social science, business & economics, sociology, health care, neuroscience, education research and many more (cf. Figure 7–4).

However, regarding the innovation system, research is necessary to analyse the innovation-related interactions between the players with the help of evaluation-oriented studies or accompanying scientific research. These analyses make it possible to identify weaknesses and best practice activities and thus provide a starting point for goal- and result-oriented innovation policy.

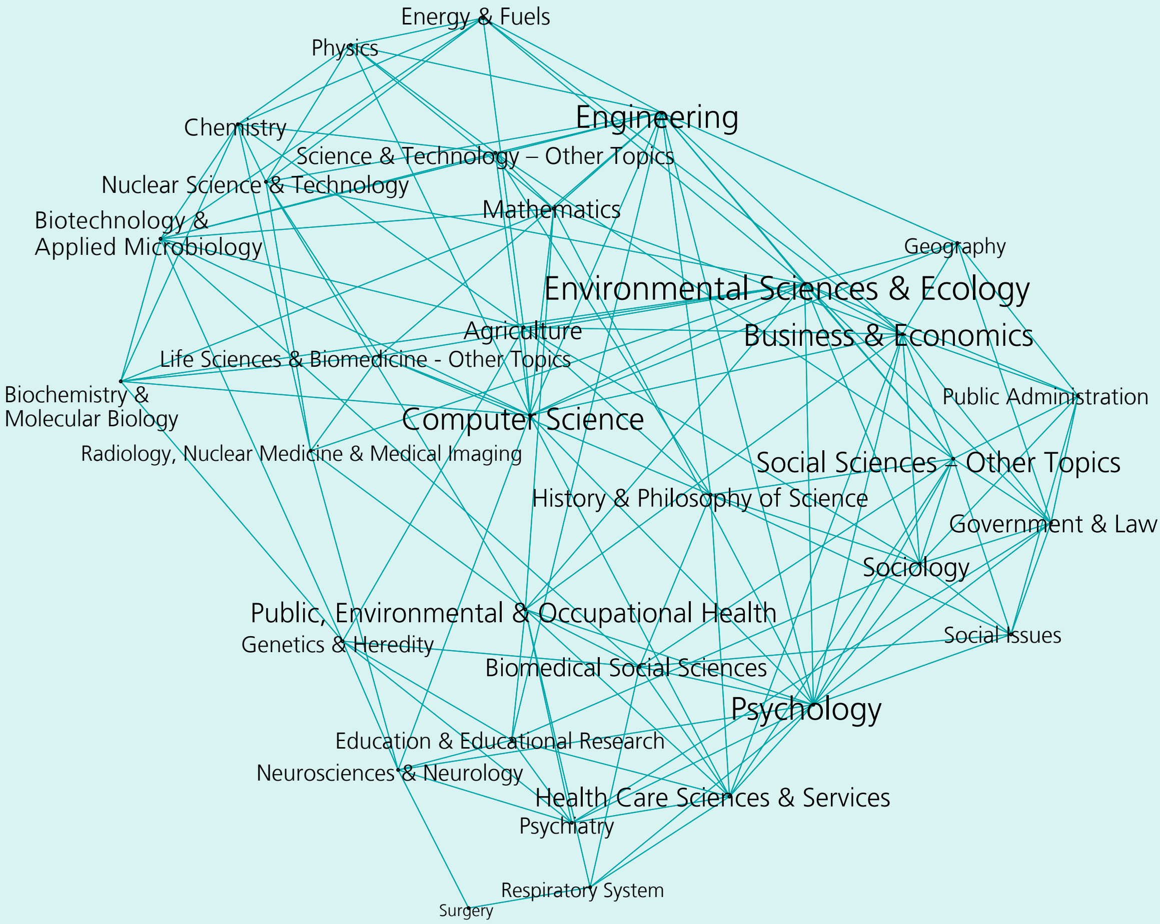
Moreover, in addition to the interactions between the economic and science systems, the interaction of these subelements with the consumers and buyers of security products and services, and in particular with actors in society is important too. Societal concerns and needs are often taken into account in the context of systemic innovation studies by including the consumers or users of technologies, systems and services. With regard to security, these concerns are not only crucial from the perspective of technological feasibility. These issues are also relevant from an individual's perspective due to possible impacts on individual and civil rights. This aspect is briefly discussed in the following section.

7.3.2 Challenge 2: Security and the societal depth of penetration

The rapid technological innovations in the security field and the associated social transformation processes result in new challenges which have impacts on innovation development and innovation potential. New security technologies have the potential to cause changes in social structures, for example, through new forms of governmental or social control (Hirsch 2008). The social impacts of security research and related ethical, legal and social aspects make higher demands of innovation system research.

One challenge is that similar social challenges are perceived differently in different contexts. The same so-called threats such as climate change, economic crises, terrorism etc. may be discussed and combated quite differently. Hotchkiss (2010), for instance, was able to show different interpretations and classifications of international threats in the field of security research using the example of the terrorist attacks of September 11, 2001. In the US, these were referred to as threats to the "culture of individualism" and, in France, as threats to social cohesion. On the one hand, international terrorism constitutes threats to the individual and, on the other hand, it seems to be an attack on social values. How important problems and threats are perceived as being within a society depends on socio-cultural interpretive and perceptual patterns ("concept of socio-cultural repertoire"). Expectations about the guarantee of security may be the driver for new technology developments or a facilitator for adopting, embedding and interpreting security technology. The perception of security threats and

Figure 7–4: Security in the dimension of subject fields



Source: own database searches in Web of Science, time horizon 2006–2011 related expectations can be regarded as a central determinant of technology development and mechanisation processes or pathways that are part of the innovation system (van Lente and Rip 1998; Geels and Smit 2000, p. 882).

In addition, different perceptions and degrees of acceptance can be observed regarding the application of security measures (e.g. the employment of body imaging technology at airports in Europe, public video surveillance in Germany and the United Kingdom). Additionally, it has been shown that the integration of security technologies at specific locations has different impacts on social demand and acceptance. For example, the use of body scanners at airports has a very different meaning than their use in other public places. The legitimate use of a technology in a particular place, such as an airport, does not imply anything about its use elsewhere (Nagenborg 2005, pp. 190ff.; 2009, p. 111).

Furthermore, ethical elements play a crucial role in security technology development and application. Ethical aspects should not only be regarded as constraints on technological advances. It is important to investigate to what extent ethics play a role in technology development and what the impact can be if ethical considerations are taken into account in technology assessment (design and implementation of technologies). The contribution of ethics is to give advice if there is a choice between alternatives which are evaluated differently from a moral point of view, to point out alternative solutions and to offer the chance to make a conscious choice between alternatives (Nagenborg 2009, p. 112). For instance, the body scanner raised constitutional concerns and met with public resistance in Germany. The question is whether employing the technology is proportional to the objectives being pursued. Regardless of the reliability and potential health hazards, the use of body scanners is still regarded as controversial and problematic from an ethical perspective. The focus is on questions and concerns about discrimination, violation of privacy and the adequacy of the legal framework (data protection, powers and training of security personnel, proliferation, and information obligation to the affected parties (Nagenborg 2011)). Using the Terahertz detection system, Rosen (2004) demonstrated that two alternatives were developed for whole-body imaging for security control, both of which completely fulfilled the purpose of detection. He argued that technology should be designed in such a way that it simultaneously serves the establishment and verification of security and the protection of privacy (cf. Nagenborg 2005, pp. 188–195; 2009, p. 499). For this example, integrating ethical perspectives in the technology assessment would have been preferable, despite the higher cost and development efforts required. Not considering ethical, social and legal concerns in the design and implementation of this technology has resulted in its being rejected by German society. Ultimately, the innovation potential of this technology has been badly affected.

Including ethical principles in technology design processes can lead to widely accepted technological advances. The concerns regarding this technology could have been avoided if societal actors had been involved in the design of the technology early on (von Schomberg 2011, p. 12). Ethics should not be misunderstood as an alternative to forms of democratic or participatory technology design (Flanagan et al. 2008). The use of technology assessment, privacy assessment and especially technology foresight is able to anticipate positive or negative impacts and define desirable impacts of research and innovation, both in terms of consumers and communities. The advantage is that these methods can reduce the human cost of trial and error and take advantage of societal learning processes of stakeholders and technical innovators. As a result, there is the possibility of anticipatory governance and the creation of products which are socially more robust.

Security research is not limited by purely technical aspects, but is increasingly embedded in a social and legal context. In the future, new technology and system developments should not only be considered in the context of costs and potential benefits of the technology. In addition, analyses have to be made of the changes in organisational processes, marketability, the required skills of security personnel and legitimisation problems (Haverkamp et al. 2011, p. 14). The focus is increasingly on questions of security perception and expectations, acceptance and anticipation of the non-intentional effects of technology solutions during development. Ethical, social and legal aspects can positively or negatively influence the realisation of technological innovations. In addition, informal and innovation-related institutions must be observed, such as values, traditions and conventions.

Open questions and starting points for further research

These ethical, social, legal aspects and the associated normative elements are considered in order to capture the importance of security measures, technological innovations, threats and risks to society. This could be a major challenge to innovation system research. A starting point is offered by the recently discussed "concept of responsible research and innovation" for systemic innovation approaches. This concept focuses on early societal intervention in the research and innovation process (von Schomberg 2011) and addresses the societal responsibility of R&D and the assignment of technological innovation within society. Bio-security and ICT are issues discussed here within security research. Early societal intervention in the research and innovation process can help to avoid technologies failing to be embedded in society or that their positive and negative impacts are better governed and exploited at a much earlier stage of the process (von Schomberg 2011, p. 9). This promising concept provides various starting points for future research.

The question asked within the analysis of the innovation system is whether, and if so, what influence socio-cultural differences, ethical concepts and the legal framework have when assessing security threats and security measures in terms of the performance and dynamics of the system. A potential market in one country may be completely ignored in another country or viewed as not practicable, despite its technological feasibility. Security technologies and measures may be accepted or not accepted depending on the context and different stakeholder situations (see Stritzel 2007, p. 363, among others). Within the framework of innovation system analysis, it is important to ensure that the respective technology is embedded in the specific spatial and legal context which shapes social demand and acceptance. It is necessary to be aware of different rules in different locations within the analysis. The specific institutional, organisational, legal, societal and ethical conditions should be considered when assessing the innovation, application, market and future potential of security technologies, systems and services. Therefore, innovation system research should be extended to take into account the ethical, social and legal conditions for both existing and future technological innovations. Questions about the socially correct, desired and needed innovation should be allowed and not just questions about the perspectives of end-users and customers. At the moment, however, it is unclear how such an extension could be achieved.

7.4 Conclusions

Security as an object of analysis fits perfectly into the framework of innovation system approaches, not only because of its specific constellation of involved actors, themes and structural characteristics, but also in terms of its diverse processes and influence factors like ethical and societal aspects. These directly influence the development, diffusion and use of new technologies and thus the performance of the innovation system (regardless which approach is used for the analysis).

However, innovation system-based research needs to be carefully adapted to the specific context of security. There are large numbers of actors involved from many disciplinary backgrounds, characterised by the distinct processes of negotiation. The dynamics of the security innovation system are also particularly influenced by the socio-cultural setting and the dynamics in political and social needs and orientations. Innovation in the field of security should thus be understood as a process of negotiation among different social actors which includes far more than just the interests of economic actors. Political and legal, but also ethical, moral and social factors are essential elements in security system design, in the interaction of elements and in the dynamics of the innovation system, which have to be taken into account in the analysis. It turns out that the topic of civil security interacts closely with the legal framework, shows sectoral overlaps and technological cross-cutting activities and is strongly impacted by normative requirements – ethical, societal and legal aspects. Thus, in the case of security, the innovation system approach can help to avoid narrowing the scope of research and policy action to focus only on technological and economic actors ex ante.

At present, however, the characteristics of the civil security (technology) system can only contribute a first insight into the issue and indicate some starting points for future research in the field of security. It has been shown that the topic of security does not fully fit into the existing heuristics of innovation system approaches, as it is likely to exceed sectoral, technological and national boundaries, and thus it is necessary to extend or combine different system concepts. For example, it would be conceivable to combine different innovation system research approaches – national, supranational and technological – in order to comprehensively analyse the field of civil security ("technological sectoral approaches are linked together over existing geographical boundaries along the constellations of actors"). Another possibility could be to integrate the innovation system school of thought into a comprehensive analysis framework with the multilevel perspective of socio-technical transition (Markard and Truffer 2008). Innovation system approaches focus on optimising the institutional environment of firm-based innovation processes or on technology-specific systemic change (Tukker et al. 2008; Bergek et al. 2008; Hekkert et al. 2007) and not on the strategic transformation of broader systems of production and consumption. The long-term strategic orientation of innovation policies and their integration with other policies like industry, environmental or foreign and domestic policy could be supported by integrating both concept strands (Weber and Rohrbacher 2012). In addition, there is the possibility that security research can identify certain characteristics of a common typical knowledge base or typical institutional arrangements as starting points.

Against this background, an innovation system approach could also serve as a fruitful basis to develop and coordinate coherent sets of high quality policy instruments which target different dimensions of the security innovation system by taking into account the complex interdependencies mentioned above. Security as a meta-issue thus represents a major challenge for innovation research and policy. Using innovation system approaches might help to fulfil the main intention of security research, namely, to provide security "for" society and not "from" society.

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8

KNOWLEDGE ANGELS

OR HOW CREATIVE PEOPLE FOSTER INNOVATION IN THE SERVICE INDUSTRY: EMERGING CONCEPTS AND INTERNATIONAL OBSERVATIONS

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8.1 Introduction

In one of the first contributions to the systemic view of innovation, Lundvall (1992) defined a system of innovation as being "[...] constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge [...]" (Lundvall 1992, p. 2). This short reference indicates three key aspects which form the focal point of this article: 1) elements, 2) relationships and interactions, and 3) new and economically useful knowledge. Within the context of the increasing importance attributed to knowledge and knowledge-related activities such as innovation (third aspect), our article focuses on the specific element (first aspect) of service firms – notably the segment of knowledge-intensive business services (KIBS) – in innovation systems, their interactions and relationships with other actors (second aspect) and also internally within their companies and company networks.

The undeniable importance of knowledge and innovation in modern economies justifies the increasing interest of researchers in studying the relationships between knowledge-intensive business services (KIBS) and innovation. This chapter delves deeper than the micro level of individual KIBS firms and focuses on creative individuals within KIBS. These individuals are suspected of playing a crucial role for the innovativeness of this kind of firm.

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According to Sternberg and Lubart (2008, p. 3), "creativity is the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints)." As such, creativity can be seen as a subtle mix of ideas, visions, market knowledge and problem-solving competences which constitutes a decisive skill in a knowledge-based economy. In the same way that business angels can play a decisive role in the development of innovative firms by providing financial support, it is assumed that creatively gifted individuals can act as knowledge "catalysts" within KIBS. Consequently, creative individuals acting within KIBS are called "knowledge angels" in analogy with business angels. In order to investigate this aspect, an ad hoc explorative methodology was developed and field research was performed in different countries.

This contribution is structured as follows: first the topic of knowledge angels is addressed from a conceptual perspective, presenting them as the possible missing link needed to fully understand what is really happening when KIBS innovate. The third section is devoted to empirical insights and the fourth section draws possible implications for local, innovation-oriented policies.

8.2 Entering the black-box of innovation in KIBS or: why knowledge angels may be the missing link for understanding what is really happening when service firms innovate

Starting with the seminal work by Miles et al. (1995), KIBS have been a research subject since the middle of the 1990s. As depicted in Muller and Doloreux (2009), studies devoted to KIBS and innovation have developed strongly over time. The initial phase of academic work focused on higher services and comprised mainly theoretical reflections – with only a weak empirical basis – recognising KIBS as a specific sector. Miles et al. (1995) proposed the first detailed elaboration of KIBS following (and inspired by) the works of Barras (1986; 1990) on the use of ICT in services as well as the taxonomy of services by Soete and Miozzo (1990). These seminal studies stressed that KIBS form a category of service activity, compared to other service branches, "which is often highly innovative in its own right, as well as facilitating innovation in other economic sectors, including both industrial and manufacturing sectors" (Miles et al. 1995). This insight, in turn, stimulated significant subsequent research efforts.

The most important subsequent development that made a significant contribution to understanding the innovation process and innovative patterns was probably made possible due to the introduction of the Community Innovation Survey (CIS). This survey was developed to collect micro-level data on the innovation activities of firms in Europe. It includes questions about innovative processes as well as innovative performance. Service innovation was also included in the Oslo Manual for collecting and interpreting innovation data, which states that "the importance of innovation in the services sector and of the services sector's contribution to economic growth is increasingly recognised and has led to a number of studies on innovation in services [...]" (OECD and Eurostat 2005, p. 38). Empirical studies of KIBS focus mainly on topics such as patterns of innovation and sources of competitiveness (Camacho and Rodriguez 2005; Evangelista 2000; Hollenstein 2003; Tether 2003; Tether and Hipp 2002), innovation and sectoral performance (Cainelli et al. 2004; 2006; Evangelista and Savona 2002; 2003) and innovation and inter-firm collaboration (Djellal and Gallouj 2001; Koschatzky 1999; Muller 2001; Muller and Zenker 2001; Tether 2003). In general, these studies show that innovative activities in KIBS are distinct from those in manufacturing firms and that KIBS are more intensively engaged in innovation and training activities than their manufacturing counterparts, but that they are less likely to collaborate with international partners or perform internal R&D. In addition, the innovativeness of KIBS is strongly linked to highly qualified employees and the intensive exploitation of human capital (cf. Muller and Doloreux 2009).

A shared finding of the above-mentioned studies which serves as a base for further KIBS-related analyses is that certain "basics" of service productions and innovations apply to every type of service company, a fortiori to KIBS, i.e.:

– synchrony of production/delivery and consumption
– intangibility (non-storable economic goods
– mainly knowledge- and competence-based (even if some artefacts and/or technologies may contribute to the process)

In emphasizing that "[s]ince KIBS' growth is much faster than that of other sectors, it cannot just be driven by the growth of these sectors that are users of KIBS", Miles (2005, p. 43) suggests that something peculiar is happening within this type of firm which cannot be explained by only the changes affecting the context(s) in which they evolve. In line with this assumption, and keeping in mind the "basics" of the service industry, the starting point of this article is that a clear research gap can be identified. In fact, something is clearly missing, namely the key factor explaining service firms' innovativeness.

Strambach (2008) distinguished horizontal and vertical knowledge domains which made it possible to go one step further in this direction.[1] Consequently, phenomena like disintegration in production, further fragmentation of value chains, modularisation and externalisation processes have led to the continued evolution of KIB structures and to new hybrid forms of organisation. These processes are reinforcing the complexity of knowledge domains around business functions and are creating new proximity–distance relationships between multiple intra- and inter-organisational actors – not only in organisational and spatial terms, but, above all, in institutional and cognitive terms.

1 Strambach (2008, p. 163) claims that these are important for understanding KIBS' evolution and innovation capacities: "We define horizontal knowledge domains with respect to business functions and understand vertical knowledge domains as sector-specific knowledge. KIBS are acting in complex horizontal and vertical knowledge domains which force them to combine and reconfigure knowledge units very flexibly from various knowledge categories and knowledge bases by producing customised 'knowledge products'. […] KIBS appear to be responding to the increasing need for coordination, communication and organisation caused by these developments with both their composite knowledge products and the mode they use in producing their services."

What if something very basic has been disregarded (or at least insufficiently stressed) so far? Without denying the importance of previous work, it must be pointed out that, for KIBS and micro-level creativity, changes and transformation are at the level of individual actors. In this respect, Andries and Czarnitzki (2012) underline that there may be a clear link between individual knowledge and innovation since it is widely accepted for any kind of organisation that there is a close link between the capability to innovate and its individual knowledge resources. In particular, they point out that various studies characterise innovative companies as knowledge creating (e.g. Nonaka and Takeuchi 1995), or as exploring innovation in the sense of a knowledge management process (e.g. Madhavan and Grover 1998). Along the same lines, according to Grant (1997) for instance, individuals are the primary agents of knowledge creation and – in the case of tacit knowledge – the principal repositories of knowledge.

Generally, and in line with Cohen and Levinthal (1990), it can be asserted that a key principle in the literature on innovation is that a firm's innovation capacity depends on its ability to create, absorb and develop knowledge. In addition, individual knowledge and skills (like other intangible resources such as brand equity) are more likely to produce a competitive advantage because they are often rare and socially complex, and therefore difficult to imitate (Hitt et al. 2001). It is obvious, however, that smart ideas alone are not enough! To be innovative or innovation-supportive is not only a question of being "bright" or "talented", but requires a set of psychological characteristics which correspond to a certain extent to the qualities of an entrepreneur. In this regard, Dyer et al. (2011) derive the following five key competencies of today's innovators from a broad range of interviews: associating, questioning, observing, networking, and experimenting. They show that innovators have certain specific characteristics on a cognitive dimension, but also behave in a specific way and are embedded in a specific, favourable environment.

Consequently, and based on the above described findings, the core assumption of our research is that there are specific individuals within KIBS, who perform tasks – based on their creative abilities – that significantly increase the creative capacities of the firms in which they are embedded. In order to obtain more evidence for this premise, the research project KAIROS (Knowledge Angels or the Reinvention of Outstanding Services), named for the Greek god of "right time and timelessness",[2] was launched to investigate whether outstanding individuals exist who play a key role in their firms' innovation activities. We call these persons *knowledge angels*; their existence in KIBS serves as a working thesis to facilitate the understanding of the impact of individuals on KIBS' innovation trajectories.[3] The underlying assumptions of our

2 Initiated in 2007, the research project was funded by the Fraunhofer Institute for Systems and Innovation Research ISI in Karlsruhe, Germany, for the regions of Baden-Württemberg and Alsace. The research performed aroused the interest of other researchers, so that the case study regions were extended to China (especially the Beijing region), the metropolitan areas of Paris and Montreal as well as to Catalonia (particularly Barcelona). This chapter is mainly based on the surveys performed in Alsace, Baden-Württemberg, the Beijing region and Catalonia.

3 Cf. also Muller (2008), Muller et al. (2009; 2010; 2012).

research can be briefly summarised as follows. Knowledge angels are (or may be) specific individuals, who: (i) typically act as consultants (but not necessarily exclusively); (ii) may have the talent to "sense" things before they happen, or make them "happen" (from the subjective point of view of an external observer); (iii) make a difference in the way knowledge is created, organised and flows within the firm and between the firm and its partners. In other words, knowledge angels are "suspected" of being able to generate their own markets (and/or to create their own jobs and working environments) to a certain extent. It is assumed that these key actors within KIBS have the talent and creativity to evaluate externally available knowledge and to match it with the KIBS' needs.[4] In this respect, there are some analogies to business angels who also – but in different ways – contribute to firms' evolution and innovation (cf. Table 8–1). Both types of angels bring pertinent assets to companies and can substantially contribute to the companies' success. However, though there are certain similarities between the two types of angels, the main difference between them is in the degree of integration in internal company issues: as active investors, business angels are external to the company they invest in, at least in the first phases of their investment. Even if they become increasingly integrated into the company in further phases of collaboration – for instance as board members – they still retain a certain distance to the day-to-day activities of the company. On the contrary, knowledge angels as presented here are wholly "internal" to the KIBS they are employed in.

Table 8–1: Core characteristics of business angels and knowledge angels

Type of angel characteristics	Business angels	Knowledge angels
Core resources	Money and business experience, contacts (and to a lesser extent ideas)	Knowledge, ideas and vision (and to a lesser extent business experience)
Strongest motivation for action	"Fun factor" and financial interest (and a willingness to support younger entrepreneurs)	Quest for freedom, self-realization, "testing" new ideas (and a willingness to support co-workers)
Main forms of knowledge support	Supporting existing knowledge creation processes and situations	Initiating new knowledge creation processes and situations

Source: own compilation; business angel characteristics based on Just (2000), Hemer (2001)

4 So far this seems coherent with other empirical findings (not specific to KIBS but to other firms, especially manufacturing and services SMEs) as described by Andries and Czarnitzki (2012, p. 19): "[...] we show that for process innovation performance, small firms benefit greatly from suggestions by non-managerial production employees. Also for product innovation performance, we find a positive effect of using non-managerial employees' ideas. This suggests that the historical focus on the entrepreneur/CEO which was broadened more recently to the study of entrepreneurial teams does not yet fully capture small firms' innovative potential."

8.3 Tracking and characterising knowledge angels

The primary goal of the KAIROS project was to validate the existence of knowledge angels and identify core characteristics of this group. The investigation was strongly exploratory in nature and did not aim at a high level of exhaustiveness but was intended to maximise the probability of detecting specific features revealing the existence and characteristics of knowledge angels, and to identify pertinent aspects for further research. A phenomenological approach was applied and an explorative and qualitative research design was chosen. The unit of analysis (Yin 2003, p. 22) stretches across both (i) the firm as an entity and (ii) individuals who might reveal themselves to be knowledge angels.

Following this conceptual approach, interviewees were selected in a two-fold manner: (i) the identification of KIBS firms and (ii) the identification of key individuals within those firms. Representative firms were chosen to fulfil the following criteria: 1) different KIBS sectors, 2) different firm sizes, and 3) different locations. Participating companies generally tended to be small to medium-sized with 10 or more employees. In order to identify appropriate KIBS, company databases were consulted and/or personal contacts used. We extracted NACE 72 (data processing and databases), NACE 73 (research and development) and NACE 74 (provision of business-related services) firms in the targeted regions. Additionally, we tried to identify persons within the companies who matched our vision of potential knowledge angels. Whenever possible, these key persons were contacted directly, but in most cases, companies did not introduce their staff on the website and suggested the interview partners themselves.

Altogether, 50 face-to-face in-depth interviews were conducted between October 2008 and the end of 2009 in five different countries focusing on a particular region in each country in order to detect references to certain regional specificities, national environments and socio-cultural influences.[5]

An interview-guideline was prepared for the interviews, which allowed open responses and an interactive conversation in order to collect information along five heterogeneous dimensions (displayed in Table 8–2, which illustrates the interviewees' parameters in each of the five survey dimensions). The main results of the interviews can therefore be displayed along the following five dimensions termed ALPHA to EPSILON: (ALPHA) individual trajectories and professional experience, (BETA) business location and regional environment, (GAMMA) knowledge access and modes of interaction, (DELTA) modes of problem solving and visionary capacities, and finally (EPSILON) firm characteristics.

Without forestalling the key results, it can be stated that there are indeed persons among our interviewees who function as knowledge angels as proposed in Table 8–1. However, depending on their socio-cultural context they perceive their role differently. They describe themselves as "knowledge brokers" (Baden-Württemberg), as "idea

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5 15 interviews were conducted in France (10 in Alsace and 5 in the Paris agglomeration), 10 in Germany (Baden-Württemberg), 10 in China (mainly in the Beijing agglomeration), 10 in Spain (Barcelona agglomeration), and 5 in Canada (mainly in the Montreal agglomeration).

Table 8–2: Synthesis of the 30 investigated cases

Case no.	Dimension					Most probable knowledge angels
	ALPHA Professional and personal background	**BETA** Business location and environment	**GAMMA** Knowledge access and interaction	**DELTA** Problem solving and visions	**EPSILON** Corporate frame, enterprise culture	
1	***	***	***	***	***	√
2	**	*	***	***	**	
3	**	**	*	*	**	
4	***	**	**	**	**	
5	***	***	***	***	***	√
6	***	***	***	***	***	√
7	***	***	***	***	**	√
8	***	**	**	***	***	√
9	***	*	*	*	*	
10	**	**	***	***	**	
11	***	***	***	***	***	√
12	***	*	*	*	**	
13	*	**	***	***	***	√
14	**	*	*	***	**	
15	**	*	*	***	**	
16	***	**	**	***	**	
17	***	***	***	***	***	√
18	***	**	***	**	**	
19	***	**	***	***	**	√
20	**	*	***	***	***	√
21	*	***	***	***	***	
22	***	***	***	***	***	√
23	***	**	***	***	**	
24	***	***	**	***	***	√
25	**	***	**	***	**	
26	**	**	**	***	***	
27	*	*	**	**	**	
28	***	***	***	***	**	√
29	**	**	**	***	***	
30	**	*	*	***	*	

Baden-Württemberg: Cases 1–10, Alsace: Cases 11–20, China: Cases 21–30
Note: *** High probability of being a knowledge angel; ** Medium probability of being a knowledge angel; * Low probability of being a knowledge angel.
Source: own compilation

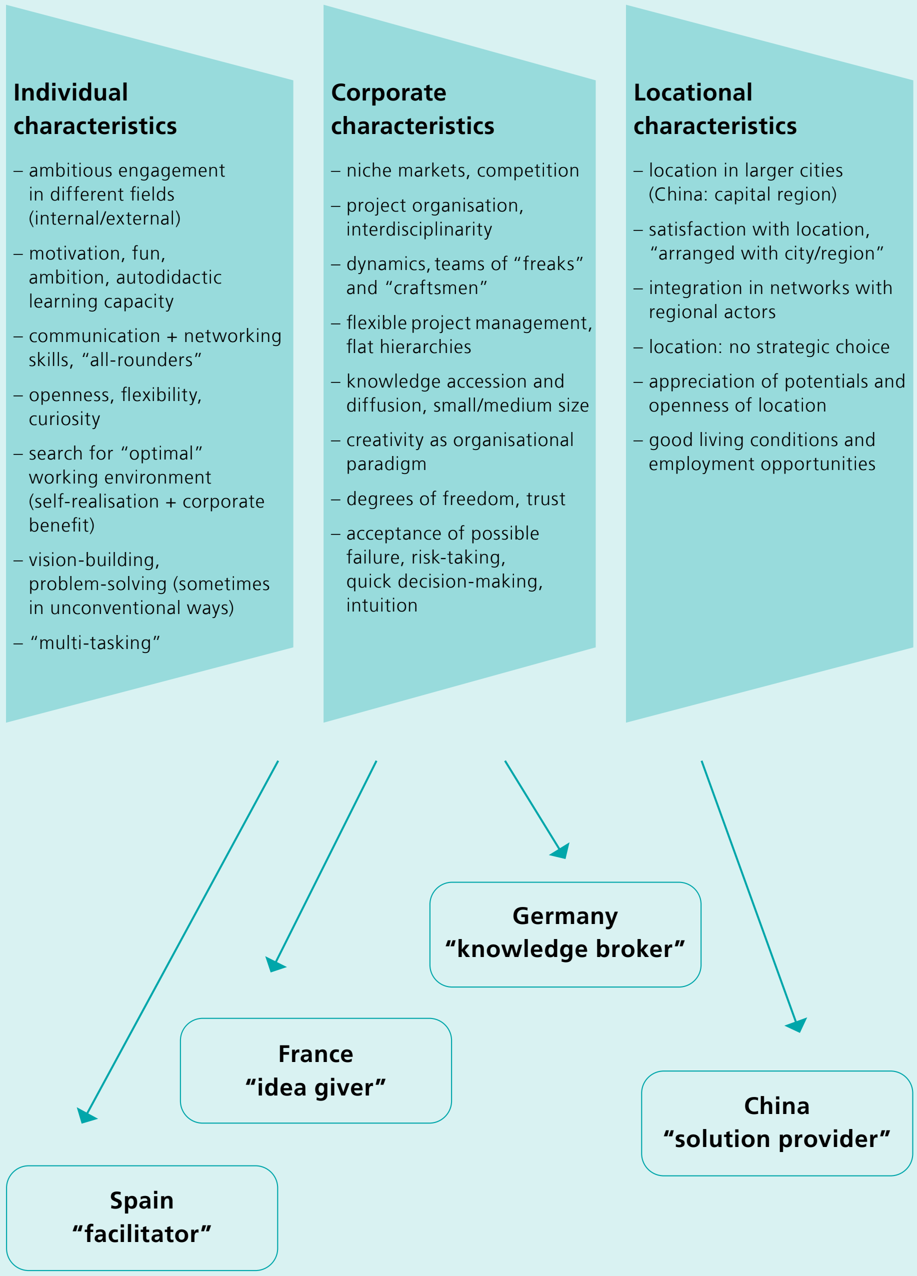
givers" (Alsace), as "facilitators" (Catalonia), or as "solution providers" (China) (cf. also Figure 8–1). They frequently hold a position between management and project level that allows them to relate "field work" with corporate strategy development and market development. Such a mediating, cross-functional position (in organisational terms) seems to be the best fitting organisational position to accommodate their specific needs and outstanding capacities.

From a conceptual perspective, knowledge angels show predominantly above-average results concerning the aspects evoked in our empirical analysis. It was obvious that most of the persons classified as knowledge angels have outstanding characteristics in their professional lives and development. They are generally very active and engaged in different fields and spheres of activity, for instance in business and science in parallel and/or as members/representatives of committees, as (co-)founders of one or several enterprise(s) and so forth. They are very ambitious, hard-working and "networkers", attributes which give them access to diverse fields of information. Perhaps it is their personality that makes them particularly open to and interested in a broad range of domains that they are then able to connect to their central field of activity. In short, it appears that knowledge angels are curious and always on the look-out for new opportunities. Common characteristics shared by all knowledge angels are their high and above-average capacity to develop visions and to solve problems. Both characteristics make them key players in their companies' innovation activities. Not only these capacities as such, but their combination with corporate functions is pivotal.

Persons classified as knowledge angels very frequently also have above-average abilities in accessing knowledge and in interacting, the latter being strongly connected to the above-mentioned aspect of networking, including soft skills and communicative abilities. Their companies developed various tools that are combined and applied in order to access new knowledge and to integrate it into the companies' innovative activities. Generally, the acquisition of external competencies (i.e. through hiring new staff, engaging students and PhD students, integration in scientific networks or visiting conferences) is combined with the development of internal competencies through qualification measures or information searches for instance. In addition, various companies reported innovative tools to diffuse and assemble contract-specific knowledge within their companies. The workers are considered to be the most important asset and capital of the companies.

Very often, the persons classified as knowledge angels work in an environment that allows them to cultivate their abilities and competencies. Generally, the companies' activities are organised in projects realised by (interdisciplinary) teams. Hierarchies are flat – at least in the European KIBS firms visited – and a high degree of exchange and communication between individuals and among teams can be observed. This kind of corporate environment leaves room for knowledge angels' abilities to be developed. Project management is flexible and understood more as a definition of priorities. Knowledge angels are granted considerable degrees of freedom in their activities; this keeps them happy in their positions and motivates them to engage in further efforts for the benefit of their companies. Companies and their activities are considered

Figure 8–1: Characteristics of knowledge angels in their corporate and territorial environments and regional specifics



Source: own illustration

to be dynamic and flexible; one interviewee mentioned the "dictate of change" in this context. Internally, creativity is strongly supported; creative ideas are considered to be the "steam" needed to run the "machine". Consequently, such creative and innovative companies can be characterised as a "mixture of freaks, moderators and solid craftsmen". In this respect, a few knowledge angels consider themselves to be "handymen", or "all-rounders" with the ability to bridge different enterprise functions and play more than one role. However, the interviewed persons are well aware that a favourable working atmosphere is necessary for them to be able to act as such and mention the importance of a positive team spirit between co-workers, motivated, for instance, through joint sports activities, modern office equipment, or financial incentives.

This does not mean that interviewees not classified as knowledge angels do not have excellent qualifications and competencies. They also frequently show above-average characteristics in one or two of our analytical dimensions. However, it appears that the outstanding characteristic of knowledge angels is the ability to combine various excellent assets to the benefit of both their companies and their own subjective well-being. This tends to be an unconscious process: by pursuing personal goals set in relation to the companies' goals – leading to the knowledge angels' success in his or her company – knowledge angels contribute to a higher level of innovation activities in their companies and also determine their own "niche" and professional development path within their firm. Contributing to innovative activities may in this respect be related to unconventional methods, to new forms of collaboration and partnership, new visionary models, etc. that may fail. It is crucial that the corporate environment leaves potential knowledge angels the freedom and scope to pursue novel ideas and visions, which involves granting them a high degree of trust and independence. To sum up, trust, freedom, and the acceptance of possible failures are crucial in this respect, both for the individual and the corporate dimension: individuals (knowledge angels) need to have the courage to introduce and implement (even apparently foolish) ideas – one interviewee spoke of companies' "openness to rebel thoughts" – and the company leaders need to grant their staff a certain degree of freedom to engage in innovative (sometimes foolish) projects. The management not only supports visionary ideas, but it is open to "freaks and visions" and trusts its co-workers, but also has the capacity to take risks and make snap decisions, often based on intuition (leading to trial-and-error-processes), but backed by discussions among a group of persons within the company.[6]

Further, when asked about the immediate spatial environment of the company, location motivations and networks and innovation-supporting factors in close proximity, knowledge angels are generally satisfied. They appreciate the potentials and openness of their companies' home locations and especially the good living conditions (cf. also Figure 8–1). Although the investigated companies are not situated in the capital cities or other well-known "hot spots" in their countries (except for China,

6 Basically, this is the case in the European context; in China, decisions tend to be taken more by the top management.

where most interviews were performed in the capital region and where a location in Beijing is perceived as an important asset in terms of professional success and talent availability),[7] interviewees emphasised the good and partly excellent conditions in terms of creativity, economic potentials, and especially concerning living conditions and the chance to employ high-quality workers (who are then not quick to leave the company for better working conditions elsewhere). They generally find their location attractive, both from a professional perspective and with respect to recreational values. In Alsace, the high density of European institutions is mentioned and appreciated.

This last aspect leads to another important point about the position of knowledge angels in their service companies: they do not necessarily belong to the management board of the company, frequently holding a position between management and project level. They have, of course, insight into strategic processes, but – and this was frequently quoted by the German respondents – they are also engaged in project work. This is very important for them independently of their precise position, because they want to stay in touch "with the base" they like to be engaged in project work. Besides the "fun factor", this is an important indication of their visionary capacity: knowledge angels can better cultivate their abilities if they are able to link "field work" with company strategies and with the market environment. In other regional contexts, this double role playing in different types of activities may have a slightly different form: in Catalonia, for instance, it tends to be realised through professional engagement in different organisations or institutions.

It can thus be stated that knowledge angels actively search for a professional position that best corresponds to their individual talents, abilities and visions. This could be observed in all our (European) case study regions. However, the way this goal is approached may differ. While knowledge angels in Germany tend to search for a "good" position within their company, their French counterparts are to a greater extent engaged in setting up their own firms (that they may also quit again after a certain period), and Spanish knowledge angels "test" several companies before finding the best one. In China, interviewees were passionate about their function as top or middle level managers and offering knowledge services. Knowledge angels have certain similarities in all the investigated regions: high motivation, self-fulfilment, curiosity, the desire to search for work that enables them to develop their visions, talents, ideas and creativity. Strongly related to their position and working mode is their communicative competence. As indicated above, knowledge angels often anchor their professional activity in different "poles", whether these are on the strategic and operative level of the same company or by holding different positions for different

7 The aspect of *Guanxi* should be mentioned in this context. Guanxi can be roughly translated as "business and/or personal relationships", but goes beyond the European understanding of this phrase. It can be described as a form of trust which forms the foundation for the establishment of relationships and networks that are then crucial for professional activities. Guanxi is established through direct or indirect personal contacts (i.e. between persons who have been formally introduced to each other or know the same persons) and is a necessary precondition for interaction.

clients. The latter means that our angels divide their working time between different jobs. This aspect of "multi-tasking" on different levels corresponds to knowledge angels' personalities and enables them to connect different persons and different types of knowledge. It should be mentioned that knowledge angels try diverse jobs in their search for the "best fitting position" (within one company, in different ones or dividing their working time between different engagements) until they find their "optimal" working environment.

8.4 Implications for local innovation-oriented policies

This section looks at some basic assumptions concerning the fact that – as shown previously – knowledge angels do not "emerge" (or "appear" or "reveal themselves") everywhere with equal probability. In other words, the concept of knowledge angels may be useful to reassess the links between knowledge, creativity and trust as well as to rethink the relationship between innovation and territories. Furthermore, this may provide some insights into the design of "knowledge-angel-friendly policies".

The creative capacity that seems to characterise knowledge angels is influenced – at least partially – by the environment in which they act. This is, of course, not specific to KIBS or to knowledge angels. For instance, Heinze et al. (2009), who investigated creativity in scientific research, provided valuable insights into how creative processes "work", including the selection of problems, methods, partners and knowledge sources.[8]

It is obvious that, beside the concept of "trust" which will be considered later on, the notion of "links" (or "ties" or more generally "networks") is central to the analysis. These "links" – which may be distant ones – never take place in a vacuum. Most often, they tend to conglomerate in cities and city-regions as pointed out by Gertler (2004, p. 6): "places have become ever more closely identified with (and by) their cultural stars and the distinct cultural movements and products they produce: their music, their architecture, their films, literature, art, fashion, and so on. This has obvious spillover benefits for both the city-region and the entire country, whose status and image abroad is strongly enhanced." It is even possible to go one step further like Cohendet and Zapata (2009, p. 32) and propose that each city provides, and at the same time benefits from, a sort of "creative underground" which is conducive to innovation: "We view this underground as the set of informal interrelationships that occur within the cities as a sociologically, culturally and historically composed field. It is the relationships that are formed through specialised events that take place in

8 Cf. Heinze et al. (2009, p. 611): "Rather than focusing on innate individual traits, work on creative processes has highlighted the opportunity structures in collaboration networks that facilitate the generation and diffusion of novel ideas. Proponents of network brokerage argue that people who are placed at the intersection of heterogeneous social groups have an increased likelihood of drawing upon multiple knowledge sources, leading to the generation of new ideas [...] In contrast, proponents of cohesive collaborative networks argue for the benefits of trust, shared risk taking and easy mobilization in facilitating information and knowledge transfer. According to these studies, individuals with cohesive social ties are more likely to be involved in innovations."

the city as well as the exchange of ideas that are a source of inspiration that happen within the city's local cultural scene."

More generally, the "emergence" of knowledge angels requires or at least is favoured by a certain type of (business and innovation) climate. One of the most important elements in such a climate is trust. It can even be assumed that knowledge angels generate such a climate of trust within their organisations. In this respect they constitute a kind of link between (firm-)internal and (firm-)external context. In such a climate individuals are more inclined to share knowledge, seek new ideas, express their creativity and, as a consequence, innovation processes become more systematic. As described by Brattström et al. (2012), systematic processes and structures do not hamper creative thinking because they create a climate of goodwill trust in the organisation, since individuals "[...] are also confident that wild ideas are appreciated and will not be ridiculed." (Brattström et al. 2012, p. 746).

According to these researchers and with regard to innovation phenomena, trust can be addressed by considering two components: competence trust and goodwill trust. Generally speaking, goodwill trust is referred to as benevolence and integrity, whereas competence trust corresponds to the other party being capable of doing what he or she promises and according to Brattström et al. (2012, pp. 743–744): "We argue that whereas goodwill trust and creativity are closely related, competence trust does not necessarily stimulate creativity. This finding complements earlier studies arguing for a relationship between trust and creativity."

Consequently, one possible impact that knowledge angels can have consists of the simultaneous enhancement of competence trust and goodwill trust. This very specific contribution from a local and/or individual perspective could be the main way knowledge angels reduce uncertainty and increase creativity. In line with Ramos (2009), the three following mechanisms characterising the interaction between knowledge angels and their environment can be stressed in this respect:

- *Absorption and generation*: based on a combination of experience, skills, vision, intuition, etc., (firm-)internal knowledge is generated by knowledge angels in parallel to acquiring new ideas from the environment.
- *Sharing for development*: knowledge angels as change agents make knowledge accessible to potentially everyone in the organisation, thus allowing new forms of learning. Both implicit and explicit interactions take place.
- *Validation and actioning*: knowledge angels are able to differentiate, in real time, which knowledge is relevant for the organisation. Actioning (in the meaning of Argyris and Schön 1996) includes the implementation orientation of knowledge angels. This leads to an improvement in how people function in the organisation, and, as a result, it supports the organisation's performance.

In a similar way, some insights provided by Heinze et al. (2009) into creativity in scientific research can also be exploited in relation to knowledge angels. First of all, the importance of extramural collaborations must be stressed for both top creative scientists and knowledge angels. In other words, the access to "external organisational boundaries" and "different" sources acts as a reservoir for serendipitous events.

Secondly, the prominence of broader profiles rather than deep specialisation seems to be important. Heinze et al. (2009) describe scientists who were successfully creative because they had changed their research field. The same could apply to knowledge angels whose success is based more on their ability to bridge knowledge gaps than on highly specialised competencies or purely niche strategies. Finally, the influence of a high risk approach must be highlighted, as well as the visionary character of highly creative individuals in extremely competitive organisations (like cutting-edge science research labs or successful KIBS). To a certain extent, some research labs seem curiously similar to innovative KIBS: "While research directors are expected to articulate a research vision, to recruit outstanding personnel, and to motivate scientists (as argued in previous literature), a new type of expectation has emerged: they need the capability to equip research organisations with appropriate funding from diverse sponsors and balance research budgets. Organisational leaders need to be successful in acquiring new grants and opening up additional funding channels. They must be competent in continuously monitoring the complex landscape of funding agencies and sponsorship programs" (Heinze et al. 2009, p. 620).

Altogether, these indications help to draw a picture of how knowledge angels "emerge, work and function" and, to a certain extent, which kind of environment may be supportive to their development as well as to their impact at local level. As a consequence, some ideas can be put forward about rethinking the underlying aims and principles of local innovation-supporting policy. Different ideas could be examined based on the knowledge gained from formulating hypotheses concerning the possible existence of knowledge angels and the implications of the empirical observations detailed in the previous sections. These ideas are presented in Table 8–3 in the form of short injunctions, which are intended to form a "counter manifesto" for local innovation-supporting policy due to their provocative nature. For instance, we assume that cluster policies may be important "triggers" for innovation in a broad range of fields. Nevertheless, cluster policies should not be considered as the "one and only" means to foster innovative actions. Table 8–3 can be considered a plea for open, flexible and experimental supportive measures that also embrace unconventional approaches.

8.5 Conclusions

Starting from a brief overview of KIBS research and the research gap this reveals concerning knowledge- and creativity-driven processes leading to innovation, this chapter provided an introduction to our conception and (explorative) empirical investigation of knowledge angels. This investigation was able to demonstrate that knowledge angels – as a "model" or archetype of creative personality – can indeed be detected in KIBS in different (regional and national) environments. Knowledge angels can therefore be considered as playing a crucial role in innovation systems and significantly enhancing the innovative activities of their companies, as well as that of other actors in an innovation system through the strong networking role of knowledge-intensive business service firms. Our analyses were also able to identify a range of specific characteristics of this type of personality, as well as of their corporate contexts

Table 8–3: Elements of a "counter-manifesto" for rethinking local innovation-supporting policy underlying principles and aims

Standard or usual underlying principles of local innovation-supporting policy	**Alternative (or knowledge angel-friendly) underlying principles of local innovation-supporting policy**
There is a need to cluster as much as possible!	Wisdom lies in virtually interconnected islands of knowledge!
What matters is the proximity to big science infrastructures!	What makes the differences is the ability to access (close or remote) knowledge!
Clear specialisation is the way!	There is always a need for eclectics!
Bigger is better!	Smaller is faster!
R&D-driven is safer!	Creativity-led is more fun!
Planning is everything!	Expect the unexpected (or just nothing)!
One must be solution-oriented!	Business is always problem-driven!

Source: own compilation by Fraunhofer ISI

and territorial environments. This is of even greater relevance for the investigation of knowledge- and innovation-related activities because it is very difficult to identify KIBS' innovation using conventional innovation statistics, since KIBS rarely have research and development activities comparable to manufacturing firms, and are also rarely referred to in patent statistics. The third part of our contribution derived some general conclusions about supportive measures from the political decision-makers' perspective. However, it is still too early – and not conducive – to propose distinct support measures. Instead, we aim to broaden the view of those involved in innovation support. This should be understood as a rather provocative way of confronting common policy visions with our research findings and should be backed by further studies of innovation and creativity.

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9

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.

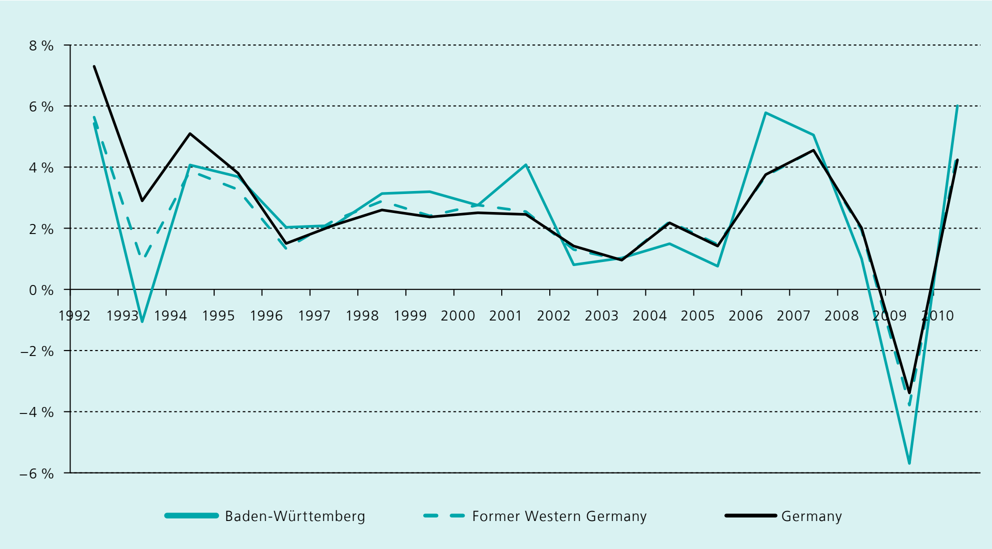
9.3 Baden-Württemberg: a "routinised" innovation system?

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.

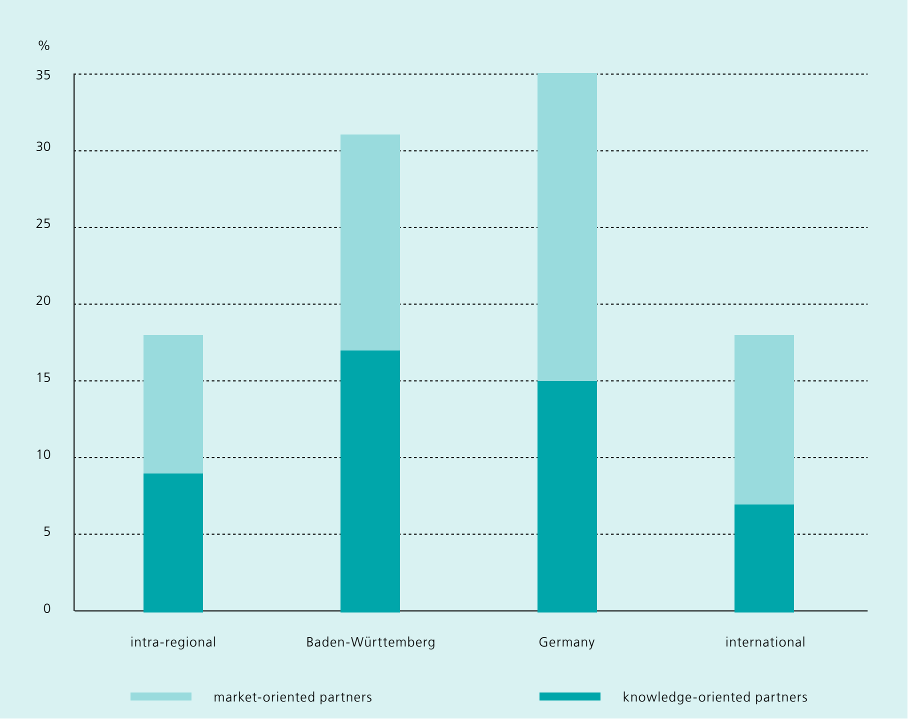
For the sake of clarity, answers for the different technology fields were aggregated and the results are displayed in Figure 9–2. The data show that regional enterprises do cooperate intra-regionally (within their own *Raumordnungsregion*), inter-regionally (with partners from Baden-Württemberg) as well 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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10

REGIONAL CLUSTERS AND DISRUPTIVE TECHNOLOGIES: THE EXAMPLE OF THE BADEN-WÜRTTEMBERG AUTOMOTIVE CLUSTER IN TRANSITION TOWARDS E-MOBILITY

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10.1 Introduction and objective of the contribution

Due to their orientation towards new propulsion technologies, the automotive industry is currently going through a phase of technological and economic realignment. Hybrid and electric engines, mobile fuel cells, new generations of batteries for mobile power trains, etc. are believed to replace conventional engine technologies in the medium to long run. Within this context, regions that are strongly dependent on the automotive industry are currently confronted with major shifts and reconfigurations within and beyond their respective value chains. Especially for these kinds of regions the shift from one technological generation to the next and related consequences caused by major disruptions in the industry vis-à-vis the established structures and the whole regional economy appears to be exceedingly relevant.

Based on the cluster concept as well as the concept of technological life cycles and the implicit hypothesis that sector-specific knowledge and technologies, specific market relations, actors' behaviours, and the institutional context are significantly influencing the development and dynamic of a cluster, the aim of this contribution is to analyse the effects caused by a technological shift related to new propulsion technologies in the automotive cluster of Baden-Württemberg as one of the most competitive automotive regions worldwide. The analysis of recent innovation activities, technological developments and shifts within the regional value chains in a strongly integrated and stable automotive cluster will be of special interest. Regarding the theoretical approach, the integration of the cluster concept and theories of technological life cycles will form the overall theoretical background of the chapter. Until now, only a small number of scientific publications have analysed the consequences for established clusters affected by technological discontinuities.

In contrast to the regional innovation system concept, the cluster approach has been chosen in this contribution because factors like value chains (incl. their shift in specific industries), inter-organisational networks and the question of life cycles of technologies and industries can be better operated by the cluster concept than by the regional innovation system approach putting much more emphasis on the role of routines, cultures and institutions rather than economic aspects. This contribution is based on the assumption that the regional innovation system of Baden-Württemberg – as applied to many other regions as well – is integrated into strong but flexible institutions as well as inter-organisational networks within the process of value creation and production. Due to the economic importance of the automotive industry (as well as a few other strongly integrated industries of Baden-Württemberg), the cluster constitutes a significant "shaping factor" of the regional innovation system as a whole.

This contribution has been structured as follows: the section following the introduction presents the theoretical background consisting of two main parts. First of all, the main dimensions and systemic advantages of clusters are highlighted before the theories of cluster and technological life cycles are related to disruptive technologies in the second section. Based on the theoretical considerations, Section 10.2.3 presents the research hypotheses which will form the guidelines for the empirical part of the contribution to be highlighted in section three. This section begins with a brief description of the structural characteristics of the Baden-Württemberg automotive cluster and the introduction of the database used for the quantitative analysis. In line with the research hypotheses the following empirical sections focus on the inter-organisational relationships within the Baden-Württemberg automotive cluster and the innovation activities or the technological capability regarding e-mobility. The final section addresses the hypotheses and turns toward the research question whether the empirical results point to a decline or on the contrary, a renewal of the Baden-Württemberg automotive cluster.

10.2 Clusters facing disruption: theoretical background

10.2.1 Dimensions and systemic advantages of clusters

In parallel with Krugman's outstanding work on the integration of the spatial dimension into mainstream economic theory (Krugman 1995; 1991), streams of literature on regional innovation systems (Cooke 1992) and regional based industrial clusters (Porter 1990) emerged in the early 1990s dealing with the geographical dimension of economics. As in the literature on national innovation systems (Lundvall 1992; Nelson 1993), on specific technologies (Carlsson and Stankiewitz 1991) or on broader sectors (Breschi and Malerba 1997), technical change and its diffusion are regarded as core drivers of economic development and competitiveness. Particularly Porter's cluster concept and the regional innovation system approach underline the importance of the systemic character of technical innovation on the regional level. According to this rationale, the institutional set-up matters as well as the interaction among various innovation and technology related actors, such as companies, research institutes, universities, public and semi-public intermediaries, etc.

Rooted in a strategic management perspective, the core statement of the cluster concept is that competitiveness is ultimately generated in individual enterprises, but cannot be simply reduced to the sum and positioning of efficient single companies in the world economy. According to Porter (1990), the determinants of competitiveness are shaped by a complex system of factor conditions (production factors which are required to manufacture a certain product), enterprise characteristics (strategies, organizational structures), demand conditions and related and supporting branches ("related industries"). By emphasizing the interplay of these interdependent levels, Porter underlines that the competitiveness of companies is the result of a complex interaction and, in this sense, has an interactive, systemic character (Messner 1995). As pointed out above, the concept of regional innovation systems is strongly integrated into regional institutions and regional cultures (Heidenreich 2005), while the cluster concept puts an emphasis on production, value chains and inter-organizational networks. Although the two approaches feature various similarities, be it the accentuation of systemic aspects for instance or the coupling of different actors, the cluster concept is a much more economic and management oriented approach with a special emphasis on the competitiveness of industries – and on an aggregated level, regions and nations – and factors influencing competitiveness.

With regard to the latter aspects, according to Schamp (2002) the external economies of scale associated with agglomeration advantages in particular play an outstanding role in the development of regional clusters and local production systems. So above all, the low transactions costs resulting from the industrial, respectively sectoral specialization are of managerial relevance for enterprises in clusters:

- Due to the spatial concentration of enterprises and institutions of a value-added chain, efficient division of labour forms of collaboration can be established which lead to minimizing transaction costs.
- In this connection, information and knowledge are more easily, efficiently and rapidly exchanged in regional branch concentrations; an innovative "atmosphere" emerges, in which knowledge very rapidly diffuses via "spillover effects" (Saxenian 1994). For this reason the high-performing and most competitive clusters are simultaneously the most innovative: the circulation and adaptation (contextualization) of knowledge taking place via informal networks, market relations or the mobility of "personified" knowledge bearers leads to fast and permanent innovation and to increases in productivity.
- In the course of time a cluster-specific material and immaterial infrastructure develops, which is either jointly created by firms acting in the cluster or other actors (e.g. joint external interest group representation, establishment and operation of joint research institutions or plants, labs, technical infrastructures) or which is put in place as part of educational, research or innovation policy

activities (e.g. specialized research and development institutes, cluster-oriented education and training systems, cluster offices).
- Development of a highly qualified labour market which provides the knowledge and skills required by the cluster companies (Huber 2010). For firms a "critical mass" of specialized employees, competences and knowledge is advantageous – particularly with a view to supra-regional competition (Enright 2003).

The specific inter-organizational networks and value chains as an essential feature of branch or technology clusters are reflected in cluster advantages. Therefore, the question of the modes of the relationship between the actors who are organized in a cluster appears to be crucial, especially regarding the importance of such (institutionally stabilized) relationships for the diffusion of technologies in general and disruptive technologies in particular. Within this context, Tichy (1997; 2001) discusses the orientation of actor relationships and, on this basis, differentiates between network clusters, star clusters and pseudo-clusters. A similar typology was also developed by Markusen (1996), who categorizes clusters according to the dimension and function of companies as well as the interaction of the actors involved. Thus hub-and-spoke districts for instance are such spatial enterprise concentrations in which small firms group around several large enterprises. Satellite industrial platforms, on the other hand, are characterized by the external "control" of the cluster, i.e. the most important firms have their headquarters outside the region, respectively the cluster, and influence the cluster development only indirectly through several more or less autonomous firms or subsidiaries (production branches). Reinau and Dalum (2008) deal with the distribution of power within the cluster and put special emphasis on the role of multinational enterprises for the spatial structure of a cluster. For Provan and Kenis (2008) networks with one or only a few members "controlling" can be seen as the alternative to a central and collective self-organization of independent actors. Such leading network members are occasionally companies taking a dominant position within the vertical value chain due to their economic strengths (Sydow 1992; Sydow et al. 2011). While such power asymmetries accompanying the dominance of single companies result in knowledge, innovation and technology advantages of these companies (Hibbert et al. 2010), a strong dependency of the other network members on the lead companies arises. Within this frame, possible supplier relationships may intensify already existing dependencies (Jungwirth et al. 2011). A typical example for these kind of cluster and network relationships are industry clusters with large original equipment manufacturers (OEMs) and various regional suppliers on the different levels of the value chain, for instance in the automotive and aviation industry.

10.2.2 Clusters, technological life cycles and disruptive technologies

The transformation and change of sectors, industries and products has inspired the development of industry life cycle theory which explains technological change and its consequences for the industry structure and its life cycle from birth to maturity (Klepper 1996). Starting with the analysis of the early concentration of the American car manufacturing industry, authors like Abernathy (1978), Abernathy and Utterback

(1978) and Klepper (2002) established a theory that ever since has been widely applied in different industries and countries. The central element of the theory is the explanation of an industry emergence as a consequence of a technological opportunity which results in the entry of a large number of firms and a high number of product innovations (Klepper 1996). In the early stage of a new industry, interactions are co-operative rather than competitive which results in a process of collective learning (Anderson 1999). After the early stage of an industry, incremental innovations based on a dominant design increase before the rate of product innovations finally drops and technological uncertainty is lowered. In this particular phase, the rate of process innovations increases in line with an expansion of production (Utterback 1994). The transitional phase is characterised by minimizing costs in order to remain competitive. In the mature phase of an industry, the overall rate of innovations decreases with the products being more and more standardized and processes efficient (Dalum et al. 2005). With a view to innovation activities, especially small firms and new entrants are responsible for innovations in the early phase, while in the mature stage, large and established firms have a certain advantage in the innovation activity (Audretsch and Feldman 1996; Klepper 1996).

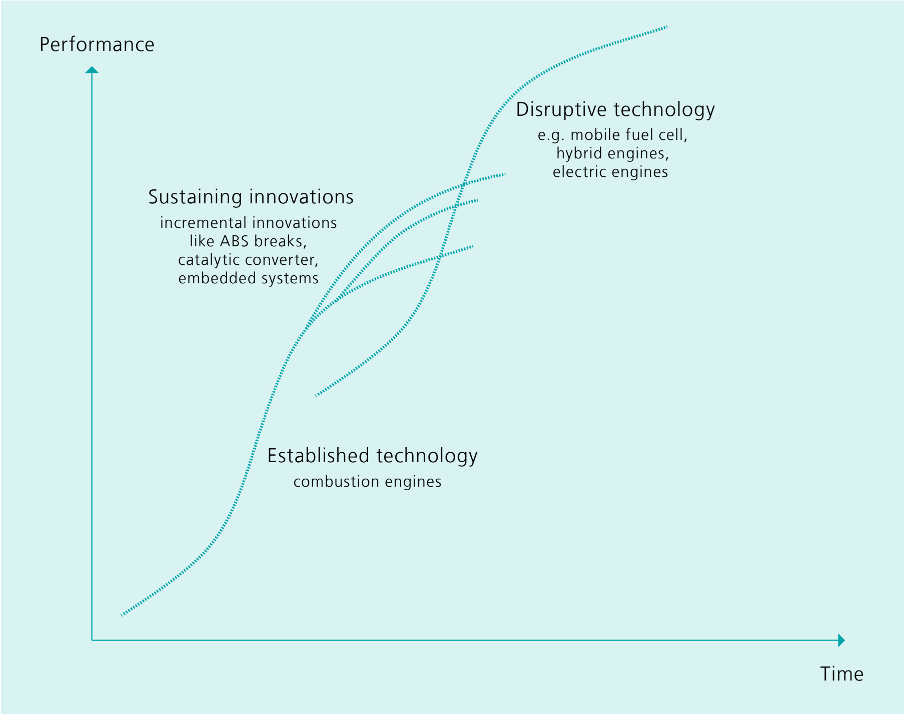
Translated into the cluster concept, it seems obvious that clusters follow the life cycle of their respective industry: Clusters begin to emerge as the industry grows which results in an increasing geographic concentration. Within the course of spin-off processes and dynamic growth rates of the clustered companies, a concentration process of the whole industry takes place. After the phase of strong growth, the industry becomes more dispersed resulting in companies moving to remote areas or closer to the intended markets. According to Pouder and St. John (1996), who analysed the development of clusters and their life cycles by applying an ecological approach, the emergence of clusters is characterised by above average growth rates of their industry compared to the rest of the industry due to a creative environment. In the course of the cluster development, the institutional and cognitive behaviour of the cluster actors are increasingly focused upon the previously successful trajectory. As cluster specific routines like networks, inter-organisational relationships, standards, cognitive and technological paths are "reproduced" over a certain period of time, former clustering advantages may turn into disadvantages. Thus, companies – and on an aggregate level, the whole cluster – may become locked into a structural, technological, cognitive and political (in the case of policy intervention) trajectory, that contributed to the success of the cluster in the past but that may be a hindering factor for its future development. Thus, Pouder and St. John (1996) conclude that the later stages of a cluster are distinguished by a decrease in innovative activity and competitiveness which results in a decline of the whole cluster.

However, Menzel and Fornahl (2009) underline that very few clusters follow a rigid life cycle, in terms of compulsive and succeeded phases from emergence to growth, to consolidation, to decline. Various examples, like the industrial districts of the Third Italy or Silicon Valley, facing a decline of the semiconductor industry in the 1980s (Grabher and Stark 1997; Saxenian 1990), indicate that an increase of the diversity of a cluster and also a variety of organizational forms may result in adjustments to external changes or even to a renewal of a cluster. Within this context, Menzel and Fornahl (2009) distinguish between small and large clusters and point to the ratio of diversity to size. They argue that the ability of a cluster and its companies for renewal very much depends on the heterogeneity of the accessible knowledge and ultimately on the heterogeneity of the companies' competencies inherent in the cluster. In line with the different phases of the cluster life cycle, the heterogeneity particularly increases in the early phase (when the size of the cluster is small and every new company is focussing on a new technological area) and decreases in the later phase when the cluster has matured and a clear technological trajectory has been institutionalised. Capacity for a cluster renewal however is limited when the technological and knowledge profile is too narrow; and the cluster declines (Menzel and Fornahl 2009). A new growth stage can be reached when the cluster increases its heterogeneity again, for instance by integrating new knowledge or more generally, by adapting to a changing environment. The adoption of new (leading-edge) technologies beyond the established technologies in a region can be seen as a more radical mode, be it through companies from outside the cluster (via their subsidiaries), new entrants (start-ups, spin-offs) or through incumbents. Accordingly, Dalum et al. (2005, p. 231) come to the conclusion that "[…] radical technological change may cause disruptions for existing clusters as well as form the foundation for the emergence of new ones."

With regard to the evolution of technology, industry and products, Utterback (1994) developed an S-curve model in which the different technological paradigms, in terms of established technologies, sustaining innovations and disruptive technologies are illustrated according to their technological performance, market penetration and time. Figure 10–1 shows the theoretical shift from combustion engines technologies – as an example of an established technology in the automotive industry – to disruptive technologies, like mobile fuel cells, hybrid engines or electric engines. However, the shift from one technological life cycle to the next may be prolonged by sustaining innovations (Dalum et al. 2005), which are rather (but not necessarily) incremental. Regarding the automotive industry such sustaining innovations may be ABS breaks for instance, catalytic converters or ICT based (embedded) systems.

However, the S-curve model should not be understood as a mandatory technological evolution path. Dalum et al. (2005, p. 232) emphasise that "many potentially disruptive technologies will not win or outperform the old technology due to technological lock-in, de facto standards, sustaining innovations, timing and so forth". Thus, with regard to the aforementioned example of the automotive industry and a possible shift to new propulsion technologies, one to the many scenarios discussed how the technological shift will eventually take place is a gradual shift over a period of 15–20 years rather than it being short term. For Tushman and Anderson (1986) technological disruptions can be either product or process disruption. The emergence of new product classes, product substitution or fundamental product improvements can be categorized as product disruptions, while a process substitution relates to a process disruption. The replacement of automobiles with combustion engines through new

Figure 10–1: S-curves for established and disruptive technologies in the automotive industry



Source: adapted on the basis of Dalum et al. (2005)

propulsion technologies for instance would be product substitution (which eventually results in disruptive process substitutions). With a view to technological evolution, Tushman and Anderson (1986) differentiate between technological breakthroughs that either enhance or destroy the competence of firms in an industry (and ultimately of the cluster). The rationale of the two authors is that "competence-destroying discontinuities" – in terms of technological breakthroughs – are primarily initiated by new firms (or outsiders) which results in increased turbulences of clusters, networks, markets and institutions (environmental turbulence). Competence-enhancing discontinuities on the other hand primarily come from the industry leaders or at least existing firms which result in decreased environmental turbulence. Therefore, a new technological life cycle may offer various opportunities for existing clusters and their renewal or new clusters establishing a new technological path.

10.2.3 Research guiding hypotheses

Over the last 20 years, research on clusters and cluster theory has generated manifold insights into clusters as an economic phenomenon, the functionality of clusters, methods on how to identify clusters and their dynamics as well as policies to establish or support clusters. By focusing on the competitiveness of cluster companies and ultimately whole regions or nations featuring clusters, cluster theory highlights so-called systemic advantages in terms of the interplay between different and heterogeneous organisations. Thus, the cluster concept puts emphasis on regional "embedded" value chains and inter-organisational networks as main drivers of innovation and competitiveness. With a view to the distribution of power within clusters, theory puts special emphasis on the role of large (multinational) companies and leading network members taking dominant positions within vertical value chains due to their economic and technological strengths. Respective power asymmetries within clusters effect inter-organisational relationships, either in terms of an intensification or weakening of existing dependencies. Regarding the impact of disruptive technologies for established cluster-relationships, the first research guiding hypothesis can be formulated as follows:

Hypothesis 1: Inter-organisational relationships in automotive clusters between large companies (OEMs) and first tier suppliers are functional in the case of disruptive technologies.

The literature on technological evolution accentuates that technological change is a cumulative process until it is disrupted by a major advance. Such technological discontinuities offer improvements over existing technologies – occasionally expressed in a better price-quality performance. The major technological shifts can be classified as either competence-destroying or competence-enhancing with respective consequences for existing clusters, networks, inter-organisational relationships, qualification requirements. With regard to the existing cluster firms, technological shifts can thus destroy or enhance their technological, sales and labour related competencies. Transferred to the case of new propulsion technologies and their impact on established automotive clusters, technological breakthroughs are primarily initiated by new firms (entrants), whereas competence-enhancing discontinuities come from the industry leaders or at least existing firms (incumbents) resulting in a lesser cluster turbulence compared to disruptions carried by cluster entrants. Against this background, a second research hypothesis can be derived:

Hypothesis 2: Clusters in transition to e-mobility are primarily disrupted by competence-destroying technological breakthroughs initiated by new firms rather than by industry leaders within the cluster itself.

The final research hypothesis focuses on the question whether e-mobility related technologies offer the potential to renew a cluster in a mature industry or technological field and establish a new cluster life cycle. For a region like Baden-Württemberg dominated by the automotive industry, the future of this particular branch is certainly a matter of concern. Within this frame, theory suggests that the adoption of new leading-edge technologies beyond the established technologies in a region can be regarded as a quite radical mode – pretty much in line with the term "disruption".

However, a "softer" technological shift occurs when competencies are enhanced and a potentially disruptive technology does not outperform the mature technology due to sustaining innovations or standards set by the regional industry leaders. Thus, the shift from one technological life cycle to the next or a cluster renewal may be prolonged. The third hypothesis circumscribes these interrelations as follows:

Hypothesis 3: Technologies with the potential to disrupt established structures or mature technologies in a cluster do not necessarily result in a new cluster life cycle when sustaining innovations prolong the current life cycle.

After the elaboration of the research guiding hypotheses, the following section presents the empirical results focussing on the automotive cluster of Baden-Württemberg with its recent technological shifts. The hypotheses will form the guideline of this section and will be addressed again in the conclusion.

10.3 The Baden-Württemberg automotive cluster in transition to e-mobility

10.3.1 Structural characteristics of the automotive cluster in Baden-Württemberg

With a GDP per capita amounting to 29 % above the European average in 2008, Baden-Württemberg clearly ranks among the most competitive, high-income regions in Europe (cf. Chapter 9 in this volume). A key characteristic of the regional economy is the comparatively great importance of the manufacturing sector, with a share of 36.1 % value added of Baden-Württemberg (8 % above the German level) (Statistisches Landesamt Baden-Württemberg 2010). Within the manufacturing sector the automotive industry, electrical and mechanical engineering are the three most important industries in Baden-Württemberg accounting for roughly 16 % of the total employment of 3.89 mill. (2008). The automotive industry in 2008 employed 189,500 persons which equates to 4.9 % of Baden-Württemberg's total employment.

As for the automotive supplier, the official statistics comprises 74,000 employees and 240 enterprises for the NACE category 34.3 (manufacture of parts and accessories for motor vehicles and engines), which means that 25.6 % of the employees of the automotive supplier industry of Germany are occupied in Baden-Württemberg (cf. Table 10–1). However, despite the significance of the automotive supplier industry as shown in the official statistics, the number of enterprises and employees tend to be underestimated. The NACE category 34.3 represents the automotive supplier only partially. Manufacturers of rubber tyres or technical plastics for instance are grouped in NACE group 25 "Manufacture of rubber and plastic products", the suppliers of aluminium alloy in NACE group 28 "Manufacture of fabricated metal products" or suppliers of batteries and headlamps in NACE group 31 "Manufacture of electrical machinery and apparatus". Therefore, the automotive suppliers industry is not adequately included in NACE group 34.3, neither in Baden-Württemberg nor in Germany as a whole. For this reason, Table 10–1 also contains extrapolated data including suppliers from other NACE categories: according to Kinkel and Zanker (2007) roughly 13 % of the employees in the chemical industry, 20 % in the rubber and plastic products industry and 32 % of the employees in the metal producing industry have to be included in the group of the automotive suppliers. The authors come to the conclusion that the values in the official statistics for the NACE group 34.3 must be multiplied by the factor 2.5 in order to realistically assess the total significance of the automotive suppliers industry. Hence, the automotive suppliers industry of Baden-Württemberg includes approx. 600 enterprises with 185,000 employees.

Table 10–1: Number of enterprises and employees in the automotive suppliers industry

	Automotive suppliers	
	Number of enterprises 2009	**Number of employees 2009**
Germany (official statistics NACE 34.3)	924	289,000
Germany (extrapolation including suppliers from other NACE categories)	ca. 2,250	ca. 700,000
Baden-Württemberg (official statistics NACE 34.3)	240	74,000
Baden-Württemberg (extrapolation including suppliers from other NACE categories)	ca. 600	ca. 185,000

Source: Statistisches Bundesamt (2010); Statistisches Landesamt Baden-Württemberg (2010); Kinkel and Zanker (2007)

In line with the size of the Baden-Württemberg automotive industry as a whole (OEMs and suppliers), the inter-organisational relationships between the companies on the different hierarchical levels and between companies and regional research institutes are particularly distinctive. According to Cooke (2001), the regional firms maintain various vertical and horizontal, market and non-market, trustful and sceptical relations with each other. For Krauss and Stahlecker (2003) incremental innovations in experience-based and institutionally stabilized paths are a central feature of the regional innovation system as a whole, which also applies to the automotive industry. The Baden-Württemberg automotive industry can be described as a production oriented cluster within the regional innovation system in which large OEMs are being integrated with significant suppliers and advance products and services input. In terms of a typology, the cluster can be categorized as a hub-and-spoke district where mostly small and medium-sized companies are grouped around a few large (multinational) companies. The latter may be large OEMs like Daimler and Porsche or first tier suppliers like Bosch, Mahle, Behr, Eberspächer or ZF Friedrichshafen. Bosch for instance ranks at the top of the 100 largest automotive suppliers worldwide. Mahle and Behr rank among the top 50, Eberspächer follows in position 65 (Dispan et al. 2009).

Database

The empirical part of this contribution is based on a written survey among automotive suppliers in Baden-Württemberg carried out by Fraunhofer ISI in cooperation with the chamber of industry and commerce Stuttgart (IHK Region Stuttgart) in the autumn of 2010. The main objective of the survey was the compilation and analysis of current data on the significance of new propulsion technologies for the future competitiveness of the companies in question. In total 97 automotive suppliers participated in the survey, among them 64 % with a share in turnover of 50 % and more with OEMs or other automotive suppliers, 27 % with a share in turnover of 20 % to 50 % and 9 % with a share of less than 20 %.

In addition to the written survey, an analysis of patent filings in the fields of new propulsion technologies in Baden-Württemberg and different countries (like Japan, USA, Korea, China, France and Italy) has been carried out in order to gain references on the technological capability and possible innovation activities in the relevant fields. In the course of the patent analysis, the following technological fields were considered: combustion engines, hybrid engines, electric motors, mobile fuel cells, and batteries for e-mobility. The patent filings at the German Patent and Trade Mark Office (DPMA), European Patent Office, and PCT-Filings (based on the Patent Cooperation Treaty) have been extracted using the PATSTAT database (EPO World Wide Patent Statistical Database). The compilation of the filings was done for the priority years 1998–2007.

10.3.2 Inter-organisational relationships within the cluster

As pointed out in the theoretical part of this contribution, the horizontal and vertical integration of companies in related and supporting industry are considered as critical for their competitiveness. The competitiveness of companies in these clusters originates on the basis of inter-organisational relationships between companies or between companies and regional institutions supporting the renewal or innovation efforts. One of the main drivers of these kinds of specialized factors which are typical for the creation of cluster advantages is the increasing complexity of innovations processes as well as technological risks, particularly regarding paradigmatic new technological fields like new propulsion technologies. Therefore, innovation processes and technological development are more and more based on a division of labour which may be formally (primarily market based) or informally arranged.

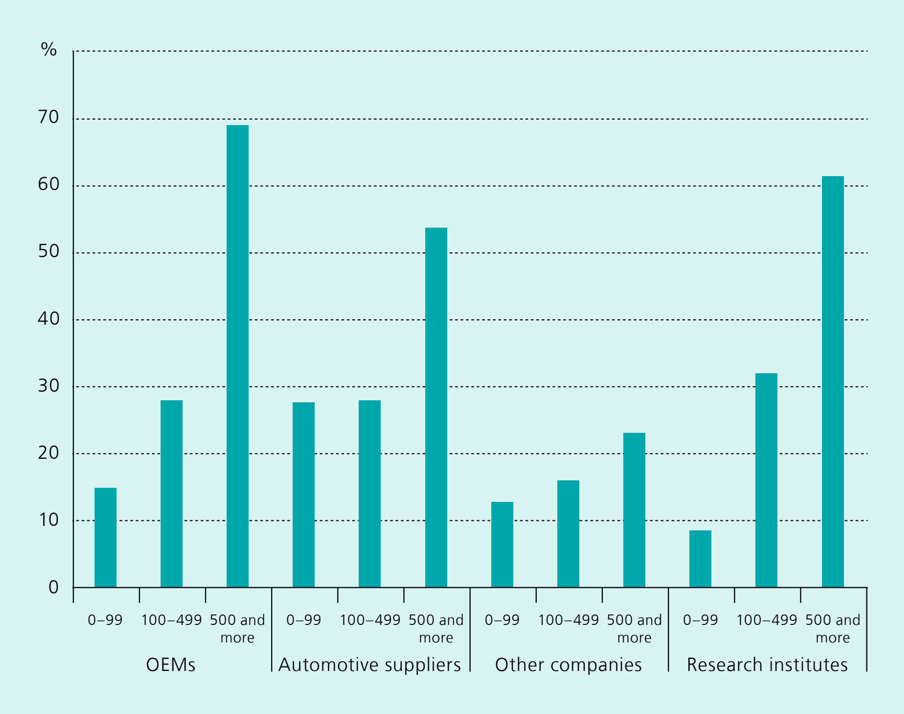
The field of new propulsion technologies is not an exception and may be understood as a technological field featuring various technological risks and uncertainties in terms of the diffusion into the markets. Due to the broad impact of a possible shift towards technologies like hybrid and electrical engines, batteries for electrical vehicles or fuel cells on the established companies and the whole automotive cluster, the respective technologies and innovations are clearly disruptive. Within this context, the data indicate that almost all automotive suppliers in the sample are cooperating in one way or another with external partners to generate innovations. In the first instance, the most important partners are other automotive suppliers, be it in the form of joint research and development activities or customer-suppliers relationships. The second most important partners in the innovation process related to new propulsion technologies are OEMs which make up 27 % of all entries. Research institutes followed with 23.5 % of all entries in third place and other companies with 15.3 % in fourth place.

When differentiating according to the size of the suppliers in the sample, a slightly different picture emerges compared to the entries of all companies (cf. Figure 10–2). From all possible partners in the innovation process, OEMs gained most of the entries from automotive suppliers with more than 500 employees. The smaller the companies are, the less relevant OEMs are as cooperation partners for new propulsion technologies. The same applies to other automotive suppliers in terms of horizontal cooperation activities (e.g. between the first tier suppliers) or vertical cooperation, for instance between first and second tier suppliers: 54 % of the entries for other suppliers come from suppliers with more than 500 employees. As for research institutes, large suppliers are the dominant group of cooperation partners as well. More than 60 % of the entries originate from large suppliers, in contrast to merely 9 % from suppliers with up to 99 employees.

As a result of this analysis, it can be stated that notably large automotive suppliers are inter-organisationally linked to external partners in the innovation process related to new propulsion technologies. Meanwhile, smaller companies which are often second and third tier suppliers are to a minor degree organisationally tied to external partners. Respective entries are significantly lower. With a view to the whole automotive cluster, the quantitatively dominant group of SMEs are obviously quite reluctant in establishing or maintaining inter-organisational relationships in the case of innovation activities in new propulsion technologies. Strong ties in the Baden-Württemberg automotive cluster seem to be primarily established among the large OEMs and (first tier) suppliers, whereas the large group of SMEs merely reacts to new technological developments rather than pushing them on. Within the cluster hierarchy, these companies found themselves strongly dependent on the large OEMs and other large suppliers. For SMEs this dependency comprises a much larger risk of investing in R&D and innovation activities compared to the large companies (and without knowing the technological standards of the future).

On the level of single companies and clusters as a whole, the generation of knowledge and information on technologies, innovations and markets, especially in the case of paradigmatic shifts towards completely new technologies and radical innovations, is certainly crucial for the competitiveness of cluster companies and the renewal of the cluster. Important knowledge sources can be clients, in terms of specific technological needs, innovation activities, new standards, etc. other companies or competitors, research institutes, working groups or journals/reports on specific technologies.

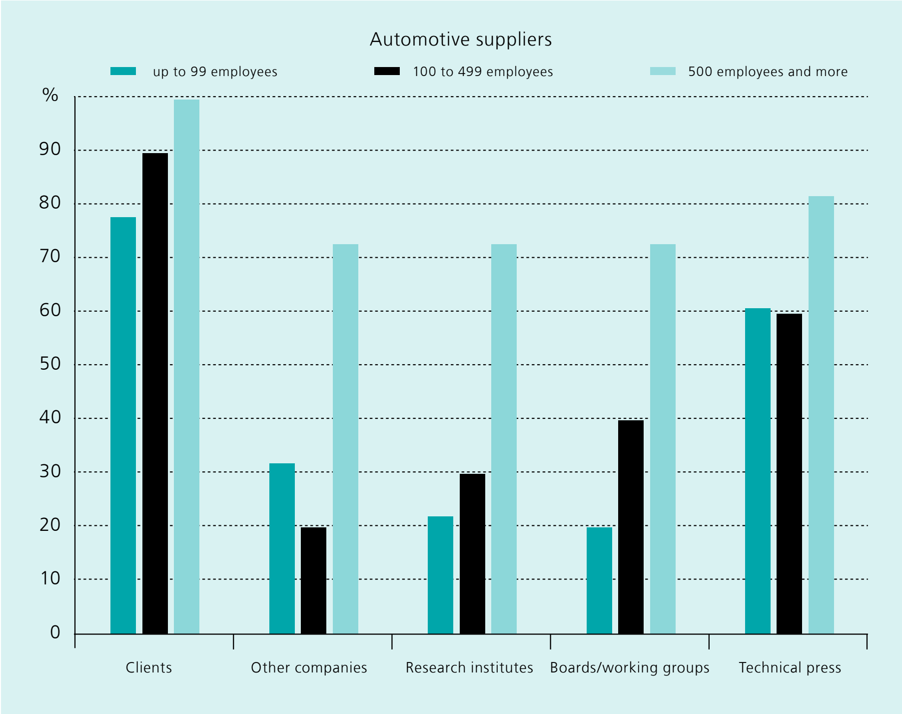
Figure 10–2: Cooperation partners of automotive suppliers within the propulsion technology related innovation process according to company size of suppliers (share of suppliers per size group on all entries per cooperation partner)



Source: Fraunhofer ISI survey 2010

Against this background, the automotive suppliers in our sample were asked which knowledge sources are used within the context of pursuing current trends and developments on new propulsion technologies. In contrast to inconsiderable differences between the various knowledge sources according to the degree of dependence upon the automotive industry (as measured as a share of total turnover with OEMs and other suppliers), the size of the supplier is obviously more relevant. As can be seen in Figure 10–3, at least three quarters of the suppliers make use of the whole range of possible knowledge and information sources, whereas small suppliers solely rely upon clients (78 %) and the technical press (61 %). For the large automotive suppliers research institutes as knowledge sources are significantly more important than for smaller companies: 73 % of companies with 500 and more employees consider research institutes as important knowledge sources compared to 22 % of suppliers with up to 99 employees. In conclusion, it can be validated that research-based knowledge and information is primarily perceived and processed by large automotive suppliers. Compared to the analysis further above, a similar pattern as regards inter-organisational

Figure 10–3: Knowledge/information sources of automotive suppliers pursuing current trends on new propulsion technologies according to company size



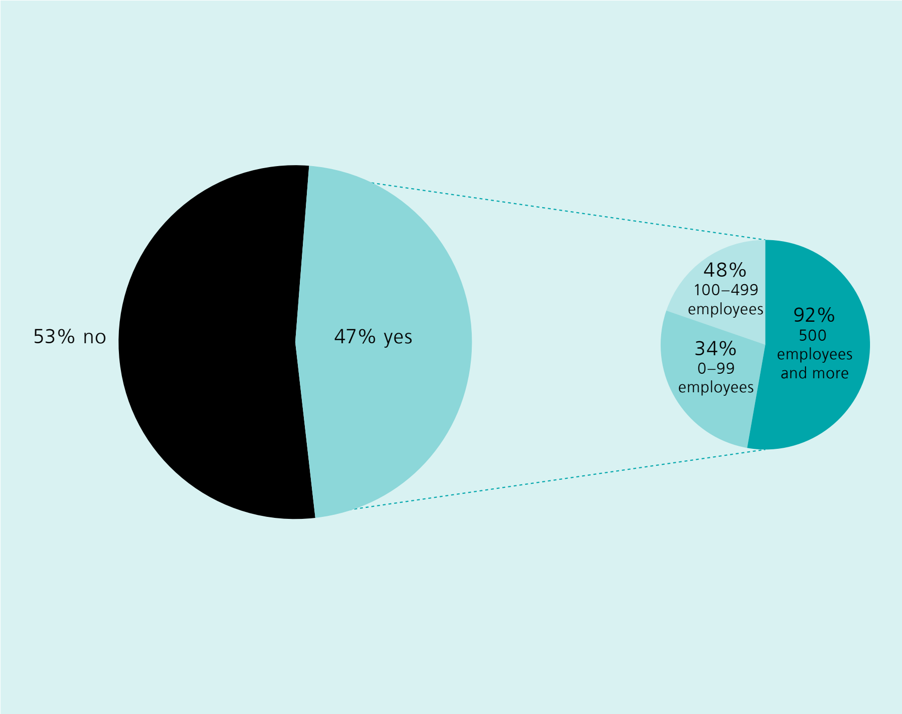
Source: Fraunhofer ISI survey 2010

relationships – both in terms of cooperation partners and with a view to knowledge sources – can be observed.

10.3.3 Innovation activities and technological capability regarding e-mobility

With a view to the Baden-Württemberg automotive cluster in transition to e-mobility, innovation activities as well as technological developments in the relevant fields are key drivers for the cluster dynamics and shifts within the regional value chain. New technologies for instance in battery technologies (on the basis of scientific breakthroughs in electrical chemistry), automotive lightweight construction (on the basis of new and advanced materials) or with regard to hybrid and electrical engines constitute the basis for disruptive innovations in the automotive industry. Against this background the companies were asked about the importance of innovation activities related to new propulsion technologies. Among the 97 suppliers in the sample, less than 50 % are engaged in innovation activities directly related to fields like hybrid engines, electrical engines, power trains, gear boxes, power electronics, air conditioning, etc. – be it in the form of systems, components or component parts (cf.

Figure 10–4: Importance of innovation activities related to new propulsion technologies according to company size



Source: Fraunhofer ISI survey 2010

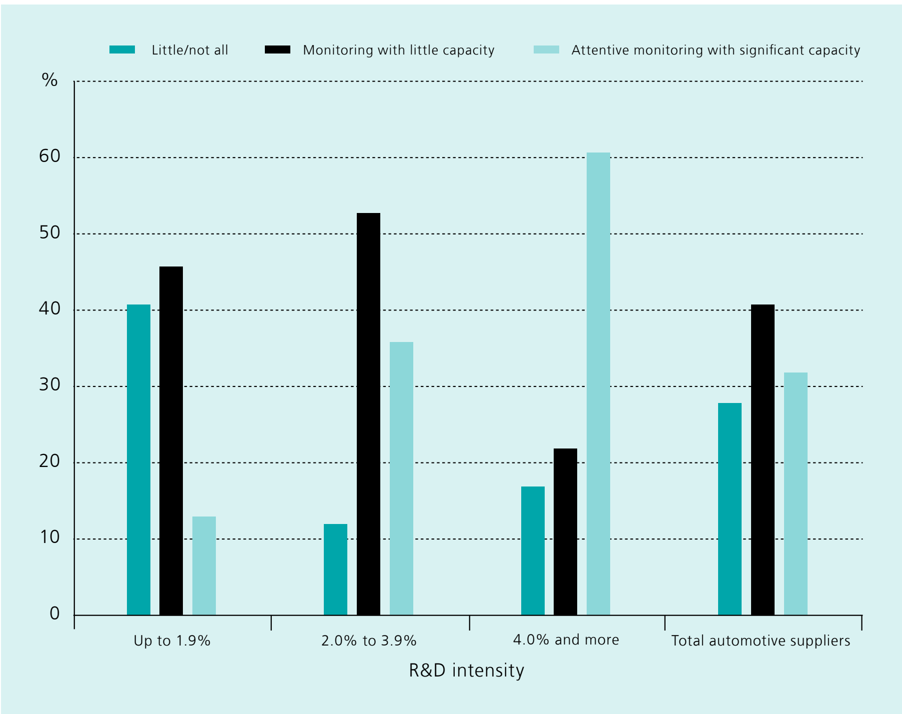
Figure 10–4). For a marginal majority of 53 % innovation activities in these fields are currently not important, a clear indication for the ambiguity regarding the shift towards e-mobility among the companies or the automotive cluster of Baden-Württemberg as a whole.

When differentiating according to company size, it can be observed that especially large suppliers with 500 employees and more are far more engaged in innovation activities than small and medium-sized companies. A considerable share of 92 % of the large companies indicated the development of new products in terms of single components, components or systems for new propulsion technologies. In contrast, only 34 % of the small companies and 48 % of the medium-sized companies are carrying out innovation activities related to new propulsion technologies.

Taking a look at the relevance of new propulsion technologies according to R&D activities of the companies in the sample, Figure 10–5 indicates that a high R&D intensity (measures as R&D investment as a share of turnover) correlates with an attentive monitoring of the relevance of new technologies for the own company. From the suppliers with an R&D intensity of at least 4 %, roughly 61 % stated that the relevance of new propulsion technologies for the own company is monitored with significant capacity. These are clearly the leading companies within the cluster both in terms of R&D activities and technological capability. They also claim to be at the technological frontier from a global point of view. Thus, disruptive technologies and innovations are to a considerable extent brought forward by large and R&D oriented companies from within the cluster itself. Furthermore, it can be assumed that the strategic orientation of this group of companies aims at first-mover advantages gained by a significant occupation of a market segment. Meanwhile, less R&D oriented firms (R&D intensity up to 1.9 %) are much more reluctant in internally examining the relevance of these technologies for the competitiveness of the own company. However, within the group of medium R&D oriented suppliers, 53 % of the companies allocate at least little capacity to pursue the development and diffusion of new propulsion technologies. As a preliminary conclusion it can be stated that especially large first tier suppliers with above average R&D orientation and a strong dependency upon the automotive industry attentively reflect questions concerning new propulsion technologies and the strategic approach.

As indicated further above, an analysis of patent filings in the fields of new propulsion technologies in Baden-Württemberg and different countries has been carried out

Figure 10–5: Relevance of new propulsion technologies for own company (Baden-Württemberg automotive suppliers) according to R&D intensity



Source: Fraunhofer ISI survey 2010

in order to assess the technological capability in technology fields like combustion engines, hybrid engines, electric motors, mobile fuel cells, and batteries for e-mobility. In addition to the results of the written survey, the analysis of patent filings has the advantage of allowing the description in which fields technological development has been considered as strategically important for companies (and also public institutions). Despite a time lag due to the delay in the publication of the filings, a patent analysis also allows for a comparison of the technological capability of different countries and regions.

Regarding the position of Baden-Württemberg within the international technological competition, first of all patent filings at the European Patent Office have been analysed for the "traditional" combustion engines in order to have a reference for the new propulsion technologies. Table 10–2 indicates that for Baden-Württemberg (analogous to Germany as a whole) filings in the field of combustion engines decreased between 2001 and 2007 from 24 % to 17 % of all filings in this field at the EPO. In absolute figures, Baden-Württemberg filings decreased from 578 to 305 in 2007 (Germany from 842 filings to 512). Japan and France meanwhile were able to increase the shares of their filings in combustion engine technologies from 28 % to 32 % (Japan) and from 4 % to 8 % (France). Taking into consideration both the absolute numbers as well as the respective shares, it can be concluded that despite a rather dynamic development in new propulsion technology fields[1], the filings in traditional combustion engines (and the related R&D investments) still indicate a certain importance in this technological path, especially for Germany, Baden-Württemberg, Japan and the US.

Table 10–2: EPA Patent filings of Baden-Württemberg in the field of combustion engines compared to other countries (shares as % of all filings in the field at the EPO)

	DE	Share of BW in DE	Share of BW in total	US	JP	KR	FR	IT
2001	36	65	24	19	28	0	4	3
2002	37	69	26	16	30	0	4	3
2003	36	59	21	18	29	0	5	3
2004	31	55	17	17	34	0	7	5
2005	29	54	16	16	35	0	7	4
2006	28	61	17	16	33	0	8	4
2007	28	60	17	15	32	0	8	4

Source: Patstat

1 As a reference, Baden-Württemberg in 2007 filed 43 patents in the field hybrid engines and 144 in electrical engines – compared to 305 in combustion engines.

Taking a closer look at the top patent applicants among the Baden-Württemberg automotive suppliers, Table 10–3 indicates that large companies like Bosch (although an automotive supplier, the company is active in many technological fields, from propulsion technologies, to IT technologies, to energy and environmental technologies), ZF Friedrichshafen, Behr and Eberspächer clearly dominate the technological priorities of Baden-Württemberg with large shares of the whole regional patent portfolio. Among the top applicants, no new entrants in terms of potential technological disrupters can be found.

Regarding the technological leaders in new propulsion technologies, the main trend is about the same compared to all patents filed by the automotive suppliers of Baden-Württemberg: Incumbents like Bosch, ZF Friedrichshafen, Behr, Eberspächer and among the OEMs, Daimler are obviously the leading cluster companies which actively focus on technological breakthroughs while at the same time trying to enhance their competencies (cf. Table 10–4). New companies as potential competence-destroyers currently play no significant role. Nevertheless, despite a certain pioneering role of the established companies in the fields of new propulsion technologies, the aggregated data point to the fact that traditional combustion engine technologies, which also include established relationships between the OEMs and their suppliers, still dominate the cluster routines and its technological and institutional path. As a first conclusion it can be noted that particularly leading network and cluster members – both suppliers and OEMs – actively address the challenges concerning the technological shift towards new propulsion technologies.

Although Baden-Württemberg appears to be quite strong in the technological development of electric motors and hybrid engines (the numbers are comparatively high), a different picture emerges when referring to the field of combustion engines as a reference value. The following Table 10–5 shows the EPO-filings for single technology fields in country comparison (2007). It can be observed that the shares of Baden-Württemberg – on the basis of the reference value for combustion engines (17 %) – are significantly weaker for all technology fields related to new propulsion technologies. Countries like Japan, the US and France show a much better balance between patent filings in traditional combustion engines and new propulsion technologies. As regards hybrid engines for instance, 32 % of all EPO-filings in this field come from Japanese and 36 % from US companies. Baden-Württemberg meanwhile makes a contribution of only 11 %, albeit the filings in combustion engines are higher than of the US, France or Italy.

Concerning the development of the filings in new propulsion technology related fields since 2001 for Baden-Württemberg, no trend can be observed in terms of a significant increase of the shares. This stagnation is confronted with a development in Japan for instance where the filings in mobile fuel cells could be increased from a share of less than 30 % to just under 50 %. The same applies to the US for the filings in hybrid engines: whereas a stagnation of Baden-Württemberg in the period 2001–2007 of about 10 % of all filings can be observed, the US could expand its share from 15 % to 36 %.

Table 10–3: Top patent applicants among Baden-Württemberg automotive suppliers (2006)

Bosch GmbH	**1,068**
ZF Friedrichshafen AG	203
Behr GmbH & Co. KG	113
J. Eberspächer GmbH & Co. KG	54
Mahle International GmbH	47
SICK AG	42
ATMEL Germany GmbH	29
ZF-Lenksysteme GmbH	26
Baden-Württemberg total (automotive suppliers)	1,847

Source: Patstat

Table 10–4: Top patent applicants among Baden-Württemberg automotive suppliers and OEMs with regard to new propulsion technologies (2006)

	Hybrid engines	Electric motors	Mobile fuel cell	Batteries for e-mobility	Com-bustion engines
Bosch GmbH	25	41		5	173
ZF Friedrichshafen AG	7				
Behr GmbH & Co. KG			5	2	14
J. Eberspächer GmbH & Co. KG			6		
ebm-papst GmbH & Co. KG		7			
Daimler AG	1		4	1	11
Mahle GmbH					24
MANN + HUMMEL GMbH					22
Porsche AG					14
Baden-Württemberg total (automotive suppliers + OEMs)	46	82	26	13	306

Source: Patstat

Table 10–5: Shares of the countries' patent filings on all filings in different technology fields in % (2007)

	DE	BW	US	JP	KR	FR	IT	CN
Combustion engines	28	17	13	36	0	8	4	0
Hybrid engines	16	11	36	32	0	7	1	1
Electric motors	28	14	13	33	2	7	2	0
Mobile fuel cell	15	3	11	48	7	6	2	0
Batteries for e-mobility	11	5	17	42	12	5	1	3

Source: Patstat

10.4 Decline or renewal of the Baden-Württemberg automotive cluster?

The contribution's main aim was to analyse the effects caused by new propulsion technologies or a shift towards e-mobility as a potential disruptive technology on the automotive cluster of Baden-Württemberg as one of the most competitive automotive based industrial regions worldwide. The cluster approach has been chosen as the appropriate "theory" as the question on how to sustain competitiveness in an industry often described as "mature" can best be addressed by discussing technological and industry life cycles and related consequences for regional value chains and the overall regional development.

The overall research question reads whether the recent innovation activities and technological priorities can be regarded as either an indicator for the renewal of the cluster or a decline or even the end of the technological and cluster life cycle. From a theoretical perspective, the integration of the cluster concept and theories of technological life cycles formed the overall background of the contribution. Three inter-related research hypotheses constituted the research agenda which structured the following sections.

First of all, the role of large automotive manufacturers (OEMs) in the cluster and their counterparts on the supplier side were analysed against the background that industrial leaders in a cluster and their relationships are critical when it comes to technological shifts or a possible hindrance of innovations and disruptions caused by new entrants. Regarding hypothesis one, empirical evidence indicates that notably large automotive suppliers are inter-organisationally linked to external partners (regional OEMs and other large suppliers) in the innovation process related to new propulsion technologies. On the other hand, a large group of SMEs merely reacts to new technological developments rather than pushing them on. Within the cluster hierarchy, these companies found themselves in a strong dependency on the large OEMs and other large suppliers. Given the fact that particularly large suppliers like Bosch, ZF Friedrichshafen, Behr and Eberspächer are clearly the technological leaders in the cluster, inter-organisational relationships between large companies (OEMs) and first tier suppliers are indeed functional in the case of disruptive technologies. *Hypothesis one* can therefore be not be rejected.

Second, the empirical analysis proved the importance of the incumbents when it comes to paradigmatic technological shifts within the cluster or potential technological disruptions. The aforementioned companies plus important OEMs like Daimler and Porsche actively focus on technological breakthroughs as regards new propulsion technologies and related breakthrough innovations while at the same time trying to enhance their competencies. New companies as potential competence-destroyers currently play no significant role in the cluster. Thus, particularly leading network and cluster members – both suppliers and OEMs – currently actively tackle the challenges concerning the technological shift towards new propulsion technologies. Therefore, the *second hypothesis* emphasising that clusters in transition to e-mobility are primarily disrupted by competence-destroying technological breakthroughs initiated by new firms rather than by industry leaders within the cluster itself has to be rejected.

Third, despite a certain pioneering role of the established companies in the fields of new propulsion technologies, the data point to the fact that traditional combustion engine technologies still dominate the cluster routines and its technological and institutional path. Less than 50 % of the automotive suppliers in the cluster are currently engaged in innovation activities directly related to fields like hybrid engines, electrical engines, mobile fuel cells, batteries for e-mobility, etc., be it in the form of systems, components or component parts. For the majority of the remaining 53 % innovation activities in these fields are currently not important, a clear indication for the ambiguity regarding the shift towards e-mobility among the cluster companies or the automotive cluster of Baden-Württemberg as a whole. With a view to the third hypothesis, the leading cluster companies and their immediate dependant suppliers are obviously pursuing a strategy of risk diversification in terms of actively tackling the challenges regarding new technologies and at the same time holding on to the “mature” technologies (primarily in connection with “traditional” combustion engines) which currently still account for a large part of the companies’ business. Hence, the empirical investigation found strong evidence that the new propulsion technologies with the potential to disrupt the established structures or mature technologies in the Baden-Württemberg automotive cluster are currently not resulting in a new cluster life cycle. Sustaining and incremental innovations along the established technological path are prolonging the current life cycle of the cluster. Thus, one can currently neither speak of a cluster decline nor of a completely new cluster life cycle rather than of an incremental renewal. *Hypothesis three* can therefore not be rejected.

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11

CHALLENGE-ORIENTED POLICY-MAKING AND INNOVATION SYSTEMS THEORY:

RECONSIDERING SYSTEMIC INSTRUMENTS

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11.1 Introduction

In their attempt to analyse the "rise of systemic instruments", Smits and Kuhlmann (2004, pp. 5–8) identify three trends that characterise the "changing nature of innovation processes and systems":

– the end of the linear model
– the rise of the systems approach and
– inherent uncertainty and need for learning

They argue that – as a consequence of these trends – systemic instruments increasingly complement classical approaches in the innovation policy portfolio (Smits and Kuhlmann, pp. 11ff.). Recently, however, the dominant rationale of innovation policy seems to be changing. Increasingly, innovation policy is expected to contribute towards addressing societal demands or even to respond to the "Grand Challenges of our time".

The Lund Declaration of 2009, which was assigned by a large group of policymakers, researchers and business representatives to the Presidency of the European Council, for example stated that these "[…] challenges must turn into sustainable solutions in areas such as global warming, tightening supplies of energy, water and food, ageing societies, public health, pandemics and security. […] Responses to Grand Challenges should take the form of broad areas of issue-oriented research in relevant

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fields".[2] This "normative turn" in innovation policy implies changes in the requirements of its instruments. Therefore our contribution seeks to revisit established notions of system-oriented innovation policy patterns in the light of the new "grand challenge-oriented" paradigm on research and innovation policies. We will discuss whether current systemic innovation policy instruments are suitable to implement a challenge-oriented innovation policy. A reflection on the now well established innovation system approach underlines that this heuristic concept focuses on the well-functioning of the system, but does not provide for a strategic or normative orientation. Such an orientation function is suggested here, followed by a few practical considerations on how this function could be translated into innovation policy, i.e. how systemic policy instruments would need to be further refined in order to address the strategic orientation of the system.

We start by describing the growing relevance of the notion of the "Grand Challenges" as a normative, strategic goal of innovation policy (Section 11.2). Section 11.3 will briefly summarise recent changes in the nature of innovation, while Section 11.4 illustrates implications posed by the system of innovation approach as the underlying heuristic of most of today's innovation policies. Section 11.5 asks whether systemic policy instruments, which are designed to address the new nature of innovation, are also suited to address new requirements of research and innovation activities implied by the normative turn of innovation policy. Here, we outline our main proposition of how an orientation function should be introduced in order to permit the normative orientation the "Grand Challenges" call for in policy-making. After these conceptual considerations, we illustrate our conclusions by analysing two prominent systemic instruments in Section 11.6, namely participatory evaluation and foresight. For both instruments we will explore how the requirements of challenge-oriented innovation policy impact on the rationale and implementation of the approach. This will finally allow us to derive possible refinements of systemic innovation policy instruments in the context of challenge-oriented innovation policy.

11.2 The normative turn of innovation policy

Innovation policy has gone through several paradigm shifts. Early attempts in the 1960s tried to balance "market failures" through funding certain basic research activities. This was followed by various forms of "mission-oriented schemes" that aimed at specific targets such as the US Apollo 1 space program; lately the innovation systems school is addressing "system failure" by enhancing systems' learning capability, by trying to improve the management of interfaces as well as by building up the capacity of different actors in the system.

2 As stated during the Swedish Presidency of the European Union in July 2009: The Lund Declaration – Europe must focus on the Grand Challenges of our time, online: http://www.se2009.eu/polopoly_fs/1.8460!menu/standard/file/lund_declaration_final_version_9_july.pdf, accessed 4 May 2012, http://www.se2009.eu/polopoly_fs/1.8460!menu/standard/file/lund_declaration_final_version_9_july.pdf.

Each paradigm emphasised different policy instruments such as direct funding of research and development, demand-side instruments (e.g. public procurement, establishment of lead markets) or systemic instruments.

Braun (2008) delineates three phases of innovation policy, the first representing the classic mission orientation. Yet the combination of instruments in a well-balanced policy mix has been emphasised since the 1980s. This second phase was characterised by the fact that the assumption of an automatic occurrence of spill-over effects from basic research to immediate application in business and industry was questioned, and the identification of non-linear, recursive interactions of heterogeneous actors became prominent in innovation studies. Still, policies solely targeted selected sectors and technologies during this phase of innovation policies. It was only with the establishment of the innovation system approaches in the 1990s that "innovation has come to be seen as the interplay of market and non-market forces and as denoting a policy of 'structuration', of framework-setting that helps to correct 'market failures' and improve interaction, within the 'innovation system'"(Braun 2008, p. 227). Notably, an important characteristic of the development of innovation policies is the fact that established forms of support measures, respectively policy instruments, were not necessarily replaced by new policy paradigms but complemented (Boekholt 2010; Gassler et al. 2006). Early innovation studies had shown that some countries were developing faster than others in spite of similar economic circumstances due to different characteristics of their innovation systems. Consequently, the idea was established of optimising "innovation ecosystems" in order to enhance innovation capability and thereby foster economic growth and competitiveness.

This rationale has been complemented in recent years. Besides competitiveness and innovation capability, several innovation policy strategies aim to foster innovation that addresses the "Grand Challenges of our times" such as health, sustainability, mobility and security and thus contribute to better living conditions worldwide. Prominent examples are the US "Strategy for American Innovation", the EC's Europe2020 strategy and the German "High-tech Strategy". In parallel, the notion of economic growth as the key driver of innovation policy is under consideration. Particularly in the wake of the current financial crises the "limits of growth" already indicated by the Club of Rome in 1972, are of public concern. Specifically, the focus on the Grand Challenges calls for indicators that not only reflect a focus on the mere quantity of the economic output and market-based innovation, but also display qualitative issues of contentment, well-being and happiness. Though this debate is beyond the scope of this contribution, it is still important to keep these aspects in mind when reflecting on implications of this normative turn in the nature of innovation activities and the fit with the innovation system approach.

11.3 Changes in the nature of innovation

For decades the dominant definition of innovation as "new products and processes that are successfully introduced to the market" was hardly ever questioned. Companies were considered the key actors of innovation landscapes and the number of science-based high-technology innovations was deployed as the most relevant measure of innovation capability. Nowadays, a new understanding of innovation is gradually emerging from a number of different directions.[3] Increasingly, phenomena like social innovation, service innovation, low-tech innovation, frugal innovation, relational innovation and value innovation are being recognised as highly relevant innovation arenas that are challenging the standard definition (among others, see Kim and Mauborgne 1999; Miles 2005; Mulgan et al. 2007). At the same time, with the notion of "open innovation" and corresponding practices such as "crowdsourcing" (Howe 2006) and "co-creation" (Prahalad and Ramaswamy 2004), the focus on the firm as the key innovation actor has substantially broadened towards social entrepreneurs, users, customers, the public sector and citizens (Chesbrough 2006; Reichwald and Piller 2006). Creativity and innovation capability is no longer exclusively assigned to specific professions such as designers and artists or entrepreneurs, but extends to "ordinary people" and everyday life (Miller et al. 2008). This goes hand in hand with a perception of innovation as a local phenomenon that is emerging across the globe wherever it is required and not just exclusively in a few innovation hubs. At the same time, markets are complemented as the main coordination mechanisms between innovation demand and supply. Due to the lowering of transaction costs caused by the widespread use of the internet and mobile devices, more and more services are being coordinated directly between the parties involved through "peer to peer production" on the base of shared common goods (Benkler 2006).

At the same time, the "normative turn" in innovation policy outlined above is creating demand for different types of innovation patterns. Findings from innovation studies indicate that addressing the Grand Challenges requires much more than just replacing the topics of RTI funding programmes; indeed a different type of research and innovation projects altogether is called for. In particular, the following characteristics of challenge-driven innovation activities have been proposed:

- *socio-technical*
  aligning social and technological innovation
- *systemic*
  focusing on system change rather than on individual elements alone
- *transition-oriented*
  Envisaging system transition rather than only incremental trajectories
- *experimental*
  providing spaces for experimenting with socio-technical and system innovations in the real world
- *glocal*
  mobilising and aligning a diverse range of local solutions to address grand challenges on a global level

3 See also the recently finalised Foresight project on the "future of innovation" INFU where eight dimensions of change in innovation patterns were highlighted (www.innovation.futures.org).

- *transdisciplinary*
  joint research and innovation across disciplines
- *participatory*
  involving users and providers as well as stakeholders in joint learning processes around innovation trajectories

Steward (2008) suggested the term "transformative innovation" for this type of innovation pattern. Joly et al. (2010) propose the concept of "collective experimentation" to characterise such "transformative" innovation journeys directed at societal issues. Other studies have emphasised that challenge-driven innovation also implies different types of scientific research. In a recent memorandum, a scientific council of the German Chancellor proposed a shift towards "transformative research" in order to address climate change (WBGU 2011). These demands have unleashed a debate on the appropriate balance between curiosity-driven and challenge-driven research and the institutional setting required to underpin this balance which is still ongoing.

To sum up, we can say that changes in innovation patterns are driven by the dynamics of socio-economic framework conditions and newly emerging technologies, on the one hand, and by new policy demands, on the other. Before turning to the implications for systemic innovation policy instruments, which is the focus of our contribution, we will now briefly revisit the system of innovation approach which forms the basis for the notion of systemic instruments.

11.4 Grand challenges and innovation systems

The field of research and innovation policy is characterised by multi-actor and multi-level structures, without one hierarchical-statist centre. This observation is acknowledged within innovations system approaches. Freeman's concept of national (or regional) innovation systems was the first attempt to illustrate a broad interaction between all types of institutional networks in the private and public sector "whose activities and interactions initiate, import, modify and diffuse new technology" (Freeman 1987, p. 1). This conceptual framework was followed by other systems of innovation approaches focusing on different aspects besides national (Freeman 1987; Lundvall 1992; Nelson and Rosenberg 1993; Edquist 2005) and regional innovation systems (e.g. Braczyk et al. 1998), like technological (e.g. Carlsson and Stankiewicz 1995) or sectoral ones (e.g. Malerba 2002). However, common to all approaches is the assumption that innovations as such are embedded within the systemic context of all relevant stakeholders and institutions (cf. Chapter 1). Innovations come to life under complex, iterative circumstances since they "[…] encompass […] the 'biotopes' of all those institutions which are engaged in scientific research and the accumulation and diffusion of knowledge, which educate and train the working population, develop technology, produce innovative products and processes, and distribute them. Hereto belong the relevant regulatory bodies (standards, norms, laws), as well as the state investment in appropriate infrastructures" (Kuhlmann et al. 2010, p. 3).

While the neo-classical, linear view of innovation referred to market failures as a rationale for state interventions, this evolutionary view of innovation has brought forward systemic failures to justify state interventions and the involvement of state actors. Among others, Chaminade and Edquist point to the different lines of theoretical reasoning: "market failure in mainstream economic theory implies a comparison between conditions on the real world and an ideal or optimal economic system. However, innovation processes are path dependent over time, and it is not clear which path will be taken as they have evolutionary characteristics. [...] what is more, the system never achieves equilibrium, and the notion of optimality is irrelevant in an innovation context" (Chaminade and Edquist 2006, p. 115). In practice, the different existing categorisations of market and system failures show that the types of imperfections are often not formulated in such a way that they can be sharply differentiated from one another and that various links exist. The current consideration of "systemic imperfections" (Woolthuis et al. 2005, p. 610) has been broadened over the past years and now includes different types identified and formulated by various scholars in the field (among others, Smith 2000; Woolthuis et al. 2005; Chaminade and Edquist 2006): infrastructure provision and investment problems, transition problems, lock-in problems, hard and soft institutional problems, network problems, capability and learning problems, unbalanced exploration-exploitation mechanisms, and complementarity problems. All these aspects of "systemic imperfections" reflect a gradual gain in knowledge in innovation research and innovation-related policies whose foundation has been – and still is – an improved understanding of the relationship between research, innovation and socio-economic development (Soete 2007, p. 278): "Sectoral explanations of either technology push or demand pull kind have gradually lost in policy influence. Instead, it is now widely recognised that economic growth and well-being is founded in a much broader, well-functioning 'knowledge and innovation system', in which all actors perform well."

Despite all the refined understanding of innovation systems, the instruments derived from the innovation system approach are mainly directed at enhancing the innovation ecosystem in order to strengthen innovation capability. So far, there is no attempt to build on the innovation system heuristic in order to modulate innovation journeys towards certain desirable objectives. So whereas system failure appears to be addressed, "orientation failure" has largely not been tackled. Systemic instruments and orientation failure.

11.5 Systemic instruments and orientation failure

The question is whether systemic policy instruments, which are designed to address the capability of innovation systems, are also suited to address new requirements of research and innovation activities implied by the normative turn of innovation policy.

Our hypothesis is the following: introducing any kind of goal orientation into complex innovation landscapes and modulating innovation trajectories requires intimate understanding of innovation systems. The orientation function can be introduced into the system only when "government" is seen as the potential "orchestrator" of the system (Shapira et al. 2010, p. 461). Systemic policy-making that allows for coordination of different parts of the system (sectors, subsystems, etc.) and engages them in discursive processes (reflexive governance, transition management), is the precondition for successful strategic policy-making. Accordingly, imposing grand challenges as a major rationale of policy and hence a major goal of research and development by a top-down organised process will most likely not lead to any real transformative innovation, but will rather lead to subsuming previous research under new headlines like putting "old wine into new bottles". Thus any innovation policy instrument underpinning transformative governance will have to embrace the notion of systemic instruments. At the same time, nurturing innovation ecosystems alone will not be sufficient. Systemic and strategic policy-making needs to be connected. Such a connection may draw on experience from policy realms with longstanding experience in strategic policy-making, such as sustainability policy. Concepts like transition management, strategic niche management (Loorbach 2010) and constructive technology assessment (Schot and Rip 1996) may provide valuable starting points.

This governance aspect of programmatic strategies is also implicitly put forward by a former OECD expert: "An innovation strategy [...], has to take account of [cultural, geographical, legislative and regulatory] conditions to ensure that any interventions combine to contribute to the policy goals and do not weaken one another [...] with emphasis on whole-of-government policies" (Gault 2010, pp. 92ff.). The identification of "whole-of-government policies" is a very important and increasingly observable feature of programmatic strategies, like for instance, the German High-tech Strategy. According to Susana Borrás, an important criterion for strategic innovation policy is the "evidence that the vision and priorities are transposed to the choice, design and implementation of innovation policy instruments" (Borrás 2009, p. 15). Whether or not this statement holds true for the already mentioned programmatic strategies is subject to evaluations in the near future. Yet considerably more research must be carried out to further define the composition, must-have features and application modes of strategic policies altogether. In order to address this conceptual shortcoming in terms of a coherent definition of programmatic strategies, we would like to undertake some practical considerations about the elements of such policies, namely, the policy instruments.

11.6 Aligned systemic and strategic policy-making: some practical considerations

From the point of view of innovation policy, it seems obvious that challenge-oriented innovation requires different types of supporting instruments and therefore narrow types of demand articulation no longer seem adequate. However, it is still little understood whether and how this type of innovation can be fostered by innovation policy. Several current challenge-driven innovation policy strategies embrace measures to address some of the characteristics of "transformative innovation" (cf. Warnke 2012 for a recent overview). The Europe 2020 strategy explicitly calls for novel combinations of policy instruments and new foci of established instruments[4]. It is widely

4 "Member States should seek to shift the tax burden from labour to energy and environmental taxes as part of a 'greening' of taxation systems." (European Commission 2010, p. 26).

acknowledged that picking the winners among key technologies – be it in terms of competitiveness or in terms of supposed contributions to abstract societal goals – will no longer do the job. Rather, options for socio-technical transition need to be identified by linking up technological and societal change into "configurations that work" in new transformative ways. But what kinds of instruments are suitable to address this?

Besides the classical canon of policy instruments that mainly fund, regulate or either provide or gather information – Bemelmans-Videc et al. (2007) also describe the set rather vividly as "carrots, sticks and sermons" – the category of systemic instruments already seems to be part of the answer, since they incorporate specific needs of innovation policy, respectively, the level of systemic management of innovation processes (Hufnagl 2010). The key feature of systemic instruments is "that they aim to address problems that arise at the innovation system level and which negatively influence the speed and direction of innovation processes" (Wieczorek and Hekkert 2012, p. 74). According to the advancing debate in innovation studies over the past years, Wieczorek and Hekkert (2012, p. 82) provided an extended and enhanced overview of the goals of systemic instruments, building on the work of Smits and Kuhlmann (2004) to:

1. stimulate and organise the participation of various actors (NGOs, companies, government etc.)
2. create space for actors' capability development (e.g. through learning and experimenting)
3. stimulate the occurrence of interaction among heterogeneous actors (e.g. by managing interfaces and building a consensus)
4. prevent ties that are either too strong or too weak
5. secure the presence of (hard and soft) institutions
6. prevent institutions being too weak or too stringent
7. stimulate the physical, financial and knowledge infrastructure
8. ensure that the quality of the infrastructure is adequate (strategic intelligence serving as a good example of specific knowledge infrastructure)

Prominent examples of systemic instruments that "influence the speed and direction of innovation processes" and therefore address transition goals is transition management and strategic niche management (Loorbach 2010; Kemp and Rotmans 2009). However, there is no widespread application of those instruments (beyond the Netherlands) and they were implemented for rather specific goals. In a similar way, the technological innovation system approaches explicitly target change in a specific direction, for instance, the uptake of a certain technology that is thought to be more desirable than others e.g. in terms of ecological impact. Finally, several scholars have proposed "demand-oriented innovation policy strategies" (Edler 2010). Rather than trying to address societal demand, these strategies deploy demand-side measures in order to foster technological innovation with no specific societal goal apart from spurring innovation.

Therefore, we see the need to further advance these and other systemic instruments in order to address the strategic orientation of the system. To convey our ideas in this regard, we chose participatory evaluation and foresight processes as illustrative examples of classical systemic instruments that need to evolve in order to underpin transformative governance approaches.

11.6.1 Participatory evaluation: Addressing normative challenges through new impact dimensions and behavioural additionality analysis

Evaluation can be understood as the study of the use or (added) value of the subject of analysis, based on academic standards considering relevant empirical data. In the field of research, technology and innovation policy, evaluation can have the following different subjects of analysis: research projects, actor networks, clusters, institutions or organisational entities, processes, (funding) programmes and other policy instruments or policies. Furthermore, evaluations of whole sectoral or national innovation systems are carried out. The evaluation of funding programmes and other policy instruments is of highest relevance in the field of innovation policy (e.g. Arnold and Guy 1997; Fahrenkrog et al. 2002; Miles et al. 2005; Edler et al. 2010) and is therefore the main subject of the subsequent thoughts. The basic purpose of evaluations can be either summative or formative and each programme evaluation can cover different aspects, such as appropriateness and consistency, effectiveness and efficiency or impacts.

Evaluation is not per se understood as a systemic policy instrument. In a more classical view, the main functions are legitimation, control, insight and understanding or learning. In the evolutionary understanding, learning is most important and policy evaluation is regarded as a source of strategic intelligence (Kuhlmann 2002) "providing actors with the information they need to develop and implement their strategies" (Smits and Kuhlmann 2004, p. 9) or to stimulate the occurrence of interactions by building consensus among the actors (Wieczorek and Hekkert 2012, p. 85). In classical evaluation studies, stakeholder involvement is often uni-directional; this means that they are involved via surveys and similar methods to provide the relevant empirical data. Thus in a systemic perspective, evaluation can be regarded as bi-directional, i.e. evaluations should ensure that relevant information is provided in a useful manner to the stakeholders and that feedback loops to the involved actors are established, in order to provide room for learning, which eventually leads to improving systemic capabilities. This bi-directionality allows us to speak of real stakeholder participation.

With our proposition as to how evaluation could be applied as a systemic instrument by adding participatory elements, the question remains how it could provide orientation in the strategic, normative sense outlined above. This is defined by the policy programme subject to the evaluation, i.e. by its goals and the terms of reference of the evaluation. Programme goals can be formulated normatively or challenge-oriented in two different ways:

- They are either defined as external goals, i.e. impacts reaching beyond the programme participants. such as contributing to less environmental pollution or

addressing issues of demographic change, or they formulate a sustainable long-term effect on the participants, i.e. a change of behaviour. In the first case, this means covering new impact dimensions beyond mere economic or technological impacts, such as sustainability or social impacts (beyond the programme participants) during the evaluation. As these new impact types occur rather intangibly in the wider society or the environment and are of a qualitative nature, they are hard to measure. Our proposition is that, in these cases, a participatory evaluation approach involving experts and different societal groups is a suitable way to include these issues. By studying new impact dimensions, participatory evaluation would need to go beyond the systemic character of evaluation sketched above.
– In the second case, the evaluation will also need to assess any transformative impacts on the actors, i.e. evidence of behavioural additionality, understood here as a change in the persistent behaviour related to R&D and innovation activities (Gok 2010).[5] In the same way as evaluation can be used as a systemic instrument to strengthen the systemic capabilities of the actors, it could be used to trigger the normative orientation of the actors. At best, the orientation function could eventually be implemented in evaluation studies by combining a participatory approach through the analysis of behavioural additionality.

In practice, however, a purely systemic participatory evaluation approach and an evaluation approach which goes beyond the systemic character and adds a normative or challenge orientation, both face implementation difficulties as the following considerations show:
– Participatory evaluation in the described systemic sense is not a common approach in evaluation practice. The feedback loops and formats like focus groups or workshops are time-intensive and can hardly be realised in short-duration contracts.
– Secondly, clients and evaluators need to share the same intentions about the evaluation. Accordingly, they must agree on the participatory approach, which obviously requires a high level of transparency of information. An example is the accompanying evaluation of the German funding programme VIP ("Validation of the Innovative Potential of scientific research"). The programme is an innovative element in the German funding landscape which aims to bridge the gap between basic research and applied R&D for marketable products. One of the goals is to strengthen the knowledge transfer and valorisation culture at academic institutions. In order to achieve this, the evaluation set out to engage the target group (researchers at publicly funded institutions) in different formats in order to contribute to a more sustainable transfer culture.
– Thirdly, participatory evaluation generates challenges to principles of good practice of evaluation, as evaluators are no longer in the role of impartial observers, but take an active part in generating impacts and shaping reality. Thus,

5 He elaborates on at least three other conceptualisations of the term in literature.

defending impartiality, independence and credibility becomes a constant task for evaluators in a participatory setting.

- The INNO-Appraisal project which compared a large number of evaluations across Europe has shown that formative evaluations, although quite numerous, do not exploit their full potential of actor involvement and learning: "Evaluations which are (at least partly) summative tend to be more often widely discussed within government and with participants/stakeholders than formative evaluations. Even if the differences are not statistically significant, it appears the results of summative evaluations, with clear 'numbers' and messages, are better suited for wider discussion, while the virtue of formative evaluation is not so much their dissemination, but the learning within the process itself" (Edler et al. 2010, p. 78).
- Another result of the project is the insight that studying new impact types (as required by challenge-oriented programmes) is not as uncommon as one might think: Almost half of the studies cover social impacts, almost one third cover environmental impacts (Edler et al. 2010, p. 132). However, this high account is linked to the high number of structural fund evaluations in the sample, and the requirement by the European Commission as a sponsor to cover economic, social and territorial cohesion in the evaluation studies (ibid., pp. 127, 136).
- The measurement problem for these new external impact types was already mentioned. A participatory approach is suggested here, however, the task of thinking about new measurement methods for social and environmental impacts in the future still remains.
- As for behavioural additionality, the INNO-Appraisal project again finds that a large number of evaluations use this concept (Edler et al. 2010, p. 127). Thus "behavioural additionality is mainly linked to direct economic impacts" (ibid., p. 139), while social impacts such as the promotion of innovation mentality, changes of risk attitudes, the awareness of societal needs, acceptance of technology or attitudes towards entrepreneurship are studied more rarely with this concept.
- Moreover, "interestingly, and neglecting its full potential, behavioural additionality is not as common in accompanying evaluations as one would assume, given the focus on interaction and learning and the need to re-adjust programme and implementation should learning effects not be observed in real time. The concept is used in formative evaluations, but not as extensively as one would think" (Edler et al. 2010, p. 154).

These considerations show that there is still a large potential for implementing evaluation as a systemic instrument, and beyond this, as an instrument to evaluate normative and challenge-oriented programmes.

11.6.2 Foresight processes: Identifying strategic priorities through joint learning processes

Foresight processes set up strategic conversations among key actors of innovation systems, thereby providing platforms for joint learning processes, combining heterogeneous elements and ultimately "wiring-up innovation systems" (Martin and Johnston 1999). In the context of innovation policy, Foresight is a systemic instrument par excellence. For more than a decade, European Foresight practitioners have been emphasising the benefits of the Foresight process for the learning capability of innovation systems. "Wiring-up innovation systems" through the "process benefit" of Foresight exercises was thought to be of equal relevance to the anticipatory intelligence arising from the actual findings of Foresight processes. Foresight, so it is argued, engages diverse actors in a joint learning process, thus creating future-oriented attitudes and linkages and therefore ultimately enhancing the responsiveness of the innovation system towards future challenges. Many Foresight processes in the realm of research and innovation policy set out to define priorities for public support for research and innovation activities. In doing so, most Foresight exercises aimed at identifying "key technologies" and selecting the ones that seem most promising to underpin the competitiveness of domestic industry through prospective debate among key stakeholders (Salo and Cuhls 2003). Typical examples are the French "Étude Technologies clés"[6], the Spanish "Ejercicio de Prospectiva a 2020"[7] and the Foresight process launched by the German BMBF from 2007–2009 (Cuhls et al. 2009). Such Foresight studies requested top experts to assess the contributions of key technologies to demand criteria such as quality of life, quality of environment and social cohesion. Even though these processes used societal benefits such as selection criteria, the demands themselves were usually taken as a given fact. Only few processes such as the German FUTUR exercise provided space for value debates and normative Foresight approaches. Thus, while the provision of orientation is an explicit goal of Foresight as an innovation policy instrument, the "orientation failure" inherent in the systemic instrument approach was reflected by most Foresight processes. Accordingly, the normative turn of innovation policy, on the one hand, and the changes in the nature of innovation that were described in the previous sections pose new requirements for Foresight processes. In the FORLEARN process, that was set up by the European Commission through the JRC IPTS in 2006 in order to foster exchange and capture of Foresight knowledge across Europe (Da Costa et al. 2008), the need for more normative Foresight elements was highlighted.

– Another issue gaining relevance in the context of systemic instruments for demand-oriented innovation policy is the uptake of insights from social sciences and humanities. In many Foresight processes, societal evolution was tackled in much less depth than technological trajectories and engineers far outnumbered social scientists among Foresight coordinators and participants (Warnke and Heimeriks 2008).

6 Étude Technologies clés 2010, online: http://www.industrie.gouv.fr/techno_cles_2010/html/sommaire.php (accessed 4 May 2012).

7 Estrategia Nacional de Ciencia y Tecnología (ENCYT) 2020. Ejercicio de Prospectiva a 2020, online: http://icono.fecyt.es/informesypublicaciones/Documents/ENCYT_prospectiva.pdf (accessed 4 May 2012).

- Instead of "wiring-up" the known "key actors" of the innovation system in terms of different contributors to technological innovation, joint learning processes between technological AND societal innovators are required. Different socio-technical trajectories need to be debated and assessed. For this, Foresight processes need to reach out to civil society as a whole. Rethinking patterns that are deeply entrenched in our culture, such as the close knit between economic growth and quality of life, requires much broader notions of "stakeholder" or "expert". New, diverse actors such as social innovators, artists, children, immigrants, the global poor, animals and robots come into the picture.
- Both sides of the coin, the "socio" and the "technical", need to be tackled with an equal level of complexity. Social innovation needs to be factored in. Accordingly, expertise from the social sciences and humanities need to be recruited at an equal level with technology expertise.
- New methods are required in order to facilitate value debate and to imagine new working configurations. Analytical prospective methods such as scenario building, Delphi surveys and cross-impact analysis need to be complemented by methods that mobilise emotions and tacit assessments such as visioning processes or approaches from ethnographic design.
- Traditionally, Foresight exercises placed great emphasis on consensus building. However, in order to address Grand Challenges, consensus might have to be challenged in some cases. Addressing issues such as global climate change involves rethinking fundamental value notions such as global justice (Hulme 2009). Foresight processes that seriously venture towards this challenge need to avoid premature closure on easy fixes and actively bring these conflicts into the open. In other cases, a greater diversity of solutions may have to be fostered in order to break out of lock-in situations (Könnöllä et al. 2007).
- In several cases, transformative innovation will require rethinking established paradigms. Rather than extrapolating today's trends, we need to imagine change in the conditions of change in order to discover the transformative potential of the present (Miller 2007). Methods that underpin exploration of new paradigms are likely to gain relevance (Schirrmeister and Warnke 2012, forthcoming).
- Even though dialogue and, in particular, value debate and socio-technical scenario building are key elements of socio-technical transition, they are not sufficient to actually identify feasible transition trajectories due to the complexity of social systems. In order to understand real life processes of possible co-evolution between society and technology, we need experimental spaces at the nexus of social and technological change where "configurations that work" can actually be tried out. Foresight needs to extend the notion of "structured stakeholder dialogue" towards "collective experimentation" (Joly et al. 2010) and link up with appropriate instruments, such as transition and strategic niche management (Kemp et al. 2007), as already practised in the realm of sustainability transition. Methods from fields like participatory design (Buur and Matthews 2008; Jegou

and Liebermann 2003; Jegou and Vincent 2009), lead user approaches (Herstatt and von Hippl 1992), behavioural economics and agent-based modelling may well have a role to play. Enabling spaces for this type of experimental Foresight processes and collective solution-seeking, such as within innovation camps or living labs, may become just as crucial for the competitiveness of innovation systems as e.g. incubators and Fraunhofer Institutes.

Yet there is no Foresight process which fully reflects all these requirements. Still, several recent Foresight processes aiming to underpin challenge-oriented policy strategies show one or more of the above mentioned characteristics:

The Netherlands Horizon Scan proposed priorities that are clearly socio-technical. Instead of settling on specific technologies, open value debates were initiated, such as "understanding what the 'greying' of society really means" or "trans-disciplinary research on issues of changing human nature and societal responses in the face of medico-technical research". The process drew on imaginative methods with one of the key results being presented in the form of a prime minister's speech. It was fully open to the citizens and used card games to foster wide public debate. A similar approach was adopted by the Danish Forsk2015[8] Foresight exercise in Denmark which resulted in complex holistic priorities such as "health and well-being of animals and people and at the interaction of bio-production with, and impacts on, the surrounding society, environment and biological diversity". Other Foresight processes such as the Poland 2020[9], France 2025[10] and the Ireland 2025[11] exercises allowed for extensive exploration of social change as well as value deliberations. Finally, the German "BMBF Foresight Process" set out from a more classical technology push approach, but ended up linking emerging technologies with changing societal patterns in priority fields, such as "production consumption 2.0, human-technology cooperation" (Cuhls et al. 2009). In the follow-up process, the ministry explicitly emphasised an in-depth exploration of demand patterns and research in social sciences and humanities.

11.7 Conclusions

The trend of the increasingly acknowledged need of innovation policy to respond to the Grand Challenges of our time was the starting point of our thoughts. Today's challenges are defined as societal and environmental tasks and are perceived to trigger a normative turn in innovation policy, which is evolving into a major rationale for policy, besides economic growth and competitiveness. This new mission orientation, however, harbours several challenges in its own right: What are the implications of this normative turn in innovation policy for research and innovation? Is the heuristic

8 The follow-up process Research2020 focuses on socio-economic challenges, online: http://en.fi.dk/research/research2015-and-research2020/research2015 (accessed 4 May 2012).

9 Bendyk (2009).

10 Online: http://www.strategie.gouv.fr/article.php3?id_article=811 (accessed 4 May 2012).

11 Online: Sharing our Future: Ireland 2025 – Strategic Policy requirements for Enterprise Development, online: www.forfas.ie/media/forfas090713_sharing_our_future.pdf (accessed 4 May 2012).

of the innovation system approach able to incorporate normative orientation? What kind of policy instruments are needed to address those challenges? We have focused our conceptual thoughts in this article on this last question and discussed in particular whether current systemic innovation policy instruments are suited to implement a strategically oriented innovation policy.

Firstly, the normative turn creates new uncertainties, such as the need for researchers and innovators to define the contribution of their research to the Grand Challenges orientation. In the light of such challenge-oriented research, the importance of curiosity-driven research is a meaningful caveat, and a good balance has yet to be found. This "normative turn", however, implies more. Findings from innovation studies indicate that addressing the Grand Challenges requires a different type of research and innovation projects altogether. "Transformative innovation" is characterised by the following aspects: socio-technical, systemic, transition oriented, experimental, glocal, transdisciplinary and participatory.

Secondly, with all the refined understanding of innovation systems, the instruments derived from the innovation system approach are mainly directed at enhancing the innovation ecosystem in order to strengthen innovation capability. So far, there is no attempt to build on the innovation system heuristic in order to modulate innovation journeys towards certain desirable objectives yet. So whereas system failure seems to be addressed by the system heuristic, "orientation failure" still remains untackled.

Accordingly, we propose that the innovation system approaches should draw on an orientation function as an integral element, in order to optimise innovation capability along the Grand Challenges orientation. The analytical and theoretical implications of national innovation systems analysis need to be widened from "only" research and innovation to socio-technical solution-seeking and therefore capture social and technological innovation equally. Specifically, approaches that focus on technologies like the technological innovation system concept therefore seem less suitable to inform open, challenge-oriented learning processes where a wide range of solutions, including non-technical ones, is taken into consideration. Particularly the active role of society as an innovative collective actor instead of simply "consumers and/or users" should be recognised.

Besides this consideration, we also see the need to further reflect on the potential and strength of "whole-of-government" policies. One prominent attempt in this regard is the German High-tech Strategy. The synergies that such a programmatic strategy can convey still need to be fostered in a more systemic manner. This statement also calls for the demand to further identify and analyse the "must-have" features of political programmes and policy instruments in order to qualify as strategic measures at all. In our view, "strategic" means more than simply goal-oriented and focused on the future. With regards to programmatic strategies like the High-tech Strategy, the term also implies a cross-ministerial, systemic effort at solution-seeking along the identified challenges.

Thirdly, based on these thoughts, we put forward some ideas and two illustrative examples of how systemic policy instruments would need to be further refined in order to address the strategic orientation of the system. The example of participatory evaluation shows how this systemic instrument could be complemented with the analysis of new impact types or behavioural additionality to account for a normative orientation of the policy programme considered. Similarly, foresight processes that explore innovation journeys in a holistic manner are a suitable orientation instrument.

More generally, these two examples indicate some common features which might apply to the question of how systemic instruments would need to be refined to address challenge orientation: They point out the value of participation and dialogue which, however, should not be restricted to stakeholders only, but reach out to society. Furthermore, technological aspects of innovation will need to be accompanied by societal aspects, meaning social impacts and transitions, or respectively, social innovations. Our considerations show the need to develop new methods, e.g. to measure new impact types or to mobilise and rethink beliefs, tacit assessments, emotions or behavioural patterns.

To sum up, we have suggested some straightforward, but as yet missing links for strategic and systemic policy-making. In particular, the examples of participatory evaluation and foresight have shown that it is not necessary to invent new policy instruments to address orientation failure; instead we should exploit the full potential of existing systemic instruments. This may lead the way to implementing strategic policy-making, which for us is still a research desideratum in itself.

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12

A FRIENDLY OR HOSTILE TAKEOVER?

THE GROWING LINKAGE OF INDUSTRY AND INNOVATION POLICIES AND INSTRUMENTS

TIMO LEIMBACH, SVEN WYDRA

12.1 Introduction

The system of innovation approach has shown remarkable success in entering discussions of innovation policy and the terminology of systems thinking has been widely adopted by policymakers. Many national innovation policy studies document the widespread usage of national or sectoral innovation system frameworks (e.g. Dodgson et al. 2010; OECD 2005). Among others, its attractiveness lies in the explicit recognition of the need for complementary policies and the attention drawn to weak links in the overall system (Soete et al. 2010). However, the development of industry has stagnated in many EU countries despite this approach having been applied in industrial sectors in particular. As a consequence, the relative share of manufacturing in total value added and employment have declined in Europe during the last decades, but the recent financial crisis and its consequences have breathed new life into the discussion about the need for a strong industrial base as the main pillar of economic growth in Europe.

This is accompanied by the debate about which are the promising sectors and industries and how they can be supported in order to strengthen the future position of Europe. In particular, typical high-tech industries like biotechnology or ICT (information and communication technologies) play a prominent role here, because they are crucial for the future competitiveness of European industries and the European economy as a whole.

Over the last decade, many of these industries were the focus of innovation policy resulting in an increase of R&D expenditures in the underlying technologies.

However, this rise and the overall high share of public R&D funding in Europe has not led to a subsequent increase in the market share or, above all, overall economic growth. This paradox, which shows some similarities with the more famous Swedish paradox (Edquist and McKelvey 1998; Bitard et al. 2008), has raised the question of why Europe is failing to turn knowledge and innovation into growth and productivity.

This perception has sparked the far-reaching discussion about whether the current innovation policies are sufficient or whether there is a need for complementing and/or new policy approaches in innovation policy. One result of this is that industrial policy has become more important again which is reflected in the related flagship initiative "An industrial policy for the globalisation era". Moreover, the connection between innovation and industrial policy is being emphasised not only in this article, but also in the respective flagship initiative dealing with innovation policy in the EU, the "Innovation Union". Both fuel the current discussion of the growing entanglement of these policies and lead to the question whether there are interrelations and tie-ins between them.

However, as yet there are only vague ideas for a concrete conceptual approach to connecting these policies. It is still an open question whether a common concept for policy rationale, design or a toolbox of common instruments will emerge. To discuss these issues we first present past and recent developments in both innovation and industrial policies, before analysing similarities and differences in rationales and instruments. Then we set this theoretical perspective against an analysis of the current state of practice in three emerging industries: nanoelectronics, software and biotechnology. The main objective is to determine whether such a combination of industrial and innovation policy can already be observed in practice, or whether this is still in the conceptual stage. Finally, we conclude by summarising our results and their implications for policymaking and further research in this area.

12.2 Past and recent developments in industry and innovation policy

For some decades in the post-war period, "traditional" industry policy aimed at the identification and support of "strategic" industries in terms of R&D funding, market regulations and investment subsidies. A prominent example of this kind of policy and in particular its failure was the attempt made to form "national champions" in the ICT industry in the 1970s as a counterbalance to the dominance of U.S. firms (e.g. Coopey 2004).

This "picking winners" strategy was increasingly challenged by the neoclassical approach, which doubted that state intervention is able to drive industrial success. According to this approach, in a perfect, i.e. completely competitive and decentralised market, market failure is caused by a lack of knowledge due to external effects, uncertainty, asymmetric information and the public/merit character of knowledge. Based on this as the reasoning for policy intervention in conjunction with a linear understanding of the innovation process, a fundamental policy change took place with policymakers focusing on horizontal, non-discriminating policies for competitiveness. In particular they focused on supporting the production of knowledge by the public sector itself or supporting knowledge-producing institutions.

This was accompanied by a shift in innovation-driven policy in the late 1980s and early 1990s as a consequence of the rise of the "system of innovation" concept (Freeman 1987; Lundvall 1992; Nelson 1993) and its more systemic view (Smits and Kuhlmann 2004). The systems of innovation (SI) approach perceives innovation as a non-linear, evolutionary and interactive process characterised by reciprocity and iterative feedback mechanisms, in which actors (e.g. firms), organisations (e.g. universities, customers, government) and institutions (e.g. regulations, culture) interact in many ways. All of these components and the relations between them can be affected by malfunctions which hinder the innovation process and are known as systemic failures. As a result, innovation policy encompasses all the policy measures which influence innovation processes, e. g. the development of new products and process innovations (Edquist 2005; Larédo and Mustar 2001; Chaminade and Edquist 2006).

The system of innovation concept had an enormous impact on innovation policy as well as on industrial policy, too, in the long run. The latter re-entered the spotlight at the turn of the century and underwent a major evolution and transformation, both conceptually and in terms of its practical tools (Aiginger 2007). One reason for this was the recognition of the productivity gap between the U.S. and Europe and Europe's apparent inability to close it. A second reason was the growing competition from rapidly developing economies, like China and South Korea due to their successful policies. This development was reinforced by the financial crisis which was shown to afflict countries with a smaller industrial base and imbalanced economy to a greater extent. As a consequence, several countries are now searching for ways to improve their industrial base, especially in new promising fields of technology (The Economist 2010; Aiginger 2012).

The re-emergence of industrial policies in Europe was marked by the 2002 Communication on "Industrial Policy in an enlarged Europe" (European Commission 2002). In 2005, a new framework for industrial policies was introduced in the Communication on "Implementing the Community Lisbon Programme: A Policy Framework to Strengthen EU Manufacturing – towards a more integrated approach for industrial policy" (European Commission 2005). The most significant change in this framework was a matrix-like approach, which combines horizontal policies with sector-specific vertical policies. One instrument introduced to support this systemic industrial policy was the Lead Market Initiative (LMI) (European Commission 2007). Another important initiative by the European Commission is the identification of six key enabling technologies (KETs) as priority fields to improve European industrial competitiveness (EC COM 2009/1257). The ongoing importance of this topic is also shown by the fact that one of the seven flagship initiatives of the new EU 2020 strategy (European Commission 2010c) addresses the need for a new industrial policy. In particular the initiative "An industrial policy for the globalization era" (European Commission 2010a) calls for a new industrial innovation policy to underpin the growing interrelations and mutual interdependencies between industrial and innovation policies. Moreover, the flagship initiative dedicated to the future innovation policy, the "Innovation Union" (European Commission 2010b) underlines the interrelations between the two as well as the necessity for clear coordination.

However, merely emphasising the interrelations in strategic documents does not indicate to what extent a consistent common concept can arise and how systemic innovation policy and industrial policy are being transformed by current developments. Traditional industrial policy differs from systemic innovation policy in the perception of the role of governments in industrial development, main instruments and policy design. So, questions here concern the quest for a shared common theoretical framework, the challenges and limitations of governance and the need for new instruments.

12.3 Rationales and instruments of innovation and industrial policy

There is no justification for strategic and specific measures of traditional industrial policy in the market failure approach (e.g. Pack and Saggi 2006). While market failures, such as external effects, are usually acknowledged for R&D activities, this is not the case for more market-related activities (e.g. construction of demonstration plants, production facilities).

The system of innovation perspective implies policy rationales with a wider scope than the market failure approach, but which are less ambitious concerning market intervention than traditional industrial policy (Dobrinsky 2009). It emphasises the dynamic rationale for intervention, which is founded on first mover advantages, experience curves, path dependency and capabilities. "The identification and support of 'strategic' technologies or sectors, even though not justified on the basis of static allocative efficiency, could then well be justified from a dynamic, innovation system perspective in terms of long term output and productivity growth" (Soete et al. 2010, p. 23). Particularly in a globalising economy, fewer static market failures (e.g. monopoly power) but more dynamic market failures originating from knowledge spillovers and innovation are becoming increasingly important. Within the innovation system, this idea is addressed by introducing the concept of systemic failure. The idea behind this is that systemic failures require political interventions which, unlike market failures, have to go beyond the production of knowledge by financing research and development or research infrastructures. Moreover, the role of policy is to support the functioning of the system as a whole. The existing literature describes several sets of possible system failures which differ most notably in the degree of granularity and less in the type of failure. Examples include lock-in or path dependency failures, i.e. the inability of the entire system to adapt to or recognise new technological paradigms, or institutional failures, i.e. the malfunction of regulatory framework or social institutions (e.g. Woolthius et al. 2005). Although this approach is now being used to justify several types of innovation policy, there is no clear concept for if and how it can be used as a rationale for modern industrial policies.

Moreover, unlike the old "picking winners" industrial policy, the basis for such a policy is not superior knowledge on the part of the government, but the limited knowledge about the size and nature of externalities of both firms and the government (European Commission KBE Expert Group 2009). The role of the state is less a top-down steering of sectors, but more a systemic coordination of the innovation process (Smits and Kuhlmann 2004). It should facilitate innovation by linking innovation stakeholders, supporting beneficial spillovers, bridging sources and users of innovation and promoting collaborative models so that actors can learn from each other (Rodrik 2004). Consequently, the approach of "modern" industrial policy inspired by the innovation perspective is a more systemic policy. A fundamental aspect of policy is then to review and redesign the links between the different parts of the system (Lundvall and Boras 2005). Synergies with other policy areas are emphasised, in particular with innovation policy: skills, research capacity, innovation systems, institutions favouring change and life-long learning are important for the competitiveness of countries at the technology frontier. In other words, the development of existing and emerging technologies and industries cannot be based on a single industrial policy alone, but needs to be complemented by compatibility with other domains of policy. Industrial policy merges with innovation policy, science and technology policy and education (Soete 2007).

In addition, the innovation system perspective reinforces the need for sector-specific instruments. The impact of each policy instrument will vary according to the sector and each sector has its own specific inputs, and competitive advantages have different sources (e.g. Aghion et al. 2009; Soete et al. 2010). Hence, the specific opportunities and constraints of the respective country and sector have to be considered. Innovation policies should take the sector-specific nature of technological change as a fundamental starting point, and then develop an appropriate set of innovative strategies that are crucial for the competitive success of different sectoral systems (Soete et al. 2010). Consequently, policy instruments should be differentiated and include a range of ambitious instruments which requires high competence. Moreover, research findings emphasise the importance of national differences in the framing conditions for innovation. The institutional settings differ as does the capacity of nations to innovate (Edquist and Hommen 2008). There is a broad consensus that there is no "one size fits all" policy across countries (Rodrik 2004; Aiginger 2007). This contextual-dependence of suitable policies is one major reason why no common set or toolbox of concrete (modern industrial) policy instruments has been developed to date. There is also general agreement that "traditional" industrial policy instruments are becoming less important, like supporting the accumulation of physical assets, supporting ailing industries, grand projects, national champions or the promotion of exports. In addition, some instruments from innovation policies are gaining importance, such as systemic policies (e.g. non-product standards, foresight programmes, information campaigns or reforms) and demand-side policies (see below). But no specific set of prioritised measures has yet been developed.

Most scholars focus less on concrete instruments and more on the design of the policy mix and measures (OECD 2010). This is especially the case for sector-specific industrial policies: "Departing from neutrality with respect to technological fields is always dangerous since it implies guessing future technological and market developments: So a central question concerns program design: how to make these […] programs less vulnerable to government failures such as wrong choices and winner-picking (European Commission KBE Expert Group 2009, p. 105)." A first suggestion of how to answer this challenge was made by Aiginger (2012), who suggests national priority setting processes for research strategies that should be transparent and open to cooperation and competition instead of sector-based approaches, which, as top-down approaches, are discriminating by nature. Hence, research has frequently been done on a suitable design of modern industrial policies. Among other things, the learning process is emphasised for policy and the coordinating role of the state (Rodrik 2004; Dobrinsky 2009). The target of innovation is not chosen ex ante (e.g. R&D institution), but by competition among the actors (e.g. R&D project funding). The scope of policy should focus largely on new activities and sectors that have the potential to drive growth and employment in the future. These sectors/markets do not necessarily have to be mass markets which are directly linked to high employment and value-added; policies for niche markets can also be of high relevance. Particularly in industries where a few dominant firms use older technologies, the existence of experimental users or niche markets, which the old technology does not serve well, is necessary for successful introduction of radical new technologies. Only in these cases are new firms able to serve a market and survive for long enough to develop the new technology to the point at which it becomes competitive on the main market (Malerba et al. 2007; OECD 2011). Policies such as public procurement for innovative technologies could help to establish such markets as was the case for computer technology, transistors, aircraft jet engines or the Internet (OECD 2011).

Not only recent evolvements of industrial policy are influenced by innovation policy, the reverse can also be the case. As innovation policy is a rather young policy field, especially from the systemic perspective, it is more difficult to single out concrete developments in its evolution. One such development may be the increasing appearance of demand-side innovation policies. Such policies are usually very specific, as they focus on certain markets and sectors. One example on the European Level was the Lead Market Initiative (LMI). The idea behind this is that LMI "identifies a first set of markets with the potential to become 'lead markets' and calls for urgent and coordinated action through ambitious action plans for these markets, in order to rapidly bring visible advantage for Europe's economy and consumers" (European Commission 2007). In 2007, a first set of LMI was implemented for six areas. This clear focus on market-driven approaches should allow European companies and the overall economy and society to benefit from promising, emerging markets. A set of policy instruments was deployed to support such markets: legislation; public procurement; standardisation, labelling and certification; and complementary measures encompassing, e.g. business and innovation support services. However, the LMI was criticised for two reasons by the midterm review (European Commission 2009b). The first criticism was the process of identifying the sectors, which refers to the aforementioned selection problem of sector-specific policies (European Commission KBE

Expert Group 2009). The second was the selection of the instruments deployed, in particular those which were missing such as the connection to other supply-side policies or the integration of user-driven innovations and consumers as such. To counteract these problems, a more integrated approach is recommended, combining market-driven and technology-push elements like R&D funding with strong coordination and governance.

Another related development is the set-up of a comprehensive innovation policy strategy for certain "key" technologies. The European Commission has identified six key enabling technologies (KETs) as priority fields to improve European industrial competitiveness and is currently working on potential policy measures (European Commission 2009a). The European Commission itself does not determine concrete policy instruments but identifies "hotspots" of policy action like financing, joint strategic programming, demonstration projects, skill upgrading, trade policy, the review of state aid policy, public procurement and others. A specially assigned High-Level Expert Group for Key Enabling Technologies then proposes a wider set of policies which mainly aims to redefine R&D in EC funding programmes in such a way that the whole innovation chain is addressed from research to product development and manufacturing (HLEG 2011). The role of policy is then to support not just research, but also pilot lines, demonstration plants and globally competitive manufacturing capabilities. However, the underlying intention of this policy strategy is not to introduce or establish a new field of policies or a new set of instruments, but to ensure that the existing innovation policy instruments are used effectively to foster the development of industries based on the funded technologies. This approach also requires strong coordination and governance of both, industrial as well as innovation policies.

To summarise, the LMI and KET initiatives show that elements from innovation policy and from industrial policy are already being combined with each other at EU level. However, the implementation of these initiatives also highlights the fact that certain key challenges of such combinations discussed in the literature still persist in new policy approaches. Firstly, the selection of the promoted industries and technologies is problematic as hardly any transparent criteria have been developed. Secondly, the justification of the policy instruments remains somewhat unclear and is not specified in these initiatives. Thirdly, the governance of these initiatives with their various instruments and the coordination of the different policymakers responsible remain challenging. At present, the EU member states have only partially followed the plea of the European Commission to implement the proposed or complementary measures.

12.4 Industrial and innovation policy in practice: insights from the software, nanoelectronics and biotechnology industries

While scholars agree to an innovation-led industrial policy in theory, it is less clear to what extent such concepts are actually being put in practice beyond the two recent European initiatives described above. We conducted several case studies for different industries to shed some light on this question. As argued above, the new approaches to industrial and innovation policies have particular implications for sector-specific measures and it is likely that variations will occur between industries regarding the chosen strategies and instruments. We chose three case studies with different features:

- Nanoelectronics is an example of an R&D- and capital-intensive industry with a long tradition of industrial policy. In particular, countries from East Asia identified these sectors decades ago as strategically important for catching up with the western world.
- Software represents a highly knowledge-intensive, but less capital-intensive industry shaped by the tension from having to be product and service oriented at the same time. For a long time the industry received no special consideration in terms of industrial policy, but perceptions have changed because of the success of some smaller countries in establishing such industries.
- Biotechnology is an often presented example of systemic innovation policy. Many innovation policies have been applied to this industry. Currently, a revival of industrial policy instruments can be observed in capital-intensive industrial applications (e.g. chemicals, plastics).

For each case study the following questions are addressed:

- Have significant changes taken place towards an innovation-oriented industrial policy?
- Which of the described features of an innovation-oriented industrial policy can be observed in reality?
- Are there any key policy factors for successfully supporting industrial development?

Nanoelectronics

Nanoelectronics is usually a broadly defined field and includes all areas of electronics in which fine structures at the level of nanometres are used. These include semiconductor components as well as highly miniaturised electronic subsystems and their integration in larger products and systems (ZEW and TNO 2010). There is a long tradition of industrial policy in the nanoelectronics industry. For decades, governments considered the semiconductor industry to be strategically important for economic development. At the same time, firms are facing declining profits, very volatile markets, high R&D and capital costs and increasing problems with the appropriateness of their innovations. As a consequence, governmental help is welcome (Brown and Linden 2009). In the following, we describe the evolvement of policies in the last decades for the leading countries in nanoelectronics.

Japan and *South Korea* were able to establish strong local industries in earlier decades due to long-term committed support from the government when the sector was still at a relatively early stage of development. In Japan, R&D consortia were brought together under the leadership of large enterprises by the Ministry of International Trade and Industry (MITI). Similarly, in South Korea, industrial policy was aligned to a few large companies, the so-called Chaebol. Implicit investment guarantees and low loans created a favourable environment for the Chaebol to make large and risky investments in new areas. In the last decades, Japan and South Korea have taken steps in the direction of a more innovation-oriented and globally-integrated approach. Direct support for selected firms has been reduced, and R&D support has been adapted in such a way that it is not just aligned to a few large companies, but also focuses more on cooperations between academia and industry. Nevertheless, there are still some sporadic specific interventions such as the bailouts of the DRAM manufacturers Hynix (KOR) and Elpida (JAP) during the recent financial crisis in 2009. Moreover, substantial regional incentives for certain high-tech industries have been increased as part of the introduction of cluster policies.

The evolution of *Taiwan's* semiconductor industry is often regarded as an example of a successful policy strategy. There was an early focus here on foreign direct investment markets with access to foreign technology, on technology parks with the participation of domestic SMEs, on the nation's own R&D capabilities and on educational policies. Beginning with labour-intensive test and assembly projects, Taiwan achieved backwards integration from wafer fabrication to design. A major ingredient for its success in this field was the establishment of new "foundries" by spin-offs from Taiwan's Technology Research Institute (ITRI) in the early 1990s (Mc Kinsey 2010). A foundry produces customised chips that are designed and marketed by other companies. This model was widely accepted by U.S. firms, which were willing to outsource and offshore chip production to Taiwan. *China's* first efforts to establish a domestic semiconductor sector in the 1970s were less successful. There were large support policies, but these were redundant and poorly coordinated (Pecht 2007). The attempt to establish state-owned IDMs (integrated device manufacturers) failed due to inefficiency and an uncompetitive technology. Inspired by Taiwan's successful development, China changed its promotion strategy in the 1990s. As in Taiwan, partially state-owned foundries were promoted. Policies concerning foreign direct investments were liberalised and import tariffs were removed as were the value-added tax benefits for domestic-based companies, partly also because of pressure from the WTO. But while the strategy and some instruments have changed, a top-down centred approach and traditional industrial instruments still dominate, accompanied by a high selectivity regarding the (nano-)electronics industry. This is also largely true for Taiwan, although to a smaller degree. Both Taiwan and China are currently granting high tax incentives for semiconductor R&D and production (Dewey and Le Boeuf 2009).[1] In addition to this, various infrastructures are being funded (e.g. clean rooms, equipment) in technology parks, public R&D institutions and private companies.

In the *U.S.* there has been a clear focus on (industry-led) R&D consortia between industry and academia. The SEMATECH program in the early 1980s successfully moved the U.S. semiconductor industry into a new generation of technology. Today,

1 E.g. Taiwan gives a 35 % credit loan for R&D expenses and personnel training which can be offset against income tax and is paid for five consecutive years to companies. If the expenditures exceed the average of the preceding two years, an additional 50 % of the excess amount may be offset against the income tax payable that year.

a significant share of funding is coordinated by the “Semiconductor Research Corporation”. Currently three major programmes have been set up (Global Research Collaboration; Focus Center Research Program; Nanoelectronics Research Initiative), which differ in their technology focus, government involvement and autonomy of academia and openness to foreign members. There has been considerable success achieved in terms of maintaining the leading position of U.S. firms (with production off-shored to East Asia) and the leading position in R&D-intensive chip design. However, because the share of production capacity has been decreasing continually, some efforts have been made to move backwards with regard to traditional industrial policy instruments. In particular, on a regional level, investment incentive programmes and large individual grants for investment in production facilities have been set up over the past few years.

In *Europe*, the semiconductor industry is not usually addressed by sector-specific policies, but by more generic measures (e.g. cluster competitions). Exemptions are joint programmes across EU member states under the Joint Technology Initiative ENIAC and the EUREKA programme CATRENE (Cluster for Application and Technology Research in Europe on NanoElectronics). However, these programmes are mostly financed by member state institutions and dominated by national interests (Wydra et al. 2010). They are accompanied by intensive institutional funding of universities or R&D centres like CEA-LETI in France, Fraunhofer CNT or NAMLAB in Germany. In the late 1990s and early 2000s, significant incentives were given for single large investment cases. But with the introduction of stricter European state aid control, the permitted maximum aid intensities for high investments for member states were significantly lowered. Consequently, there was a noticeable downturn in the value of grants. But despite the largely generic support, government interventions can still have important effects on the industry. In France, mainly existing actors benefit from the promotion of the Minatec cluster in the cluster competition and the high grants for the leading firm ST Microelectronics in the Nano 2012 programme.

In conclusion, the example of nanoelectronics shows some transition towards a more innovation-oriented industrial policy. The implemented policy instruments have changed in all of the countries and some policies like import tariffs have been reduced or abandoned. Overall, a broader set of policies has been implemented to address the various system failures. However, traditional industrial policy instruments still persist in nanoelectronics. Because of the high intensity of R&D and capital, subventions still play an important role. In addition, several governments have rescued memory chip manufacturers in the wake of the recent economic crisis (e.g. South Korea, Japan). However, hardly any demand-side innovation policies have been put onto a policy agenda. Public procurement played a decisive role in building up the semiconductor industry in its beginnings, but this industry’s cross-cutting character makes such policy interventions difficult as they would have to address very different markets and sectors.

Software

The software industry, which is understood here as software products as well as IT services, is one of the most prominent examples of a highly attractive and dynamic innovative industry. It has often attracted the attention of policymakers for several reasons. On the one hand, software and IT services seem to be a relatively low-investment industry with high growth rates and therefore an interesting field of development for many countries. On the other hand, it has become a crucial element for businesses and administrations worldwide, i.e. software (production, usage, and maintenance) has become a major cost factor for administrations as well as businesses all along the value chain for all goods and services from development and production through distribution to maintenance. However, the increased attention here is a fairly recent development boosted by the dot-com boom in the 1990s. In the 1970s and 1980s, support focused mostly on ICT hardware and, in a wider sense, on ICT systems. The software industry presents a specific set of problems to policymakers. Unlike other technologies with the same significance, software is a very dynamic one due to several specific social, economic and technological characteristics like the strong differentiation into various segments and the related specialisation, the layered structure of applications, and the broad range of required skills (Tessler et al. 2003). Altogether, this has led to a situation where software policies have to serve different, often contradictory aims in a volatile, risky and highly dynamic environment. As a consequence, a broad range of successful and unsuccessful approaches can be identified that will be described in the following.

Most obvious is the case of the *U.S.*, which is home to most of the world's leading software companies. On the one hand, there is a long tradition of the U.S. government to not pursue sector-specific policies. Therefore the policies are aimed more at providing a generally business-friendly climate, providing a well-educated workforce, maintaining infrastructure etc. There are also several horizontal programmes of R&D funding (e.g. the ATP program) as well as a strong, often defence-driven, pre-commercial state procurement (e.g. SBIR program). The software industry profits from all of these, as shown by different examples throughout the whole time span from the 1960s to the present, but the measures are not sector-specific. Moreover, the great variety of public as well private initiatives and partnerships are considered to be one of the reasons for the dominance of the American software industry worldwide, because of its ability to not only develop but also commercialise new technologies (Wessner 2004; NAS 2007). In *Europe*, the interest in software and its related industries only developed with the dot-com bubble in the late 1990s and in many countries led to the launch of measures in support of these industries, for example in the area of venture capital or R&D support. However, once the bubble burst, of course, most of this support ceased because of the obvious failures and, driven by the EU development, most countries turned to globally integrated programmes with a strong focus on the demand side. One remarkable exception is the case of Ireland. Since the 1980s, the government there has pursued a national economic development and employment strategy to attract labour-intensive services to Ireland. The strategy to attract especially foreign direct investments of multinational companies (MNC) was based on different, complementary pillars: increasing the human capital base, creating a favourable tax environment and further investments in infrastructure. It was quite successful in attracting especially American MNC in the software industry. These often used Ireland as their hub to Europe and turned Ireland into a leading export nation in IT and software. While this strategy bears the risk that the MNC may one day disappear, Ireland has managed to develop its own domestic software industry in the wake of this development. This was influenced by the presence of the MNC, but also by measures to intensify the links between science and industry and create good conditions for spin-offs and other entrepreneurial activities (Sands 2006; Breznitz 2007). Therefore, Ireland still has a software strategy as part of its national development strategy (Leimbach and Friedewald 2010).

Japan is traditionally considered one of the leading countries in ICT. While Japan managed to become a leading producer of computer hardware in the 1970s and 1980s, it failed to establish a strong software industry even though the software industry was the subject of the same industrial policy approach as the hardware industry, i.e. industry consortia steered by MITI. The reasons for this failure are widely discussed in the literature (e.g. Cusumano 1992; Baba et al. 1996; Kim and Choi 1997). They include the lack of qualified employees, technological deficiencies, inefficient processes as well as the market structure, but also the inability of the ministry to steer an industry in such a volatile environment. Japanese producers only reached a position equivalent to the computer hardware industry in computer and video games as well as embedded software, but this relates more to the strength of Japanese producers in consumer electronics and machine tools (e.g. Campbell-Kelly 2002). Later on, Japan started to develop an integrated overall Information Society strategy similar to ones in Europe, which is also reflected in the current Digital Japan Creation Project. *South Korea* was another example of a leading country in exporting electronic consumer and computer hardware, which did not succeed in developing a domestic software industry. In the aftermath of the economic downturn in the late 1990s, the government here introduced a series of measures targeting the software industry as part of a general framework to promote information technology. As a consequence of the software development promotion act adopted in 1997, the Korean IT Promotion Agency (KIPA) was founded and software and multimedia research centres were established. This course of action was reinforced in the following years by the Software Industry Promotion Act, which also addressed measures like public procurement and was renewed after major restructuring in 2009 (Giron et al. 2009). However, so far, the hoped-for success has not yet arrived, which is shown by the fact that the successful mobile devices of Samsung are still dependent on an American software system.

In contrast to the above cases, the failure of *India* to build up its own hardware industry led to a shift in its focus onto the development of software and made India into a leading nation in exporting IT services. After the liberalisation of India's economy, which had its turning point in 1991, the Indian software industry experienced major growth, which was mostly export driven. The foundations were laid by different software policies throughout the 1980s, focusing on human capital formation, the establishment of domestic companies and trade policy for the software industry. After liberalisation, support was continued in the form of specific tax incentives for exports, the provision and improvement of infrastructure as well as further improvements in education and research. Overall these helped to make India one of the world's leading countries in the export of software goods and services (e.g. Breznitz 2007; Athreye 2006; Commander 2005; Carmel 2003). In recent years, the Indian government has not attempted to make any major changes to these policies; instead they have sought to reinforce and supplement them by initiatives aimed at fostering the potential of the domestic market. Another successful example of developing a software industry is *Israel*. This process began back in the late 1960s and 1970s, when Israel started a programme for high-tech industries, especially in the defence sector. Subsequently, policies were implemented which targeted a larger human capital base, improved scientific quality and strengthened science-industry relations. Overall, the goal was to build up a science-based industry focused on high-tech defence products. After the economic crisis of the 1980s, the focus shifted to other industries steered by the newly founded Office of the Chief Scientist (OCS), which aimed at supporting high-tech companies throughout the whole life cycle. This office launched several programmes of which the YOZMA programme, which was aimed at creating a venture capital market, turned out to be a huge success, in particular for the emerging software companies. However the policies were not industry-specific. As a consequence of this development, the software industry in Israel is highly product-orientated unlike India and is also very specialized in niche products, which explains why the industry has such a high export turnover (Commander 2005; Breznitz 2006; 2007; OECD 2009a). In other emerging countries like *China* or *Brazil*, the development of the software industry has mostly been driven by the domestic market, in particular by efforts to modernise the domestic economy. Although policies are now turning more towards exports, it is still unclear whether they will succeed in the long term (Giron et al. 2009).

To sum up, the patterns of success and failure in developing a domestic software industry provide some interesting insights. While in Israel there was a strong orientation towards high-tech industries before the software industry took off, India and partly also Ireland were not considered ideal places for the development of high-tech industries. On the other hand, a highly developed country like Japan, which pursued successful strategies in other ICT industries, failed to develop a successful software sector. A common characteristic of nearly all the successful examples is the intended or unintended interplay of more innovation-oriented policies like supporting human capital formation and other more industry-targeted measures like specific trade policies, financial support schemes or attracting MNC. This clearly underlines the existence and potency of such combined approaches. However, this interplay and interrelations of policies is often overlooked or at least neglected in existing studies, but closer examination reveals that effective governance is still a challenge, which needs to be understood more systematically in order to exploit the potentials.

Biotechnology

Biotechnology is often taken as the ideal example of systemic innovation policy. Although the industry is very science-driven, many countries not only deploy R&D measures, but also have policies to support commercialisation. "International competitiveness in the biotechnology industry relies strongly on the ability of small start-up firms to find financing on venture capital markets and to convert research done in publicly funded universities and research laboratories into products and services while preserving the intellectual property rights of innovators" (Hart 2004, p. 50). Unsurprisingly, the dominating countries are those whose innovation system best fits these needs. The *U.S.* in particular were not just successful in research, but in supporting the industrial development. Incentives to commercialise the research results were set by intellectual property rights. In addition, considerable government funding of young biotech companies was able to attract subsequent venture capital investments in these companies. This was because public funding of young companies made it possible for the firms to move their products forward to the point at which they became interesting to investors (Lange 2006). On the demand side, the very high levels of subsidised spending on healthcare ensured market opportunities for the usually more costly biotechnological products.

There are mixed results for the policy pursued in Europe (Göransson and Pålsson 2011). Considerable success has been achieved by regional innovation policy. In Germany, for example, the BioRegio cluster initiative in Germany in the 1990s is widely acknowledged to have made a considerable contribution to the development of the domestic biotechnology industry (Dohse 2000).[2] However, the expectations of industrial development have not yet been reached. In particular, the efforts to establish a biotechnology cluster in areas with few related industries (pharmaceutical, chemistry) have had little success. Similar observations can be made in Asia. One example is the BioValley in Malaysia. Although a large infrastructure was set up, the right incentives for companies were not set and the project suffered from a lack of tradition in high-tech entrepreneurship (Lerner 2009).

Overall, the case of biotechnology highlights the fact that government policies have to address many aspects of the system of innovation. Not only tools for science and technology policy have become more important, but also other stages of the innovation cycle, such as education, collaboration between academia and industry, creation of business venture, establishment of technological platforms or the creation and development of clusters encompassing scientific and educational institutions as well as manufacturing companies (Göransson and Pålsson 2011). These tools are not completely new to industrial policy, but they mark a different focus of policy measures compared to the traditional approach. In addition, they tend to be implemented more in competition-based programmes rather than being part of a top-down strategy.

2 "[...] the new policy instrument cannot solve the fundamental information problem associated with government intervention into the process of technological change, but that it goes into the right direction by taking the regions seriously and giving prominence to the well-functioning interplay of the various elements of regional innovation systems" (Dohse 2000, p. 1111).

However, classical industrial policy may regain importance in the upcoming application fields of industrial biotechnology. Already today, different industrial products are being manufactured using biotechnological processes like fuels,[3] chemicals and materials such as plastics (OECD 2009b).[4] The market penetration of biotechnology is expected to increase significantly in the future (Wydra et al. 2010). The related upscaling of biotechnological products to production facilities up to 200kt means this industry is highly capital-intensive. Government support for physical infrastructure (pilot, demonstration, commercial plants) has recently increased significantly. There are already several reported cases with quantified or qualitative information about investment incentives for commercial production facilities all over the world (Wydra 2012). In the future, investment incentives may become even more important, as the capacities of the plants rise and their local economic impact increases. In such cases, the geographical differences in the related policies will probably increase, as the commitment and opportunities differ widely between countries. In addition, strategic resource policies will become more significant. Various regulations (import tariffs, subsidies for farmers etc.) impact the availability and price of renewable resources/biomass. Demand-side policy plays a mixed role for industrial biotechnology. While this is widely used for bioethanol, so far it has only rarely been implemented for material use, with the exception of the Bio Preferred programme in the U.S., which sets regulations for public procurement.[5] Similar challenges arise as for nanoelectronics (e.g. coordination between ministries or countries in the case of EU, cross-sectional use of products).

12.5 Conclusions

12.5.1 Discussion

The case studies confirm that some of the issues indicated by the theoretical approaches to innovation and industrial policy are indeed being applied in practice and are of crucial importance. As Table 12–1 indicates, successful policies tend to have an enabling and coordination role as proposed by the systemic innovation perspective; attempts at top-down steering have mostly been less successful. Support programmes are conceived as competitions, which enable a market-based decision on winners.

Examples of these include cluster competitions or entrepreneurial policies offered to a wide range of actors. But it is obvious that traditional industrial policy instruments like investment incentives for single firms, tax rebate programmes etc., still play a crucial role in R&D and capital-intensive sectors such as industrial biotechnology

3 Please note that policies for bioethanol are not included in the policy analysis, but only material products which are produced with biotechnological processes.

4 Many countries have introduced strategies and action plans for bio-based products.

5 In Europe, different measures ranging from Public Procurement to tax incentives, regulation, quotas or mandatory use for bio-based products have been proposed in the Lead-Market Initiative for bio-based products. So far, only standardisation activities have been implemented.

Table 12–1: Overview of key results of the case studies

	Semiconductor	Software	Biotechnology
R&D intensity	Very high	High	Very high
Capital intensity	Very high	Rather low	Depends on application field
Traditional policy approach	Long tradition of industrial policy	Low specific focus on industry until 1990s	Mostly systemic innovation approaches
Recent developments in policy	Abundance of some traditional measures and more orientation towards innovation system perspective; but strong government intervention persists	Mostly orientation towards innovation system perspective, in particular R&D funding	Resurgence of traditional policy instruments for industrial applications ("industrial biotechnology")
Characteristics of successful policies	Co-evolution of policy with changes in industrial structure and globalisation	Interplay of more innovation-oriented policies like supporting human capital formation and more industry-targeted measures like specific trade policies, financial support schemes or attracting MNC	Address many aspects of innovation system
Most important policy measures related to industrial development	Investment incentives Strong support for collaboration between academia and industry	Entrepreneurial policies; policies for financial capital development, cluster policies, support for collaboration between academia and science	Strong support for collaboration between academia and industry; entrepreneurial policies; support of regional clusters
Role of government	Differences between countries: top-down steering (TW, CN) vs. bottom-up (GER, FR)	Mostly supporting role, different approaches concerning sectoral vs. generic policies	Different: often coordinating role, but some strong specific interventions

Source: own draft

and semiconductors. Hence, the mix of innovation and industrial policy instruments differs between countries and sectors. This is very obvious for demand-side innovation policies. These are attractive tools for innovation and industrial policy, because they can unlock path dependencies based on inferior technologies, redirect innovation and technology diffusion to better meet societal needs and boost domestic industrial development. However, so far at least, they have only played a limited role in those high-tech sectors which are related to cross-cutting technologies such as nanoelectronics, software or industrial biotechnology (Edler 2007). In the industries observed, these are not a major tool to boost industry or technology in a comprehensive way, as this would imply strong interventions in almost every sector in the economy due to their cross-cutting nature.

This renders policymaking tricky because the case studies indicate that a mix of different policies should be tailored to the specific needs of industries. The strong interactions between different policies have to be recognised when new or adapted measures are being designed. A range of supply and demand side factors needs to be in place (Athey 2010). Despite the fact that we were not able to study the respective innovation systems in-depth in these brief overviews of policies in industries, the examples still indicate the need for the right balance and smooth interaction between the many different factors involved. This also underlines the fact that isolated policies – such as traditional industrial policy instruments supporting the construction of buildings or science parks or those providing tax and investment incentives – are not sufficient for successful industrial development. Most countries have recognised this and are deploying sets of policies in the various high-tech sectors.

But while public policies undoubtedly matter for developing high-tech industries, usually policy alone was not able to spark a dynamic industry development; this required a whole range of favourable framework conditions. Such favourable conditions may include a locational advantage, such as existing related industries (e.g. pharmaceuticals, chemicals for biotechnology), research infrastructure, natural assets, or human capital and/or favourable contexts and policies. Examples are the needs of the defence sector in the case of the emergence of the U.S. software and semiconductor industry, or policy strategies to liberalise economies like those in India and/or to attract foreign direct investments like in Ireland or Taiwan. This finding indicates that policies that work in some countries might not work in others. Indeed, countries have been successful with different kinds of strategies and combinations of instruments in the various industries, which have sometimes been unintended rather than actually planned. Therefore, an analysis of general framework conditions as well as industry specific conditions is required to properly understand the needs and failures.

The success examples do show that policies have to address the specific needs of the industries. This has either been achieved by sector-specific policies or by horizontal programmes, if these favour the respective industry, as was, for example, the case for the venture capital programme YOZMA in Israel for software, or the SBIR programme in the U.S. for software and biotechnology. Although these instruments are often highlighted in the debate, other complementary measures were also shown to be key success factors, which underlined that, in these cases, instruments of industrial and innovation policy interacted successfully. However, the coordination and governance of the measures proved to be very challenging.

Finally, another conclusion is that the results indicate a "friendly" combination that incorporates elements from both concepts. As shown by the case studies and outlined by the analysis, the success of such a mixture of policies is built on the fact that the two policies are on an equal footing to enable an interplay of different measures.

12.5.2 Implications for further research

Despite the outlines given for an appropriate design of industrial and innovation policy, there are still some major questions remaining and the need for further work on the conceptual approach combining innovation and industrial policy. While the systems of innovation policy undoubtedly provides a new policy rationale for industrial policy, this approach it is still vague regarding the justification of policy measures. Analytical tools therefore have to be developed based on a concept like system failures (Woolthius et al. 2005) which offers a consistent approach to identifying failures as well as to deriving rationales based on the identified failures. A first approach could be process analysis as used in the technological innovation system (TIS) approach, but this still needs refinements. It is still unclear whether the rationales should be reconsidered, given the major challenges due to the increasing globalisation of innovation processes (Borras et al. 2009). Specifically, open questions concern the justification for interventionist measures of traditional industrial policy such as investment incentives. This has not been sufficiently clarified in the innovation system perspective and, as a consequence, very few clear conclusions can be made about this combined perspective of industrial and innovation policy, e.g. concerning the intensively debated European state aid control (Wydra et al. 2010).[6]

Another challenge is the identification of concrete instruments and their combination within an existing framework. As shown by the case studies, there are clear interrelations between innovation and industrial policies for developing industries in fields like public procurement or the formation of financial and human capital. Analysing them indicates that in many cases success was dependent on the right interaction of different measures and the ability to steer the underlying measures. Moreover, the case studies also revealed that successful combinations varied between different industries as well as different countries. Although the formation of human capital was often important, it is difficult to direct this or other measures to the needs of the different emerging industries. Sometimes this was done in a more top-down manner, sometimes more by coincidence. Since top-down bears risks and leaving things to chance is not an option there is a clear need for a systematic understanding of the different possible instruments, their interactions with each other and with different framework conditions in order to grasp the governance and steering of such policies. This also includes ways to measure progress and success in order to support the steering and governance process.

We can conclusively state that the innovation system perspective provides a fruitful starting point to further develop this combined approach, because it highlights the differences between countries in sectors concerning innovations and their commercial exploitation. As outlined, there are possibilities for conceptual contributions like the further development of the system failure concept to be used as a tool to identify weak ties and justify policies. Moreover, approaches like the technological

6 First attempts have been made by Benhassine and Raballand (2009). They conceptualise a matrix of different types of justification based on the degree of selectivity of instruments and extent of price subsidies. However, they focus only on some systemic failures.

innovation system and its process analysis can be used to develop industry-specific instruments. Finally, the system of innovation approach can also be used to develop taxonomies. Such taxonomies of sectors (Pavitt 1984) and countries (Dodgson et al. 2010) have been developed to some extent on their modes of innovation. However, these taxonomies have not been specified regarding the need or success probability of certain policies. Such specifications could provide policymakers with clearer advice and help to avoid mistakes by not simply trying to copy the best-practice examples of other countries and sectors.

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13

IMPACTS OF POLICY MEASURES ON THE DEVELOPMENT AND DIFFUSION OF MICRO CHP TECHNOLOGY IN GERMANY

HANS MARTH, BARBARA BREITSCHOPF

13.1 Introduction

The utilisation of combined heat and power (CHP) generation is an important component of Germany's CO_2 emission reduction strategy. Since 2002 the CHP law (*Kraft-Wärme-Kopplungsgesetz KWKG*) has set the target for CHP to attain a share of 25 % in German electricity generation capacity by 2020. This target is part of the EU's 2020 targets to reduce greenhouse gas emissions by 20 %, increase the share of renewable energy in final energy consumption to 20 % and realise 20 % of energy efficiency improvements (European Commission 2010).

CHP technology has been applied for decades in large-scale commercial power plants as well as in medium and small scale decentralised installations. However, micro CHP (capacity of less than 5 kWel) technology is still emerging because crucial components have only been developed recently or are still at the stage of technological development and demonstration.

Since the KWKG came into force in 2002, a number of policy measures have been taken to promote the use of micro CHP technology. While this has led to an increase in sales numbers for mini CHP plants with capacities between 5 and 50 kWel, smaller units have not benefitted in the same way. Therefore, the aim of this work is to examine the impact of policy measures on the development and diffusion of micro CHP technology in Germany.

There has been considerably more political activity in the energy sector than in other sectors. Numerous technical decisions have therefore been triggered by policy measures. Due to the prominent role of policy measures in the development and deployment of low-carbon technologies, it is appropriate to analyse the impact of these measures. Micro CHP as a potential technology for future electricity and heat supply for households is an interesting field for this analysis.

Before analysing their impact, policy measures affecting micro CHP technology development and diffusion have to be identified and categorised and further framework conditions affecting CHP like administrative requirements and energy market conditions are defined. At the company level, a number of relevant factors for innovation decisions regarding micro CHP can be found. These factors are then discussed and based on a framework for development and diffusion activity, key questions for the methodological approach of the study are derived.

Since the character of this study is exploratory, qualitative expert interviews were chosen as a method. Most of the innovation activity in the micro CHP sector is accomplished by corporate actors, therefore company representatives were chosen as interview partners. The results presented here are based on expert interviews with representatives of five different firms.

The contribution is structured as follows: the next section will give an introductory overview of the state of micro CHP technology and market development. Section 13.3 provides the theoretical background, consisting of the underlying understanding of innovation, the categorisation of the political framework and the structure of the interview process. In Section 13.4, the results of the expert interviews are presented and in Section 13.5, recommendations for a more efficient policy design are derived. Section 13.6 contains a discussion of results and final conclusions.

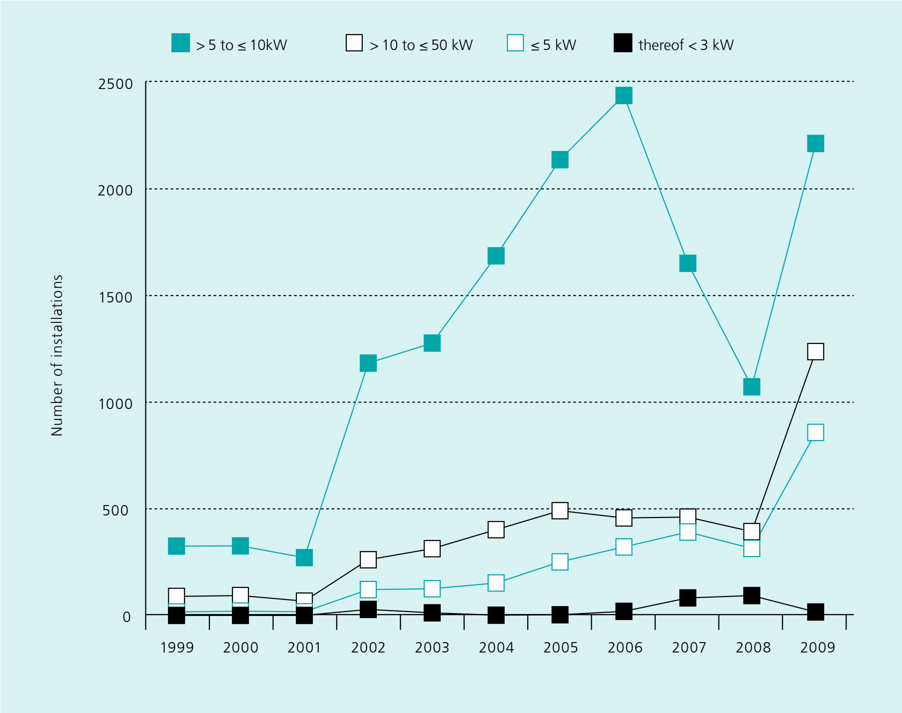
13.2 State of micro CHP technology and market development

Currently, there are three main technology groups competing in the micro CHP market. Most available units are equipped with internal combustion engines (ICE), while considerable development activity can be seen in the area of stirling engines (SE) and fuel cell systems. Out of 30 products monitored by a micro CHP information service[1], as of November 2011, twelve are commercially available. Eight units rely on ICEs, three are equipped with SEs and one unit used a free-piston engine, but is no longer available because the manufacturer declared bankruptcy.

CHP generation in Germany mainly takes place in large plants. In 2001, only 6.7 % of CHP electricity production came from small-scale CHP installations (Bauer 2009), since then the market structure has not changed significantly. After the KWKG came into force in 2002, there has been an increase in the number of smaller installations, but installed capacities have not yet reached levels comparable to large scale commercial power plant CHP production. The development of installation numbers for mini and micro CHP plants in Germany from 1999 to 2009 is illustrated in Figure 13–1. The figure clearly illustrates that the share of micro CHP installations below 3 kWel is still insignificant.

1 See http://www.stromerzeugende-heizung.de.

Figure 13–1: Mini and micro CHP installations in Germany from 1999 to 2009



Source: own illustration, Federal Office of Economics and export control data

In 2010, electricity production in CHP plants reached 15.8 % of total generation. Almost 60 % of CHP electricity production comes from natural gas fired installations, 22 % from coal fired installations and a growing share of currently almost 13 % is produced using renewable energy sources, i.e. biomass (UBA 2012).

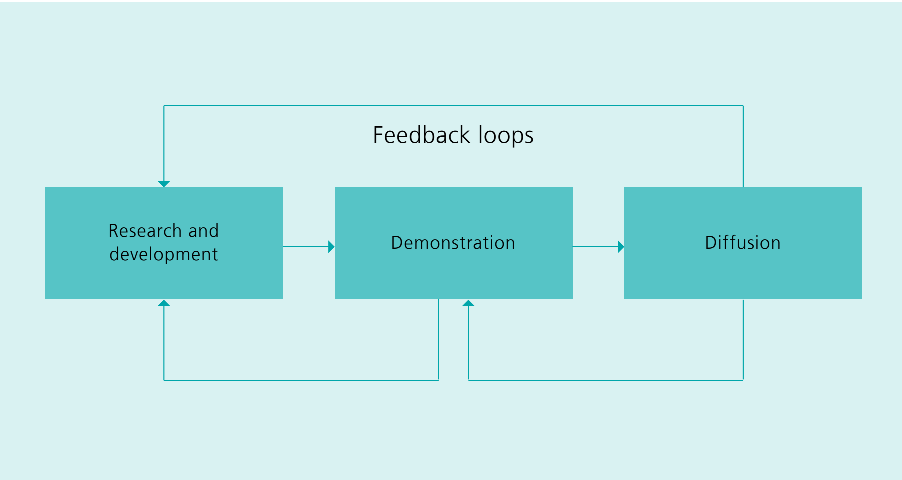
13.3 Theoretical background

In a market economy, politics cannot directly participate in economic decision-making. Instead, influence on corporate decisions and innovation activities can be exerted by a number of different policy mechanisms and institutions. The political support for CHP installations in Germany is based on the technology's positive effect on CO_2 emissions and primary energy consumption described in the first section. In the following section, underlying concepts will be described, policy mechanisms will be systemised, and the existing policy framework for micro CHP in Germany will be described.

13.3.1 The innovation process

To start with, the innovation concept underlying this study has to be clarified. Innovation processes consist of three overlapping and interacting phases which are not intended to be understood as a linear process. It is however possible to determine a sequence of phases. First, knowledge has to be generated (research and development). In a next step, this knowledge has to be translated into products (demonstration), and finally these products have to be distributed and adapted to consumer requirements (diffusion) (Pavitt 2005). There are various feedback loops between these phases, making the process non-linear. (Edquist 2005). This understanding of the innovation process is illustrated in Figure 13–2.

Figure 13–2: Phases of the innovation process



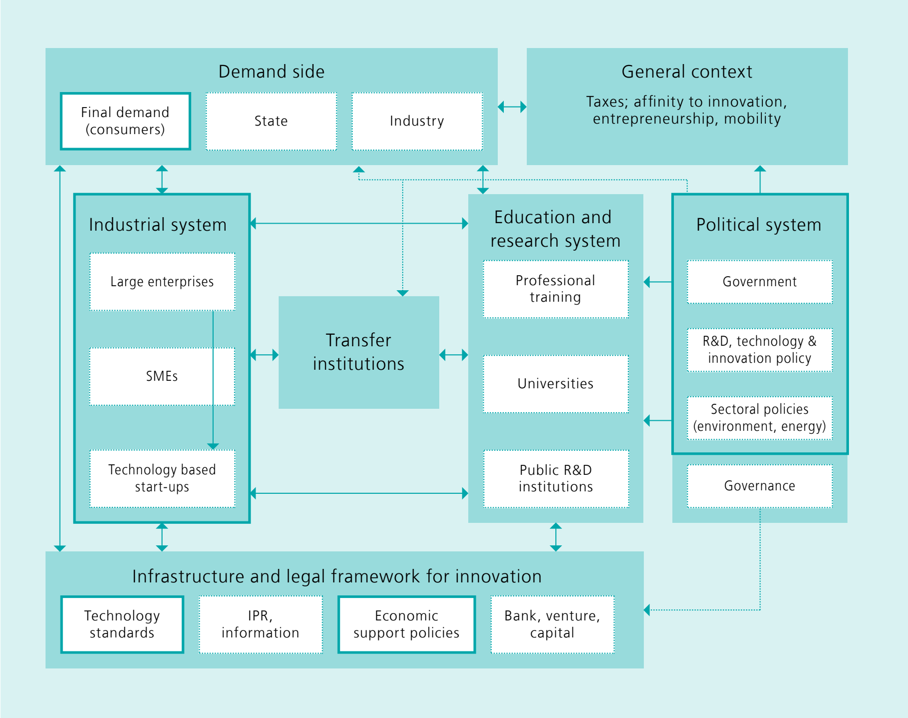
Source: based on Pavitt (2005)

When analysing technological innovation systems (cf. Carlsson 1995), technology development and, accordingly, framework conditions are the focus of attention. Suurs (2009) describes the approach as related to the micro-level of innovation processes, so it is an approach suitable to investigate firms' reactions to the political framework, which is the aim of this work.

Legal framework conditions are an important part of the technological innovation system. Besides technology development and diffusion, a number of other components in the innovation system interact with the political system, but the scope of this work has to be limited to selected parts. Based on the innovation system heuristic commonly used in studies by Fraunhofer ISI (cf. Chapter 1 of this volume), Figure 13–3 clarifies which areas of the (technological) innovation system were selected for the analysis. It also depicts where policy measures for CHP have effects and which actors play important roles in technology development and diffusion.

On the demand side, the focus of this study is on final demand, since private consumers constitute the largest share of home owners in the area of detached one- and two-family houses. On the supply side, no limitations regarding firm size or other

Figure 13–3: Relevant technological innovation system components and their interaction



Source: own translation of Edler (2007, p. 42)

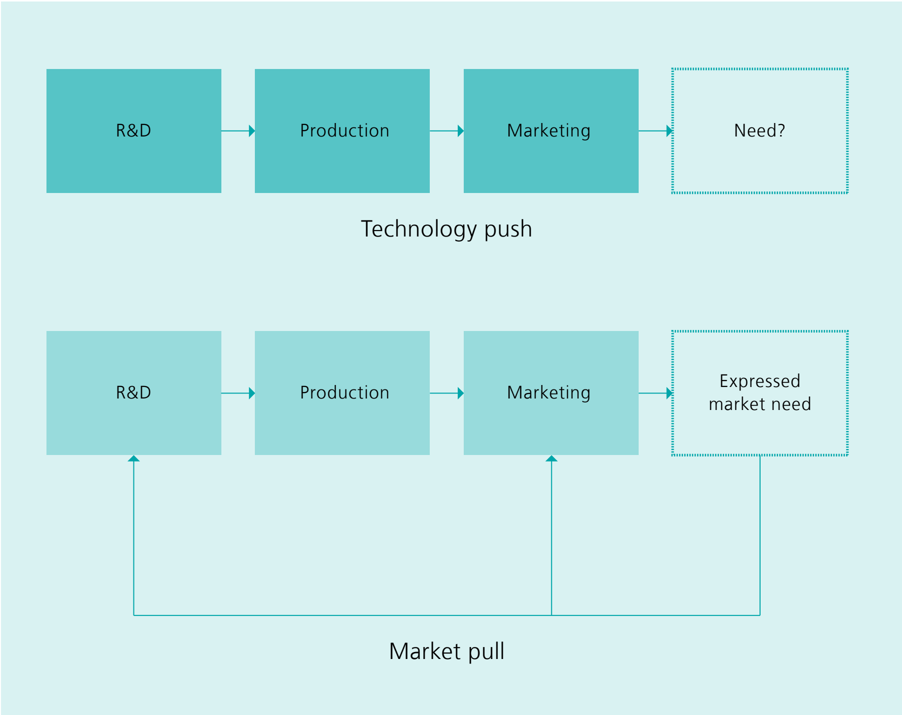
specifics were taken because the number of firms active in the area of micro CHP is quite small. Infrastructure and legal framework conditions investigated included technology standards and economic support policies. Financing and intellectual property right (IPR) information was included wherever possible, but due to the sensitivity of this data, this was not the centre of attention. With regards to the political system, pre-interview analysis was limited to the investigation of existing policy measures. Governance style and non-legally binding measures were not included to keep the scope concise.

Public education and research and transfer institutions were excluded from the study because most micro CHP development activities take place in private companies and cooperation with public research institutions only occurs to a very limited extent.

13.3.2 Categorisation of policy measures

As noted in the previous subsection, policy measures to promote CHP technology impact different elements of the technological innovation system. In this section, a classification of policy measures is undertaken. This classification is useful because

Figure 13–4: Technology push and market pull



Source: Martin (1994, p. 44)

innovation processes exhibit a number of different mechanisms. On the one hand, innovation processes can be triggered by research and development activities and inventions that give the respective company a competitive advantage which can be taken to market. In this case, final demand for the product is uncertain. The technology driven introduction of new products is called "technology push" (cf. Figure 13–4). This development contrasts with the so-called "market pull" mechanism, where an innovation process is initiated by an expressed or perceived demand for a certain product or service (Martin 1994). To correspond to these mechanisms, policy measures can be classified as being either demand-side or supply-side oriented.

A further useful distinction of policy measures is offered by Edler (2007). He describes direct, indirect and regulatory measures. Following this categorisation, policy measures relevant to micro CHP technology can be classified as shown in Table 13–1. In the next sections, German policy measures for the CHP sector will be identified according to this scheme.

Table 13–1: Supply and demand side policy measures relevant for micro CHP development and diffusion

	Supply side	Demand side
Direct support	(Financial) R&D support	Subsidies, bonuses and tax rebates
Indirect support	Educational and regional economic policy	Raising of awareness, information
Regulation	Product requirements	Technology standards (best available technology, building efficiency requirements), mandatory use of technology

Source: own compilation

Supply side policy measures

Supply side policy measures do not play a prominent role in German CHP policy. The only exception is strong R&D support for fuel cell research (OECD 2011), which is potentially a technology that can be applied to micro CHP installations. The National Hydrogen and Fuel Cell Technology Innovation Programme (NIP) has a volume of 1.4 billion euros, spanning from 2008 to 2016. It benefits the sectors transport, stationary energy supply in industry and households, and special markets.

The Callux project is a large-scale field test programme for fuel cell heating appliances, co-funded by industry and the NIP with up to 86 million euros. As of March 2012, 211 fuel cell heating units have been installed under this programme.

Further supply side measures mainly address energy and resource efficiency issues with merely indirect results for the micro CHP sector. There is no public R&D supply for combustion engine driven CHP units listed in current funding databases of both the Federal Environment Ministry and the Federal Ministry of Education and Research. Also, only very limited activity by universities or other public research bodies can be monitored.[2] The only topic apparently receiving some academic attention is the application of micro CHP units in virtual power plants, i.e. the coupling of decentralised generators to level out fluctuation in renewable energy electricity generation (Houwing et al. 2009). A recent study investigating the technological innovation system for micro and mini CHP in Germany concludes that the micro CHP sector in Germany has mainly developed due to corporate activities, and not because of public R&D support (Praetorius et al. 2010).

Demand side policy measures

On the demand side, the political framework for micro CHP technology is more

2 Exceptions are micro CHP field trials conducted by the chair for energy economy and application technology at Technische Universität München and a number of CHP related research projects coordinated by the Fraunhofer Information-Centre for Regional Planning and Building Construction.

comprehensive. Besides direct support mechanisms, a number of regulatory measures influence technology diffusion.

The first direct demand side support mechanism is a feed-in tariff for electricity generated in CHP installations. The KWKG guarantees a premium of 5.11 euro cent/kWh over a period of 10 years for operators of CHP installations with a capacity of less than 50 kWel. Furthermore, the KWKG guarantees prioritised grid access for electricity from CHP installations, which may only be denied if grid stability is endangered. However, the installation and grid connection of new CHP plants is complicated by a number of technical and legal restrictions and connecting conditions imposed by grid operators. A successful diffusion of micro CHP technology would require the removal of a number of technological and economic barriers (Watson et al. 2008).

Operators of micro CHP installations can benefit from further financial incentives. They may be exempted from energy taxes paid for fuel that is consumed and for electricity produced and consumed in close proximity to the installation. If the CHP plant is operated with biomass, instead of receiving the KWKG feed-in tariff, operators can also apply for funding through the Renewable Energy Act (*Erneuerbare-Energien-Gesetz EEG*), which offers a higher fixed remuneration over a period of 20 years.

Rather than aiming at reducing the operating costs of CHP installation, a second set of direct support mechanisms helps to reduce the initial investment. The "Impulsprogramm", a support programme for micro and mini CHP installations, granted an investment subsidy of 1550 euros/kWel for installations with a capacity of up to 4 kWel from 2008–2009. Due to the unexpected success of the programme, from August 2009 onwards, no more funding notifications were issued, and in March 2010 the end of the programme was backdated to August 2009. In January 2012 however, a new subsidy programme was announced, supporting new installations with 1500 euros/kWel for a capacity of up to 1 kWel and 300 euros/kWel for capacities of 1–4 kWel. When the programme was announced, no volume or funding time limitations were published, and changes to support rates can be made at any time. Furthermore, the state owned KfW bank issues loans with reduced interest rates for energy efficient building renovations.

In terms of regulatory measures, the Renewable heat act (*Erneuerbare-Energien-Wärmegesetz EEWärmeG*) obliges home owners to include renewable energy sources in the heat supply of new buildings. They can be exempted from this obligation if a micro CHP unit is installed.

Hawkes and Leach (2008) point out that energy efficiency measures like the Energy Saving Ordinance for new buildings (*Energieeinsparverordnung EnEV*) combined with support for micro CHP installations may be problematic. The resulting CO_2 emission reductions can be small or non-existent if the building's heat demand is too low to allow for efficient operation of the CHP plant. The authors demand that support for CHP installations is coupled with the requirement to prove that there is sufficient heat demand and that the installation is dimensioned accordingly.

Public procurement can also support the diffusion of innovative technology (Edler 2007). In this context, the public building refurbishment programme can be seen as potentially relevant for CHP diffusion because one focus of this programme is on energy efficiency of buildings.

The previous sections have shown that there are a considerable number of policy measures influencing the market for micro CHP in Germany. The overall context of these measures is the commitment to reduce CO_2 emissions and reach international climate policy targets. The main focus of micro CHP-related policy measures is on the demand side, consisting of direct support as well as regulatory mechanisms. On the supply side, only one instrument could be identified. Furthermore, a lack of indirect support instruments is noticeable; possibly resulting in reducing the effectiveness of direct measures (cf. Table 13–2).

Table 13–2: Summary of policy measures for CHP technology in Germany

	Supply side	**Demand side**
Direct support	NIP	KWKG, EEG, Impulsprogramm, tax exemptions
Regulation		EEWärmeG, EnEV

Source: own compilation

Besides policy measures, further framework conditions influence CHP technology development and diffusion.

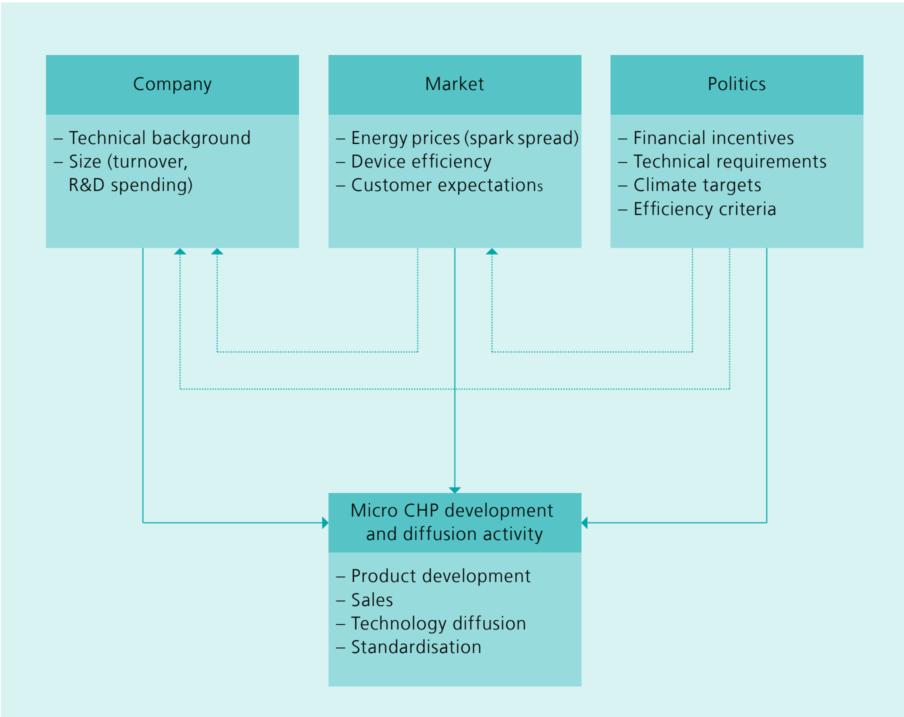
- legal aspects: grid connection conditions, purchase obligation for grid operators
- market development: competing technologies, (fossil) fuel and electricity prices
- administrative procedures (as follows)

To receive full financial support for micro CHP installations, it is necessary to go through numerous procedures. The comprehensive demand side support results in an increase in administrative requirements when operating micro CHP plants. Potential users have to contact at least three different additional authorities compared to one when installing a condensing boiler if they want to benefit from all the preferential treatments available. These authorities are the Federal Office of Economics and Export Control (for investment subsidies and feed-in remuneration), the customs office (for tax exemptions) and the local area electricity grid operator (for grid connection). The additional effort is compensated with revenues from several support mechanisms which reach around 8 % of heat generation costs for a typical micro CHP installation. Even with these subsidies in place, micro CHP installations are still not cost competitive in most cases.

13.3.3 Structure of the interview process

The aim of the interview process was to gain insights on how actors in the German micro CHP market perceive the influence of policy measures on their development and diffusion activities. Since these activities are influenced by a number of factors, these will first be discussed briefly. Then, the three main questions that form the underlying structure of the interview process are presented. In total, there are three main groups of influences on micro CHP development and diffusion activity which are summarised in Figure 13–5. First, prevailing expertise and origin of business (path dependency, cf. Dosi 1982) of the company predetermine the scope and direction of their activities. Second, market factors have a strong influence on development and diffusion activity. Third, and centrally for this investigation, politics influence development and diffusion activity as well as the other two groups of factors. Because of numerous additional interdependencies between the three groups, it is difficult to isolate one of them. Instead, this study attempts to gain an overview and then weight the influence of different factors. Accordingly, the main questions that served as the guideline for the interview process relate to the influencing factors identified.

Figure 13–5: Influences on micro CHP development and diffusion activity



Source: own illustration

The first main question tries to answer what degree of development and diffusion activity is shown by the interview participants. It aims to capture their motivation to enter the micro CHP market (cf. Beckenbach 2007), and who they see as their main competitors.

The second main question is how the interviewees perceive the importance of individual policy measures for their development and diffusion activities. One of the interviews' aims also was to determine what degree of independence from policy measures micro CHP manufacturers want to achieve and to what degree they could accept a dependence on policy measures.

The third main question is related to the participants' future expectations regarding market and framework conditions development. This includes asking which factors would benefit future technology development and what future framework conditions should look like to enable successful technology diffusion. This question also served as the basis for policy recommendations derived from the interview process.

13.4 Expert interview results

To gain insights from an actors' perspective on the impact of the German policy framework for micro CHP support, five expert interviews with company representatives were conducted. The interviews were structured around three main questions described in the previous section. In this section, the results are briefly summarised, according to the structure of these questions.

The expert interviews have yielded a number of interesting results. Albeit there are a considerable number of policy measures to support CHP technology, the positive effect of these measures is perceived to be fairly limited. The rate of diffusion of micro CHP is still very low. On the one hand, there still are not many devices that are commercially available. On the other hand, technology diffusion is also slowed down by a number of administrative barriers that are faced by prospective technology adopters.

13.4.1 Corporate innovation activity

The motivation for corporate activity in the micro CHP sector is mainly driven by path dependencies. Most actors have previous experiences in the condensing boiler market. Development activity is strongly motivated by politically imposed efficiency criteria and emission reduction targets, but financed by corporate funds. Other than in the area of fuel cell development, cooperation between manufacturers only plays a minor role, resulting in mainly independent technology development and diffusion activities of large producers of heating systems.

The participants expressed that they did not want to enter the micro CHP market as fast as possible, but rather aim to develop a technically sound product. Due to the long lifespan of heating systems, reliability is a very important product feature and malfunctioning systems would endanger the manufacturer's reputation.

In total, while there are no direct political requirements for micro CHP development and corporate activity is mainly motivated by firm-internal competencies, indirectly overarching efficiency and climate policy have an influence on these activities. However, the degree of these activities shows that political signals are too weak to override firm internal structures or development paths.

13.4.2 Influence of policy measures

The focus of the interviews was not on fuel cell development, therefore results regarding the relevance of policy measures for technology development and diffusion are related to engine driven micro CHP plants. The results are divided into impacts of direct support and regulatory policy measures.

For the relevance of direct support mechanisms, the participants' perception is congruent. The KWKG is described as a suitable and stable support mechanism, but its overall influence on technology development and diffusion is seen as low – possibly due to the fact that is has been in force for a relatively long time span. Most participants only took up activities in the micro CHP sector several years after the KWKG's enactment.

The Impulsprogramm is seen as a good support mechanism for an early stage of technology diffusion. However, the insecurity that was created by backdating changes to the programme is seen as an important barrier, neutralising the programme's positive impact. Several participants voiced the opinion that they would rather pass on investment subsidies in return for clearly set political and technical framework conditions. In sum, the positive impact of direct support mechanisms is not seen as strong enough to justify development activity, which is rather driven by firm internal factors, as described in the previous subsection.

The role of regulatory policy measures is seen as more differentiated. Efficiency requirements imposed by EEWärmeG and EnEV are generally perceived as beneficial for micro CHP because they increase customer awareness and final demand. Thus, these regulatory measures make markets accessible for the technology. If micro CHP competes against heat pumps or solar thermal heating support, its operation becomes financially more attractive than it would be in a situation where condensing boilers set benchmark prices. In this respect, the obligation to use renewable energy or micro CHP in heat supply for new buildings imposed by the EEWärmeG supports the technology. However, strict insulation requirements for new buildings limit the scope of application of the technology, making the impact of the EnEV ambivalent. Also, the degree of technical complexity makes it difficult for final customers to fully understand all exemptions and requirements, even leading some CHP producers to take over approval and accounting processes for their customers and, hence, inducing the development of service innovations.

In addition to complex administrative requirements, the role of local electricity grid operators is criticised. Technical requirements for grid connection are unclear, and, according to the interviewees, response time and collaboration with some grid operators are not satisfactory.

A positive indirect effect is seen to come from climate policy, which raises awareness of energy efficiency issues and thus helps to promote CHP technology. But all participants emphasise that positive political signals are outweighed by the previously named barriers. In total, the influence of the political framework is seen as rather a hindrance and, above all, inconsistent. The results for individual policy instruments are summarised in Table 13–3.

Table 13–3: Summary of interview participants' opinions on policy impacts on micro CHP development and diffusion

Direct support	**KWKG**	**Few explicit statements; weak positive signal for development activity**
	Investment subsidy (Impulsprogramm)	Positive signal for diffusion, negative impact due to lack of predictability
Regulatory measures	EEWärmeG	Stimulation of demand (micro CHP as replacement measure); raising of awareness and opening markets for diffusion
	EnEV	Negative impact on diffusion by reducing heat demand in new buildings; positive impact by favourable primary energy factor for CHP
	CO_2 reduction target	Positive impact on development and diffusion by raising of awareness, CHP perceived as efficient technology

Source: own compilation

13.4.3 Future developments

Participants expect that the diffusion of micro CHP technology can take place quite rapidly if an accordant political framework is set. Currently, a lack of predictability in micro CHP related policies as well as in energy policy in general is seen as an important impediment. Due to the current ambivalent design of policy measures, other areas of influence are perceived to have a relatively small impact on technology diffusion. If technical restrictions and administrative requirements are simplified and clear political signals for technology support are given, the manufacturers are confident that they can provide an efficient technology that may help to reduce primary energy consumption and CO_2 emissions. Given the right conditions, participants are also convinced that they can quickly become independent of direct financial support mechanisms.

In conclusion, it can be observed that one important point of criticism is the lack of coherence of policy measures. Interview participants appreciate the direct support for CHP technology through the KWKG and the Impulsprogramm. At the same time, these support mechanisms are slowed down by administrative complexity and technical difficulties which could be removed quite easily, increasing the effectiveness of existing support mechanisms.

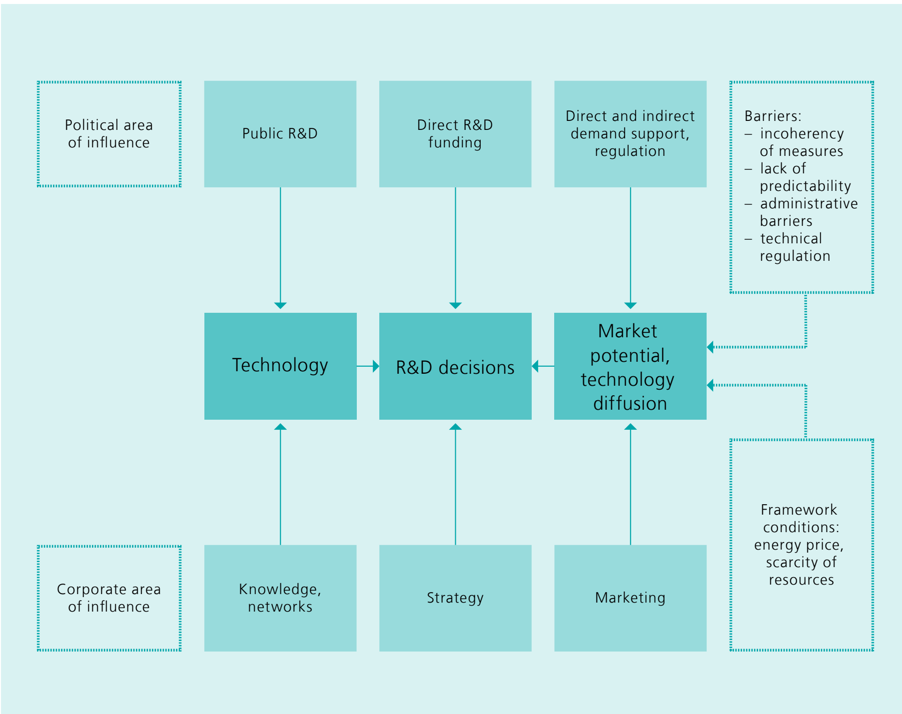
Another important result is that all participants claim that they want to become independent from direct support mechanisms. Even investment subsidies like the Impulsprogramm are only considered useful if they are combined with consistent framework conditions and reliable information on volume and time span of such support mechanisms. If these conditions are given, direct investment subsidies can considerably accelerate the diffusion of micro CHP technology. But currently, consumer uncertainty is fuelled by a lack of predictability of energy related political decisions.

Future expectations of interview participants can be summarised as pretty optimistic. They believe that micro CHP is a promising technology which offers considerable scope for application. Should producers be able to gain significant market shares, they are confident to be able to offer a competitive product and become independent of financial support mechanisms. However, until now, the influence of policy measures on technology development and diffusion is seen as rather small. A positive evaluation of existing policy measures to support micro CHP development and diffusion based on the results of the expert interviews can therefore not be given.

13.5 Policy recommendations

Based on the results presented in the previous section, a number of policy recommendations can be derived. The aim of these recommendations is to serve as guidelines for a more efficient policy framework design that can support technology development and diffusion without unjustifiable preferential treatment of micro CHP compared to competing technologies. However, it has to be kept in mind that the interviewees' opinions may be biased, and neutrality of results cannot be guaranteed.

Figure 13–6: Summary of determinants of corporate innovation activity



Source: own illustration

The results have shown that the direct influence of policy measures on corporate innovation activity in the area of micro CHP can be seen as relatively low. However, policy influence, technical regulation and perceived uncertainty on the demand side have a conflicting impact on technology diffusion and thus on the perception of market attractiveness by technology providers. Corporate innovation activity is determined by a number of firm internal and external factors, offering a number of starting points for policy measures. These are summarised in Figure 13–6.

Since most policy measures aim at direct demand support and also most barriers are identified in this area, recommendations derived from the interview results focus on the demand side politics:

- Removal of administrative barriers: Currently, mini and micro CHP installations have to pass the same approval procedures. Since micro CHP installations are mainly dedicated to non-commercial purposes, standardised processes could help reduce the administrative burden for potential customers.
- Modified calculation of avoided electricity network charges: If micro CHP installations are not used by their owner, but by tenants, the current incentive structure is not very attractive. Tenants will benefit from reduced heating costs, while the owner only receives the feed-in bonus for produced electricity and remuneration for avoided network charges. Interview participants find it questionable whether current calculation methods correctly capture these charges. They call for a modification, which could make micro CHP more attractive for operators who do not intend electricity and heat production for their own consumption.
- Improved design of investment subsidies: Both the previous and the current investment subsidy programme lack clear signals regarding volume and duration of the programme. The positive diffusion effect of such subsidies could be increased considerably if their predictability was improved. The current on and off-policy leads to extremely unstable markets.
- Adapted training of heating installers: Otto et al. (2009) suggest that heating installers are also trained in electrical engineering. Against the background of increased popularity of heat pumps and photovoltaic systems, this proposal is particularly relevant. A combined training would enable heating installers to promote the use of innovative heating technology such as micro CHP.

Compared to direct financial support, a probably less costly policy measure would be an information campaign to advertise micro CHP's efficiency advantages. Such a campaign could also be combined with advice on the correct dimensioning of installations and it could contribute to increasing the perceived attractiveness of the technology. To ensure its success, technical and administrative barriers would have to be removed beforehand. Concluding, Table 13–4 summarises the policy recommendations proposed in this chapter.

Table 13–4: Summary of policy recommendations

	Supply side	Demand side
Direct support	No need for action – support of fuel cell research sufficient, funding of micro CHP development by manufacturers	Positive evaluation of policy instruments, but predictability must be improved significantly
Indirect support	–	Information campaign could be a cost-effective way to promote micro CHP
Regulatory measures	–	Largest need for improvement: grid connection and administrative requirements pose important barriers for successful technology diffusion

Source: own compilation

13.6 Discussion and conclusions

As mentioned in the introduction to the previous section, the results from this study must be seen with caution because of the participants' bias. There are a number of other limitations to qualitative research which shall briefly be discussed in this section, before a conclusion will be drawn.

13.6.1 Discussion of results

The study did not aim to yield statistically significant results, but to conduct a first exploratory evaluation of the German micro CHP sector. Since this is still a relatively small market, even with a low number of participants, it was possible to gain broad insights into actors' perspectives. This does not make further research redundant; for example, surveys on customer acceptance and economic feasibility of micro CHP devices can offer important insights as soon as the number of available devices has increased.

When investigating corporate innovation activity, one general problem is that interviewees are asked for extremely sensitive data. While all interview results were made anonymous, still not all questions could be answered in all interviews, making some of the results incomplete. At the same time, results yielded have to be seen with caution, since all participants had the opportunity to prepare for the interview situation. Therefore, it cannot be ruled out that in some points the participation was seen as an opportunity to express political or marketing opinions. Thus, the assessment of political framework conditions undertaken in this study is not objective, but may be influenced by corporate interests. One important step for future research would be to triangulate results with opinions of different actor groups such as grid operators, politicians or final customers. In this study, this was prevented by a limited time frame.

One policy measure that was probably not assessed properly is the KWKG. Only one of the five participants was already employed in his current position when the

KWKG came into force, making it difficult for the other participants to fully acknowledge its impact on strategic decisions and innovation activity. This may result in an underestimation of the KWKG's positive effect on technology development.

A positive aspect that should be emphasised is that all participants were very interested in the topic of the study. The interviews took place in a very constructive atmosphere, and the interview results are broadly consistent with hardly any contradictions between different interview partners. Thus, the overall quality of the obtained results can be judged as fairly reliable.

13.6.2 Conclusion

In this study, a qualitative assessment of the impacts of policy measures on development and diffusion of micro CHP technology has been conducted. A partial analysis of the technological innovation system was undertaken by interviewing company representatives and gathers their views on the political framework and other influencing factors. The results allow insights into decision making processes and technology development activities.

The existing incoherent political framework has an ambivalent influence on the development and diffusion of micro CHP technology. While regulatory measures like EnEV and EEWärmeG favour high efficiency technology, requirements for grid connection and extensive administrative procedures when installing and accounting for micro CHP plants neutralise positive effects to a large extent. The direct support mechanisms KWKG, Impulsprogramm and tax exemptions had a positive impact on technology diffusion until backdated changes in subsidy legislation negatively impacted confidence in the political framework conditions. Interview participants claim that since these changes were made, demand for micro CHP plants has been very hesitant.

There were three main questions underlying the interview process. First, corporate innovation activity is mainly driven by internal factors and – with the exception of fuel cell development – not supported by public research funding. Second, the relevance of policy measures for technology development and diffusion is seen as ambivalent. Direct support mechanisms were seen as suitable instruments in an early technology diffusion phase, but participants call for a coherent policy framework rather than extensive financial support measures. The third and final question is related to future expectations and framework condition requirements for successful technology diffusion. Participants expect that, given suitable administrative and regulatory conditions, micro CHP can successfully compete in the heating market. It is now a matter of reaching significant sales numbers to build up political pressure in order to improve these conditions.

This leads to the final conclusion for an efficient policy design to facilitate micro CHP technology diffusion. A consistent, predictable policy framework is required for this, especially regarding direct support mechanisms. Reducing technical and administrative barriers to an acceptable level would result in a considerable improvement of micro CHP's competitiveness and accelerate technology diffusion. For the new investment subsidy programme, it is advisable to give clear indications with regard to duration and volume of the financial support to reduce consumer uncertainty. In general, the interview participants see a very promising market potential which can be fostered by a positive political framework.

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14

CROSS-SECTORAL COORDINATION OF STI-POLICIES: GOVERNANCE PRINCIPLES TO BRIDGE POLICY-FRAGMENTATION

RALF LINDNER

14.1 Introduction[1]

The innovation systems (IS) perspective implies that successful innovation policy needs to integrate a broad range of different policy areas. Typically, these include the chief innovation policy domains education, science/research and economic policy. Depending on the innovation which is to be fostered, additional sectors such as health, environmental, energy, consumer, transportation or defence policy have to be covered as well. While the systems of innovation framework is clear about the importance to develop and implement "comprehensive and coherent policies that are characterized by a good match between individual instruments and objectives [...] in different policy areas" (OECD 1999, p. 71), much less guidance is provided to governments on how to cope with the practical challenges of coordinating the broad range of political-administrative decision-making processes and actors in the relevant policy areas. Despite marked differences in the actual distribution of policy competencies between different governmental departments/ministries in different countries, the core responsibilities for science, technology and innovation (STI) policy are usually concentrated in at least two departments. Moreover, in federal countries the sub-national level partially duplicates governmental responsibilities in the area of STI-policy.

1 This article largely draws on a Fraunhofer ISI working paper (Lindner 2009) that was developed in the context of a study on cross-cutting coordination processes in the area of the public governance of medical devices (see Lindner et al. 2009).

This contribution addresses the issue of horizontal policy-coordination in the area of STI-policy by (1) presenting the main obstacles to effective policy coordination, (2) applying a two-dimensional framework which differentiates between the main areas of coordination (administrative and policy coordination) and (3) introducing different modes of coordination (such as negative, positive and strategic coordination). Based on a discussion of different institutional and procedural approaches to improve cross-sectoral and cross-departmental policy coordination that can be empirically observed in the field and by drawing on previous research by the Fraunhofer ISI (e.g., Edler et al. 2003), the article proposes governance principles with the aim of providing policy-makers and analysts with general guidelines on how to facilitate policy-coordination between different governmental departments.

14.2 Rationales for coordination

14.2.1 Theoretical considerations

Coordination represents a longstanding challenge not only for the governance of knowledge and innovation policies, but for the effective management of structures and processes within the public sector per se. The need for coordination and coherence goes hand in hand with increased specialisation and organisational differentiation within the public sector, as has been frequently asserted by organisational theory (e.g., Mintzberg 1979; Thompson 1967). In addition to organisational differentiation of modern bureaucracies creating the need for more coordination, the growing interrelatedness of economic and societal problems of the past decades increasingly requires policy responses that cut across established institutional boundaries of government departments and agencies. Arguably, compared to other policy areas, STI-policy analysis – which is inspired by the systems of innovation heuristic –, has been at the forefront of calling for well-coordinated and integrated policy approaches. However, during the past decade, a new emphasis on coordination and improved public management in general could be observed in the OCED world (Bouckaert et al. 2010).

14.2.2 Rationales derived from IS perspectives

At least since the late 1990s, the systems of innovation approach has established itself as the most influential paradigm within the international innovation policy research community. The systems of innovation perspective does not only frame the scientific debates dealing with innovation, it also provides conceptual orientation for many governments and international and supranational organisations such as the OECD and the European Union (Fagerberg and Verspagen 2009; Lindner 2010). And despite the fact that the German federal government and the Länder have thus far refrained from embracing the rhetoric of IS, it can be observed that they are implicitly pursuing STI-policy that contains important elements of the systems of innovation philosophy (Edler and Kuhlmann 2008).

The chief proposition of the IS approach is that innovations are the result of interactive and interdependent processes in which various actors from different subsystems participate (cf. different chapters in this volume). Accordingly, innovations do not occur in isolation within a single firm. Instead, innovation is understood to be a collective and collaborative process spanning across sectors and subsystems (Edquist 2005). Furthermore, the IS approach assigns the state with a constructive role within an innovation system (Lundvall 1992).[2] However, in order to fulfil this role, governments rely less on traditional forms of hierarchical, top-down "command and control" steering and increasingly depend on cooperation, negotiation, moderation and consensus building. This stronger emphasis on governance as opposed to government, and the associated focus on the management of interdependencies between collective actors as well as the application of a dynamic mix of different regulating mechanisms (hierarchy, markets, majority rule, negotiation, networks) can also be observed in many other policy areas (see Benz 2004; Bröchler and von Blumenthal 2006; Mayntz 2006).

While contemporary innovation policy faces the challenge of being conducive to the increasingly systemic, horizontal and cross-cutting nature of innovation processes, the question is raised whether established governmental institutions and their processes are "fit-for-purpose" to meet the requirements of modern innovation governance. Political institutions are often criticised for being too narrow in their policy focus, hierarchical in their operations and departmentalised in their orientation, resulting in fragmented instead of systemic policy approaches (Edler et al. 2003).

The typical weaknesses identified in innovation-related policy arenas fall into two highly interrelated categories: an institutional and a procedural dimension. With regard to the structural weaknesses of the political-administrative systems, particularly the high degree of sectoralisation and departmentalisation are often pointed out as detriments to coordination and the effective development of horizontal policy approaches. In addition, institutional inertia and the actors' organisational self-interests are often serious barriers to the rearrangement of established institutional structures and responsibilities (Smits and Kuhlmann 2004). On the procedural side, a low degree of cross-departmental information exchange and cooperation can frequently be observed, causing insufficient common understanding about policy objectives and how to reach these goals. Jacobsson and Johnson (2000) note that under-coordinated STI policy typically results in low degrees of knowledge transfer, poorly articulated demand, the dominance of incumbent actors and policies favouring incumbent technologies, and a lack of effective fora for exchange and deliberation among organised actors.

The demand for coordination in STI policy has significantly increased in the last few years due to the programmatic shift to mission-orientation which puts a new emphasis on the so-called "grand challenges" to contemporary societies such as climate change or public health (cf. Chapter 11 in this volume). One of the most prominent manifestations of this problem- or need-oriented approach, which cuts across

2 The idea of a strong interdependence between innovating firms, the knowledge generating system and government is also the essential element of the so-called "triple-helix" (Etzkowitz and Leydesdorff 2000), a concept that has been quite influential within innovation research in the past decade.

established thematic areas, is the European Union's Lund Declaration of 2009.[3] Along similar lines, the German High-tech Strategy, which was introduced in 2006 and renewed in 2010, attempts to address global challenges with a mission-oriented and cross-cutting approach (BMBF 2010). No doubt, policy areas such as climate change are highly complex and span across a large number of sectors and institutional boundaries, bureaucratic lines, actor groups and subsystems.

In order to meet these demands, STI policy needs to be reconfigured in order to bridge the fragmented institutional landscape and effectively enable horizontal and systemic coordination.

14.2.3 General considerations derived from contemporary policy science

The new emphasis on coordination is not the sole domain of STI policy. On a general level, a number of governments have started to refocus on coordinating policy and public management in the last few years. These so-called "whole-of-government" initiatives such as "joined-up government" in the United Kingdom, "horizontalism" in Canada or "reviewing the centre" in New Zealand all have in common an increased focus on horizontal collaboration and policy integration between different government departments and levels, public organisations and agencies (Bouckaert et al. 2010). Many authors conclude that the increased attention directed towards coordination and policy integration is a response to the problems caused by the New Public Management (NMP) reforms that were initiated in the 1980s and 1990s. The breaking-up of large public organisations in small, semi-autonomous bodies based on public choice theory and neo-institutional economic philosophy resulted in increasing specialisation and thus institutional fragmentation (6 et al. 2002; Richards and Smith 2006). In consequence, governments partly lost their capacity to effectively steer the policy process towards the desired policy goals (Matthews 2011). The aspiration to regain sufficient governing capacity within the fragmented policy arenas can at least partly explain the growing attention directed towards coordination.

Next to the objective to regain governing capacity, coordination typically tries to achieve two main objectives (Painter 1981):

1. *Efficient and cost effective government*
- avoidance or reduction of duplication
- avoidance of inconsistent and contradictory activities
- minimisation of political and administrative conflicts
2. *Coherent decisions and policies*
- achieving thematic coherence and agreeing on accepted priorities among the relevant actors
- facilitating a holistic perspective in order to counter particularistic and sectoral interests

3 http://www.se2009.eu/polopoly_fs/1.8460!menu/standard/file/lund_declaration_final_version_9_july.pdf.

Particularly the second chief goal exhibits a large concordance with the systemic perspective of modern innovation policy as both seek to fruitfully bring together different domains and sectors in order to pursue jointly developed priorities and strategies.

14.3 Modes of coordination

14.3.1 Concepts and approaches

Despite the fact that a number of rationales endorsing coordination can be identified – reaching from overlap, contradictions and gaps in programmes to loss of governing capacity –, the actual meaning of coordination seems less clear. The existence of numerous synonyms for coordination is a case in point. The terms cooperation, coherence, cohesion, integration, alignment and collaboration are often used interchangeably with coordination. Furthermore, a closer examination of the complexities associated with coordination in a public policy context shows, for instance, that coordination encompasses at least two main dimensions: coordination as a *process* through which decisions are joined together, and an *outcome* of that process (Alexander 1995). In policy analysis and public administration literature, a broadly accepted definition for coordination is lacking.[4] For the purpose of this article, a definition presented by Bouckaert et al. (2010) will be applied as it puts special emphasis on the process dimension of coordination and underlines the role of strategies and instruments governments apply:

> "[C]oordination in a public sector interorganizational context is considered to be the instruments and mechanisms that aim to enhance the voluntary or forced alignment of tasks and efforts of organizations within the public sector. These mechanisms are used in order to create greater coherence, and to reduce redundancy, lacunae and contradictions within and between policies, implementation or management […]." (Bouckaert et al. 2010, p. 16)

Coordination can refer to quite different functions and processes within a public policy context. A very useful analytical distinction between different foci or areas of coordination can be made between primarily policy-related (1) policy coordination and (2) administrative coordination (see Braun 2008a). Both focal points of coordination need to be taken into account if a systemic approach to STI is taken seriously:[5]

1. *Policy-coordination*: Coordination in this area has the objective of developing clear, consistent measures and activities, the agreement on priorities and the formulation of implementation strategies.
2. *Administrative coordination*: Here, coordination primarily deals with the actual implementation of the goals and strategies that have been agreed upon.

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4 For an overview and discussion of definitions for coordination see Alexander (1995).

5 The following is largely based on Braun (2008a).

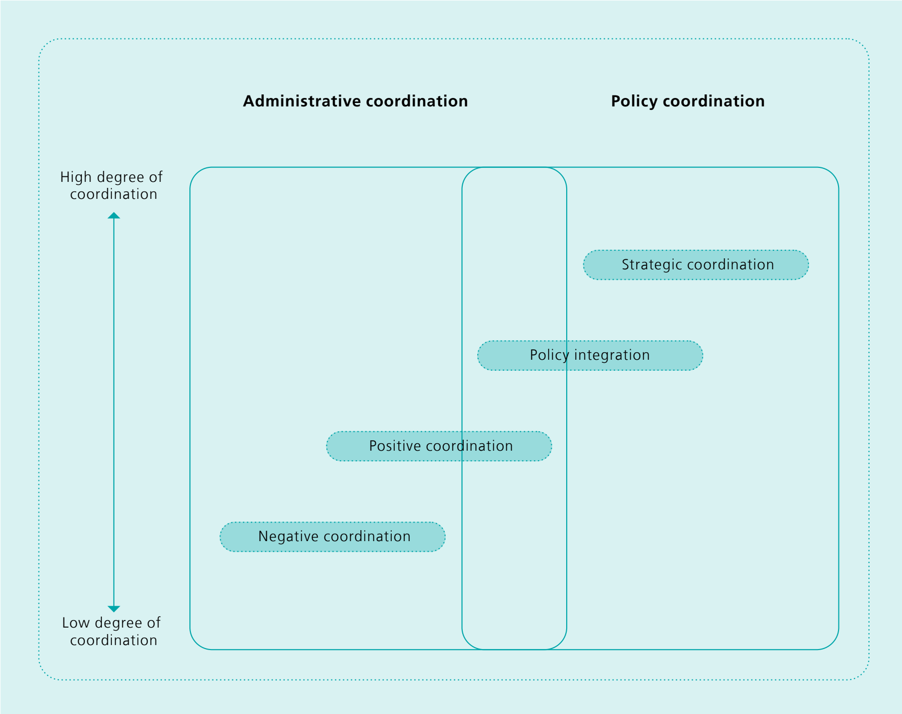
For the practice of STI policy this means that efforts aiming at effective coordination need to embark on the development of a shared strategy and the setting of policy priorities. This strategic process is usually highly political as the actors involved are required to negotiate and agree upon goals and priorities. In a second step, the administrative actors' willingness to cooperate is necessary in order to successfully translate the policy goals into concrete measures and actions. In these two coordination processes different groups of actors with different interests and logics of action are involved that are related to each other hierarchically.

In addition to the basic differentiation between the two coordination areas (policy coordination and administrative coordination), the literature also distinguishes between different *modes* of coordination. These coordination modes differ with regard to quality (intensity) and scope of coordination activities. The four most relevant modes of coordination can be ordered according to a qualitative hierarchy, reaching from a low to a high degree of coordination:

- *Negative coordination*: This coordination mode, which can often be observed in public administrations, meets the minimal standards of coordination processes. In effect, negative coordination produces mutual adjustment of the actors involved. This prevents an undesirable spill-over effect due to information exchange, but a shared orientation among the actors or cohesion of their activities is neither aimed at nor accomplished (Scharpf 2000). The mechanisms involved in procedures of negative coordination are usually highly formalised (e.g., routine information exchange between governmental departments). The requirements of a systemic innovation policy are not met by this coordination mode.
- *Positive coordination*: Compared to negative coordination, this mode of coordination achieves significantly more than mutual adjustment. Positive coordination is characterised by a shared perspective of the actors involved, who jointly work on solving a policy problem or reaching certain goals. A chief prerequisite for the success of this type of collaboration is that all actors recognise the individual advantages of positive coordination (Peters 2006). Positive coordination typically takes place in interdepartmental committees, for instance in the course of joint development of activities and measures. From the IS perspective, this coordination mode is clearly superior to negative coordination.
- *Policy-integration*: In contrast to the previous two modes that are primarily relevant for processes of administrative coordination, policy integration chiefly takes place in the area of policy coordination. For the most part, this mode can be observed with regard to the coordination of policy goals between different actors (Peters 2006).
- *Strategic coordination*: This mode of coordination exceeds policy integration by an additional qualitative step because the actors jointly develop far-reaching visions and future-oriented strategies (Peters 2006). Thus, policy integration and strategic coordination largely comply with the requirements postulated by a systemic-oriented innovation policy.

Figure 14–1 provides an overview of the four basic modes of coordination and how they relate to the two main areas of coordination (administrative and policy-coordination).

Figure 14–1: Modes of coordination



Source: based on Braun (2008b, p. 231)

14.3.2 Meeting the coordination challenge

As outlined above, high quality coordination processes in the area of policy-coordination are a key enabling element in the realisation of systemic innovation policy. It is particularly important to develop a common understanding among the relevant policy-makers from different departments about the STI-policy goals and the strategic focus. In comparison, the area of administrative coordination plays a slightly less significant role, but should not be neglected in order to increase the likelihood of implementation according to the strategic intensions.

Against this background, how can effective coordination in STI-policy actually be realized? According to the public administration and policy science literature, successful coordination needs to overcome a number of barriers. On the individual level, simple ignorance and the lack of interest in a meaningful exchange with other organisations can be a significant barrier to effective coordination. And even if the individual actors are willing and flexible, which is indispensable, to change established behavioural patterns, there might not be sufficient information available about other governmental organisations to actually engage in coordination. In many instances, the reluctance to share information is generated through the fear of losing organisational bargaining power and influence. Another primarily political barrier to coordination can be linked to the dynamics of partisan politics within coalition governments (Döring 1995). Similarly, but not necessarily partisan, ideological positions and beliefs about policy goals and appropriate means to reach these objectives within a certain policy area are among the most challenging obstacles to effective coordination. The belief systems, cognitive maps or ideologies held by policy-makers and experts about policies shape the different conceptions of a problem and predefine the desirability of certain solutions and instruments (Campbell 2001; Majone 1993; Nullmeier 1993). Moreover, different organisational cultures, professional values and behavioural patterns constitute another notable barrier to coordination (Bouckaert et al. 2010). With regard to STI-policy, a comparatively high degree of institutional complexity and diversity of actors, which is caused by the broad scope of innovation related sectors and subsystems (education, basic and applied research, industry etc.), need to be taken into account as well.

From a theoretical perspective, a number of institutional and procedural approaches to meeting the coordination challenges can be conceived of. In the following, the six most promising coordination solutions are presented and briefly discussed (Braun 2008a; 2008b):

1. *Interdepartmental coordination*: This type of coordination refers to negotiations between different organisations. Due to the distribution of relevant responsibilities in the area of innovation policy between different departments, STI-policy requires interdepartmental negotiations in many countries. However, administrative and policy science literature is very sceptical regarding the prospects of successful positive coordination due to the institutional self-interests of the departments (maintaining control over areas of influence, seeking autonomy in decision-making) (Arnold and Boekholt 2003; March and Olsen 1989; Peters 1992). Coordination processes between large organisations tend to be very complex and time-intensive. Compared to the launch and implementation of large funding programmes, entering the laborious interdepartmental coordination processes promises considerably less public attention and political prestige – and these are chief incentives which influence the behaviour of government departments. A prerequisite for successful interdepartmental coordination is that the advantages of collaboration for all participants are larger than the costs. Unfortunately, due to context dependencies, it cannot be specified under which conditions this requirement is fulfilled.
2. *Modes of interaction*: Hierarchy is a ubiquitous phenomenon in public administrations. However, as a mechanism to foster coordination between different organisational units within a department, successful hierarchical steering is limited due to the high complexity and the pronounced fragmentation within most ministries. Other forms of interaction, such as voluntary agreements, seem to be more suitable to stimulate coordination. The various governance mechanisms which have been introduced under the label of New Public management (NPM) have thus far delivered rather ambivalent results due to unintended consequences and the actors' responses guided by institutional self-interests.

According to Braun (2006), NPM has some potential to render vertical administrative relationships more efficiently, but this governance concept does not provide sufficient incentives for horizontal coordination. Similarly, the experiences with interdepartmental negotiations are not very encouraging (Braun 2008a). Even if these negotiations are performed under the "shadow of hierarchy" (Scharpf 2000, p. 323), they tend to produce negative coordination or generate results based on the lowest common denominator. Against this background, Braun (2008a) argues that the most promising approach to stimulate actors' willingness to engage in coordination is to generate moral obligation. In order to create moral obligation for the individual actor, persuasion of the addressee by the means of deliberation (arguing as opposed to bargaining), participation and the joint development of shared perspectives are essential.

3. *Establishment of institutional coordination capacities*: Bridging institutions can be established in order to facilitate interdepartmental coordination processes. Set up as relatively stable structures, bridging institutions are responsible for the coordination processes within a certain policy area or sector of the innovation system. Such institutions have the potential to facilitate the exchange across sector and ministerial boundaries. International experiences suggest that the effectiveness of specialised coordination institutions is significantly enhanced if they are endowed with a strong mandate (Lindner et al. 2009, pp. 79–127).
4. *Internal coordination through organisational mergers*: This institutional solution attempts to overcome the restrictions of interdepartmental coordination by merging the distributed competencies within a single super ministry. Promoters argue that all relevant responsibilities for STI-policy would be combined under one minister within a uniform hierarchical structure, making it easier to pursue coherent policies. However, such an institutional solution is likely to increase the internal coordination needs due to the heightened organisational complexity. Moreover, the institutional inertia of the formerly separate organisational units cannot easily be resolved. Taken together, the international experiences with internal coordination through mergers are not very promising (Braun 2008b).
5. *High-level political leadership*: Both interdepartmental coordination as well as coordination through organisational mergers require clear decisions at cabinet level. Two conditions need to be met if the head of government or cabinet are to make these types of decisions: a) the initiative has to have the potential to garner public support and b) a concept that is superior to the status-quo needs to be on the table. In order to be able to assess the latter, decision-makers require appropriate strategic intelligence.
6. *Strategic intelligence*: Acquiring and retaining power are basic elements of political behaviour. However, political decisions are also influenced by ideas and the search for solutions to problems (Heclo 1974; Singer 1993). One of the important sources for ideas and policy-solutions that can be harnessed by innovation policy is so-called strategic intelligence. Scientific policy advice, advisory commissions, analyses, technology assessment, foresight and evaluation can provide

substantial contributions to this type of knowledge. A main function of strategic intelligence is the assessment of policy alternatives and a "rationalisation" of political debates. Inserting convincing arguments into the policy arena can help to mitigate contentious "distributive arguments" that tend to dominate the political process and impede effective coordination.

Particularly the last two approaches – high-level leadership and strategic intelligence – are recognised as essential elements for the realisation of well-coordinated, systemic innovation policy. In the absence of strong high-level political leadership and without corresponding and substantiated policy goals, it can hardly be expected that the lower levels of the politico-administrative system will engage in effective coordination processes.

14.4 Conclusion: governance principles to improve the coordination of STI policies

Policy-makers often call for tool boxes with which the multifaceted challenges of modern innovation policy can be mastered. However, given the complexity of innovation systems combined with the dynamics of scientific-technological change, generic recipes on how to deal with innovation policy challenges are not available. Innovation is a cumulative process and therefore largely path- and context dependent. Thus, successful innovation policy needs to begin by taking into account the specific contexts in which innovation takes place. In this sense, designing innovation policy will to some extent always be characterised by the collective search for adequate solutions, puzzling, and trial and error.

Despite this qualification, the insights of international innovation policy research and administrative science allows for the formulation of general guiding principles for successfully coordinating STI-policy. The following governance principles of improved coordination are committed to a systemic approach to innovation policy:

- Systemic innovation policy requires appropriate institutional structures at the level of governance (ideally supranational, national/federal and sub-national), at the level of funding agencies and at the level of R&D infrastructures. In order to develop further existing structures towards an improved institutional setup, the corresponding reform processes need to be designed prudently, involving the relevant stakeholders and using the insights provided by strategic intelligence. The aim of a reconfiguration of administrative structures should be the facilitation of flexible horizontal coordination between formally separate organisational entities. Concrete measures can include enhanced mobility of personnel, permeable carrier paths between sectors, integrated teams etc.
- A culture of exchange, collaboration and coordination between departments should be pursued; appropriate institutional structures need to be developed in order to foster shared perspectives.
- The establishment or the expansion of bridging institutions that are vested with robust and clearly defined coordination mandates can represent an important

element in the endeavour to improve coordination processes in certain sectors or policy areas.
- Coordination in complex multi-level structures is increasingly gaining importance in order to arrive at a reasonable division of responsibilities between the system levels, transparent decision-making and effective implementation processes. Additional institutionalisation of coordinating capacities in the vertical dimension can have supporting effects.
- Cross-sectoral and cross-departmental strategic orientation is a key condition if a systemic and horizontal innovation policy is to be realized. Using strategic intelligence (particularly technology assessment, foresight, evaluation, benchmarking) can contribute to transcending institutional self-interests of actors and organisations by rationalising debates and by convincing the actors of the strategic goals.
- Strong political leadership and clear strategic direction provided by the cabinet and the heads of the departments are important prerequisites for the successful implementation of integrated STI-policies on the lower administrative levels. Without this political orientation, signalling high political priority to all actors, it can hardly be expected that institutional self-interests will be overcome in favour of a more holistic approach.
- Developing a shared understanding of the innovation policy, which is to be pursued, is essential for effective coordination. Governance mechanisms such as hierarchical steering, traditional negotiations or New Public Management are increasingly inapt to meet the requirements for coordinating the complex interactions of diverse elements of innovation systems. In addition to strong political leadership which signals unambiguous support for a certain innovation policy, strategic intelligence as well as transparent, inclusive and participatory processes are key factors that help to develop a common orientation among the relevant actors.

Despite the importance of effective coordination within institutionally fragmented governmental structures to meet the requirements of a systemic and coherent innovation policy, it should not be forgotten that coordination is not a value as such. Coordination efforts should focus on the improvement of interfaces between relevant institutions and domains, and contribute to strategic and policy coherence. While the lack of coordination comes at a price, the same is true for too much coordination. Each innovation domain needs specifically tailored policies, and overemphasising coherence entails the danger of neglecting specific sectoral needs. What is more, coordination tends to cloud political responsibilities and can therefore dilute democratic accountability. Thus, striking the appropriate coordination balance remains a challenge that needs to be continuously addressed.

14.5 References

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Since the foundation of the Fraunhofer Institute for Systems and Innovation Research ISI in 1972, Fraunhofer ISI has adopted a systemic research perspective based on the heuristic concept of innovation systems. To mark Fraunhofer ISI's 40th anniversary, this book offers an overview of current innovation system analyses in the field of conceptual and methodological issues from the national, technological, industrial, and regional perspective, and with regard to the public governance of innovation.

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