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**Knowledge-intensive Sectoral Innovation Systems  
of Southern Great Plain Region**

Theses of doctoral dissertation

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## **1. Introduction and motivation**

The notion of innovation is originated from the Austrian economist, Joseph Schumpeter, who published his main work, the Theory of Economic Development in 1911 in German and translated it to English in 1934. He defined innovation as the new combination of existing resources, and put a great emphasis on the role of innovation in social and economic development (Fagerberg 2005). He distinguished five different types of innovation: new products, new method of production, new sources of supply, the exploitation of new market and new ways to organize business.

It has been proven for over hundreds of years that the major sources of productivity growth and the increase of prosperity are the technological change and the different forms of innovation (Edquist 2005a). But if we want to describe, understand and evaluate the whole process of technological change and innovation, it is essential to take all the factors into account that influence these processes. This is ensured by the approach of innovation systems. The appearance of the concept was a turning point in innovation research, which is demonstrated by the large number of publications issued in the last two decades (Lundvall 1992, Edquist 2005a, Fagerberg – Sapprasert 2011, Vas – Bajmócy 2012).

The approach of innovation systems provides understanding on the interactive and collective nature of innovation, and describes the role of the variety of actors, information, knowledge, interactions and complementarities among agents involved in the process of innovation. Innovation system approach has emerged since its initial concept, the theory of national innovation systems appeared (Freeman 1987, Lundvall 1992, Nelson 1993), and has extended with the notion of regional (Cooke et al 1997, Doloreux 2002), technological (Carlsson – Stankiewicz 1991) and sectoral (Malerba 2002, Breschi – Malerba 2005) innovation systems.

The approach of sectoral innovation systems explores that sectoral innovation activities and the performance depends primarily on the nature of the sectors, especially on the characteristics of the sectoral knowledge and knowledge base. However, Malerba – who developed the conceptual framework of sectoral innovation systems – reveals that sectoral innovation systems may be highly localized, and go under the impact of regional economic conditions (Malerba 2002, Breschi – Malerba 2005). Innovation activities and the performance is primarily dependent on sector-specific characteristics, secondly it is under the influence of national and regional framework conditions. This explains why same sectors have different patterns of innovation.

Knowledge-intensive sectors have attracted much attention in recent years in economic analyses, aiming at identifying factors that have impact on knowledge creation, diffusion and use. Knowledge-intensive sectors differ from traditional industries in many aspects. Knowledge-based activities have reached dominant role in production and services, and they are different in terms of intensity of innovation activities and innovation performance (Tödting et al. 2006, Isaksen 2006, Rehnitzner 2008, Csonka 2011, Vas 2010). Knowledge-intensive industries form special kinds of sectoral innovation systems, due to the characteristics of the actors, knowledge base, technological standards, development cooperation and intensity of innovation activities. Increasing number of empirical research focus on them, because they have higher value added and could become the catalysts of regional economic growth and development. This led to choose knowledge-intensive sectors as the object of my research.

Knowledge-intensive sectoral innovation systems cannot be analyzed separately from other types of innovation systems. The literature highlights that sectoral, national, regional and technological innovation systems complement each other, and interact with each other. It has been pointed out (Lundvall et al. 2002), and detailed (Casper – Soskice 2004, Lee – Tunzelmann 2005) how interdependent relationship of sectors and national system exist. It is often examined how sectors explore clustering from the viewpoint of regional innovation systems (Cooke 1997, Asheim – Coenen 2005) or how firms in regional clusters reveal better innovation performance (Porter 2000a, Porter 2000b, Sölvell 2009, Beaudry – Breschi 2003). In many case, the Hungarian literature builds on the theoretical framework of national innovation systems (Inzelt 1999, Borsi 2004, OECD 2007, Havas 2009), and reveals the regional specificities of innovation systems (Lengyel – Leydesdorff 2008, Csizmadia 2009). But it is less discussed – even in the international and national scientific literature – that how spatiality of sectoral innovation systems forms, and how the mutual impact of sectoral innovation system and regional economy develops.

There are even less attempts to reveal how this evolves if sectoral innovation systems are located in less developed regions, which can be found even in Hungary. Most of the foreign case studies describe the operation of regional innovation systems in developed regions, and show evidence on knowledge-intensive sectors located in advanced regions. The literature barely addresses the function of regional innovation systems in less developed regions, and the impact of such regions on the innovation activities of knowledge-intensive sectors.

The analytical framework of regional conditions is given by the concept of regional innovation systems. The approach highlights the embeddedness of innovation activities in social settings, and emphasizes the interactive nature of innovation and learning on regional level (Cooke – Schienstock 2000, Cooke 2005). There are two subsystems where interactive learning takes place in the regional innovation system: the subsystem of knowledge production and diffusion, and the subsystem of knowledge exploitation and exploration (Autio 1998, Tödting – Trippel 2005, Lengyel 2010). When we search for the differences between developed and less developed regions, we have to examine the function of the subsystems, the relationships within and between the subsystems and the skills and capacity of the actors. These factors are the primary reasons for the differences in innovation performance.

Problems outlined above determine the direction of my research. The dissertation aims at analyzing the innovation activities of knowledge-intensive sectors in a certain less developed region, taking two phenomenon into account: on the one hand knowledge and interactive learning are interdependent; on the other hand same sectors are characterized by different innovation patterns depending on their spatial affiliations.

## **2. Objectives of the research and the theoretical background**

My research focuses on assessing the activities of knowledge-intensive firms aiming at knowledge production, diffusion and application, and takes the particularities of the sectors and the Southern Great Plain region into account. The dissertation focuses on the following theoretical thesis: processes of knowledge production, diffusion and use depend not only on the nature of the sectors, but they are also affected by the regional environment.

The thesis raises the following research question: *what are the sectoral and regional characteristics of innovation activities of knowledge-intensive sectors located in the Southern Great Plain region, especially from the aspect of knowledge and learning*. Placing the question into the conceptual framework of innovation systems: *what are the characteristics of knowledge production, diffusion and use of knowledge-intensive sectoral innovation systems embedded in Southern Great Plain region, and in what extend do they depend on the nature of the sectors and the region*.

To answer the research question, the dissertation deals on the one hand with the notion of innovation systems, especially on the approach of sectoral innovation systems, on the other

hand attempts the adaptation of the approach related to knowledge-intensive industries located in less developed region.

The notion of *innovation systems* origins from both institutional and evolutionary economics. The central idea of the innovation system approach is the following: innovation and the spread of technologies are results of both individual and collective processes; factors that determine technological change are based not only on the individuals, and take place not only within the companies, but depend jointly on the elements (actors, relationship, institutions, infrastructure) of innovation systems (Edquist 2001).

The approach of innovation systems is rooted from more scientific workshops. The birth and the development of the concept – which started with the approach of national innovation systems – took place in the 1980s and the early 1990s. The theory is attributed to three different research groups (Sharif 2006): the SPRU (Science and Technology Policy Research) research group at the University of Sussex and its prominent figure, Christopher Freeman; Richard Nelson (USA); and the IKE (Innovation, Knowledge and Economic Dynamics) at the University of Aalborg (Denmark) led by Bengt-Ake Lundvall.

Innovation systems are *”elements and relationships which interact in the production, diffusion and use of new and economically useful knowledge”* (Lundvall 1992, p. 2.). According to the well-known definition of Edquist, innovation systems consist of *”all economic, social, political, organization, institutional and other factors that influence the development, diffusion and use of innovation”* (Edquist 2005b, p. 182.).

Several researchers have not found the national level appropriate to explore the characteristics of innovation process, and to understand the aspects of innovation systems related to economic and innovation performance. Other approaches of innovation systems have emerged: the concept of regional innovation systems (Doloreux 2002, Cooke 2004), sectoral innovation systems (Malerba – Orsenigo 1997, Malerba 2002) and technological systems (Carlsson – Stankiewicz 1991, Carlsson et al. 2002).

A *sectoral innovation system* is an outcome of the learning process of firms and individuals. It is based on the interactions of actors with different knowledge and competences, where the interactions can be competitive or cooperative, market or non-market, formal and informal ones, influenced by a specific institutional setting (Malerba 2002, Breschi – Malerba 2005). Breschi and Malerba (2005, p. 131.) defines: a sectoral innovation system is a *“system (group) of firms active in developing and making a sector’s products and in generating and utilizing a sector’s technologies”*.

Major characteristics of sectors are the knowledge base, the interactive learning between actors, organizations beside the enterprises, the institutions, and the co-evolution of the several elements (Dosi 1988, Malerba – Orsenigo 2000, Asheim – Gertler 2005).

The sectoral innovation system itself however cannot be examined separately. The Aalborg School of innovation systems highlights the complementary nature of innovation systems, and reveals that different types of innovation systems are not mutually exclusive, but complementary (Lundvall et al. 2002). *Innovation systems are open in space, overlap each other, their boundaries are blurred, and embedded in a global system* (Frenz – Oughton 2005, Asheim et al. 2011).

Boundaries of sectoral innovation systems can be determined by the characteristics and the specialization of the sector, and go through regional and national borders (Frenz – Oughton 2005). The national innovation system may comprise several sectors, thus different sectoral innovation activities and patterns (Lundvall 1998). Lundvall and his co-authors (2002) highlighted that national innovation system is particularly important for those sectors where innovation activities need trust-based relationships and tacit knowledge.

Pattern of innovation in sectoral innovation systems depends on the nature of the sector, however it is also affected by the location of the sector. If we consider the structure of the sector, the actors, the dynamics of the system or the possibility of cross-border relations, we realize that it is not the most obvious way to examine sectoral innovation systems between their national borders. Sectoral innovation systems are often localized, and defined not only by national, but also regional framework conditions (Malerba 2002, Breschi – Malerba 2005). Sectoral innovation systems are geographically concentrated on subregional level, thereby define the specialization of the regions.

In practice, it has been proved that there are significant differences between sectors concerning to the characteristics and degree of innovation activities, the spatial distribution and the technological opportunities. However, the same sector in different countries show similarities, and these similarities can be traced back to the knowledge base and the learning processes (Malerba 2002). In the same time, there are exceptions. National innovation systems may play different role in case of sectoral innovation systems, due to for example the intellectual property rights (Lundvall 1992, Freeman 1995, Malerba 2004). The same can be experienced if we analyze sectoral innovation systems on regional level.

Regional and sectoral innovation systems are closely related to each other. Literature reveals that enterprises can have higher level of innovation performance due to localized learning processes (UNESCAP 2006). A regional innovation system may include and affect

several sectoral innovation systems, where companies, organizations of knowledge creation and exploitation systematically related to each other. However a sectoral innovation system may be wholly or only partly covered by a regional innovation system (UNESCAP 2006).

The characteristics of regional innovation systems describe the differences among the same types of sectors and their innovation activities. Differences can be traced back to the level of technological development, the opportunities, the effectiveness and the abilities to acquire new technologies (Dosi 1982).

Overall, a sectoral innovation system can be characterized by local (regional), national and global factors. In my research I focus on the influence of sectors on regional specialization, and the interaction of sectors and less developed regions hosting the sectors.

### **3. Structure of the dissertation, hypotheses and research method**

To answer the research question, first I described the theoretical approach of sectoral innovation systems in details, second I carried out a primary and secondary research. The theoretical framework consists of three main chapters. Since the concept of innovation systems was a milestone in innovation research, in the *second chapter*, I present the origins and the main characteristics of the innovation systems. Subsequently, I describe the four types of innovation systems: the national, the regional, the sectoral and technological innovation systems.

Since the impact of innovation systems on technological change cannot be considered in isolation, *in the third chapter*, I present the relationship and the mutual impact of innovation systems. In this chapter I make an outlook to the interpretation of proximity in economics, and I reveal the role of geographical and relational proximity in innovation systems. This outlook is necessary, because the importance of proximity in knowledge-based interactions and innovation is well-known. I show how the relationships of actors in innovation systems depend on the dimensions of proximity. In addition, I attempt to place the notion of clusters in the innovation system literature, because the approach of innovation systems is suitable to analyze not only the innovation activities and the pattern of innovation in nations, regions, sectors and technological areas, but in clusters. I highlight that these organizations should be examined not only in the theoretical framework of regional innovation systems – as it has been made so far – but in the intersection of all types of innovation systems.

As my research analyzes the interaction of sectors and regions, *in the fourth chapter*, I investigate the correlation between knowledge and spatiality in the conceptual framework of

sectoral innovation systems. First, I present the importance of knowledge and learning in sectoral innovation systems, the impact of knowledge on innovation activities, the spatial distribution of sectors, and I introduce the knowledge-based taxonomy of sectors. Second, I discuss the interaction between sectors and regions in details. I sketch a demonstration model to show how sectors determine regional economic performance and specialization, and how regional and national framework conditions influence sectoral innovation activities. Since, the question arises as to what extend sectoral innovation systems in developed regions are different from systems that are located in less developed regions, I attempt to capture the properties of less developed regional innovation systems. Overall, through all these, I develop the theoretical framework of my dissertation.

After the presentation of the theoretical background, I divide the research question into two for the better understanding. The research question involves two subquestions. First, *in what kind of regional knowledge-base are the knowledge-intensive economic activities embedded in the Southern Great Plain region.* Second, *what are the special features of knowledge production, diffusion and use in knowledge-intensive sectors, and how these characteristics depend on the nature of the sectors and the regional framework.*

Since in any innovation system, companies are the main actors, therefore I put the companies in the focus of my research. Moreover, I only examine the first two elements out of the four essential elements (actors, relationships, institutions and infrastructure) of innovation system

To answer the research question, I drew the following hypotheses, based on the literature. All hypotheses are related to the knowledge-intensive sectors of the Southern Great Plain region.

*1. Hypothesis: The regional knowledge base of Southern Great Plain – except for the large urban areas – is dominated by synthetic knowledge base. In large urban areas analytical and symbolic knowledge base also can be detected.*

*2. Hypothesis: Knowledge-intensive manufacturing enterprises have more intense innovation activity compared to the knowledge-intensive services located in the Southern Great Plain.*

*3. Hypothesis: Constraining factors of innovation activities in case of knowledge-intensive sectors in the Southern Great Plain are rather region, and not sector-specific.*

*4. Hypothesis: Knowledge-intensive enterprises in the Southern Great Plain build on a complex system of knowledge and learning-based partnerships during their innovation cooperation. Typically they interact with at least three different types of actors from the regional innovation system.*

I test the first hypothesis based on statistical data, in the *fifth chapter*. Results of the other three hypotheses come from my own primary, questionnaire-based research, and presented in the *sixth and seventh chapter*. The questionnaire is based on the Community Innovation Survey, but it has been modified, to put more emphasis on the spatiality of innovation activities.

The survey was carried out in June, 2012. The population of the survey was defined according to the nature of economic activity, corporate form, spatial location, number of business years and number of employees. Knowledge-intensive sectors are classified following the OECD (2001) and Eurostat (2009) methodology. The questionnaire covers questions related on the one hand to the general characteristics of the enterprises, on the other hand to the innovation activities carried out between 2009 and 2011. During my research, I applied different statistical tools to test my hypotheses: descriptive statistical tools, statistical inference theories, cross tabulation analysis, non-parametric Mann-Whitney U test, Kruskal-Wallis and Friedman test and two-step cluster analysis to reveal relationships, the importance of the variables, and to classify enterprises (Sajtos – Mitev 2007).

I demonstrate the main results of the primary research after the presentation of the descriptive statistics of the sample. An innovation system is defined by what is produced in the system and by what processes. Therefore the last chapter of my dissertation presents the purpose of innovation activities, the types of implemented innovations, other activities related to innovation (like R&D, training, IPRs), the barriers of innovation activities, the relations of innovative partners, and finally the sector and region-specific characteristics of innovation. After the evaluation of the empirical results, the thesis is closed by the summary. These are formulated on the basis of the literature review and the empirical research.

#### **4. Main results**

One of the main results of my research is the extensive literature review of innovation systems. Novel result of the dissertation is the study of sectoral innovation systems, which has been less specified in Hungarian research. Synthesizing the literature of innovation systems, I

gained an insight to all the factors that affect the process of innovation. I pointed out that the concept is suitable to analyze nations, regions, sectors and technological areas, to understand the changes and the dynamics of innovation, and to identify the factors, which influence the innovation activities and performance of technologies, enterprises, regions and nations.

During the presentation of the conceptual framework of the research question, I revealed that approaches of innovation systems cannot be examined separately, but together. Even if innovation systems can be delimited from spatial, sectoral and technological point of view, the systems are not mutually exclusive, but complementary and have mutual impact on each other. This was a particularly important theoretical result in my research to analyze sectoral innovation systems. It became clear that same sectoral innovation systems are similar to each other, even if they are in different regions. In the same time, same sectors may deviate from each other, because of the specific characteristics of the regions and nations. I demonstrated the interdependence in a model, which shows that knowledge and its dimensions define the characteristics of innovation activities, and the spatial distribution of sectors.

In the literature it has not been reviewed so far, that how sectoral innovation systems differ depending on their spatial affiliation. Therefore, I targeted to reveal that what kind of framework conditions do the sectoral innovation systems face in a less developed region. To answer this question, I had to explore the characteristics of less developed regional innovation systems. After synthesizing the literature, it becomes clear that the differences between developed and less developed regions can be detected from several aspects. The problems in a less developed regional innovation system arise from the orientation and the degree of interactions between and within the regional innovation subsystems, the lack of critical mass in the subsystem of knowledge exploitation and exploration, the lack of actors from the subsystem of knowledge generation and diffusion, the weakness of the institutional background and the low level of innovation efforts.

These factors should be taken into account, when we analyze knowledge-intensive sectoral innovation system in less developed regions. Therefore my empirical research starts from the following theoretical finding: *Innovation activities and the performance of sectoral innovation systems depends primarily on the sector-specific characteristics, and secondly on the influence of the regional innovation system. In a less developed region it depends on the orientation and degree of interactions between and within the regional innovation subsystems, the level of critical mass, the innovation efforts and the institutional background.*

I examined the less developed Southern Great Plain region testing the first hypothesis, from the perspective of knowledge and sectoral knowledge base. It meant a novel approach to map

regional knowledge base by analyzing potential leading sectors and defining the sectoral dominant knowledge base. It is a limitation of my research that the mapping was carried out based solely on knowledge-intensive sectors and not on traditional and knowledge-intensive sectors together. Despite this, the analysis provides important information on the regional knowledge base, from the aspect of knowledge-intensive economic activities. Another advantage, that I could make my further analysis on knowledge-based sectoral innovation systems only in the light of knowledge-intensive regional knowledge base. By the analysis of regional knowledge base (based on the values of location quotient on subregional level), I highlighted those knowledge-intensive sectors that have the potential for clustering. Later, subregional data were summarized for the whole region. By testing the first hypothesis I set up the following thesis.

*1. Thesis: Regional knowledge base of Southern Great Plain is characterized by the dominance of synthetic knowledge base. Exceptions are the large urban areas, where analytical and symbolic knowledge bases also dominate.*

Through secondary data, I examined also the spatial distribution of knowledge-intensive economic activities. It is justified to analyze manufacturing and service activities separately, since manufacturing activities are highly concentrated in space, and the differences compared to services are significant.

Testing the second hypothesis, I examined the impact of the nature of economic activity, in addition the impact of dominant knowledge base on the intensity of innovation activities. As it has been presented earlier, an innovation system is defined by what is produced in the system and by what processes. That is why, first I analyzed the types of innovation that was carried out by the knowledge-intensive enterprises. Based on the results, it turned out that not only the nature of the economic activity, but even the types of dominant knowledge base did not result significant differences among the knowledge-intensive enterprises. We have to take into consideration that the results might be affected by the faults of the survey, the size of the sample or the lack of the respondent's knowledge regarding innovation.

However, it turned out that knowledge-intensive enterprises in the sample are more innovative than the enterprises – examined independently from their knowledge-intensity – in national and international statistics. This suggests that the intensity of innovation activities is sector-specific, and depends on the sectoral affiliation.

Even if the differentiating role of the nature of economic activity in terms of types of innovation was not proved, there are significant differences if we take a look at the aims of innovation activities and the other activities related to innovation.

Overall, the following aims were more important for knowledge-intensive manufacturing enterprises: improving quality of goods or services, increasing capacity and efficiency for producing goods or services, and increasing range of goods or services. Manufacturing enterprises have more intensive research and development activities, and put greater efforts to protect their knowledge by intellectual property rights. Based on the results I formulated the second thesis.

*2. Thesis: Knowledge-intensive manufacturing enterprises have more intense innovation activity, compared to the knowledge-intensive services located in the Southern Great Plain.*

Differences are significant in R&D and IPR activities according to not only the nature of the economic activity, but the type of dominant knowledge base. It came to light that sectors with analytical knowledge base – in harmony with the literature – put more emphasis on scientific activities, on protecting intellectual properties and to codify knowledge. It has been proved that sectors with analytical knowledge base are more intensive in certain areas of innovation compared to sectors with synthetic knowledge base. Therefore I complement my second thesis.

*Knowledge-intensive sectors in the Southern Great Plain region have different level of innovation activities, depending not only on the nature of the economic activity, but the dominant knowledge base.*

The research also revealed the constraining factors of innovation activities. It became clear so far that innovation activities and the performance depends on the sectoral affiliation. It turned out that there were no significant differences between manufacturing and service enterprises in this respect. It has been revealed that the constraining factors are not sectoral, but national and regional-specific. The third hypothesis was formulated, however further evidence is needed to fully support the hypothesis.

*3. Thesis: Constraining factors of innovation activities in case of knowledge-intensive sectors in the Southern Great Plain region are primarily region specific, come from the weaknesses of the regional innovation system, and not from the operation of the sectoral innovation systems.*

The most informative analysis of innovation activities was carried by the examination of the actors and their relations. I analyzed actors from several perspectives: types and location of actors, interactions, sources of information and knowledge and spatiality of knowledge sources. Both manufacturing and services companies have regional, but primarily national oriented interactions. Results are similar when we classify sector according to the dominant knowledge base. Interactions are dominantly national oriented in case of sectors with both analytical and synthetic knowledge base. Slightly higher number of enterprises with synthetic sectoral knowledge base builds on regional relations, and higher number of enterprises with analytical sectoral knowledge base has international relations. These results may be associated with the dominance of tacit or codified knowledge in the sectoral knowledge base, and with the factors constraining knowledge transfer.

It also turned out that there is no group of enterprises which has only regional partnerships. It needs further analysis to explore that: is it the result of nature of the sectors, or is it the influence of the level of development of the region.

It has been proved – in harmony with the results of international and national statistics – that the most relevant interactions with the aim to gain information and manage innovation are created with the customers, suppliers and competitors (mainly SMEs). Universities are more important for manufacturing industries, and for sectors with analytical knowledge base. Overall, it can be seen that knowledge-intensive enterprises build on the combination of different knowledge sources. Enterprises have interactions with at least three different types of partners, and these partners are typically located outside the Southern Great Plain region. This led to formulate the last thesis of my empirical research.

*4. Thesis: Knowledge-intensive enterprises in the Southern Great Plain region build on a complex system of knowledge and learning-based partnerships during their innovation cooperation. They interact with several, at least three different types of actors from the regional innovation system.*

These results also indicate that the interactions are minimal with the actors from the subsystem of knowledge creation and diffusion, and from the subsystem of the regional policy. The results also underline what was observed in case of less developed regions: the constraining factors of innovation activities are not the quality and quantity of infrastructure, not only the recent economic conditions or the lack of financial support, but the lack of

interactions with the actors from the subsystem of knowledge generation and diffusion. It also turned out that obstacles of innovation activities origins not from the geographical, but relational proximity.

It can be concluded that knowledge-intensive enterprises are part of an open regional innovation system, with strong business relations outside the region. It is clear that Tödtling's and Trippl's model for regional innovation system is less applicable in less developed regions (Tödtling – Trippl 2005, Trippl – Tödtling 2008). Types of regional innovation systems in the international literature characterize the more advanced regions, and these models represent regions as distinct territorial units. The survey revealed that the models for developed regions cannot be applied for Southern Great Plain region due to the core-periphery relations. This is one of the most important theoretical results that confirm previous findings of other authors. Theoretical basis of regional innovation systems in less developed regions should be clarified by further research.

During the research, a number of further research questions have arisen which may define the direction of new research in the future. The dissertation focused on the analysis of the interaction of sectoral and regional innovation systems. But it became clear that the relationship between technological and other innovation systems barely researched. It could be the subject of a future research to reveal the impact of regional and sectoral institutions on innovation activities and performance.

Differences in sectoral innovation systems located in developed and less developed regions should be demonstrated by case studies. The purpose of the thesis was not to draw conclusions regarding to innovation policy, but by further analysis we can obtain results that lead to rational innovation policy. It would be worth to find other, complex methods to map regional knowledge base. An interesting research direction would be to look at interactions and their spatiality within and between sectors classified according to their dominant knowledge base. Finally, further research is needed to reveal the specific features of clusters in the intersection of innovation systems.

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## 6. Publications related to the dissertation

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