Effects of Cities on Firm-level Innovation – Empirical Studies for Germany

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Dissertation

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Abstract

The relevance of cities has grown markedly. Not only that the process of urbanization, i.e. the growing concentration of population in cities, has accelerated. Cities are also referred to as sources of creativity and innovation. This dissertation relates to the connection between firm-level innovation and cities in Germany by comprising three empirical studies that assess the effects of cities on innovation in firms and their underlying mechanisms. It develops along the following key questions: Apart from the general finding of innovation being concentrated in cities, are there industries exhibiting stronger tendencies to allocate their innovative activities in cities? Does being located in or close to a city demonstrably foster innovation in firms? Which city-specific assets promote the innovativeness of firms?

The first study applies a micro-geographic approach based on postcodes in order to assess the spatial patterns of firm-level R&D activities and their connection to cities. Based on a method developed by Duranton and Overman (2005), it develops measures that integrate cities in industry-specific spatial analyses of innovation. The second contribution is devoted to distance-based effects of cities on innovation in Knowledge Intensive Business Services (KIBS). Setting up a Knowledge Production Function (KPF), it quantifies the effects of cities on different types of innovation by simulating innovation likelihood progressions depending on distances of establishments to cities. The third study is designed as a case study. It investigates which city-specific assets foster innovation in Knowledge Intensive Service (KIS) firms.

The results of the analyses show that cities above average host innovative activities of research-intensive services. Moreover, being located in a city maximizes the likelihood of most types of innovation pursued by KIBS. The case study suggests that the innovativeness of city-located KIS is connected to both cooperation with city-based external partners and the usage of city-specific innovation support infrastructures. For economic policies aiming at regional convergence the substantiated allocation patterns and beneficial effects of cities on innovation in knowledge-intensive (business) services pose a challenge as they are likely to induce considerable regional differences regarding innovative performance and hence economic growth.

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Contents

List of Abbreviations

AME	Average Marginal Effect
BBR	Bundesamt für Bauwesen und Raumordnung
CBD	Central Business District
CIS	Community Innovation Survey
DO	Duranton and Overman
EFI	Expertenkommission Forschung und Innovation
EG	Ellison and Glaeser
ERIS	European Regional Innovation Survey
EP	IAB Establishment Panel
ES	IAB Employment Statistics
EU	European Union
FUA	Functional Urban Area
IAB	Institut für Arbeitsmarkt- und Berufsforschung
KfW	Kreditanstalt für Wiederaufbau
KIBS	Knowledge Intensive Business Services
KIS	Knowledge Intensive Services
KTR	Karlsruhe Technology Region
KPF	Knowledge Production Function
MAUP	Modifiable Areal Unit Problem
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne
NIG	New Industrial Geography
NIS	National Innovation System

NUTS	Nomenclature des unités territoriales statistiques
OECD	Organisation for Economic Co-operation and Development
R&D	Research and development
REGIS	Regional Innovation Systems: Designing for the future
RIS	Regional Innovation System
SME	Small and medium-sized enterprises
SMEPOL	SME Policy and the Regional Dimension of Innovation
TIM	Territorial Innovation Models
UIS	Urban Innovation System
UK	United Kingdom
US	United States
WZ	Klassifikation der Wirtschaftszweige

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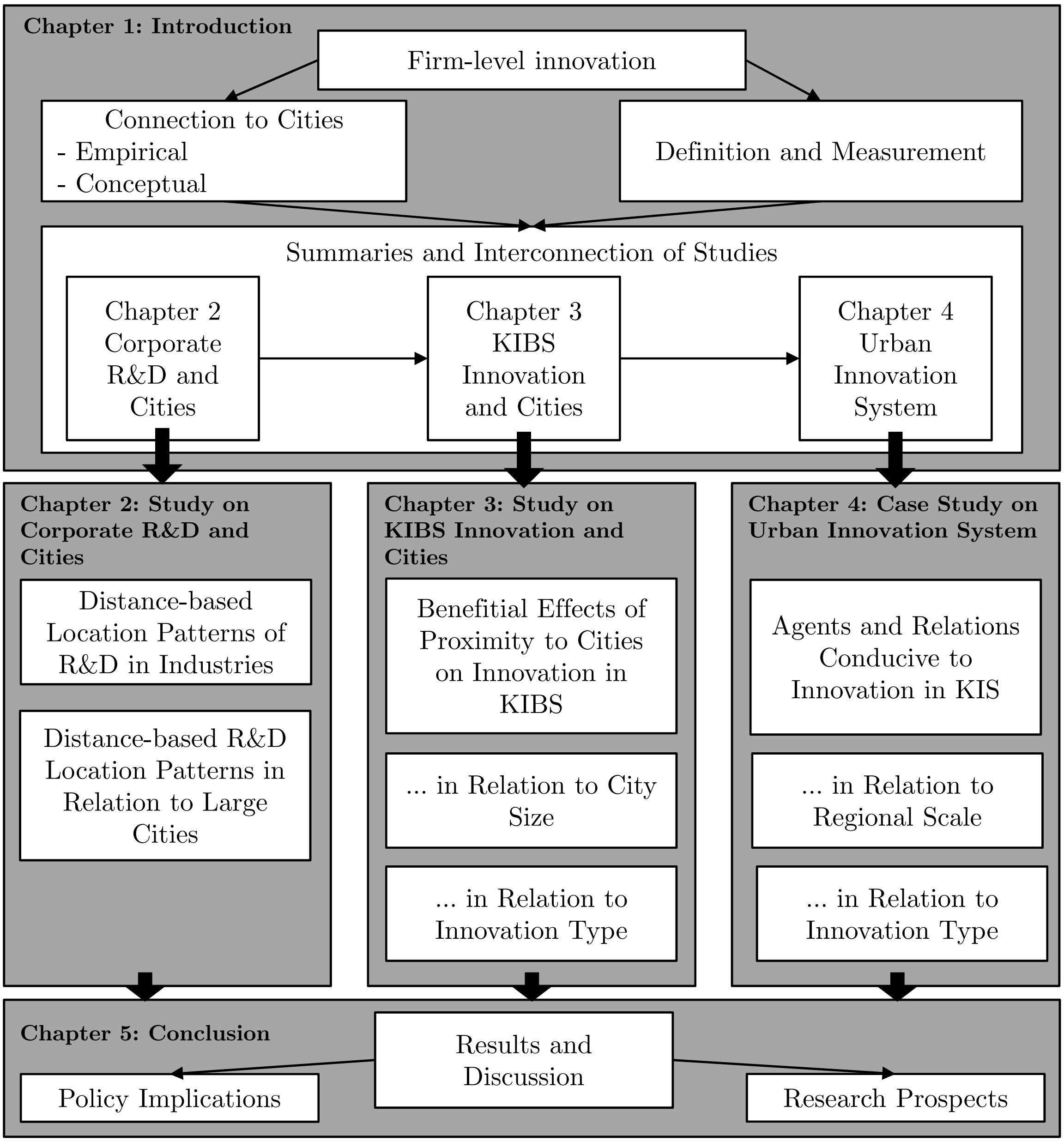
Chapter 1

Introduction to cities and firm-level innovation

In advanced economies, innovation – being crucial for economic growth and development – is concentrated in cities. This dissertation aims to answer key questions regarding this observable spatial pattern. It does so by introducing three empirical studies that analyze the effects of cities on firm-level innovation in Germany. The analyses refer to the following interrelated key questions: Apart from the general finding of innovation being concentrated in cities, are there industries exhibiting stronger tendencies to allocate their R&D activities in cities? Does being located in or close to a city foster innovation in firms? And if yes, is variation of these effects with respect to the type of innovation pursued and to city sizes observable? Which assets of cities foster the innovativeness of firms?

In order to address these key questions and derive policy implications, the thematic organization of the studies is structured as follows. *Chapter 2* is devoted to the observable spatial patterns of corporate R&D activities and their connection to cities. Applying a distance-based micro-geographic approach to the location patterns of corporate R&D establishments reveals – among other findings – that research-intensive and thus especially knowledge-dependent service industries tend to locate in large cities in Germany. This observation is one of the foundations on which the research design in *Chapter 3* is based. Also applying a micro-geographic data set, it analyzes the effects of proximity to cities on innovative activities in these knowledge-dependent service industries referred to as Knowledge Intensive Business Services (KIBS). One of the central findings in *Chapter 3* is that innovativeness in KIBS is fostered by proximity to cities and that this beneficial effect of proximity increases with city size. *Chapter 4* moves from the quantitative

Figure 1.1: Structure of the dissertation



aspects of cities, i.e. city size in terms of population, to their qualitative aspects. In a case study, the city of Karlsruhe is modeled as an *Urban Innovation System (UIS)* in order to account for city-specific endowments that possibly foster firm-level innovation in Knowledge Intensive Services (KIS). The results indicate that innovation of firms localized in cities is positively affected by cooperation with nearby higher education organizations and proximate vertically connected firms. Moreover, they demonstrate beneficial effects on innovation of financial support and innovation support infrastructures provided in the city. In *Chapter 3* and *Chapter 4* a comprehensive approach to innovation is chosen covering several types of non-technological as well as technological innovation. Thus, the general results indicated above are differentiated according to the type of innovation pursued. Finally, *Chapter 5* summarizes, discusses and connects the results together with policy implications. The structure of the dissertation is depicted in *Figure 1.1*.

Before presenting the results in more detail in the respective chapters and introducing fundamental concepts in the following sections, two key terms referred to in this dissertation need further clarification: Cities and urbanity. A major difficulty in empirically studying cities is to find a viable way to define them. In this dissertation cities are defined according to their administrative borders. Their outlines are thus congruent with NUTS3 level. The term urbanity consequently relates to the same spatial delimitation. The introduction in this chapter gives an overview on empirical evidence and theoretical reflections regarding the beneficial effects of cities on firm-level innovation in *Section 1.1*. Moreover, *Section 1.1* discusses the specificities of the German city system. *Section 1.2* briefly introduces the definition and measurement of innovation and relates to features connected to innovation in services. Finally, *Section 1.3* gives a brief summary of each study presented in the chapters and points out their interrelations and connecting factors.

1.1 Firm-level innovation, cities and the German city system

Empirical indications that firm-level innovation is concentrated in cities are manifold. In general, patents[1] and R&D tend to concentrate in cities (OECD 2013). Moreover, studies demonstrate that patents per capita augment with increasing city size or metropolitan density indicating a super-linear relationship between urbanity and invention (Sedgley and Elmslie 2011, Bettencourt et al. 2007, Ó hUallacháin 1999). Analyzing product announcements, Audretsch and Feldman

[1]Most evidence on a positive relationship between innovation and cities relies on patent data. Using patent data as measure of innovative activities has been criticized as patents reflect only major product innovation and might be affected by patenting strategies as for example defensive patenting or secrecy (Griliches 1979, 1990, Acs, Anselin and Varga 2002). However, according to Acs, Anselin and Varga (2002) patents provide a relatively accurate assessment of the geography of product innovation for US Metropolitan Areas.

(1996) find that world-first new products tend to be introduced in large cities. Duranton and Puga (2001) demonstrate that new industries emerge in large cities and then relocate within the urban hierarchy, i.e. from (large) diversified to (smaller) specialized cities, once production processes become more standardized. Other contributions show that cities tend to concentrate creative talent (Florida 2002a, for Germany see Fritsch and Stützer 2007) and highly skilled individuals (Glaeser 2000a,b) both constituting major input factors for invention and innovation. Finally, there is evidence of a strong positive relationship between innovation activities of firms and the city-based allocation of R&D in universities (Acs, FitzRoy and Smith 2002).

This sound empirical evidence is related to several partly overlapping theoretical conceptions. While each of them addresses different ways whereby the urban, local context can contribute to firm-level innovativeness, the theoretical conceptions are all based on the same fundamental assumptions: Firms rely on outside interactions to innovate and these are in turn greatly facilitated in cities. As demonstrated in the influential works of Nelson and Winter (1982) and Kline and Rosenberg (1986), firms not only rely on internal resources in order to innovate but also – by interacting with other actors – apply knowledge external to the firm. To acquire this external knowledge "being there" matters (Gertler 2003, Storper and Venables 2004). It matters principally because the exchange of tacit information, i.e. information that cannot be transferred in codified forms, requires face-to-face contact.[2] If agents are closer – as it is the case in cities – then there is more potential for interaction and knowledge transfer.

Much attention has been devoted to the mechanisms by which knowledge transfer between agents actually occurs. Marshall (1920) identifies three main channels of knowledge transfer being specialized inputs, labor market sharing and knowledge spillovers. However, while initially localized knowledge spillovers were defined as pure external effects in the tradition of endogenous growth models[3], the rai-

[2]The concept of tacit knowledge goes back to Polanyi (1967). While the codified component of knowledge can be expressed using symbolic forms of representation and is hence transmittable in formal and systematic language, its tacit elements cannot be communicated in any direct or codified way (Howells 2002). Thus, tacit knowledge is best acquired experientially via face-to-face contact (Storper and Venables 2004).

[3]The work of Romer (1986) and Lucas (1988, 1993) incorporates the transmission of knowledge as external effect in the theory of endogenous growth. While Romer argues that the creation of new knowledge by one firm has a positive external effect on the production possibilities of other firms, Lucas suggests that spillovers from education and training investments by individual agents increase the productivity of both physical capital and the wider labor force.

sing popularity of the concept since then has broadened the meaning of localized knowledge spillovers: They have become a summary variable for a number of geographically bounded knowledge flows no matter if they are non-pecuniary or based on economic transactions (Breschi and Lissoni 2001). Given the openness of firm-innovation, the spatial limitation of knowledge flows and the concentration of actors and thus knowledge in cities, the following concepts address mechanisms by which geographically bounded knowledge flows in cities lead to firm-level innovation.

Referring to the above described logic of face-to-face contact fostering knowledge transmission and being maximized with city size directly leads to the notion of *urbanization economies* (Rosenthal and Strange 2004). This concept describes cities as places with both a large population and a high population density, resulting in multiple (potential) face-to-face encounters on a relatively small spatial scale (Glaeser et al. 1992, 1995, Henderson et al. 1992, Glaeser 1999). *Urbanization economies* thus are innovative activities due to knowledge spillovers that arise from the city itself, i.e. its scale in terms of population and its structure in terms of population density, independent from other factors like economic structures or city-specific characteristics. According to the reasoning of *urbanization economies* the combination of population density and city size in terms of population promote unscheduled or serendipitous encounters that are most likely to result in the juxtaposition of new types of information which in turn may lead to innovation.

The concept of *urbanization economies* is in close connection to the concept of *Jacobs-externalities* (Jacobs 1969). This concept relates to the idea that innovation arises from *diverse* economic activities within urban contexts that foster cross-fertilization between technologies (Jacobs 1969, Desrochers 2001, Duranton and Puga 2000, Florida 2002b). Jacobs (1969) relates to diversity as the major engine of innovation, as according to her reflections the greater the variety of the "...division of labour, the greater [is] the economy's inherent capacity for adding still more kinds of goods and services." (Jacobs 1969, p59). Her theory hence emphasizes that the variety of industries within a city promotes knowledge spillovers and ultimately innovation.

The third concept is based on the works of Marshall (1920), Arrow (1962) and Romer (1986). It was formalized by Glaeser et al. (1992) and since then is often referred to as *Marshall-Arrow-Romer-externalities*. It claims that the concentration of an industry in a city – often referred to as *specialization* – promotes knowledge spillovers between firms and facilitates innovation in that industry. It thus relates to the intra-industry transmission of knowledge being conducive to innovation. A closely related debate concerns the degree of competition within an industry. In his *Cluster* approach Porter (1990, 1998) argues that local competition rather than monopoly favours growth and the transmission of knowledge and hence innovation in spatially concentrated, i.e. clustered, industries. These cluster dynamics also emphasize the existence of interactions between firms in the same or related industries. While the concepts of *Jacobs-externalities* and *Marshall-Arrow-Romer-externalities* often have been referred to as being opposites, one has to keep in mind that they in fact are not mutually exclusive.[4] In large cities, a number of specialized clusters often prevails while the cities themselves do have a diversified economic structure. Regarding empirical evidence on both *Jacobs-externalities* and *Marshall-Arrow-Romer-externalities*, multiple studies have been conducted with different outcomes (for a thorough overview on the studies and their central findings see Beaudry and Schiffauerova 2009).

However, as pointed out by Iammarino (2011), the debate to which degree one particular characteristic of a city or its economic structure is conducive to innovation, might be technical, as it misses an evolutionary perspective where cities follow individual path-dependent trajectories and dispose on different, individual characteristics (for a case study on metropolitan areas under transition, see Boje et al. 2010). This idea, to some degree, is reflected in the concept of Regional Innovation Systems (RIS) that was developed in parallel to Porter's *Cluster* approach (Cooke 1992, Cooke et al. 2002). At its core, the concept of RIS puts "...an emphasis on economic and social interactions between agents, spanning the public and private sectors to engender and diffuse innovation within regions..." (Asheim et al. 2011, p878). Thus, it stresses that each locality accommodates its individual institutions and culture which are more or less beneficial to the exchange of knowledge fostering innovation. The approach of *Urban Innovation Systems (UIS)* that is applied in *Chapter 4* of this dissertation constitutes a special form of RIS by defining a city as region to be analyzed. Research on *UIS* follows two strands: City-based case studies on innovation in specific industries or types of firms[5] and comparative studies on innovation systems in different cities[6]. RIS – and implicitly also *UIS* – stands in the tradition of approaches summarized under the terms "New industrial Geography" (NIG) (Martin and Sunley 1996, Breschi and Lissoni 2001) or "Territorial Innovation Models" (TIM) (Moulaert and Sekia 2003). These

[4]For a description, see Beaudry and Schiffauerova (2009).

[5]See, for example, Doloreux (2004) for SMEs in Ottawa, Blažek and Žižalová (2010) for biotechnology firms in Prague and Trippl (2011) for the food industry in Vienna.

[6]See, for example, Revilla Diez (2000) and Fischer et al. (2001) on Barcelona, Stockholm and Vienna and Simmie et al. (2002) on Amsterdam, London, Milan, Paris and Stuttgart.

approaches – i.e. New Industrial Districts (Bagnasco 1977, Becattini 1979, Garofoli 1981, Brusco 1982), Innovative Milieus (Aydalot 1986, Perrin 1988, Maillat and Lecoq 1992, Camagni 1995) and Cluster (Porter 1990, 1998) – emphasize the role of local specificities for innovation opportunities but do not necessarily refer to cities.

Relating the empirical evidence and the concepts addressing the beneficial effects of cities on innovation to the studies introduced in this dissertation, the following points have to be made. *Chapter 2* steps back from theoretical concerns as referred to in the concepts but aims to contribute to the empirical examination of industry-specific agglomeration patterns of innovative activity with respect to cities. It provides industry-specific analyses of the spatial organization of R&D – being an input to innovation – in relation to cities. By depicting which industries concentrate their innovative activities above average in cities, it contributes to the empirical literature on cities and innovation. *Chapter 3* focuses on *urbanization economies* and controls for both *Jacobs-externalities* and *Marshall-Arrow-Romer-externalities* in order to empirically assess the effects of cities and their size in terms of population on innovation. The study presented in *Chapter 4* refers to the concept of *UIS* in order to determine the degree to which cooperation activities with and usage of city-specific institutions lead to firm-level innovation.

As the studies on innovation and cities in this dissertation are all related to Germany and hence a specific national framework, it is necessary to take a closer look at the spatial features under which the results hold. With an area of about 357 square kilometres, Germany is ranked the 63rd largest country among 257 countries in the world (Central Intelligence Agency 2017). The longest geographical extent of linear distance is 876km from North to South and 640km from East to West (Statistisches Bundesamt 2010).

Apart from being a relatively small country in terms of geographic size, the German city system – i.e. the spatial distribution and size of the cities as well es their interconnections – is characterized by a high degree of polycentricity. The concept of polycentricity implies that economic and / or economically relevant functions are distributed over the city system in such a way that a multitude of cities rather than one or two gains significance (Blotevogel 2000, Meijers et al. 2005). Comparing national city systems in Europe in terms of poly- or monocentricity, Meijers and Sandberg (2008) follow Parr (2004) by analyzing both city sizes, i.e. population, and the spatial distribution of cities. Regarding city sizes, their analysis of national rank size distributions of Functional Urban Areas (FUA)[7] reveals that Germany is the most polycentric country in Europe. Analyzing the spatial distribution of FUA on NUTS 2 level shows that Germany is in mid-range (rank 15 of 26). In their overall index of polycentricity Germany is ranked six among 25 European countries.

Blotevogel (2000) points out that this high degree of polycentricity is due to historical developments: After the formation of the Deutsche Reich in 1871, Berlin developed to a metropolis[8], strengthening its dominant position relative to Hamburg and regional metropolises like Munich, Leipzig and Dresden. However, the second World War and the separation of Germany resulted in a deep cut of the German city system with Berlin losing and Bonn, Hamburg, Düsseldorf, Köln, Frankfurt and Munich winning metropolitan functions. Today, the German city system is characterized by a multimodal tip consisting of about six to ten leading regional metropolises (Blotevogel 2000, Volgmann 2014, Heineberg 2017).[9] In a recent contribution, Volgmann (2014) identifies Berlin, Munich, Frankfurt, Hamburg, Cologne, Stuttgart, Düsseldorf, Bonn and Hannover as cities with the strongest metropolitan functions. Looking at the linear distances between these cities reveals that their average distance is about 320km with a minimum of 24 km (Bonn – Cologne)[10] and a maximum of 512km (Berlin – Stuttgart). This admittedly very brief introduction to the German city system illustrates the spatial framework under which the distance-based results in the studies presented in *Chapter 2*, *3* and *4* are valid.

[7]A FUA is composed of a city and its commuting zone. For more information on the concept, see Eurostat (2015).

[8]In literature on spatial planning, metropolises are commonly defined by analyzing metropolitan functions of cities. These are generally referred to as innovation and competition function, decision-making and control function and gateway function, in some cases supplemented by symbol function. For an overview on the functions and their operationalisation, see Bundesamt für Bauwesen und Raumordnung (BBR) (2005).

[9]The number varies according to criteria applied.

[10]Bonn, Cologne and Düsseldorf are part of the Rhine-Ruhr Region which itself is an archetype of a multi-core polycentric urban region (Münter 2011).

1.2 Firm-level innovation – Definition and measurement

The concept of innovation and the indicators used to measure innovation applied in this dissertation are inspired by two manuals – published by the Organisation for Economic Co-operation and Development (OECD) – that both constitute standard works regarding the survey-based measurement of innovation, namely the *Oslo* and the *Frascati Manual* (OECD 2002, 2005). While the *Oslo Manual* serves as a guideline for collecting and interpreting data on innovation output[11], the *Frascati Manual* proposes standard practices for surveys on R&D and thus innovation input.

Following a Schumpetarian tradition[12], the *Oslo Manual* defines firm innovation as "...the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations." (OECD 2005, p47). This broad definition of innovation encompassing technological as well as non-technological forms of innovation[13] lies at the heart of *Chapter 3* and *Chapter 4* in this dissertation. Analyses of innovation in these chapters are based on surveys inspired by the *Oslo Manual* and thus confined to different types of innovation.[14]

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[11]The *Oslo Manual* constitutes the conceptual base for the Community Innovation Survey (CIS) of the European Union (EU) that is performed every two years.

[12]The first author defining firm-level innovation is Joseph Schumpeter whose work has greatly influenced our current conception and theory of innovation. In his seminal work on innovation being at the core of a process of "creative destruction" where innovating firms replace non-innovating firms, he proposes a list of five different technological and non-technological types of innovation, namely introduction of new products, introduction of new methods of production, opening of new markets, development of new sources of supply for inputs and creation of new market structures in an industry (Schumpeter 1934).

[13]In fact, the first edition of the *Oslo Manual*, published in 1992, provided a more restricted notion of innovation, defined as technological product and process innovation. It thus implicitly addressed innovation in manufacturing industries only (Bloch 2007).

[14]The *Oslo Manual* defines the following four types of innovation (OECD 2005, pp48):
- *Product innovation*: A good or service that is new or significantly improved. This includes significant improvements in technical specifications, components and materials, software in the product, user friendliness or other functional characteristics.
- *Process innovation*: A new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.
- *Marketing innovation*: A new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.
- *Organisational innovation*: A new organizational method in business practices, workplace organization or external relations.

Analyzing different types of innovation is of major relevance as the studies focus on the innovation behavior of service firms exercising activities that require above average knowledge inputs. Depending on their client structures these services are either denoted as Knowledge Intensive Business Services (KIBS) or Knowledge Intensive Services (KIS). In general, their innovation behavior differs substantially from that in manufacturing firms. First, as described by Gallouj (2002), innovation in KIS / KIBS is often intangible in the sense that it is not technology-based or embodied in material products. Thus, their innovative output is often described as non-technological and manifests itself in organizational changes (Tether and Tajar 2008). Second, innovation in KIS / KIBS is cooperative, as it involves a considerable degree of interaction both within the firm and with external partners. As R&D departments in KIS / KIBS firms are often absent, internal innovation processes are mostly organized in project-specific teams involving actors from various departments (Gallouj 2002, Hipp and Grupp 2005). Compared to manufacturing firms, access to external knowledge resources seems to be more important for innovating KIS / KIBS firms (Koschatzky 1999). These external knowledge resources are mostly firms along the value chain, i.e. customers and suppliers (Gallouj 2002, Hipp and Grupp 2005, Freel 2006, Amara et al. 2009). To summarize, innovation in KIS / KIBS is strongly associated with highly qualified employees, constituting internal knowledge resources, collaboration activities with external sources and learning by doing (Freel 2006, Simmie and Strambach 2006).

While the studies presented in *Chapter 3* and *Chapter 4* are based on survey data aiming at measuring innovation output inspired by the current edition of the *Oslo Manual* and taking into account specificities of innovation in services, the study in *Chapter 2* relates to R&D as an input measure of innovation. The survey-based data set is based on the *Frascati Manual* which is devoted to measuring R&D inputs (OECD 2002) and which defines R&D as comprising "...creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications." (OECD 2002, p30).

However, although R&D is a sophisticated measure of the knowledge potential and the 'absorptive capacity' of firms, as pointed out by Kleinknecht et al. (2002), measuring R&D as innovation indicator has a number of drawbacks. First, as R&D only reflects the input side of innovation, it does not provide information about the actual introduction of innovations into commercial use. Second, R&D is only one out of several inputs that might result in innovation output. Regarding the connection between innovation output and innovation output, a central finding in the literature on innovation is that a firm does not innovate in isolation (Fagerberg 2004). Knowledge that is combined in order to innovate is not only internal but also external to the innovating firm. Thus, interaction and knowledge transmission between different actors play a crucial role in the generation of innovation (Nelson and Winter 1982, Kline and Rosenberg 1986).[15] Third, R&D surveys tend to underestimate the R&D activities in smaller firms[16] and in services[17]. Nevertheless, R&D data still is widely used in order to analyze innovative activities in firms (Smith 2005).

1.3 Summary and interrelation of chapters

This section gives a brief overview on each of the studies presented in *Chapters 2, 3* and *4* and points out their interrelations and connecting points. It also includes back references to definitions, measures, empirical evidence and concepts introduced in *Sections 1.1* and *1.2*.

Chapter 2: Spatial patterns of corporate R&D activities and their connection to cities – A distance-based approach

The study presented in *Chapter 2* builds on two central empirical findings regarding spatial patterns of innovative activities in developed economies. First, in general innovation-related activities are more spatially concentrated than economic activities of firms[18]. Second, over and above being spatially concentrated, they also tend to concentrate in cities. Having these rough empirical findings in mind,

[15] The chain-linked model developed by Kline and Rosenberg (1986) – based on empirical and historical research on the link between science, technology and innovation – stresses three basic aspects of innovation being an interactive process:

- Innovation is not a sequential (linear) process but one involving many interactions and feedbacks in knowledge creation.
- Innovation is a learning process involving multiple inputs.
- Innovation does not depend on an initiating factor, it rather tends to be undertaken as problem-solving within an ongoing innovation process.

[16] For small and medium-sized companies a questionnaire inspired by the *Frascati Manual* is often too complicated. Many of them tend to report none of their small-scale and informal R&D (Kleinknecht et al. 2002).

[17] For a comprehensive review on the potential under-estimation of R&D in services see Miles (2007).

[18] Economic activities of firms are, for example, selling or producing services or products.

the study aims to step back from theoretical concerns but contributes to the empirical literature by analyzing the spatial patterns of innovation related activities in more detail. It is the first study using a micro-geographic approach to assess spatial patterns of corporate R&D for a whole economy.

The study uses a distance-based methodology developed by Duranton and Overman (2005) in order to analyze industry-specific spatial patterns of R&D in Germany. Building on the industry specific results, the methodology is modified in order to assess if and to which degree the industry-specific location patterns of innovational input are related to cities. Thus, the approach relates to two perspectives by analyzing industry location patterns of *(a)* R&D and *(b)* of R&D in relation to cities. In order to derive statistically significant results on spatial patterns, the methodology compares distance-based kernel density functions of industry-specific R&D to confidence bands based on simulations of counterfactual scenarios. The results indicate if and how spatial patterns of R&D in different industries[19] deviate from the overall spatial distribution of R&D in Germany.

Looking at industry location patterns of R&D reveals that especially production industries tend to concentrate spatially. However, the spatial scale of localization is relatively high as it mostly occurs around 100km. Contrary, for R&D in service industries – especially when they are research-intensive – data reveals dispersion. This implies that service industries are less concentrated in space than one would expect by taking the overall spatial distribution of R&D as a reference.

The picture of this sector-specific spatial distribution of R&D changes radically when cities[20] are taken into account by modifying the estimation methodology in order to integrate them in the analyses. In fact, accounting for the role of cities in industry-specific location patterns of R&D adds an explanatory factor helping to further classify the findings regarding industry-specific patterns of R&D location. For production industries, if R&D activities are urban localized – in the sense that they tend to locate above-average in or near to cities – they tend to locate at a certain radius *around* the city's borders. For service industries two central findings emerge. First, spatial dispersion found in industry-specific patterns of R&D location is connected to centripetal forces of large cities. Above average concentration of service R&D directly *in* cities is observable. Second, this holds true especially for research-intensive services that devote above average financial resources to knowledge creation in the form of R&D.

[19]Industries are defined on 2- and 3-digit levels according to NACE Rev.2.

[20]The definition of cities follows administrative boarders. It encompasses all cities in Germany with more than 100,000 inhabitants.

Relating to these central results, one should keep in mind that the overall spatial distribution of R&D is taken as a reference in order to construct counterfactual scenarios and derive industry-specific results. Thus, especially findings of spatial dispersion do not contradict the notion of R&D being spatially concentrated and, moreover, localized in cities. Having this general pattern in mind, the study adds to the literature by disclosing industry-specific spatial variations within an already highly concentrated innovation-related activity. In *Chapter 3* the finding of a relative concentration of service industries devoting above average resources to knowledge creation in cities is taken as one of the motivations to investigate whether and to which degree these service industries profit from being located in or close to a city in order to innovate.

Chapter 3: Distance-based effects of cities on innovation in Knowledge Intensive Business Services (KIBS)

The study depicted in *Chapter 3* builds on three observations regarding the location of Knowledge Intensive Business Services (KIBS) being defined as services that rely to an above average degree on knowledge as production input. First, as demonstrated in *Chapter 2*, these services tend to allocate their investments in knowledge creation – i.e. their R&D activities – in cities. Second, KIBS establishments themselves are concentrated in cities with a tendency towards the top of the urban hierarchy, i.e. in the largest cities. Third, founding activities of KIBS primarily occur in cities leading to a reinforcement of their concentration pattern. In their review on the current state of research regarding KIBS, Muller and Doloreux (2009) find that the connection between KIBS innovation and their location preferences regarding cities remains under explored in KIBS studies. This leads us to explore that connection along two lines of questions: First, does being located in or close to a city foster innovation in KIBS? If yes, are variations of this beneficial effect with respect to innovation types and city sizes observable?

In order to first theoretically address the research questions and deduct corresponding hypotheses, two concepts that connect innovative activities and cities are applied and linked to innovation in KIBS. The first concept formalized by Glaeser (1999) – *urbanization economies* – theorizes that cities foster knowledge transfer and thus innovation. The bigger a city the more it promotes interaction due to a greater number of potential contacts constituting knowledge resources. The second concept is a spatial analytic model of McCann (2007) inspired by von Thünen (1826). It implies that – depending on the number of necessary face-to-face contacts – different types of innovation tend to locate concentrically around a central place[21] in a city. Other studies find that although KIBS are engaged in R&D themselves, they rely more on external resources to innovate than other industries. Thus, the beneficial aspects of cities should hold especially for these kinds of services.

As in *Chapter 2*, a distance-based micro geographic approach in order to conduct the empirical analyses for Germany is applied. Innovation activities in KIBS are modeled using a Knowledge Production Function (KPF) that relates variable vectors of innovational input to innovational output of KIBS (Griliches 1979). Great circle distances of a KIBS establishment to the closest city constitute one input factor to KIBS innovation and serve to measure *urbanization economies*. Applying a synthesis approach to innovation in services, the effects are analyzed for different types of innovation new to the firm, namely product introduction, product improvement, process innovation and organizational innovation.[22] In order to account for city sizes, all cities in Germany are grouped in three categories according to their population: Small cities (50,000 to less than 100,000 inhabitants), large cities (100,000 to less than 500,000 inhabitants) and metropolises (500,000 and more inhabitants). The analyses are conducted using two models. The first model (*Model 1*) abstracts from city sizes. It measures the general effect of cities on KIBS innovation. The second model (*Model 2*) takes city sizes into account.

In *Model 1 urbanization economies* for every type of innovation are found. However, simulating innovation probabilities according to distances reveals that they are strongest for product improvement and process innovation. Differentiating according to city sizes in *Model 2* reveals that especially for these two types of innovation *urbanization economies* are stronger with growing city size. Additionally, for product introduction *urbanization economies* emanating from metropolises are found while large and small cities exert no effects. For organizational innovation, the results do not indicate *urbanization economies*. There is also evidence on concentric allocation patterns regarding organizational innovation and product improvement with product improvement being relatively more likely to occur at closer proximity to metropolises and large cities.

To summarize, the results regarding product improvement, product introduction and process innovation in KIBS reveal that innovation probabilities decrease con-

[21]Centrality, here, is defined as the location offering a maximum of face-to-face contact, e.g. a CBD.

[22]Note that product introduction, product improvement, process innovation and organizational innovation are defined in accordance with the *Oslo Manual* (OECD 2005).

siderably with growing distance to metropolises. Decreases in innovation probabilities for distances from large and small cities, if significant, occur to a lesser extent. This leads to the conclusion that cities foster innovation in KIBS and thus exert centripetal forces on innovation-related activities of KIBS. Moreover, the centripetal forces are stronger with increasing city size.

As theorized in this chapter, innovation in KIBS is positively affected by proximity to cities and this positive influence increases with city-size. However, apart from their quantitative endowments in terms of population and thus possible contacts, cities also provide qualitative resources conducive to innovation. While both city size and its qualitative endowments might interact mutually, the results indicated above still leave open the questions if and to which degree a city's qualitative endowments contribute to innovation. These questions are addressed in *Chapter 4*.

Chapter 4: Urban Innovation System – Case study on Knowledge Intensive Services (KIS) in Karlsruhe

The study presented in *Chapter 4* is set up as a case study. It aims at investigating which local, city-specific infrastructures and knowledge resources foster innovative activities of city-located Knowledge Intensive Services (KIS). Thus, it shifts the focus from size-effects of cities, i.e. *urbanization economies*, on innovation in knowledge-dependent services to city-specific endowments. The city referred to in the case study is Karlsruhe. Karlsruhe is situated in the German Federal State of Baden-Württemberg. With around 300,000 inhabitants it is the second largest city in the Federal State after the capital Stuttgart. As KIS are relatively strongly concentrated in Karlsruhe, the city constitutes a suitable research subject.

In order to analyze the effects of city-specific endowments on innovation in KIS, the study relates to the concept *Urban Innovation Systems (UIS)*. In brief, the concept relates to the notion of innovation being a local, city-based process involving interactions between organizations that span both public and private sectors (Cooke et al. 1997, Cooke 2001, Doloreux and Parto 2005). These organizations have a dual function regarding the promotion of innovation. On the one hand they act as cooperation partners in innovation and on the other hand they shape the local infrastructure conducive to innovation. Specific organizations involved in the innovation process are firms, non-university research and development organizations, higher education organizations (e.g. universities), governmental organizations and finance providers.

For analyzing the effects of city-specific innovational input on the innovative output of KIS in Karlsruhe, a KPF is applied to a survey-based data set provided by the city administration of Karlsruhe. It relates four types of innovation in KIS – product or service innovation, process innovation, organizational innovation and business model innovation[23] – to the Karlsruhe-specific input vectors innovation support infrastructure (i.e. city-specific financial services and support services by industrial and governmental organizations) and cooperation partners.

The results of the analyses show positive effects of both city-specific innovation support infrastructures and cooperation partners in the city itself on innovation in KIS and thus demonstrate that innovation in knowledge-dependent services is positively affected by the city's qualitative endowment. However, these beneficial effects vary with respect to the type of innovation pursued. Process innovation in KIS is positively affected by cooperation activities with local customers and suppliers as well as higher education organizations situated in Karlsruhe. Product or service innovation is neither positively influenced by city-specific innovation support infrastructures nor by cooperation with local partners. Contrary, for organizational innovation positive effects of the usage of city-specific financial resources and cooperation with local suppliers and customers are detectable. Finally, business model innovation is positively affected by city-specific innovation support services as they are for example provided by the Steinbeis Association. Local cooperation activities alone appear to be insufficient in order to foster that type of innovation in KIS.

In general, the results of the study reveal that apart from *urbanization economies*, qualitative endowments of cities – namely city-specific innovation support infrastructures and the nature of cooperation partners – also foster innovation in knowledge-based service activities. Thus, the centripetal forces of cities regarding location of establishments and innovative resources are constituted by quantitative as well as qualitative effects being beneficial to innovativeness in knowledge-based services.

[23]Note that product or service innovation, process innovation and organizational innovation are defined in accordance with the *Oslo Manual* (OECD 2005).

Chapter 2

Spatial patterns of corporate R&D activities and their connection to cities – A distance-based approach

The content of this chapter is based on a cooperation with Vladimir Korzinov (Karlsruhe Institute of Technology, KIT) and Florian Kreuchauff (Stifterverband für die Deutsche Wissenschaft).

2.1 Introduction

Economists have theoretically and empirically demonstrated a positive relationship between investments in research and development (R&D), resulting innovations and economic growth. Models of endogenous growth lead to the conclusion that R&D is one of the main drivers of national economic growth (Romer 1990, Grossman and Helpman 1991, Aghion and Howitt 1992). Multiple empirical studies also have confirmed the importance of R&D for technological progress, productivity and economic growth (see, for example, Akcay 2011 for a recent survey of this literature).

Analyzing the spatial patterns of R&D within countries leads to two central findings. First, while general economic activity tends to be geographically concentrated, innovation-related activities – like, for example, R&D activities – are even more spatially concentrated (Audretsch and Feldman 1996, especially for R&D activities see: Carrincazeaux et al. 2001, Buzard and Carlino 2009, Carlino et al.

2012). Second, not only is spatial R&D concentration relatively high, evidence also shows that R&D exhibits a strong tendency to concentrate in a certain type of area: cities (Bairoch 1988, Feldman and Audretsch 1999, Chatterji et al. 2014). These observable spatial patterns of R&D might be related to multiple Marshallian channels, i.e. specialized inputs, labor market sharing and knowledge spillovers. However, empirical evidence indicates that they are mostly linked to knowledge spillovers which are not only limited in space (Rosenthal and Strange 2004, Ellison et al. 2010) but also fostered by high densities of people (Glaeser et al. 1992, Henderson et al. 1992, Glaeser 1999, Bettencourt et al. 2007, Sedgley and Elmslie 2011) and industrial structures (Marshall 1920, Jacobs 1969, for a recent overview on *Marshall-Arrow-Romer-externalities* and *Jacobs-externalities* see: Beaudry and Schiffauerova 2009). This leads to the conclusion that even though the yield of R&D activities is influenced by multiple aspects, the exchange of ideas and thus the case of physical proximity remains a key ingredient.

Given the broad literature regarding the spatial distribution of innovation, R&D and industrial activity, this chapter aims to fill an important gap regarding location patterns of R&D input by empirically exploring micro-geographic data for Germany. In order to measure spatial concentration early studies, as for example Krugman (1991) and Audretsch and Feldman (1996), use a locational Gini coefficient. However, as argued by Ellison and Glaeser (1997), one problem with the locational Gini coefficient is that it may spuriously indicate the localization of an industry resulting from the lumpiness of plant employment[1]. Ellison and Glaeser (1997) improve on the locational Gini coefficient by offering an alternative index that controls for the industrial organization of an industry by adopting a so-called dartboard approach (EG approach). The approach compares the degree of spatial concentration of employment in a given sector with the degree of concentration that would arise if all plants in that sector were located randomly across locations. However, the approach has mainly been criticized as it relies on a discrete definition of space and is thus affected by the underlying spatial zoning system, i.e. shape, size and relative position of spatial units.[2] This critique together with enhanced availability of micro-geographic data sets in recent years has lead Duranton and Overman (2005) to develop an approach (DO approach) that is based on continuous space by utilizing address data of establishments. In order to assess

[1]The expression lumpiness of plant employment relates to different patterns of plant size distributions each leading to the same amount of total employment.

[2]For further elaborations on the so-called Modifiable Areal Unit Problem (MAUP) see Briant et al. (2010).

statistical significance of the deviation from randomness, the density distribution of bilateral distances is compared to counterfactuals constructed by simulations.

Although both the EG and the DO approach have been widely adopted in the literature in order to measure industrial concentration, the latter more recently[3], few studies use them to determine agglomeration patterns of innovation-related activities. Moreover, the scarce evidence on innovation-related activities based on the DO approach mostly refers to patent data and technology classes (Inoue et al. 2013, Murata et al. 2014, Kerr and Kominers 2015). To the best of our knowledge, only two studies by Buzard and Carlino (2009) and Carlino et al. (2012) relate to the DO approach in order to analyze location patterns of R&D establishments. However, they only cover geographic partial areas of the United States and do not differentiate between industries.

The work in this chapter contributes to the literature on spatial R&D organization in three ways. First, it is the first to consider the spatial distribution of corporate R&D activity applying measures of continuous space for a whole economy. Second, by differentiating between industries it derives statements on the variation of spatial R&D activities according to industries. It demonstrates if and how spatial R&D patterns of specific industries significantly deviate from the overall location pattern of corporate R&D. Third, new distance-based measures in order to assess effects of cities on industry-specific spatial R&D organization are developed. This allows to demonstrate if and how spatial corporate R&D patterns of specific industries significantly deviate from the general location pattern of corporate R&D in relation to cities.

In order to conduct the analyses data provided by the "Stifterverband für die Deutsche Wissenschaft" (Donors' Association for the Promotion of Sciences and Humanities in Germany) is used. It constitutes the most comprehensive database for private R&D in Germany. In total, the analyses are based on 19,804 company R&D establishments in Germany that employ 476,575 researchers in all economic sectors – agriculture, production industries and service industries. Locations of R&D establishments are geocoded referring to centroids of 8,212 postcodes. For the analyses of the spatial distribution of corporate R&D the distance based micro-geographic approach developed by Duranton and Overman (2005) is applied. Note that by taking the overall spatial distribution of R&D establishments as a

[3]See, for example, Duranton and Overman (2005, 2008) for the UK, Albert et al. (2012) for Spain, Nakajima et al. (2012) for Japan, Barlet et al. (2013) for France and Koh and Riedel (2014) for Germany.

reference, industry-specific variations of location patterns within R&D activities are investigated.

Analyzing the location patterns of R&D activities on the level of 3-digit industries leads to the determination of industry-specific allocation patterns of R&D and their relation to cities. Regarding the spatial distribution of R&D establishments in Germany, we find that with reference to the overall spatial distribution of R&D, 40.8% of 3-digit industries exhibit significantly different patterns of spatial R&D organization. In general, deviations occur more often in the production industry than in the service sector. Moreover, production industries exhibit a higher propensity to concentrate in space. However, taking distances into account, concentration of R&D activities in production industries mostly occurs at relatively high distances of around 100km. Deviations from spatial randomness in service industries tend to exhibit dispersion, i.e. for service industries statistically significant larger distances between R&D establishments are found than one would expect from taking the overall spatial distribution of R&D as a reference.

Relating to the evidence on cities being major attractors of R&D activities, the DO approach is modified in order to integrate cities in the analyses of industry-specific location patterns. This leads to further insights and helps to determine if and to which degree the observed location patterns of R&D establishments are connected to cities. The findings add explanation to the general location patterns of R&D in industries. On the one hand, they reveal an interconnection between industry-specific R&D concentration and localization in relation to cities. On the other hand, especially for service industries, they disclose that dispersion of spatial R&D patterns is connected to or even induced by centripetal forces of large cities on R&D. Furthermore, the analyses reveal that – especially in services – research-intensive industries that devote above average financial resources on R&D activities are more likely to locate their R&D in and around large cities than one would expect from the overall geographic distribution of R&D.

This chapter is organized as follows. *Section 2.2* introduces the database and the basic estimation methodology. Results on spatial patterns of industry-specific R&D are presented in *Section 2.3*. *Section 2.4* integrates cities in the analyses. Finally, results are discussed in *Section 2.5*.

2.2 Data and basic estimation methodology

This section introduces the data used in order to analyze the spatial distribution of R&D in Germany together with the basic estimation methodology (DO approach). The introduction of the database includes both its thorough description and descriptive statistics on R&D on the level of industry divisions. Subsequently, the basic estimation methodology applied to depict industry-specific location patterns of company R&D establishments is presented. It implies estimating industry-specific estimations of kernel density functions and counterfactuals based on measures of great circle distances[4]. The methodology is illustrated by exemplary location patterns of R&D on the level of 3-digit industries.

2.2.1 R&D-survey and descriptive statistics on R&D in Germany

In order to identify location and size of R&D establishments in Germany, data from the biennial R&D-survey conducted by the "Stifterverband für die Deutsche Wissenschaft" (Donors' Association for the Promotion of Sciences and Humanities in Germany) is used. It constitutes the most comprehensive data-base for firm-level R&D in Germany. By means of a standardized written survey the Stifterverband collects data reflecting different aspects of company R&D activity – e.g. internal and external R&D-expenditures, R&D-personnel, location and size of R&D establishments – on behalf of the German Federal Ministry of Education and Research. The survey is designed as full census, such that it raises the claim to cover the whole population of companies conducting R&D in Germany. Reporting unit on company level is usually the smallest independent accounting unit. All companies in Germany that are assumed to conduct R&D are included in the survey. They are identified by preceding R&D surveys and auxiliary variables – including industry, company size and information on public R&D funding. However, as pointed out by the Stifterverband, the detection of all companies in Germany that conduct R&D remains a challenge as no complete database exists. Thus, although the survey is designed as a full census, the coverage might be incomplete; especially with respect to small and medium-sized companies.[5]

[4]Great circle distances depict the shortest linear distance between two points based on latitude and longitude details, taking into account the earth's curvature. For example, while the linear distance between postcodes 70173 (belonging to Stuttgart) and 10115 (belonging to Berlin) is 511.560km, great circle distance is 512.282km. The driving distance by car is about 630km.

[5]For a detailed description see the report of the Stifterverband presenting the results of the recent R&D survey (Stifterverband für die Deutsche Wissenschaft 2015).

Table 2.1: Size distribution of companies and R&D companies in Germany

	Employees subject to social insurance				
	0 to <10	**10 to <50**	**50 to <250**	**250 and more**	**Total**
No. of companies [Germany, 2013]	3,290,579	268,263	57,712	13,112	3,629,666
Share [%]	90.7	7.4	1.6	0.4	100.0
No. of companies [Stifterverband]	3,139	7,431	5,510	2,790	18,870
Share [%]	16.6	39.4	29.2	14.8	100.0

Table 2.1 compares the overall company structure in Germany in 2013 to the R&D company structure extracted from the database provided by the Stifterverband. The size distribution of R&D companies in the database is skewed towards bigger companies. This leads to the assumption that – compared to the overall company size distribution – bigger companies are more likely to conduct R&D activities. This conclusion is in accordance with evaluations for Germany based on the KfW SME panel[6] over the years 2005 to 2012. Shares of companies conducting R&D increase from 24.0% for companies with 0 to less than 10 employees over 41.0% for companies with 10 to less than 50 employees up to 60.0% for companies with 50 to less than 250 employees (Baumann and Kritikos 2016). However, we still need to keep in mind that some of the small and medium-sized companies that conduct R&D might be missing in the database.

As the study aims to identify spatial patterns of firm-level R&D activity, the adequate unit of analysis is not the company but the company's R&D establishments. Because the survey collects information on the postcodes of a company's R&D establishments and of the fraction of total R&D workforce employed in these establishments, it allows to identify both the location of R&D establishments and their size in terms of the number of researchers employed. Thus, for every R&D establishment its postcode, its 2- and 3-digit industrial classification (NACE Rev. 2) and its size are detectable. Assuming that R&D activity is a long term investment, five consecutive surveys of the years 2005, 2007, 2009, 2011 and 2013 are subsumed to generate the data set. This allows to gather data on 19,804 R&D establishments

[6]The KfW SME panel ("KfW Mittelstandspanel") is a representative survey of micro, small and medium-sized companies in Germany that have an annual turnover of up to 500 Million Euro. It does not have a lower threshold regarding the number of employees.

Table 2.2: Size distribution of R&D establishments

	Number of researchers				
	0 to <10	10 to <50	50 to <250	250 and more	Total
No. of R&D establishments	14,398	4,042	1,080	284	19,804
Share [%]	72.7	20.4	5.5	1.4	100.0

that occupy in total 476,575 researchers in Germany.[7] As each establishment is assigned a unique identifier, multiple entries are excluded by taking the most current information available in the database. In total, 81 industries at the 2-digit and 235 industries at the 3-digit level of industrial classification with at least one R&D establishment are identified. Of the 235 industries at the 3-digit level, 140 have more than ten R&D establishments. *Table 2.2* shows the size distribution of R&D establishments. The majority of R&D establishments (72.7%) employ less than 10 researchers, while the fraction of big R&D establishments with 250 and more researchers employed is only 1.4%.

Table 2.3 and *Table 2.4* depict the descriptive statistics at the 2-digit industry level, i.e. statistical divisions, for agriculture, production industries and the service industries in terms of the number of establishments, R&D establishment-company ratio, average number of researchers per R&D establishment and number of 3-digit industries contained. Analyzing the number of establishments and the number of researchers employed shows a dominance of production industries, especially of manufacturing (divisions 10 to 33), concerning not only the number of R&D establishments but also and even more the number of researchers employed: While 67.0% of all R&D establishments and 81.1% of the R&D workforce are in manufacturing (70.6% and 82.0% in production industries), 25.6% of R&D establishments and 17.6% of R&D workforce are in the service sector. However, the biggest divisions with more than 1,000 R&D establishments[8] are not only in manufacturing, but also in the service sector. In the production industries, the majority of industry divisions shows an R&D establishment-company ratio greater one, indicating

[7] Note that by merging five consecutive surveys it is implicitly assumed that the spatial distribution of R&D establishments in space is solid and they are not easily moved in space. This is a quite restrictive assumption on spatial dynamics of R&D. However, merging of data is necessary in order to collect information on as many R&D establishments as possible as the DO approach requires at least ten establishments per industry in order to derive significant results on location patterns.

[8] *25 Manufacture of fabricated metal products, except machinery and equipment*, *26 Manufacture of computer, electronic and optical products*, *28 Manufacture of machinery and equipment n.e.c.*, *62 Computer programming, consultancy and related activities*, *71 Architectural and engineering activities; technical testing and analysis*, *72 Scientific research and development*

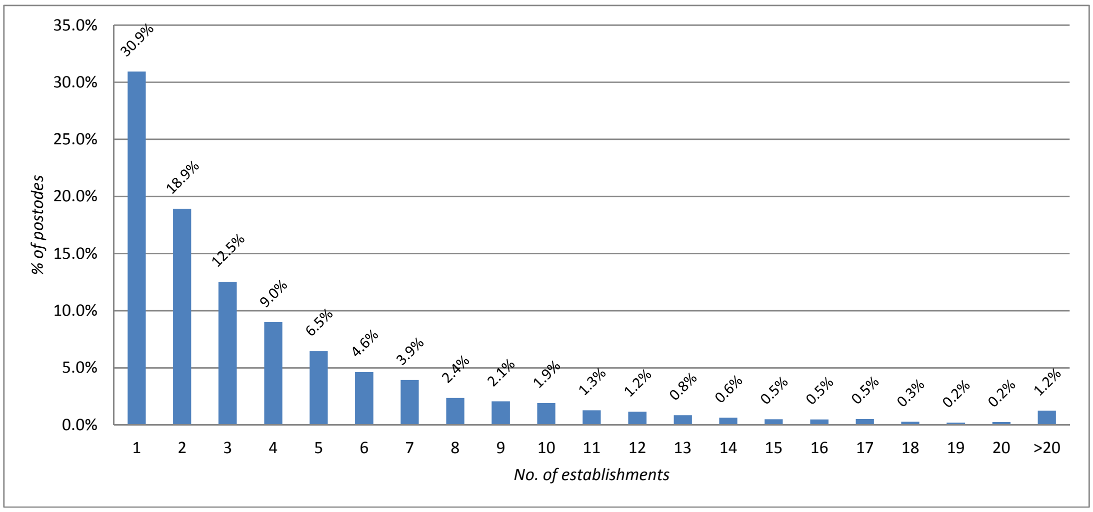


Figure 2.1: Frequency distribution of R&D establishments per postcode

that in most divisions the number of R&D establishments exceeds the number of companies conducting R&D (*Table 2.3*). In contrast, in the service sector divisions the ratio often is exactly one indicating that in many service industries R&D companies only dispose on one R&D establishment (*Table 2.4*). However, as the total R&D establishment-company ratio is 1.05, establishing several R&D establishments seems to be quite rare for most companies that conduct R&D. Looking at the average number of researchers per R&D establishment shows substantial differences among divisions ranging from 2.5 (*56 Food and beverage service activities*) to 212.6 (*29 Manufacture of motor vehicles, trailers and semi-trailers*) researchers per R&D establishment. The average size of R&D establishments in terms of R&D workforce is 24.1.

The locations of establishments are geocoded by using centroids of postcodes. In Germany, postcodes are very useful for locating establishments because they cover relatively fine grained areas. In comparison to 402 NUTS3 regions, 8,212 postcode areas are identified. In 4,865 of them at least one R&D establishment is located. *Figure 2.1* shows the overall frequency distribution of R&D establishments according to postcodes and *Figure 2.2* the corresponding distribution in space. On average, each postcode belongs to 4.1 establishments with a minimum value of one R&D establishment for 30.9% of the postcodes and a maximum value of 106 R&D establishments for one postcode in Berlin. More than 90% of the postcodes are home to less than ten establishments.

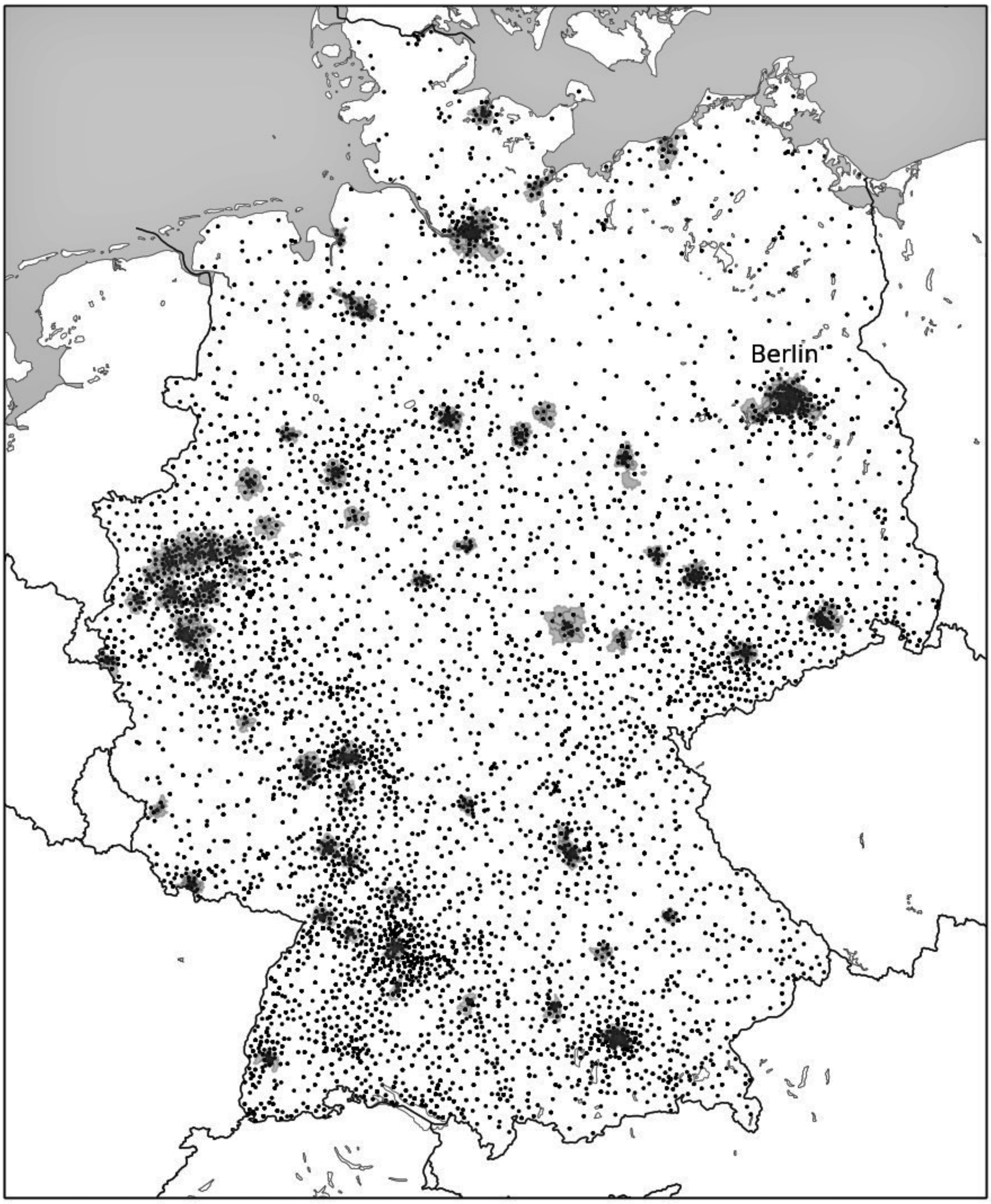


Figure 2.2: Location of R&D establishments in Germany

Table 2.3: Descriptive statistics on industry divisions: Agriculture and production industries

Industry division		No. of R&D est.	Ratio R&D est. / R&D comp.	Resear-chers	No. of 3-digit industries
Agriculture					
1	Crop and animal production, hunting and related service activities	95	1.22	17.6	6
2	Forestry and logging	.	.	.	2
Production industries					
5	Mining of coal and lignite	.	.	.	2
6	Extraction of crude petroleum and natural gas	.	.	.	2
7	Mining of metal ores	.	.	.	1
8	Other mining and quarrying	29	1.00	4.3	2
9	Mining support service activities	8	1.00	7.9	2
10	Manufacture of food products	307	1.09	11.1	9
11	Manufacture of beverages	35	1.00	4.0	2
12	Manufacture of tobacco products	.	.	.	1
13	Manufacture of textiles	270	1.01	5.8	4
14	Manufacture of wearing apparel	79	1.00	12.2	2
15	Manufacture of leather and related products	29	1.00	7.7	2
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	118	1.02	5.2	2
17	Manufacture of paper and paper products	122	1.05	8.7	2
18	Printing and reproduction of recorded media	64	1.00	19.0	2
19	Manufacture of coke and refined petroleum products	19	1.00	26.9	2
20	Manufacture of chemicals and chemical products	841	1.09	32.9	6
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	269	1.09	92.5	2
22	Manufacture of rubber and plastic products	779	1.07	14.7	2
23	Manufacture of other non-metallic mineral products	494	1.05	9.6	8
24	Manufacture of basic metals	298	1.12	21.4	5
25	Manufacture of fabricated metal products, except machinery and equipment	1,446	1.02	8.6	8
26	Manufacture of computer, electronic and optical products	2,436	1.06	29.7	8
27	Manufacture of electrical equipment	907	1.06	28.7	6
28	Manufacture of machinery and equipment n.e.c.	3,178	1.03	18.8	5
29	Manufacture of motor vehicles, trailers and semi-trailers	480	1.28	212.6	3
30	Manufacture of other transport equipment	198	1.14	88.8	5
31	Manufacture of furniture	136	1.02	5.7	1
32	Other manufacturing	553	1.03	12.1	6
33	Repair and installation of machinery and equipment	207	1.11	18.7	2
35	Electricity, gas, steam and air conditioning supply	85	1.04	14.1	3
36	Water collection, treatment and supply	15	1.00	6.2	1
37	Sewerage	5	1.00	3.6	2
38	Waste collection, treatment and disposal activities; materials recovery	73	1.03	3.5	3
39	Remediation activities and other waste management services	6	1.00	3.5	1
41	Construction of buildings	74	1.03	8.4	2
42	Civil engineering	64	1.02	4.1	3
43	Specialised construction activities	346	1.02	4.2	4

(.) Statistical confidentiality because of 3 or less R&D establishments in the industry

Table 2.4: Descriptive statistics on industry divisions: Service industries

Industry division		No. of R&D est.	Ratio R&D est. / R&D comp.	Resear-chers	No. of 3-digit industries
Service industries					
45	Wholesale and retail trade and repair of motor vehicles and motor-cycles	45	1.02	10.6	4
46	Wholesale trade, except of motor vehicles and motorcycles	486	1.02	7.7	8
47	Retail trade, except of motor vehicles and motorcycles	118	1.03	5.0	8
49	Land transport and transport via pipelines	28	1.08	14.0	4
50	Water transport	4	1.00	4.3	3
51	Air transport	4	1.00	17.7	2
52	Warehousing and support activities for transportation	54	1.00	11.4	1
53	Postal and courier activities	.	.	.	2
56	Food and beverage service activities	4	1.00	2.5	2
58	Publishing activities	112	1.00	5.8	2
59	Motion picture, video and television program production, sound recording and music publishing activities	11	1.00	2.6	2
60	Programming and broadcasting activities	.	.	.	2
61	Telecommunications	35	1.17	81.7	4
62	Computer programming, consultancy and related activities	1,618	1.03	16.8	1
63	Information service activities	113	1.02	15.9	2
64	Financial service activities, except insurance and pension funding	15	1.07	29.1	3
65	Insurance, reinsurance and pension funding, exc. comp. social sec.	17	1.00	24.5	1
66	Activities auxiliary to financial services and insurance activities	4	1.00	206.9	2
68	Real estate activities	16	1.07	7.1	3
69	Legal and accounting activities	.	.	.	1
70	Activities of head offices; management consultancy activities	200	1.03	10.6	2
71	Architectural and engineering activities; techn. testing and analysis	1,436	1.04	11.8	2
72	Scientific research and development	1,017	1.04	22.1	2
73	Advertising and market research	34	1.00	8.8	2
74	Other professional, scientific and technical activities	61	1.02	6.9	4
75	Veterinary activities	4	1.00	6.9	1
77	Rental and leasing activities	19	1.12	3.7	3
78	Employment activities	4	1.00	3.0	2
79	Travel agency, tour operator and oth. reservation service and rel. act.	.	.	.	1
80	Security and investigation activities	.	.	.	2
81	Services to buildings and landscape activities	16	1.00	4.0	3
82	Office administrative, office support and oth. bus. support activities	103	1.00	6.0	4
84	Public administration and defense; compulsory social security	.	.	.	1
85	Education	10	1.00	8.4	3
86	Human health activities	31	1.00	3.4	3
87	Residential care activities	.	.	.	2
88	Social work activities without accommodation	.	.	.	2
90	Creative, arts and entertainment activities	4	1.00	3.0	1
93	Sports activities and amusement and recreation activities	4	1.00	3.0	2
94	Activities of membership organizations	7	1.00	3.7	2
95	Repair of computers and personal and household goods	6	1.00	4.0	2
96	Other personal service activities	65	1.00	4.3	1
	TOTAL (divisions 01 to 96)	19,804	1.05	24.1	235

(.) Statistical confidentiality because of 3 or less R&D establishments in the industry

2.2.2 Basic estimation methodology

As noted in the previous section a distance based micro-geographic approach developed by Duranton and Overman (2005) is adopted in order to analyze the spatial distribution of corporate R&D activities in Germany. The methodology is applied on the 2- and 3-digit levels of industries according to NACE Rev. 2 in order to determine if and how the spatial allocation of R&D on these industry levels deviates significantly from the overall spatial distribution of company R&D activities in Germany. Taking the overall spatial pattern of R&D establishments as a reference, industry-specific variations of location patterns within R&D activities are investigated. In the following, the methodology used is described and illustrative examples for industrial R&D distributions are provided.

Estimating kernel density functions
To assess the spatial concentration of R&D establishments in an industry, first great circle distances[9] between all R&D establishments in that industry are calculated. This generates $\frac{n(n-1)}{2}$ unique bilateral distances. As great circle distances only serve as a proxy for true geographical distances, we – as suggested by Duranton and Overman (2005, 2008) – kernel-smooth, i.e. we estimate a real valued function of the industry specific distribution of bilateral distances between R&D establishments. The estimator of the density of R&D establishments in a given industry m at any distance d is:

$$\hat{K}_m(d) = \frac{1}{n(n-1)h} \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} f\left(\frac{d - d_{ij}}{h}\right), \tag{2.1}$$

where h is a bandwidth parameter defined according to Silverman (1986) and f a standard Gaussian kernel function. $d_{i,j}$ depicts the bilateral distance between R&D establishments i and j. n is number of R&D establishments in a given industry m.

Counterfactuals
In order to assess whether the estimated kernel density functions significantly deviate from the overall location pattern of R&D and thus from random spatial distribution, counterfactuals for each industry are constructed. All sites in Germany where R&D facilities could possibly be located are determined by defining the overall location pattern of R&D in Germany as a reference. Note that the general

[9] $d = acos(sin\phi1 * sin\phi2 + cos\phi1 * cos\phi2 * cos\Delta\lambda) * R$, with d=distance, ϕ=latitude, λ=longitude, R=radius

spatial distribution of R&D activity in Germany – which is taken as a reference – was formed historically being influenced by a variety of factors. As depicted in *Figure 2.2*, R&D in Germany is unequally distributed in space with areas, e.g. Berlin, where R&D establishments are concentrated and areas, especially in eastern Germany, where R&D establishments are relatively scarce. However, addressing the question of why this general location pattern of R&D occurs goes beyond the scope of this study. Instead, by taking the spatial distribution of R&D as a reference, the analyses explore whether there are deviations from this general picture, implicitly controlling for other factors that have influenced the observable general spatial pattern of R&D. Counterfactuals are then constructed by randomly drawing n R&D establishments from the population of all R&D establishments in Germany and determining kernel density functions for their bilateral distance distributions. Following Duranton and Overman (2005, 2008) 1,000 simulations for each industry are run.[10]

Confidence bands
After calculating $\hat{K}_m(d)$ and constructing the counterfactuals, both need to be compared. To make comparison easier across industries and to account for the redundancy of information on long distances[11], a threshold of 456km is chosen. This corresponds to the median distance of all R&D establishments in Germany. In order to be able to make statements about deviations from randomness over the entire range considered in the analyses, global confidence bands on a 5% level are calculated, such that only 5% of the randomly generated kernel density functions cross the upper $\bar{K}_m(d)$ and lower $\underline{K}_m(d)$ global confidence bands for all $d \in [0, 456]$.[12] If $\hat{K}_m(d) > \bar{K}_m(d)$ for at least one distance $d \in [0, 456]$, R&D in that industry is said to exhibit localization. Accordingly, if $\underline{K}_m(d) > \hat{K}_m(d)$ for at least one distance $d \in [0, 456]$ and no localization is detected, R&D in that industry exhibits dispersion. Note that localization or dispersion of R&D in industries is conditional on the overall spatial distribution of R&D. R&D localization (dispersion) in an industry is thus observed when there are more (less) R&D establishments at

[10]Own sensitivity tests with up to 10,000 simulations confirmed that 1,000 simulations lead to virtually equal distributions.

[11]Redundancy occurs as the area under each kernel density function needs to sum to unity. Thus, information on long distances is redundant if we know what happens at relatively short distances.

[12]In the study *global* confidence bands are implemented meaning that their construction relates to the whole range of distances. The literature also sometimes refers to *local* confidence bands defined for each distance independently. This constitutes a less strict definition of deviation from randomness.

shorter distances than randomness would predict from the general spatial distribution of R&D. *Figure 2.3* illustrates examples of one localized (a), one random (b) and one dispersed (c) industry at the 3-digit level together with their respective maps of R&D establishments. In (a) we observe $\hat{K}_m(d) > \bar{K}_m(d)$ for all distances from 0km to 232km and thus localization of R&D activity. In (c) we detect no localization but $\underline{K}_m(d) > \hat{K}_m(d)$ for all distances from 0km to 99km. This leads to the conclusion that the industry exhibits dispersion. Industry (b) exhibits a random location pattern. Note that the shape of the confidence bands reflects the distribution of R&D in Germany for an average industry with the same amount of establishments as in industry m.

Indices

Following the reasoning set out above,

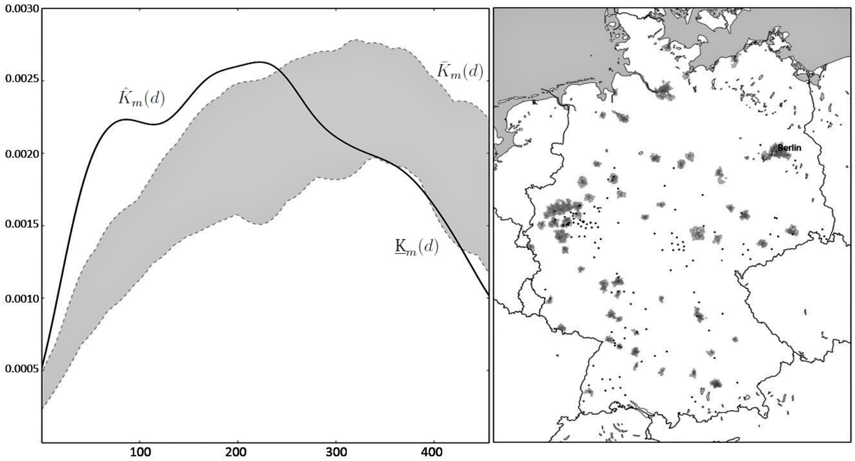
$$\Gamma_m(d) \equiv max(\hat{K}_m(d) - \bar{K}_m(d), 0) \tag{2.2}$$

is defined as an index of localization and

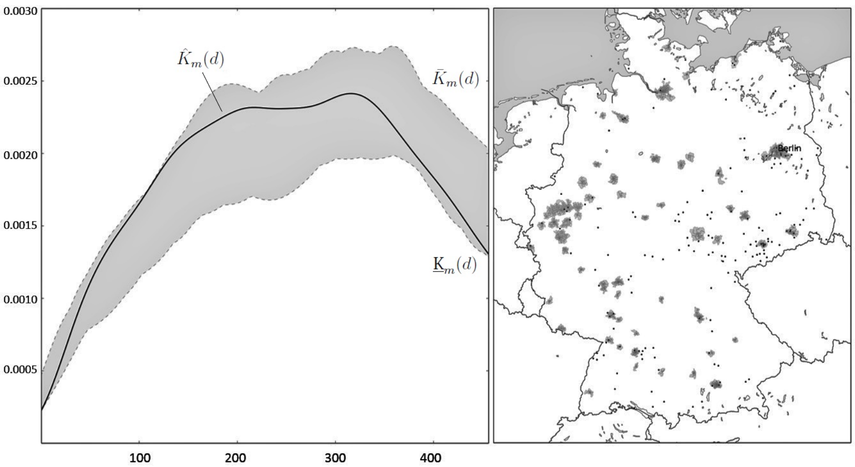
$$\Psi_m(d) \equiv \begin{cases} max(\underline{K}_m(d) - \hat{K}_m(d), 0), \text{if } \sum_{d=0}^{d=456} \Gamma_m(d) = 0 \\ 0, otherwise \end{cases} \tag{2.3}$$

as an index of dispersion. To reject the hypothesis of randomness of R&D for industry m at distance d because of localization (dispersion) $\Gamma_m(d) > 0$ ($\Psi_m(d) < 0$) is sufficient. In order to indicate to which degree an industry is dispersed or localized the following cross-distance indices $\Gamma_m \equiv \sum_{d=0}^{d=456} \Gamma_m(d)$ and $\Psi_m \equiv \sum_{d=0}^{d=456} \Psi_m(d)$ are defined as indices of localization and dispersion across all distances $d \in [0, 456]$.

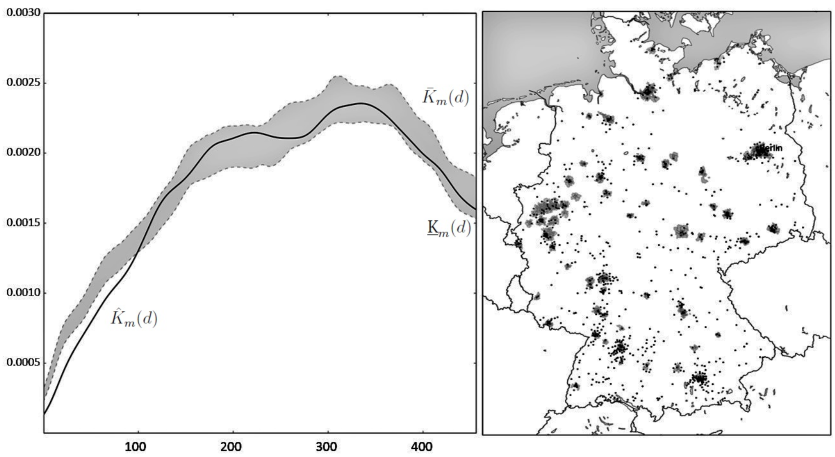
As noted by Duranton and Overman (2005) the methodology described is sensitive to the number of R&D establishments in an industry. Industries with relatively few R&D establishments will show a very broad confidence band since there are many possible ways to randomly draw this small number out of the whole population of possible R&D establishment sites. It is thus adequate to analyze location patterns of industries with more than ten establishments only. This leads to simulating and analyzing 140 industries on the level of 3-digit industries of which three are in agriculture, 100 are in the production industry and 37 in the service sector.



(a) 255 Forging, pressing, stamping and roll-forming of metal



(b) 432 Electrical, plumbing and other construction installation activities



(c) 620 Computer programming, consultancy and related activities

Note: X-axis on a graph indicates distances in km and Y-axis probability density.

Figure 2.3: Examples for industry location patterns of R&D establishments

2.3 Spatial patterns of industry-specific R&D in Germany

Section 2.3 is structured in two parts. First, the basic estimation methodology introduced in *Section 2.2.2* is applied in order to determine if industrial location patterns of corporate R&D are random, localized or dispersed in relation to the overall distribution of R&D. Calculating cross-distance indices of localized and dispersed R&D activities in industries leads to the identification of industries exhibiting relatively strong deviations from randomness. The results derived are put in relation to findings on location patterns of economic activities in Germany. Second, by modifying the basic estimation methodology, the level of analysis is shifted from R&D establishments to the individual researcher. This researcher-weighted approach allows to derive further insights regarding the spatial organization of R&D.

2.3.1 Location patterns of corporate R&D establishments

First the sectoral scope of location patterns is explored in order to detect if 3-digit industries belonging to the same industry division – and thus conducting R&D for the same group of products or services – exploit identical spatial organization patterns of R&D. *Table 2.5* and *Table 2.6* depict the shares of localized, dispersed and randomly distributed 3-digit industries within each industry division. In general, 3-digit industries in the same division do not follow identical patterns of R&D location. This leads to conclude that, even within divisions, R&D activities follow their own specific spatial patterns. This observation holds especially for the production industry where diverse location patterns within industry divisions are found. For example, the six 3-digit subindustries of industry division *20 Manufacture of chemicals and chemical products*, are to one third localized, dispersed and randomly distributed across geographical space.

Table 2.5: Industrial scope of location patterns in agriculture and production industries

Industry division		No. of 3-digit industries	Localized [%]	Dispersed [%]	Random [%]
Agriculture					
1	Crop and animal production, hunting and related service activities	3			100.0
Production industries					
8	Other mining and quarrying	2			100.0
10	Manufacture of food products	7		28.6	71.4
11	Manufacture of beverages	1			100.0
13	Manufacture of textiles	4	25.0		75.0
14	Manufacture of wearing apparel	2	50.0		50.0
15	Manufacture of leather and related products	1			100.0
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	2		50.0	50.0
17	Manufacture of paper and paper products	2			100.0
18	Printing and reproduction of recorded media	1			100.0
19	Manufacture of coke and refined petroleum products	1			100.0
20	Manufacture of chemicals and chemical products	6	33.3	33.3	33.3
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	2		50.0	50.0
22	Manufacture of rubber and plastic products	2	100.0		
23	Manufacture of other non-metallic mineral products	8	37.5	12.5	50.0
24	Manufacture of basic metals	5	60.0		40.0
25	Manufacture of fabricated metal products, except machinery and equipment	8	50.0	12.5	37.5
26	Manufacture of computer, electronic and optical products	7	42.9	57.1	
27	Manufacture of electrical equipment	6		33.3	66.7
28	Manufacture of machinery and equipment n.e.c.	5	80.0		20.0
29	Manufacture of motor vehicles, trailers and semi-trailers	3	66.7		33.3
30	Manufacture of other transport equipment	4	50.0	25.0	25.0
31	Manufacture of furniture	1	100.0		
32	Other manufacturing	5	20.0	40.0	40.0
33	Repair and installation of machinery and equipment	2		50.0	50.0
35	Electricity, gas, steam and air conditioning supply	2		50.0	50.0
36	Water collection, treatment and supply	1			100.0
38	Waste collection, treatment and disposal activities; materials recovery	2			100.0
41	Construction of buildings	1	100.0		
42	Civil engineering	3			100.0
43	Specialized construction activities	4		25.0	75.0

Table 2.6: Industrial scope of location patterns in service industries

Industry division		No. of 3-digit industries	Localized [%]	Dispersed [%]	Random [%]
Service industries					
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	2			100.0
46	Wholesale trade, except of motor vehicles and motorcycles	8	12.5		87.5
47	Retail trade, except of motor vehicles and motorcycles	3			100.0
49	Land transport and transport via pipelines	1			100.0
52	Warehousing and support activities for transportation	1			100.0
58	Publishing activities	2			100.0
61	Telecommunications	1			100.0
62	Computer programming, consultancy and related activities	1		100.0	
63	Information service activities	2		50.0	50.0
64	Financial service activities, except insurance and pension funding	1			100.0
65	Insurance, reinsurance and pension funding, except compulsory social security	1			100.0
68	Real estate activities	1			100.0
70	Activities of head offices; management consultancy activities	2		50.0	50.0
71	Architectural and engineering activities; technical testing and analysis	2	50.0	50.0	
72	Scientific research and development	2		50.0	50.0
73	Advertising and market research	2			100.0
74	Other professional, scientific and technical activities	1			100.0
77	Rental and leasing activities	1			100.0
82	Office administrative, office support and other business support activities	1			100.0
86	Human health activities	1			100.0
96	Other personal service activities	1		100.0	

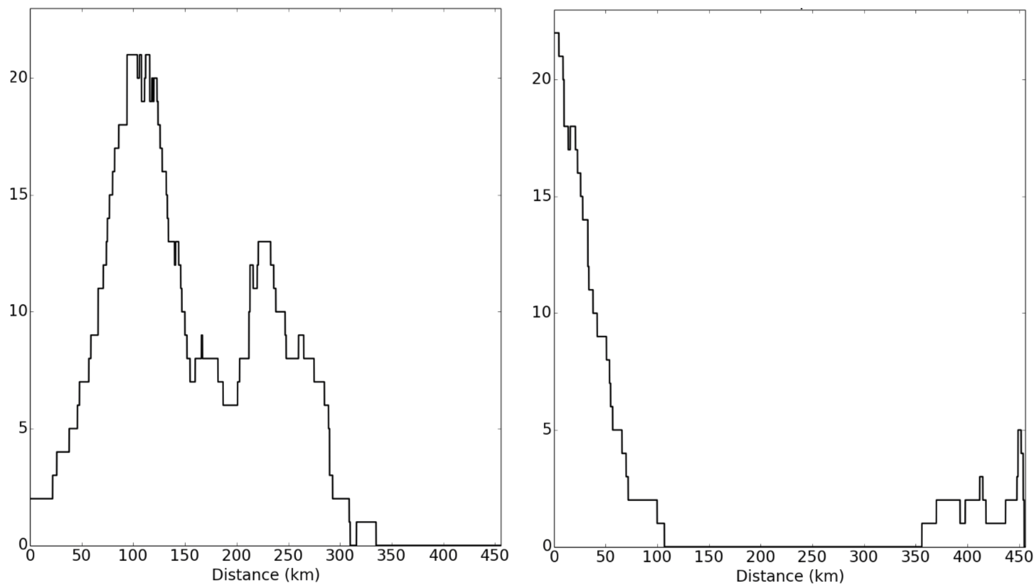
Thus, when analyzing spatial R&D patterns of industries, it is advisable to relate to the lowest aggregation level possible, namely the 3-digit level. The results are also reported highlighting production and service industries because the nature of R&D activity in these sectors differs significantly regarding organization and content. In service industries, R&D is not always organized as formally as in the production industry; for example, it is unusual for firms in most service industries to have an own R&D department. Major developments are more likely to be conducted by temporary project development groups (Gallouj 2002, Hipp and Grupp 2005). Regarding content, social sciences and design activities play a more prominent role in service R&D than in production-oriented R&D.[13]

Comparing the kernel density estimates for R&D in every industry on the 3-digit level with the industry specific counterfactuals shows that R&D activities of 40.8% of industries deviate significantly from random spatial location patterns of total R&D and thus are localized or dispersed. Deviation from randomness occurs more often in production than in service industries: While 50.0% of all industries in production deviate from random spatial distribution, the share of diverging industries in services is only 18.9%. In agriculture, spatial distribution of R&D activity is random for all industries implying that the location of innovation creation centers in the agricultural sector is influenced by factors affecting the overall spatial distribution of R&D in Germany.

Looking at the direction of deviations from spatial random distribution, i.e. the general distribution of R&D, 22.9% of all industries are localized and 17.9% are dispersed. Differentiating between production and service industries leads to further insights. With 30.0% of localized industries within the production sector, the share of localized industries is considerably higher than in services where only 5.4% of industries exhibit localized R&D patterns. Regarding dispersion, dispersed R&D activities in 20.0% of production and in 13.5% of service industries are detected. Thus, knowledge creation in production industries tends to be more localized than in services.

Taking a more detailed look at the spatial patterns of localized and dispersed industries depicts at which distances these location patterns are observable. *Figure 2.4* shows the number of localized and dispersed industries at each distance for all 3-digit industries that have been identified as being localized or dispersed according to the definition set out in *Section 2.2.2*. Note that if both localization and dispersion occur in the same industry, localization drives out dispersion and this industry is defined as localized. Consequently, an industry is only identified as being dispersed, if for all distances $d \in [0, 456]$ no localization occurs. Thus, dispersion occurring in localized industries is not represented by the distance-based frequency distributions set out in *Figure 2.4*. While only 6.3% of localized R&D activities are localized at a distance interval from 0km to around 20km, we ob-

[13] In their definition of R&D activity the Stifterverband follows the comprehensive concept put forward in the *Frascati Manual* (Stifterverband für die Deutsche Wissenschaft 2015, OECD 2002). However, although this concept relates to a relatively broad definition of R&D aimed at covering both organizational and content-related differences between R&D in production and service industries, it may lead to under-coverage of R&D activity in the service sector. For a comprehensive review see Miles (2007). Bryson et al. (2004) list R&D sources in service industries.



(a) Localization *(b) Dispersion*

Figure 2.4: Distance patterns of industries exhibiting localization and dispersion in R&D

serve a constant increase of localized industries up to a distance of approximately 95km where 65.6% of all localized industries show significant localization. The frequency distribution of dispersed industries shows a sharp decrease of dispersion with growing distance: The share of all industries exhibiting dispersion in R&D is maximized at a distance of 0km (88%) and decreases to zero until a distance of around 110km. These spatial patterns of localization and dispersion are observable for both R&D in production and service industries (*Appendix A.1*, *Figure A.1.1*).

As the study is the first to apply the DO approach in order to analyze spatial variations of industry-specific R&D activities with reference to the overall spatial pattern of R&D, results cannot be classified with respect to other studies. However, comparing the findings on R&D to location patterns of economic activity leads to further interesting insights. The comparison mainly refers to Koh and Riedel (2014) who applied the DO approach on all plants in manufacturing and services in Germany with at least one employee subject to social insurance.[14] Taking the overall establishment distribution in Germany as a reference, they find that 78.0% of industries are localized and that the share of localized industries is substantially higher in services (98.0%) than in manufacturing (71.0%). Accordingly, they find low shares of dispersed industries. Relating their observations to distances they –

[14]The results of Koh and Riedel (2014) are based on industry classification NACE Rev 1.1 (WZ 2003) at the four digit-level. Nevertheless, rough comparisons to the results in this study are possible.

in accordance with other studies on the spatial distribution of economic activities (e.g. Duranton and Overman 2005, Barlet et al. 2013) – find localization at small distances and a quite equal distribution of dispersion over all distances. These results differ considerably from the aforementioned findings of industry-specific R&D activities. In general, the different findings lead to the conclusions that a.) Industry-specific deviations from the general spatial distribution are rarer in R&D than in economic activity and b.) if deviations from the overall spatial patterns occur, than dispersion is of more relevance for industry-specific R&D patterns than for industry-specific economic activity. These general differences become even more pronounced when we look at services.[15]

Analyzing the geographical patterns of the most localized and dispersed industry-specific R&D activities identified by cross-distance indices Γ_m (*Equation 2.2*) and Ψ_m (*Equation 2.3*) leads to further interesting insights regarding allocation patterns of R&D. *Table 2.7* and *Table 2.8* each depict the ten most localized and dispersed 3-digit industries in production industries. With *243 Manufacture of other products of first processing of steel*, *255 Forging, pressing, stamping and roll-forming of metal*, *259 Manufacture of other fabricated metal products* and *257 Manufacture of cutlery, tools and general hardware* four of the most localized industries in terms of R&D activity are part of the metal processing industry. The highest index of localization is measured for *243 Manufacture of other products of first processing of steel* where spatial concentration of R&D establishments can be found in the Ruhr area.[16] For *255 Forging, pressing, stamping and roll-forming of metal*, *259 Manufacture of other fabricated metal products* and *257 Manufacture of cutlery, tools and general hardware* additionally to spatial concentration of R&D establishments in the Ruhr area, concentration can be observed in other parts of North Rhine Westphalia, Baden-Württemberg, Thuringia and Saxony. R&D in the industries *293 Manufacture of parts and accessories for motor vehicles* and *222 Manufacture of plastic products* exhibits relatively high localization indices. However, taking into account the distance intervals of localization reveals that they are quite broad ranging from about 60km to 290km. We thus see significant localization for R&D in these industries; localization – in terms of distance – yet occurs on a relatively

[15]Note that the analyses in this study do not compare the distribution of economic activity and R&D activity in general. The statements do not refer to the spatial concentration of the one relating to the other but on the within variation of activities with reference to the respective overall spatial distribution. Thus, the findings described here do not contradict the statement that R&D in general is more concentrated in space than economic activity.

[16]Maps of localized industries where reference is made to specific regions or cities in Germany are depicted in *Appendix A.7*.

Table 2.7: Most localized R&D activities in production industries

3-digit industry		No. of R&D establishments	Γ_m
243	Manufacture of other products of first processing of steel	36	0.1044
255	Forging, pressing, stamping and roll-forming of metal	143	0.0463
293	Manufacture of parts and accessories for motor vehicles	365	0.0395
222	Manufacture of plastic products	667	0.0226
231	Manufacture of glass and glass products	126	0.0163
284	Manufacture of metal forming machinery and machine tools	458	0.0148
259	Manufacture of other fabricated metal products	327	0.0127
139	Manufacture of other textiles	181	0.0122
143	Manufacture of knitted and crocheted apparel	20	0.0114
257	Manufacture of cutlery, tools and general hardware	343	0.0107

Note: An overview on all cross-distance indices of localization and dispersion is provided in *Appendix A.6*.

large geographical scale. R&D in industry *231 Manufacture of glass and glass products* is observable in Thuringia and Saxony. Like in *293 Manufacture of parts and accessories for motor vehicles* and *222 Manufacture of plastic products* the distance interval of significant localization is broad and on a relatively large geographical scale starting at 86km and ending at 280km. For *284 Manufacture of metal forming machinery and machine tools* concentration of R&D establishments is observable in Baden-Württemberg. Finally, R&D activities in the textile related industries *139 Manufacture of other textiles* and *143 Manufacture of knitted and crocheted apparel* in particular exhibit spatial concentration in the North of Bavaria and Saxony but also in some regions in Baden-Württemberg and North-Rhine Westphalia.

Indices of dispersion Ψ_m are on a lower level than indices of localization Γ_m indicating that deviations from randomness are weaker for dispersed than for localized R&D activities. In production industries, industries connected to the medical sector (*325 Manufacture of medical and dental instruments and supplies, 212 Manufacture of pharmaceutical preparations)* and to the production of electrical equipment (*271 Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus, 279 Manufacture of other electrical equipment*) as well as industries *251 Manufacture of structural metal products*, *236 Manufacture of articles of concrete, cement and plaster* and *205 Manufacture of other chemical products* are among the most dispersed. Compared to the overall spatial pattern of R&D in Germany, we see less-than-usual concentrations of these industries in areas that are quite populated with R&D establishments (e.g. Ruhr Area and around Stuttgart). Although we observe significant dispersion for R&D in both industries *266 Manufacture of irradiation, electromedical and electrother-*

Table 2.8: Most dispersed R&D activities in production industries

3-digit industry		No. of R&D establishments	Ψ_m
325	Manufacture of medical and dental instruments and supplies	379	0.0028
212	Manufacture of pharmaceutical preparations	231	0.0023
266	Manufacture of irradiation, electromedical and electrotherapeutic equipment	124	0.0022
271	Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus	379	0.0017
251	Manufacture of structural metal products	247	0.0015
279	Manufacture of other electrical equipment	275	0.0014
303	Manufacture of air and spacecraft and related machinery	80	0.0011
108	Manufacture of other food products	122	0.0010
236	Manufacture of articles of concrete, cement and plaster	135	0.0007
205	Manufacture of other chemical products	281	0.0007

Note: An overview on all cross-distance indices of localization and dispersion is provided in *Appendix A.6*.

apeutic equipment and *303 Manufacture of air and spacecraft and related machinery*, distance intervals that exhibit dispersion start at relatively high distances, i.e. 370km and 356km. R&D activities in *108 Manufacture of other food products* show dispersion because they are located in more rural areas in North Rhine Westphalia and Saxony where general R&D activity is relatively low.

As mentioned above, the share of non-random spatial R&D distribution in service industries compared to production industries is relatively low. *Table 2.9* and *Table 2.10* show indices of localization Γ_m and dispersion Ψ_m for R&D in all service industries that deviate from randomness. The two service industries *711 Architectural and engineering activities and related technical consultancy* and *467 Other specialized wholesale* are the only service industries in which R&D activities are localized. However, distance intervals exhibiting localization start at 166km and 106km. This indicates that R&D activities in these industries are localized at relatively long distances. Additionally, comparing the index values shows stronger localization of R&D in the ten most localized production industries than in the localized service industries. In total, five service industries with dispersion of R&D establishments are found. Interestingly, the four most dispersed industries *620 Computer programming, consultancy and related activities*, *721 Research and experimental development on natural sciences and engineering*, *712 Technical testing and analysis* and *631 Data processing, hosting and related activities* are all service

Table 2.9: Service industries exhibiting localized R&D activities

3-digit industry		No. of R&D establishments	Γ_m
711	Architectural and engineering activities and related technical consultancy	1,175	0.0018
467	Other specialized wholesale	88	0.0002

Note: An overview on all cross-distance indices of localization and dispersion is provided in *Appendix A.6*.

Table 2.10: Service industries exhibiting dispersed R&D activities

3-digit industry		No. of R&D establishments	Ψ_m
620	Computer programming, consultancy and related activities	1,617	0.0061
721	Research and experimental development on natural sciences and engineering	994	0.0057
712	Technical testing and analysis	261	0.0022
631	Data processing, hosting and related activities	93	0.0021
702	Management consultancy activities	152	0.0008

Note: An overview on all cross-distance indices of localization and dispersion is provided in *Appendix A.6*.

industries that are identified as being research-intensive[17] and thus devote above average financial resources on R&D. In terms of index values, these dispersed service industries display index values higher or quite close to the index values of the ten most dispersed production industries. In *702 Management consultancy activities* the index of dispersion shows a relatively low value.

Again, comparing the results on geographical patterns of the most localized and most dispersed industrial R&D activities to patterns found in economic activities adds to the understanding of spatial R&D organization. Regarding economic activities in production industries, traditional manufacturing industries that evolved with the industrial revolution in the 19th century (e.g. industries connected to metal processing and textile) are among the most localized industries showing persistent localization patterns in traditional regions (Koh and Riedel 2014). The analyses of localized industries reflect this observation regarding R&D activities in these traditional manufacturing industries. This leads to conclude that *relative* spatial organization of R&D is partly congruent with *relative* spatial organization

[17]Gehrke et al. (2010, 2013) define research-intensive industries and services on a 3-digit level for Germany based on different data sources. The main criterion for identification is a threshold of 3% of R&D expenditures on sales. A complete list of research-intensive industries is provided in *Appendix A.2*, *Tables A.2.1* and *A.2.2*.

of economic activity in these traditional manufacturing industries.[18] However, turning attention to location patterns in services, the results on R&D distribution do not reflect the strong localization patterns regarding the administration of financial markets and the entertainment sector found for economic activity as R&D activities in these industries are randomly distributed.

The analyses lead to three major conclusions regarding the spatial distribution of R&D establishments in Germany. First, 40.8% of 3-digit industries exhibit patterns of spatial R&D organization significantly deviating from randomness. Second, deviations from the overall pattern of R&D occur more often in the production industry than in services. Third, analyzing the character of deviation from randomness reveals that localization of R&D occurs primarily in industries associated with production. However, the distance distribution of localized industries reveals that localization mostly occurs at a distance of around 100km and localization of R&D is quite rare in very close proximity, i.e. at a distance interval from 0km to 20km.

2.3.2 Researcher-weighted location patterns of corporate R&D

So far, these conclusions are based on the spatial distribution of R&D establishments. In other words, when assessing the deviation from randomness the location of R&D establishments is taken into account regardless of the number of people that conduct research there. However, in order to deepen our understanding of the spatial organization of R&D, it seems reasonable not only to focus on places where people are employed in knowledge creation, but also to take into account how many of them are involved in the process. This approach shifts the unit of analysis from the individual R&D establishment to the individual researcher. The issue of R&D establishment size in terms of researchers employed is crucial as R&D establishment-size distributions, like company-size distributions, are skewed. For example, 72.7% of R&D establishments in the data set employ less than ten researchers but account for only 11.2% of total R&D workforce.

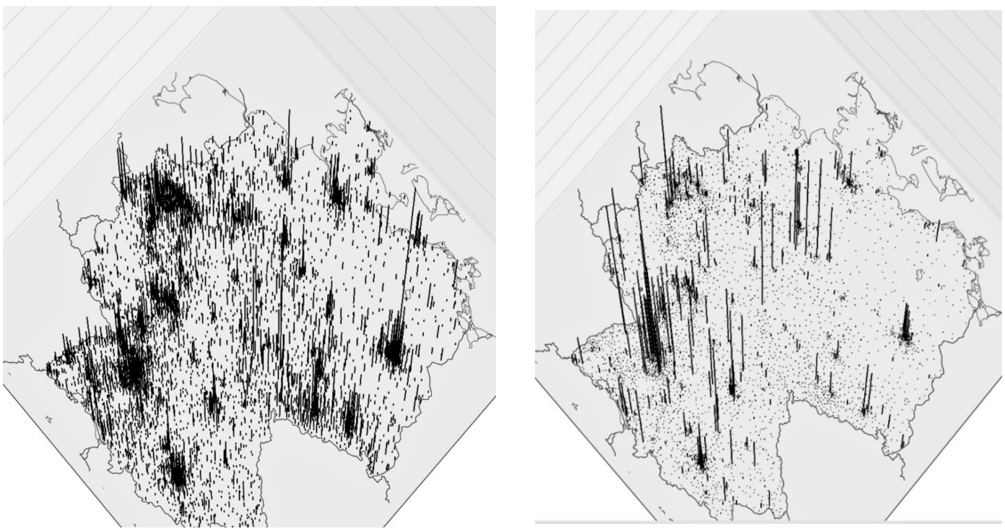
Some previous studies concerned with spatial patterns of economic activity tackled the issue of skewed company-size distributions by censoring smallest plants in industries applying absolute or relative thresholds or by weighting according to the number of employees. The former for this study is not advisable as, given the

[18] The term *relative* here refers to the point that the analyses are conducted with the general distribution of establishments and R&D establishments as reference.

limited size of data in terms of R&D establishments compared to establishments reflecting general economic activities, it will lead to omitting a number of industries in the analysis. Thus, weighting according to the number of researchers employed in R&D establishments is adequate. Following Duranton and Overman (2005) in this shift in unit of analysis from establishment to workforce, zero distances between researchers employed at the same R&D establishment are excluded in order to avoid that localization might be driven by the concentration of research personnel within a particular establishment. Formally, denoting $r(i)$ as research personnel of R&D establishment i and respectively $r(j)$ as research personnel of R&D establishment j, the researcher-weighted kernel density function of industry m takes the following form:

$$\hat{K}_m^r(d) = \frac{1}{h \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} r(i)r(j)} \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} r(i)r(j) f\left(\frac{d - d_{ij}}{h}\right). \tag{2.4}$$

All other variables are defined according to *Equation 2.1*.



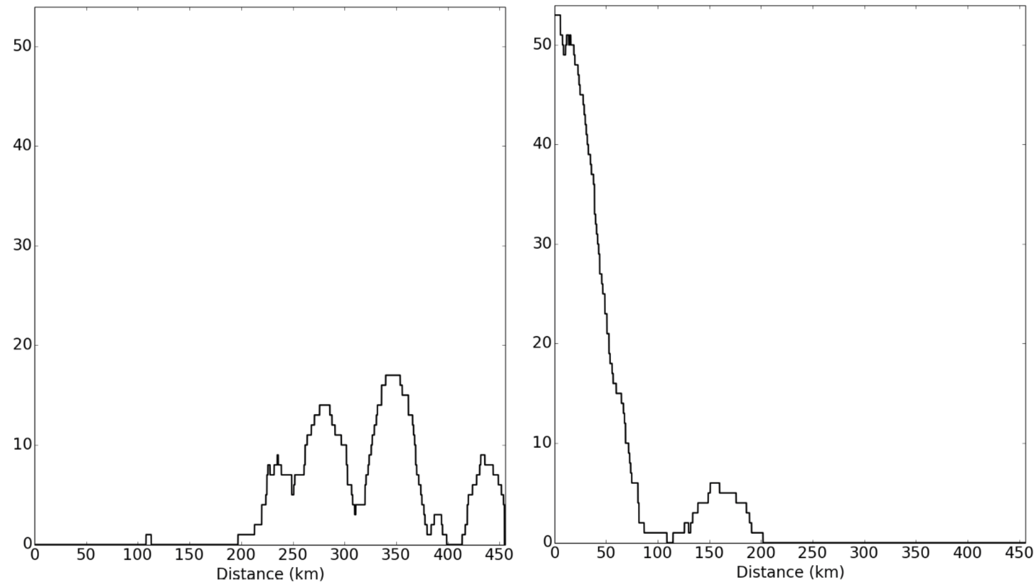
(a) R&D establishments *(b) Researchers*

Figure 2.5: Spatial frequency distribution of R&D establishments and researchers

Counterfactuals, confidence bands and indices are constructed following the procedure described in *Section 2.2.2*. Technically, taking into account that the spatial modeling is based on postcodes, in constructing counterfactuals the base for simulations is a new distribution of selection probabilities for postcodes. Before turning to the results of the researcher-weighted approach, some attention should be devoted to the implications of this shift in approaches. *Figure 2.5* visualizes the resulting differences in distributions and thus selection probabilities that constitute the base for the counterfactuals. At first sight, we not only see a general shift of R&D activity towards south-western regions of Germany but also a higher concentration of R&D activities in individual postcodes implying that the distribution in the researcher-weighted approach becomes more skewed. This change is reflected by the fact that the Gini-coefficient for the frequency distribution of postcodes augments from 0.49 in the unweighted approach to 0.81 in the researcher-weighted approach. Statistically, the selection probability of 55 postcodes increases more than tenfold, including three postcodes where it augments by more than 100. The researcher-weighted approach also induces changes regarding the weighting of industries in the reference distribution of R&D.[19] Although the Gini-coefficient for the frequency distribution of industries only increases slightly from 0.78 in the unweighted approach to 0.86 in the researcher-weighted approach, we see one industry, *291 Manufacture of Motor Vehicles*, which accounts for 0.3% of establishments and 11.7% of R&D personnel. Thus, selection probability of postcodes occupied by that industry increases by factor 41 when the number of researchers is taken into account instead of R&D establishments. Taking a closer look at industry *291 Manufacture of Motor Vehicles* reveals that 57 R&D establishments in total employ 55,702 researchers. Moreover, 94.5% of all these researchers are employed by seven automotive manufacturers: Daimler, Volkswagen, BMW, Audi, Porsche, Opel and Ford. Thus, analyzing the results for researcher-weighted postcodes, it is important to keep in mind that not only selection probabilities are distributed more unequally between postcodes but also that they are influenced considerably stronger by the location pattern of the motor vehicles industry that in turn is dominated by very few big automotive manufacturers.

In total, the researcher-weighted analyses show that 58.6% of industries deviate from randomness with 17.2% being localized and 41.4% exhibiting dispersion. Looking at industry sectors, in production industries 63.0% industries deviate from randomness of which 21.0% exhibit localization and 42.0% dispersion. In services 48.6% industries are not randomly distributed with 8.1% being localized and 40.5% dispersed. Overall, more deviation from randomness occurs in the researcher-weighted approach than in the establishment-based approach. Especially the share of industries exhibiting dispersion increases in both services and the production industry.

[19] As we know from the descriptive data in *Section 2.2.1*, production industries represent 70.6% of R&D establishments and 82.0% of researchers.



(a) Localization *(b) Dispersion*

Figure 2.6: Distance patterns of researcher-weighted industries exhibiting localization and dispersion in R&D

A detailed look at the distances at which industries are localized or dispersed (*Figure 2.6*) reveals pictures similar to the unweighted approach.[20] However, if before most of the localized industries were observable at a distance of around 100km, we now see that they are concentrated around 260km and 350km. This means that industrial clusters of R&D activity from the perspective of an individual researcher occur at a higher distance. In total, the results indicate that taking into account the size of R&D establishments in terms of researchers employed there, leads either to dispersion or random distribution at close distances from 0km to 200km. This implies that at this distance interval the number of researchers in an industry either follows the general distribution of R&D workforce or is even less than one would expect from taking the general spatial distribution of researchers as a reference. Again, we need to keep in mind that these results do not contradict the notion of R&D itself being concentrated compared to economic activities. They indicate that clustering of researchers at short distances is not connected to the 3-digit industries in which they are employed.

Calculating the cross-distance indices for localization and dispersion in the researcher-weighted approach reveals major changes in both production and service in-

[20]Distance patterns for production industries and service industries are provided in *Appendix A.1*, *Figure A.1.2*.

dustries in relation to the approach based on R&D establishments.[21] Not only that – as one might conclude from the distance distributions depicted in *Figure 2.6* – indices of localization become weaker and indices of dispersion become stronger, but also radical shifts in location patterns occur. For example, four of the most dispersed production industries (*325 Manufacture of medical and dental instruments and supplies*, *271 Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus*, *251 Manufacture of structural metal products* and *205 Manufacture of other chemical products*) and the two most dispersed service industries (*620 Computer programming, consultancy and related activities*, *721 Research and experimental development on natural sciences and engineering*) in terms of R&D establishments become localized. However, these localization patterns occur at relatively large distances and this is why these industrial spatial patterns are not explored in more detail.

2.4 Spatial relation of R&D and cities in Germany

After analyzing the spatial patterns of R&D in Germany, the results are now related to cities as they are likely to exert influence on the observed spatial variations of R&D activities. This section is organized in three parts. First, the motivation to integrate cities in the analyses is explained and a modification of the estimation methodology in order to incorporate distances to large cities is developed. Second, location patterns of industrial R&D in relation to cities are determined. They are presented on both the aggregated and the industry-specific level. Third, in analogy to *Section 2.3.2*, the unit of analysis is shifted from R&D establishments to the individual researcher.

2.4.1 Integration of cities in the estimation methodology

The methodology applied in *Section 2.2.2* allows to determine whether the location pattern of corporate R&D activity in an industry significantly differs from the overall spatial distribution of R&D establishments. However, the approach does not address other forces than industry-based concentration that might influence the spatial variation of R&D activities. This section takes a step forward to address this open issue by introducing the effects of cities on the spatial distribution of

[21] An overview on all cross-distance indices of localization and dispersion is provided in *Appendix A.6*.

R&D. The motivation here is twofold. First, mapping the results in *Section 2.3*, some industries reveal the tendency to locate their R&D establishments in or relatively close to cities, while others don't. Second, as has been already pointed out to in the introduction, apart from this rough exploratory observation, there is strong empirical evidence that R&D activities tend to concentrate in cities (Bairoch 1988, Feldman and Audretsch 1999, Chatterji et al. 2014).

The target is to build on these observations in order to deepen the understanding regarding the spatial distribution of industry-specific patterns in R&D activities along two lines of questions: With the general spatial distribution of R&D as a reference, which industries tend to significantly cluster in or around cities? Do we find spatial patterns of industry R&D activities that are connected to centrifugal forces pushing them away from cities? In order to integrate cities in the spatial analyses of R&D, postcodes of large cities in Germany with more than 100,000 inhabitants[22] are identified (*Appendix A.3*, *Table A.3.1*). In total, 1,364 postcodes belong to these large cities. 6,179 R&D establishments, which are a fraction of 32.0% of all R&D establishments, are located in postcodes of large cities. Any distance between an R&D establishment and the next large city is computed as the minimum great circle distance of the postcode of this establishment to the closest postcode belonging to the next large city.[23]

Estimating kernel density functions

Modifying the DO approach, the kernel density of bilateral distances between R&D establishments of an industry and the closest large city to each R&D establishment in that industry is estimated. Thus, with n R&D establishments in an industry, n minimum distances to large cities for that industry are measured. As in *Section 2.2.2*, because great circle distances between centroids are only a proxy for true

[22]Reference date: 31.03.2014.

[23]*Table A.3.2* in *Appendix A.3* indicates the descriptive statistics of distances between R&D establishments and large cities on the level of industry divisions. While the minimum distance for each division is zero – indicating that for each industry division at least one establishment is situated in a large city – substantial differences regarding maximum and average distances to large cities are found. While maximum distances to large cities vary between 45.9km (*19 Manufacture of coke and refined petroleum products*) and 129.7km (*31 Manufacture of furniture*) in the production industry, in the service sector divisions are found where establishments are at most 10km or less away from a large city (*51 Air transport*, *59 Motion picture, video and television program production, sound recording and music publishing activities*, *64 Financial service activities, except insurance and pension funding*, *66 Activities auxiliary to financial services and insurance activities*). Moreover, looking at average distances to large cities, 15 of 42 industry divisions in services show average distances to large cities of 10km or less. In contrast, the minimum average distance to large cities in the production industry is 10.5km (*19 Manufacture of coke and refined petroleum products*).

geographical distance, we kernel-smooth to estimate the distribution of bilateral distances. Consequently, the kernel density function representing the location of R&D establishments in industry m for any distance d to large cities is

$$\hat{K}_m^u(d) = \frac{1}{nh}\sum_{i=1}^{n} f\left(\frac{d - d^u}{h}\right). \tag{2.5}$$

Again, h is a bandwidth parameter according to Silverman (1986) and f a standard Gaussian kernel function. Parameter d^u represents the distance to cities of each R&D establishment in industry m, operationalized by the minimum great circle distance to a large city.

Counterfactuals
In order to analyze the spatial deviation between R&D establishments of an industry and the overall location pattern of R&D with respect to cities, counterfactuals are constructed. As in the basic approach in *Section 2.2.2*, a counterfactual should consider a hypothetical industry distributed randomly in space with the same amount of R&D establishments as the industry under consideration. Thus, counterfactuals are constructed by randomly drawing from all 19,804 R&D establishments and measure their distance to cities. For each industry, 1,000 simulations are run. Kernel density functions are estimated as for the actual industry.

Confidence bands and indices
In order to determine industry specific location patterns of R&D in relation to cities, $\hat{K}_m^u(d)$ is compared to the counterfactuals constructed. To define a threshold rendering comparisons between industries easier and accounting for redundancy of information on long distances, the average distance of any R&D establishment to a large city which is 18.8km is chosen. Note that this threshold is quite small compared to the threshold of 456km applied in *Section 2.2.2*. This is due to two major reasons. First, the polycentric city structure in Germany together with a high degree of federalization leads to a relatively even distribution of large cities in space. This implies that the maximum possible distance of any R&D establishment to a city is relatively low. Second, as we know from other studies, R&D itself is likely to allocate in cities. In fact, the maximum distance of an R&D establishment to the next large city according to the data set is 129.7km. It is also worth noting that by defining postcodes as belonging to a large city or not, each city is treated as a uniform entity. Thus, location patterns of R&D establishments are not analyzed within cities themselves or in reference to a specific point in a city. Any distance

$d^u > 0$ indicates that an R&D establishment is allocated in a postcode outside of a city and 18.8km defines a radius relative to this city's borders. Note that, by choosing a fixed distance as threshold, we do not take into account the actual size of a city and thus implicitly assume that the spatial influence of a city is independent of its size. In order to account for size variations between large cities, a dynamic threshold could be defined. Although, this is beyond the scope of the paper, a basic model that implements dynamic threshold measures is provided in *Appendix A.4*.

In analogy to *Section 2.2.2*, $\bar{K}^u_m(d)$ is defined as the upper and $\underline{K}^u_m(d)$ as the lower global confidence band for distance to the next large city. The confidence bands for each industry are constructed such that they are hit by 5% of the simulations over the distance range from 0km to 18.8km. When $\hat{K}^u_m(d) > \bar{K}^u_m(d)$ for at least one $d^u \in [0, 18.8]$, R&D establishments are defined to exhibit significant urban localization. Turning to dispersion, urban dispersion of R&D activity in an industry occurs if $\hat{K}^u_m(d) < \underline{K}^u_m(d)$ for at least one $d^u \in [0, 18.8]$ given that this industry does not exhibit localization. Note that urban localization and urban dispersion of R&D in an industry are conditional on the overall spatial distribution of R&D in relation to cities. Thus urban localization (dispersion) is detected if there are more (less) R&D establishments in or at shorter distances to large cities than would be predicted from the general distribution of R&D. Formally,

$$\Gamma^u_m \equiv \sum_{d=0}^{d=18.8} \Gamma^u_m(d), \text{where } \Gamma^u_m(d) \equiv max(\hat{K}^u_m(d) - \bar{K}^u_m(d), 0) \tag{2.6}$$

is defined as an index of urban localization and

$$\Psi^u_m \equiv \sum_{d=0}^{d=18.8} \Psi^u_m(d), \text{where } \Psi^u_m(d) \equiv \begin{cases} max(\underline{K}^u_m(d) - \hat{K}^u_m(d), 0), \text{if } \sum_{d=0}^{d=18.8} \Gamma^u_m(d) = 0 \\ 0, otherwise \end{cases} \tag{2.7}$$

as index of urban dispersion.

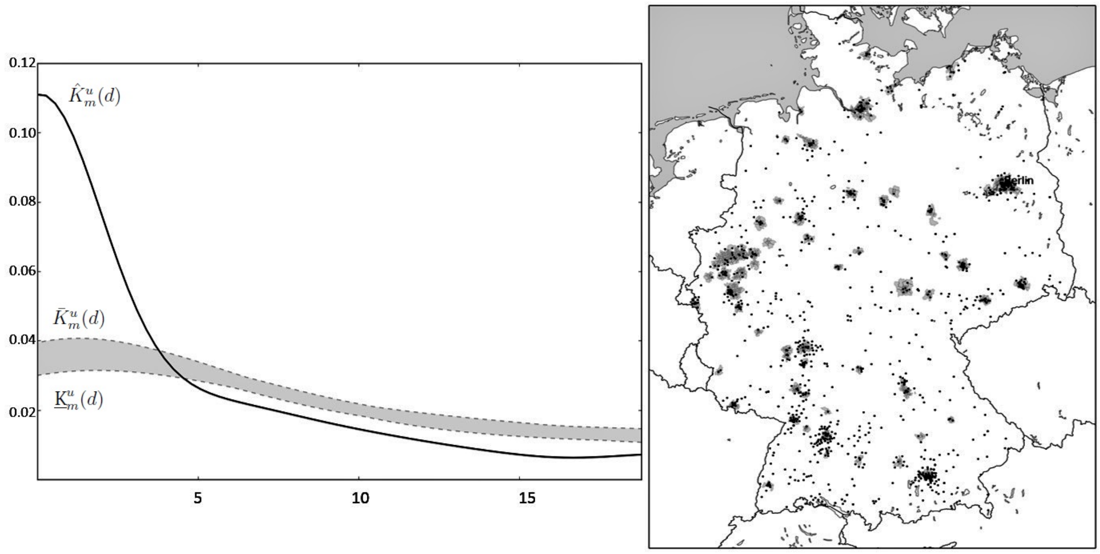
Figure 2.7 shows kernel density functions, confidence bands and locations of R&D establishments for two illustrative industries where location patterns with respect to cities deviate significantly from randomness. R&D in industry (a) exhibits urban localization[24]. Consequently, its kernel density function indicates that R&D establishments in that industry are more frequently located in and around cities. R&D establishments in industry (b) exhibit urban dispersion implying that they tend to locate relatively less in and around cities. Note that we only focus on the urban localization and omit the urban dispersion that is also present in industry (a) here. The approach that defines a small area of urban influence around cities only allows to generally assess the direction of deviations. Thus, regarding overall spatial patterns either urban localization or urban dispersion, if there is no urban localization, are detected. Global confidence bands reflect the spatial distribution of R&D in relation to cities for an average industry with the same number of establishments as industry m.

2.4.2 City-related location patterns of R&D establishments

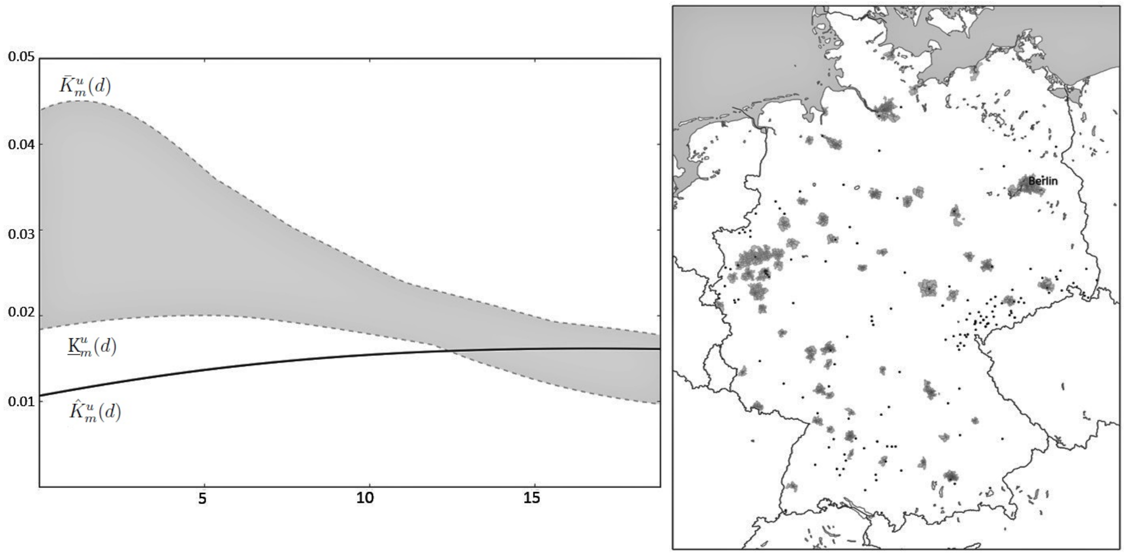
Looking at the industrial scope of deviations from randomness regarding the urbanity of R&D activities in industries, more uniformity in location patterns than in the analyses provided in *Section 2.3.1* is found. However, as still some industry divisions show different location patterns for their 3-digit-subindustries, again the 3-digit level of industries is referred to in order to analyze spatial patterns of R&D. The industrial scope of R&D distribution with respect to cities is depicted in *Appendix A.5, Table A.5.1*.

Regarding the spatial distribution of R&D in relation to large cities in Germany, location patterns of 34.3% of 3-digit industries deviate from randomness. The share of deviating industries in services is higher (45.9%) than in the production industry (30.0%). Fractions of urban localization and urban dispersion for all industries are 18.6% and 15.7%. This indicates that significant deviations from randomness are not dominated by one specific spatial pattern. However, differentiating among industry sectors reveals that R&D establishments in service industries are more likely to exhibit urban localization (40.5%) than in production industries (11.0%). Consequently, with 19.0% the share of urban dispersed R&D in production indus-

[24]Note that, similarly to the methodology depicted in *Section 2.2.2*, by definition localization drives out dispersion. Thus, although both urban localization and urban dispersion are observable, the industry depicted in *Figure 2.7(a)* is defined as being urban localized.



(a) 620 Computer programming, consultancy and related activities



(b) 139 Manufacture of other textiles

Note: X-axis on a graph indicates distances in km and Y-axis probability density.

Figure 2.7: Examples for industrial patterns of urban localization and urban dispersion of R&D establishments

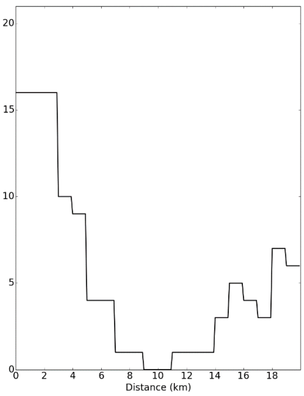
tries is substantially higher than in service industries (5.4%).[25]

[25]Although they do not explicitly include location patterns related to cities in their analysis, Koh and Riedel (2014) find that service industries in Germany seem to be more urbanized than manufacturing industries by comparing the median population of municipalities hosting localized service and manufacturing industries. This very general picture of industrial location also can be deducted for R&D.

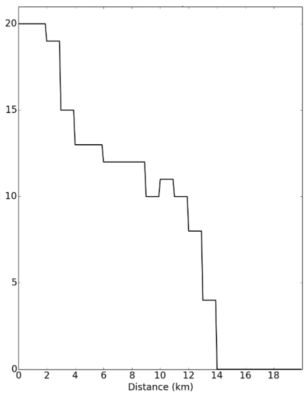
Figure 2.8 shows the numbers of urban localized and urban dispersed 3-digit industries according to distances. The representations relate to all industries that have been identified as being urban localized or urban dispersed according to the definitions set out in *Section 2.4.1*. Thus, if both urban localization and urban dispersion occur in the same industry, urban dispersion is driven out by urban localization and this industry is defined as being urban localized. Consequently, an industry only exhibits urban dispersion, if for all distances $d^u \in [0, 18.8]$ no urban localization occurs. Thus, urban dispersion occurring in urban localized industries is not indicated in the distance-based frequency distributions depicted in *Figure 2.8*. As we see substantial differences of distance patterns according to industry sectors, distance distributions for all industries (a) and (b), production industries (c) and (d) and service industries (e) and (f) are indicated separately. Apart from the aforementioned tendencies of R&D in production industries to exhibit urban dispersion and R&D in service industries to exhibit urban localization, both kinds of deviations from randomness are maximized in cities, i.e. at $d^u = 0$, and decrease with growing distances to cities. However, especially for urban localization in both R&D in production and service industries urban localization is also found at a distance radius around cities. This leads to conclude that for R&D in some industries, large cities exert centripetal forces leading to increased proximity, however, at a certain distance from the city's borders.

Turning to the level of industries, *Table 2.11* depicts that R&D in industry *212 Manufacture of pharmaceutical preparations* exhibits the highest index of urban localization in production industries. Specifically, concentrations of R&D establishments in and close to Frankfurt, Berlin, Düsseldorf and Cologne are observable.[26] In the basic analysis in *Section 2.3.1*, R&D in this industry was among the most dispersed industries. Urban localization of industries connected to the manufacture of electronic and optical products (*265 Manufacture of instruments and appliances for measuring, testing and navigation* and *267 Manufacture of optical instruments and photographic equipment*) is also observable in and around cities. However, whereas we could identify concentration of R&D in specific cities for *212 Manufacture of pharmaceutical preparations*, urban localization for R&D activities in these industries is rather connected to cities in general. In the analyses on spatial R&D patterns in *Section 2.3.1* R&D establishments in industry *222 Manufacture of plastic products* were among the most localized with a broad distance interval of localization starting at a relatively high distance. Now, urban localization of R&D

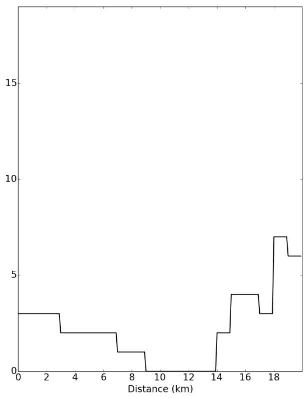
[26]Maps of urban localized industries where reference is made to specific regions or cities in Germany are depicted in *Appendix A.8*.



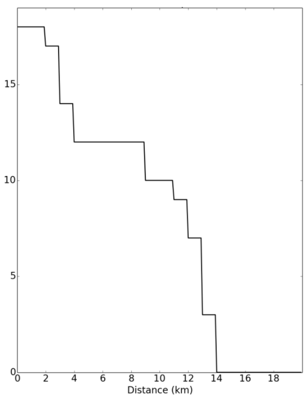
(a) Urban localization all industries



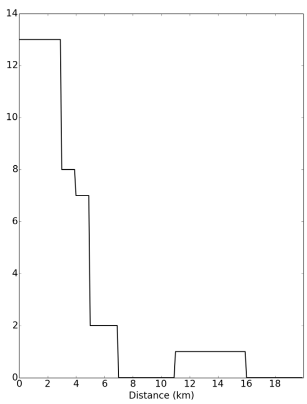
(b) Urban dispersion all industries



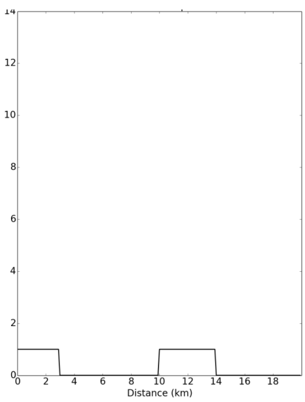
(c) Urban localization production



(d) Urban dispersion production



(e) Urban localization services



(f) Urban dispersion services

Figure 2.8: Distance patterns of industries exhibiting urban localization and urban dispersion in R&D

at a distance interval starting at 11.3km is determined. However, urban localization occurs in combination with dispersion starting in large cities. For *274 Ma-*

Table 2.11: Most urban localized R&D activities in production industries

3-digit industry		No. of R&D establishments	Γ_m^u
212	Manufacture of pharmaceutical preparations	231	0.2061
265	Manufacture of instruments and appliances for measuring, testing and navigation	1,247	0.0720
222	Manufacture of plastic products	667	0.0231
274	Manufacture of electric lighting equipment	90	0.0051
282	Manufacture of other general-purpose machinery	897	0.0039
259	Manufacture of other fabricated metal products	327	0.0021
267	Manufacture of optical instruments and photographic equipment	185	0.0011
256	Treatment and coating of metals	304	0.0010
289	Manufacture of other special-purpose machinery	1,185	0.0007
284	Manufacture of metal forming machinery and machine tools	458	0.0006

Note: An overview on all cross-distance indices of urban localization and urban dispersion is provided in *Appendix A.6*.

nufacture of electric lighting equipment and industries related to the manufacture of machinery and equipment (*282 Manufacture of other general-purpose machinery*, *289 Manufacture of other special-purpose machinery* and *284 Manufacture of metal forming machinery and machine tools*) similar spatial pictures emerge as for *222 Manufacture of plastic products*: urban localization at a certain distance from large cities occurring in combination with dispersion starting in large cities. For R&D in two industries connected to metal processing (*259 Manufacture of other fabricated metal products*, *256 Treatment and coating of metals*) analysis in *Section 2.3.1* reveals relative concentrations of R&D in areas of North Rhine Westphalia, Baden-Württemberg, Thuringia and Saxony. Additionally, now significant urban localization around large cities is found.

Table 2.12 depicts the most urban dispersed production industries. On average indices of urban dispersion are higher than indices of urban localization. Thus, stronger deviations from randomness for urban dispersed production industries are observable. These deviations are due to centrifugal forces exerted by large cities. In addition, it is worth pointing out that *139 Manufacture of other textiles* and *231 Manufacture of glass and glass products* are among the most localized production industries and that these location patterns of R&D establishments are not connected to cities.

Table 2.13 and *Table 2.14* list the ten most urban localized service industries as well as the urban dispersed service industries *749 Other professional, scientific and technical activities n.e.c.* and *452 Maintenance and repair of motor vehicles*. In terms of index values, indices of the most urban localized service industries are substantially higher than those for the most urban localized production industries. With

Table 2.12: Most urban dispersed R&D activities in production industries

3-digit industry		No. of R&D establishments	Ψ_m^u
162	Manufacture of products of wood, cork, straw and plaiting materials	97	0.2654
139	Manufacture of other textiles	181	0.2597
322	Manufacture of musical instruments	22	0.1802
310	Manufacture of furniture	136	0.1446
132	Weaving of textiles	24	0.1408
251	Manufacture of structural metal products	247	0.1200
231	Manufacture of glass and glass products	126	0.0883
252	Manufacture of tanks, reservoirs and containers of metal	47	0.0792
171	Manufacture of pulp, paper and paperboard	55	0.0664
236	Manufacture of articles of concrete, cement and plaster	135	0.0582

Note: An overview on all cross-distance indices of urban localization and urban dispersion is provided in *Appendix A.6*.

722 Research and experimental development on social sciences and humanities and *721 Research and experimental development on natural sciences and engineering* service industries conducting scientific research and development as main activity of their business concentrate their R&D establishments in cities above average. Service industries *522 Support activities for transportation*, *581 Publishing of books, periodicals and other publishing activities*, *620 Computer programming, consultancy and related activities* and *639 Other information service activities*, *712 Technical testing and analysis* also exhibit urban localization starting in cities. However, we see a general pattern towards above average urban localization that is not connected to specific cities. Contrary to this none-specific tendency to locate R&D establishments in or very close to large cities, focal cities of R&D localization in *582 Software publishing* – namely Munich, Stuttgart, Berlin, Dortmund and Essen – are observable. For *651 Insurance*, R&D is concentrated in and close to Munich and Frankfurt. R&D in *702 Management consultancy activities* shows a general tendency to concentrate in large cities. However, some non-urban R&D in Baden-Württemberg is detected. It is worth noting that three of the most urban localized service industries – namely *702 Management consultancy activities*, *721 Research and experimental development on natural sciences and engineering* and *620 Computer programming, consultancy and related activities* – are among the dispersed service industries in *Section 2.3.1*.

The results on location patterns with respect to cities show considerable differences in industry-specific spatial organization patterns of R&D. However, note that these patterns are depicted in reference to the overall location of R&D establishments in relation to cities. Thus, urban dispersion of R&D – as found especially

Table 2.13: Most urban localized R&D activities in service industries

3-digit industry		No. of R& D establishments	Γ_m^u
722	Research and experimental development on social sciences and humanities	23	0.9704
522	Support activities for transportation	54	0.8911
582	Software publishing	92	0.7868
702	Management consultancy activities	152	0.6837
651	Insurance	17	0.6623
721	Research and experimental development on natural sciences and engineering	994	0.6533
620	Computer programming, consultancy and related activities	1,617	0.5490
639	Other information service activities	20	0.3014
581	Publishing of books, periodicals and other publishing activities	20	0.2522
712	Technical testing and analysis	261	0.2502

Note: An overview on all cross-distance indices of urban localization and urban dispersion is provided in *Appendix A.6*.

Table 2.14: Urban dispersed R&D activities in service industries

3-digit industry		No. of R& D establishments	Ψ_m^u
749	Other professional, scientific and technical activities n.e.c.	50	0.0323
452	Maintenance and repair of motor vehicles	12	0.0021

Note: An overview on all cross-distance indices of urban localization and urban dispersion is provided in *Appendix A.6*.

in production industries – does not contradict the general notion of R&D activities being concentrated in cities.

The findings regarding location of R&D establishments in relation to cities reveal three further interesting aspects in conjunction with industry-specific spatial organization patterns. First, we can observe that analyzing spatial patterns of R&D in relation to cities indeed enhances the understanding of spatial patterns detected in *Section 2.3.1*. On the one hand, we observe some localized industries that also exhibit urban localization and thus an interconnection between both industry-specific R&D concentration and concentration in relation to cities (e.g. *222 Manufacture of plastic products*, *259 Manufacture of other fabricated metal products*). On the other hand, especially for service industries but also for *212 Manufacture of pharmaceutical preparations*, analyzing spatial patterns with respect to cities reveals that dispersion is connected to urban localization. In these industries, forces leading to agglomeration of R&D activities are less connected to the industries themselves, i.e. to the products and services provided, but to other assets associated with cities. Second, looking at the spatial patterns of R&D establishments with respect to cities on the 3-digit level reveals that in both production and service industries urban dispersion of R&D in research-intensive industries is not found. Even more, half of the industries exhibiting urban localization of R&D, by definition, are research-intensive[27], i.e. they devote above average financial resources on R&D activities (Gehrke et al. 2010, 2013). This finding leads to conclude that above average investments in the acquisition on knowledge are connected to cities and might even indicate centripetal forces of cities due to knowledge resources available. Third, localization of R&D in traditional manufacturing industries that evolved with the industrial revolution in the 19th century (e.g. industries connected to metal processing and textile) is observable. However, in relation to cities now a mixed picture of location patterns in these industries occurs. Some of them are among the most urban localized and some of them are among the most urban dispersed industries. This finding indicates a complex relationship between the two approaches to R&D location analyzed but also hints to interdependencies of economic development, research activities and city development. However, analyzing these patterns is beyond the scope of this paper.

Section 2.4.2 addressed the effects of cities on the spatial distribution of R&D establishments. The aims were to evaluate whether R&D in industries tends to concentrate in or very close to cities and whether cities constitute centripetal forces for R&D. From the analyses of the spatial connection between cities and R&D locations four major conclusions can be drawn. First, about one third of industries deviate from randomness regarding their spatial distribution of R&D in relation to cities. Second, referring to industry sectors, R&D in service industries is more likely to exhibit urban localization than R&D in production industries. Third, if urban localization is detected, the patterns tend to differ according to sectors. In production industries urban localization is mostly found *around* large cities, i.e. at a certain radius from city borders. In contrast, urban localized service industries tend to exhibit urban localization directly *in* large cities. Fourth, urban dispersion is rarely found for R&D establishments in services but a considerable share of urban dispersed R&D activities in production industries is depicted.

[27]The main criterion for identification of an industry as being knowledge-intensive is a threshold of 3% of R&D expenditures on sales (Gehrke et al. 2010, 2013). A complete list of research-intensive industries is provided in *Appendix A.2*, *Tables A.2.1* and *A.2.2*.

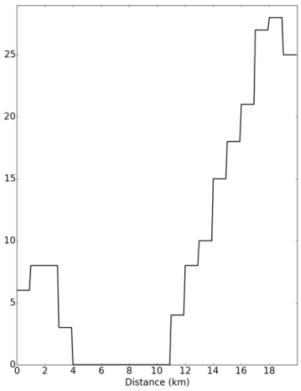
2.4.3 City-related location patterns of researchers

In order to evaluate if the results still hold when the unit of analysis is shifted from R&D establishments to the individual researcher, the analyses are weighted according to the number of researchers. Formally, the researcher-weighted kernel-density function in relation to cities takes the following form:

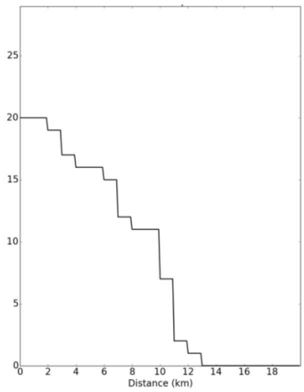
$$\hat{K}_m^{u,r}(d) = \frac{1}{n^r h} \sum_{i=1}^{n^r} f\left(\frac{d - d^{u,r}}{h}\right). \tag{2.8}$$

Where n^r represents the number of researchers and $d^{u,r}$ depicts the distance to the nearest city of each researcher in each R&D establishment in industry m. It is operationalized by the minimum great circle distance to a large city. All other variables are defined according to *Equation 2.1*.

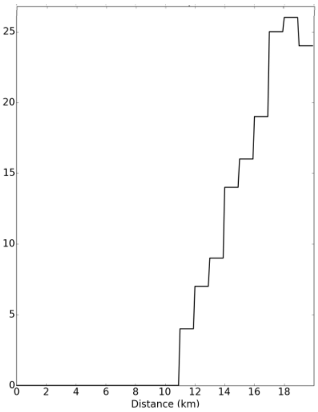
Counterfactuals, confidence bands and indices related to cities are constructed following the procedure described in *Section 2.4.1*. As before, we have to keep in mind that the shift in perspective considerably changes the selection probabilities of postcodes which in turn shape the upper and lower confidence band based on the counterfactuals. Note that, as described in *Section 2.3.2*, the researcher-weighted approach implies increasing inequality regarding selection probabilities of postcodes and changes in weights of industries. Thus, these implications are briefly related to cities by comparing shares of R&D establishments and R&D personnel in relation to minimum distances from large cities in *Table 2.15*. While approximately one third (32.0%) of R&D establishments is located in large cities, nearly half of R&D personnel (45.8%) is hosted by large cities. At a distance interval of >0 to <10km the shares of R&D establishments with 18.0% and R&D personnel with 20.0% are almost equal. For higher distance intervals the shares of R&D establishments are always slightly higher than those of R&D personnel. Thus, the shift in analysis from R&D establishments to researchers implies a more urban reference scenario regarding the confidence bands. Selection probabilities of postcodes belonging to a large city become substantially higher. This is also reflected by the decrease of the average minimum distance to the closest large city from 18.8km for R&D establishments to 13.9km for an individual researcher. Graphically, we should observe an upward shift of global confidence bands for $d^u = 0$ and a rather moderate downward shift for distances from 10km to 18.8km to large cities.



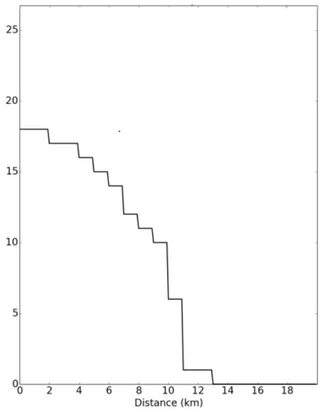
(a) Urban localization all industries



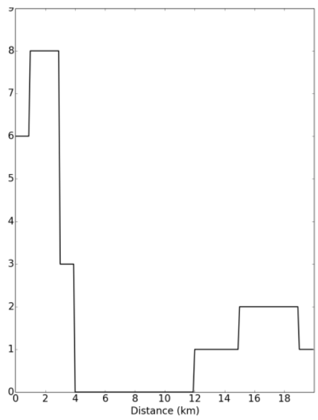
(b) Urban dispersion all industries



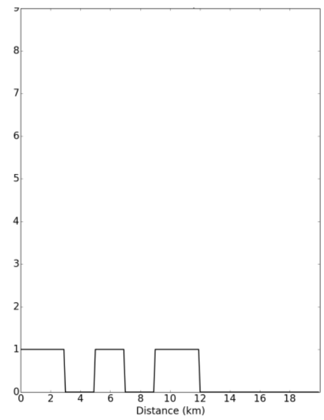
(c) Urban localization production



(d) Urban dispersion production



(e) Urban localization services



(f) Urban dispersion services

Figure 2.9: Distance patterns of researcher-weighted industries exhibiting urban localization and urban dispersion in R&D

Table 2.15: R&D and minimum distances to large cities

	Minimum distance to a large city [km]							
	0	>0 to <10	10 to <20	20 to <30	30 to <40	40 to <50	50 and >50	Total
R&D est. [%]	32.0	18.0	13.9	10.4	8.3	6.5	10.9	19,804
R&D pers. [%]	45.8	20.0	9.2	6.7	6.0	4.3	8.0	476,575

Evaluating the general patterns of urban location in the researcher-weighted approach shows that 42.1% of industries deviate from spatial randomness. The majority of the deviating industries exhibits urban localization (26.4%). 15.7% are dispersed in relation to cities. The shares of deviating industries differ according to sectors: They are 45.0% in the production industry and 32.5% in services. In both sectors the percentage of industries showing urban localization of their R&D workforce (27.0% in production industries and 25.0% in services) is higher than the percentage of urban dispersed industries (18.0% in production industries and 7.5% in services). In comparison to the establishment-based approach of urban location patterns, a higher degree of deviation from randomness for the production industry and a lower degree for services is found. It is worth noting that these shifts in spatial patterns are mostly due to alterations regarding the share of urban localized industries which are increasing in production and decreasing in service industries.

Distance patterns according to industries exhibiting urban localization and urban dispersion in the researcher-weighted approach are depicted in *Figure 2.9*. In the analyses based on establishments, deviations from randomness for both urban localization and dispersion are maximized in cities. Now distance patterns of urban localization for all industries in *Figure 2.9(a)* are shifted outwards with a maximum of 75.0% at a distance of around 17km. Thus, weighting for researchers leads to increased urban localization around but not in cities. The picture becomes even more pronounced when patterns of urban localization and urban dispersion for production and service industries are separated: For production industries in *Figure 2.9(c)* urban localization in cities is not observable anymore while for service industries in *Figure 2.9(e)* the distance distribution still depicts urban localization in cities.

Turning to the level of individual 3-digit industries reveals rather moderate changes connected to the implementation of the researcher-weighted approach. The most urban localized production industries mainly remain localized in the researcher-weighted approach. However, industries *212 Manufacture of pharmaceutical preparations* and *267 Manufacture of optical instruments and photographic equipment* become randomly distributed. As R&D establishments in both industries exhibit urban localization starting in large cities, i.e. at $d^u = 0$, randomness in the researcher-weighted approach is due to the upward shift of the confidence band at relatively low distances. For the most urban dispersed production industries some shifts from urban dispersion to urban localization are observable. However, these shifts are connected to urban localization starting around large cities. In total, as can be seen in *Figure 2.9(c)*, weighting for researchers enhances the tendency of R&D in urban localized production industries to allocate at a certain radius from large cities and not directly in them. For R&D of urban localized service industries, only minor variations in location patterns are detected. However, industries with relatively low indices of urban localization (*639 Other information service activities*, *581 Publishing of books, periodicals and other publishing activities*, *712 Technical testing and analysis*) do not remain localized.[28] As was observable for R&D in production industries starting at $d^u = 0$, this is mainly due to the upward shift of the confidence band at relatively low distances.

2.5 Discussion

This chapter empirically contributes to the literature about concentration of innovation and R&D activity by indicating if and how spatial patterns of R&D in industries deviate from the overall spatial distribution of R&D in Germany. Two perspectives in analyzing deviations of the spatial patterns of firm-level R&D activity from randomness are taken. The first addresses the industry-specific distribution of R&D. The second relates the industry-specific pattern in relation to cities.

Before summarizing the central results and giving an outlook to further research, some points regarding the validity of the obtained results have to be made. They refer to incomplete data coverage and methodological issues. Data coverage of R&D in Germany might be incomplete due to two reasons. First, as already described, especially small and medium sized companies are most presumably under-represented in the data set. Second, as innovation processes in services are organized differently than in manufacturing and often do not involve formal R&D,

[28] An overview on all cross-distance indices of urban localization and urban dispersion is provided in *Appendix A.6*.

their innovative activities are potentially under-estimated in the data. As already hinted by Duranton and Overman (2005), their approach is sensitive to the number of establishments within an industry: The less R&D establishments we find in an industry, the broader the confidence band and consequently the lower the probability to detect localization or dispersion, i.e. a deviation from the general spatial pattern of R&D.

Nevertheless, analyzing the industry-specific location pattern of R&D on a 3-digit level shows that 40.8% of 3-digit industries deviate significantly from random spatial location patterns. In production the share of localized industries is substantially higher than in services. Consequently, in service industries dispersion occurs more often than localization. Especially research-intensive service industries exhibit strong cross-distance indices of dispersion. Investigating distance patterns of localization in service and production industries reveals localization over relatively long distances of about 100km. This effect is even reinforced in the researcher-weighted approach. Thus, at proximate distances, spatial patterns of R&D mostly exhibit dispersion or are random. Evidence on industry-specific spatial concentration of R&D is relatively weak. Note that this result does not contradict the notion of R&D itself being concentrated. It rather depicts that concentration of R&D at short distances is only weakly connected to the industry-level.

When cities are integrated in the analyses, the picture of the sector-specific spatial distribution of R&D alters substantially. For service industries spatial dispersion found in industry-specific patterns of R&D activities is connected to urban localization. Especially dispersed research-intensive industries exhibit urban localization. Moreover, analyzing distance patterns of urban localization reveals above average concentration of service R&D occurring directly *in* cities. For production industries, if R&D activities are urban localized, they tend to localize at a certain radius *around* city borders.

While the analyses in the study explicitly step back from theoretical concerns but aim to contribute to the empirical examination of industry-specific agglomeration patterns of innovative activity, they nevertheless implicitly relate to the continuing debate on *Marshall-Arrow-Romer-externalities*, *urbanization economies* and *Jacobs-externalities*. All concepts relate to knowledge spillovers due to spatial proximity. While *Marshall-Arrow-Romer-externalities* basically refer to the notion that a city's specialization in industries fosters knowledge spillovers and thus innovation, the concept of *Jacobs-externalities* puts forward the beneficial effect of diverse economic activities on innovation. The idea of *urbanization economies* abstracts from industrial structures but emphasizes the number of possible encounters or contacts which in turn are maximized in cities as they provide a high population density. Assuming that the expected returns to R&D activities are taken into account when companies decide where to locate them, as for example demonstrated in Duranton and Puga (2001), the location of R&D and thus knowledge potential in space hints to anticipated knowledge spillovers. Interpreting localization as indicator for *Marshall-Arrow-Romer-externalities* suggests that they are either of minor relevance for industry-specific R&D activities or occur over relatively long distances. Taking urban localization as indicator for *urbanization economies* and/or *Jacobs-externalities* reveals that production and service industries benefit from innovation advantages emanating from cities – however, at different spatial scales. Taking this reasoning into account, the analyses lead to conclude that *urbanization economies* and/or *Jacobs-externalities* prevail in the spatial organization of corporate R&D activities.

The research presented in this chapter can be enhanced by further thorough investigation of the actual forces that lead to the observed patterns of dispersion and localization in R&D using multivariate analysis. Additionally, an alternative and more comprehensive measure of distance to cities, as sketched out in *Appendix A.4*, will help to better reveal the influence of cities. Finally, utilizing the distribution of economic activity as a reference for counterfactuals will lead to further insights by indicating if and in which direction location patterns of innovative activities deviate from economic location patterns in the same industry. Answers to these further questions will bring us closer to understanding the choices made by firms in locating their R&D activities and thus contribute to the advancement of regional innovation policies.

Chapter 3

Distance-based effects of cities on innovation in Knowledge Intensive Business Services (KIBS)

The content of this chapter is based on a cooperation with Stephan Brunow (Institut für Arbeitsmarkt- und Berufsforschung, IAB). Furthermore, it constitutes the base for a common paper with Philip McCann (University of Sheffield).

3.1 Introduction

KIBS are services that are processing, generating and diffusing knowledge within the economy. In these functions they are largely regarded as important (co-)producers of innovation and thus relevant contributors to economic growth (Miles et al. 1995, den Hertog 2002, Gallouj 2002, Desmarchelier et al. 2013). While other services preponderantly involve relatively basic tasks, KIBS feature high shares of high skill jobs associated with knowledge work as production input (Miles 2008). On the output side, KIBS firms for the most part provide non-material intangible services – i.e. training, research and development, engineering services as well as consultancy (Muller and Zenker 2001).

Empirical evidence shows that KIBS concentrate in cities. However, this spatial pattern alters according to city sizes: The largest cities gather the highest concentrations of KIBS establishments (see, for example, Polèse and Shearmur 2006, Aslesen and Isaksen 2007, Shearmur and Doloreux 2008).[1] Additionally, founding activities of KIBS are more frequent in locations that already host above-average KIBS concentrations (Schricke et al. 2012). This re-enforcing spatial organization pattern of the KIBS sector towards cities is observable across countries – despite differences in both economic structures and institutional contexts (Simmie and Strambach 2006). Moreover, the analyses in *Chapter 2* reveal that apart from being concentrated in cities, KIBS also concentrate their R&D activities in large cities.

While the modes of KIBS innovation and the extent to which they are distinct from manufacturing firms have been adequately studied, the connection between their innovative activities and their propensity to agglomerate in cities remains under-researched (Doloreux and Shearmur 2012). Accordingly, this chapter seeks to contribute to this debate by integrating – as suggested by Shearmur and Doloreux (2008) and Doloreux and Shearmur (2012) – innovation literature on KIBS, geography and regional science. In order to investigate the effects of cities on KIBS innovation, this study refers to the concept of *urbanization economies*. In brief, *urbanization economies* are knowledge spillovers emanating in cities due to their size in terms of population and a high population density. Thus, cities are locations that maximize the number of (possible) face-to-face contacts necessary for knowledge transmission (Glaeser et al. 1992, 1995, Henderson et al. 1992, Combes et al. 2012). It is hypothesized that proximity to cities fosters innovation in KIBS, the beneficial effect of proximity to cities is growing stronger with augmenting city sizes and, as modeled by McCann (2007), the spatial patterns of KIBS innovation alter according to the type of innovation pursued.

To support these claims a Knowledge Production Function (KPF) is applied to technological and non-technological types of innovation – namely product introduction, product improvement, process innovation and organizational innovation – pursued by KIBS.[2] It considers innovation as outcome of three different sets of determinants representing *(a)* characteristics of KIBS establishments that might influence their innovation behavior, *(b)* sources of agglomeration economies connected to specialized and diversified structures of economic environments and *(c)* a vector of variables based on great circle distances to city types. The KPF thus

[1]Other authors also find that within manufacturing knowledge-intensive industries tend to concentrate more in cities than manufacturing in general (Jofre-Monseny et al. 2014).

[2]By doing so, we implicitly adopt a synthesis approach to innovation in services, i.e. a measurement framework that accounts for innovation in services as well as in manufacturing. For further elaborations, see Gallouj and Savona (2009).

takes into account internal as well as external sources of innovation. In order to control for endogeneity connected to location decisions of KIBS firms that might be influenced by the availability of urban resources, a variable vector covering locational fixed effects is included. The micro-geographic data set is generated from three data sources available for Germany: official employment statistics provided by the Institute for Employment Research (IAB) at the German Federal Employment Agency, survey data of the IAB Establishment Panel and geographic data on centroids of all approximately 8,200 postcodes in Germany. In total, the representative data set covers 7,073 KIBS establishments.

The empirical results indicate a positive relationship between innovation in KIBS and proximity to cities: Innovation probabilities in KIBS decrease with growing distances to cities. However, the negative effect of being located relatively remote from a city varies according to the type of innovation pursued by a KIBS firm. It is strongest for product improvement, followed by process innovation, product introduction and organizational innovation. Differentiating the analyses by taking city sizes into account, reveals that *urbanization economies* are positively affected by the size of a city. This leads to the conclusion that especially innovation opportunities provided by the biggest cities in Germany with more than 500,000 inhabitants might act as centripetal forces for KIBS allocation.

The chapter is organized as follows. *Section 3.2* introduces the theoretical background by connecting what is known about innovation in KIBS to the concept of *urbanization economies*. In *Section 3.3* the data bases, their interconnection and the KPF are presented. The empirical results in *Section 3.4* comprise descriptive results and results based on multivariate probit-regressions. The descriptive results relate to observable location patterns of KIBS and their innovative activities represented by different types of innovation. Multivariate analyses for each type of innovation are based on two models. While the first model *(Model 1)* aims at measuring general effects of cities on the probability of innovation, the second model *(Model 2)* differentiates between city sizes and thus detects connections between city sizes and *urbanization economies*. In order to interpret the results for both models, probability functions of innovation types depending on distances to cities are simulated. *Section 3.5* summarizes and discusses the central findings together with political implications and directions for future research.

3.2 Influence of cities on innovation in KIBS: Theory and hypotheses

This section introduces to innovation in KIBS and connects the insights to the concept of *urbanization economies*. The elaborations are concluded by hypothesizing that innovations implemented by KIBS are positively affected by spatial proximity to cities and that positive effects increase with augmenting city sizes. Investigating the variation of effects depending on the type of innovation pursued constitutes an additional task.

3.2.1 What we know about innovation in KIBS

While initially KIBS were seen as important co-producers of innovation in mainly manufacturing user firms, since the beginning of the 2000s they are increasingly perceived as being major innovators themselves (Muller and Doloreux 2009). Measuring and describing innovation in KIBS is closely connected to efforts that have been conducted to analyze innovation in services in general. In this context, Coombs and Miles (2000) refer to three different perspectives, namely assimilation[3], demarcation[4] and synthesis approach. According to Gallouj and Savona (2009) the synthesis approach – and thus a commonly applied measurement framework for both manufacturing and services that covers technological and non-technological types of innovation – is now state of the art, while the demarcation and assimilation approaches are in mature or even declining phases of application.[5]

Applying the synthesis approach allows to identify differences of innovation patterns between KIBS and manufacturing firms. According to a comprehensive overview on KIBS literature conducted by Muller and Doloreux (2009), studies reveal that innovative activities in KIBS are distinct from those in manufacturing firms. In general, KIBS are less likely to perform internal research and development activities than their manufacturing counterparts. Instead, their innovativeness is strongly associated with highly qualified employees, collaboration activities

[3]The assimilation approach applies the measurement framework developed for manufacturing to services and thus follows a technologically oriented approach to innovation.

[4]The underlying notion of the demarcation approach is that service innovation is fundamentally different from innovation in manufacturing and thus requires separate surveying.

[5]This synthesis view on innovation in manufacturing and services is also applied – as described in *Chapter 2* – in the current edition of the *Oslo Manual* (OECD 2005).

with external sources[6] and learning by doing (Freel 2006, Simmie and Strambach 2006).

Tödtling et al. (2006) find that external knowledge resources for innovation are more important for KIBS than for high-tech manufacturing firms. Moreover, in comparison, cooperation activities for innovation – especially with customers and clients – of KIBS are more confined to the region. However, the results of the above mentioned study refer to different types of product innovations, and thus reflect a technological assimilative view on innovation in KIBS. Broadening the concept of innovation and in consequence differentiating between technological and non-technological forms of innovation, namely product, process, delivery, strategic, managerial and marketing innovation, Amara et al. (2009) show that the impact of external knowledge resources on KIBS innovation differs according to the type of innovation pursued. They find a positive impact of market sources of knowledge – clients, competitors, suppliers, other firms – on delivery, managerial and marketing innovation. Generally available resources (e.g. conferences, trade fairs) positively affect product, strategic, managerial and marketing innovation. This indicates a complex relationship between innovation in KIBS and the usage of external resources depending on the type of innovation pursued.

3.2.2 How KIBS benefit from urbanization economies

Although there is no doubt a great variety of ways in which the effects of cities on innovation in KIBS could be theorized, this chapter concentrates on the well-established approach of *urbanization economies*. *Urbanization economies* are knowledge spillovers that are due to city size and population density. The concept identifies the number of possible face-to-face contacts – which is maximized in cities and thus a positive function of city size – as source of knowledge transmission resulting in innovation (Glaeser et al. 1992, 1995, Henderson et al. 1992, Combes et al. 2012).[7]

Urbanization economies relate to the importance of face-to-face contact for know-

[6]Nowadays it is commonly accepted that innovations are brought forward in a collaborative process of knowledge generation and application. In order to be innovative, firms need to rely on a large variety of external and complementary sources of knowledge and at the same time dispose over absorptive capacity to use and apply knowledge acquired (Cohen and Levinthal 1990).

[7]It is important to demarcate *urbanization economies* from agglomeration externalities stemming from sectoral economic structures (*Jacobs-externalities* and *Marshall-Arrow-Romer-externalities*). For an introduction to these concepts, see *Section 1.1*.

ledge transmission that in turn is closely linked to the distinction between codified and tacit knowledge (Polanyi 1967). In fact, these types of knowledge are two ends of a continuum running from wholly codified forms to wholly tacit forms of knowledge (Howells 2002). The codified component of knowledge can be expressed using symbolic forms of representation and is hence transmittable in formal and systematic language. However, tacit elements of knowledge cannot be communicated in any direct or codified way either because the performer is not fully self-aware of her performance or because – even though self-awareness is fully achieved – language is inadequately developed in order to express the performance. Thus, tacit knowledge is best acquired experientially via face-to-face contact. The preponderance of face-to-face contact as communication technology for tacit knowledge encompasses two aspects (Storper and Venables 2004). First, face-to-face encounters permit unrivaled depth and speed of feedback. Second, face-to-face contact allows for multidimensional communication spanning verbal, physical, contextual, intentional and non-intentional levels of communication simultaneously. Related to cities the conception of tacit knowledge and the resulting importance of face-to-face contact for knowledge transmission as well as innovation, lead to the notion of *urbanization economies* and thus urban innovation advantages as cities provide the possibility of interacting with a greater number of potential contacts that constitute external knowledge resources.

The notion of a city as being the place of increased face-to-face contact has been taken up and converted to formal models by Glaeser (1999) and McCann (2007). In Glaeser's model people acquire knowledge through random face-to-face contact with other individuals. The number of face-to-face contacts is an increasing function of city size. This leads to the conclusion that knowledge acquisition in cities is faster and hence innovative activity is fostered by cities. This reasoning is in line with the findings of Herstad and Ebersberger (2015) who find a significantly stronger commitment to local collaboration in capital region KIBS. In his spatial analytic approach, inspired by von Thünen (1826), McCann (2007) argues that the frequency of face-to-face contacts necessary to acquire knowledge and to engage in innovative activity is likely to vary according to the type of innovation pursued as not all types of innovation appear to require the same frequency of face-to-face interaction. Modeling the relationship between innovation, frequency of face-to-face interaction and location costs – which presumably grow with augmenting centrality – results in different rent gradients depending on the opportunity costs of less than continuous face-to-face interaction. This leads to the conclusion that different types of innovation will be optimally located in different locations – relative to a city's central business district – according to the importance of face-to-face contact in order to pursue the innovative activity in question.

However, although *urbanization economies* exclusively relate to quantitative aspects in terms of city size, one has to keep in mind that cities also offer qualitative aspects that are closely related to their size. These are knowledge resources that are typically concentrated in cities and contribute to an urban innovation supporting infrastructure including firms, higher education organizations, non-university research and development organizations, venture capitalists, industrial and governmental organizations (Cooke 2001). Moreover, as cities are national and international nodes for the transfer and sharing of knowledge, they offer opportunities not only to relate to local, but also national and international knowledge inputs (Simmie 2003, Simmie and Strambach 2006).

The reflections set out above show that KIBS depend crucially on external knowledge resources in order to innovate. Their strong tendency to locate in cities and towards the top of the urban hierarchy – i.e. in the largest cities of an economy – leads to hypothesize that this empirically observable location pattern is strongly connected to *urbanization economies* and thus quantitative and qualitative knowledge resources that are concentrated in cities offering innovation advantages. However, as indicated by studies on different types of KIBS innovation and by the reasoning of different rent gradients leading to concentric patterns of innovation types around cities, it should be considered that the effect of *urbanization economies* varies according to the type of innovation pursued by the individual KIBS firm.

Empirical evidence on spatial innovation patterns and *urbanization economies* of KIBS is scarce and, to our knowledge, limited to the case of Canada. In their study on the spatial innovation patterns of KIBS in the Canadian province of Quebec, Doloreux and Shearmur (2012) observe distance based patterns of KIBS innovation for product, process, marketing and management innovation. However, the patterns vary according to the type of innovation, its novelty grade (new to the firm "basic" vs. new to the market "radical") and city sizes. While basic marketing and basic product innovation rise with proximity to a major metropolitan core[8], this is not the case for basic process and basic management innovations. Regarding radical innovations, they find increasing propensities to innovate with

[8]According to the setup of the study, metropolitan cores are the central business districts (CBD) of the major metropolitan areas Montreal (3.5m inhabitants), Ottawa-Gatineau (1m inhabitants) and Québec City (0.65m inhabitants).

distance to major metropolitan cores for process, management and marketing innovation. For radical product innovations, no spatial patterns are observable. For distance to small metropolitan cores[9], the results show a different picture of innovation activities: While basic product, process and management innovations tend to decrease with proximity to small metropolitan areas, the propensity for radical process and management innovations increases. Taking these results into account, Doloreux and Shearmur (2012) conclude that most types of KIBS innovation are influenced by proximity to large and/or medium sized cities and thus reveal wider spatial patterns of KIBS innovation. However, their analyses show that in some cases KIBS firms are more innovative in remote areas than in cities. So, apart from their findings of proximity to metropolitan areas as being conducive to basic marketing and product innovations, these empirical results partly contradict the notion of *urbanization economies* and thus show that effects may vary substantially between innovation types and city sizes.

Research hypotheses resting upon a distance-based approach to cities

It becomes evident that the analysis of firm-level innovation in KIBS should follow a synthesis approach and hence encompass both technological and non-technological types of innovation. In order to innovate, KIBS crucially depend on external knowledge resources. As knowledge flows are highly localized, cities offer innovation advantages because they provide firms with both quantitative and qualitative advantages regarding knowledge resources. However, as theorized by Glaeser (1999) and McCann (2007) and empirically investigated by Doloreux and Shearmur (2012), *urbanization economies* should differ according to city sizes and the type of innovation pursued by the individual KIBS establishment. Altogether, the innovation patterns of KIBS and the notion of *urbanization economies* lead to the deduction of three central hypotheses.

Hypothesis 1: Proximity to cities has a positive effect on innovation in KIBS
It is assumed that proximity to cities fosters innovation of KIBS. Being places that offer both a high quantity of face-to-face contacts and a concentration of specific knowledge resources, cities offer innovation advantages for KIBS firms. It is thus

[9]According to the setup of the study, small metropolitan cores are the CBD of small metropolitan areas, defined as cities that are more than 100km from a major metropolitan area and that have more than 45,000 inhabitants. These are Sherbrooke (183,000 inhabitants), Saguenay (149,000 inhabitants), Trois Rivières (139,000 inhabitants) and Rimouski (46,000 inhabitants).

hypothesized that the innovation probability of a KIBS establishment depends on its geographical distance to a city: The closer it is located to a city, the higher its propensity to innovate.

Hypothesis 2: The bigger a city, the stronger its positive effect on innovation in KIBS
As demonstrated by the theoretical model of Glaeser (1999), these distance decay effects are expected to be stronger with increasing city sizes. The theoretical reasoning states that bigger cities offer more face-to-face contacts and hence knowledge resources conducive to innovation. Moreover, it is likely that they also offer more qualitative knowledge resources. This should hold especially in the German polycentric city system where federal state capitals that combine multiple qualitative aspects are among the biggest cities in the country.

Hypothesis 3: The positive effect of cities on innovation in KIBS varies according to the type of innovation pursued
Referring to the theoretical reflections of McCann (2007), the effect of proximity to cities is expected to vary according to city sizes and to show different spatial patterns depending on the type of innovation pursued by the individual KIBS establishment. According to this reasoning, innovation types that require more interaction are more likely to be maximized with increasing spatial proximity to a city as opportunity costs of less than continuous face-to-face interaction are minimized. As spatial innovation patterns of different innovation types have been rarely addressed and spatial analytic or distance based approaches are not commonly used in analyzing the effects of cities on innovation, this third hypothesis remains exploratory in the sense that an order of concentric circles of innovation types is not hypothesized.

3.3 Data and empirical model

After the theoretical reflections in *Section 3.2*, *Section 3.3* introduces the data bases and the empirical model used in order to evaluate the hypotheses. The combination of two data sets provided by the Institute for Employment Research (IAB) with distance data on postcodes in Germany allows to address the research questions by applying a micro-geographic approach. The hypotheses are tested using a Knowledge Production Function (KPF) that relates innovative output of KIBS establishments to establishment-specific control variables, their individual economic environment, variables indicating distance patterns in relation to cities and location characteristics.

3.3.1 Data bases used in the analyses

In order to test the hypotheses derived in *Section 3.2* data provided by the IAB at the German Federal Employment Agency is combined with distance measures derived from a distance matrix based on approximately 8,200 postcodes in Germany. KIBS are identified on a 2-digit level according to NACE Rev. 1.1 including computer and related activities (industry division 72), research and development (industry division 73) and other business activities (industry division 74).

Firm-level dependent variables and control variables are generated combining two data sets of the IAB – namely the IAB Employment Statistics (ES) and the IAB Establishment Panel (EP) – via a unique common establishment identifier.[10] The ES is generated from official German employment statistics and rests on administrative data which is collected by means of the German Social Security system. It covers all employees subject to social security. Thus, self-employed individuals and civil servants are not included in the sample.[11] Via the unique establishment identifier, individual daily employment spells are aggregated on the level of establishments during the entire year. This allows for a detailed description of size and structure of the workforce employed in an establishment. In addition to this information, the ES provides establishment specific data on industry, location (i.e. postcode) and the first occurrence of the establishment number. The other data source – EP – is an annual survey of German plants collected in personal interviews.[12] The sample for the EP is drawn from the population of all German establishments with at least one employee subject to social security and is stratified across both plant size and industries. It provides a wide range of self-reported establishment-specific variables including, among others, innovative activities, turnover and information on the legal form. Regarding firm level data that is generated from ES and EP, the unit of observation is the individual establishment, as opposed to the concept of a firm that could comprise several establishments. This level of observation is

[10]For a detailed description of the combined database and the construction of variables see also Brunow and Blien (2015).

[11]As of December 2016, the number of total workforce in Germany was 43.540m. As of March 2016, the number of employees subject to social security was 31.195m (Statistisches Bundesamt 2016).

[12]For further information on the IAB establishment panel (EP) see Fischer et al. (2008) and Ellguth et al. (2014).

particularly suitable for spatial analysis because regional characteristics would be diluted by multi-establishment firms.

Distance is modeled using a database on all approximately 8,200 existing postcodes for Germany. For each postcode latitude and longitude of its centroid is calculated. Measurement of distance between centroids is orthodromic and thus based on the spherical law of cosines formula.[13] The distance matrix is applied for the calculation of two distance-based groups of variables. First, each postcode is assigned a spatial feature identifying it as belonging to a specific type of city according to city size. Thus, minimum distances between the postcode of an establishment and the next postcode assigned to a certain type of city can be calculated. Second, the distance matrix is used to model the individual economic environment of each KIBS establishment. By drawing a circle with a predefined radius around the centroid of an establishment postcode, all centroids of postcodes within the radius are identified. Using data provided in the ES enables the calculation of diversity and specialization measures for the areas defined. These measures are utilized to include agglomeration externalities due to specialization (*Marshall-Arrow-Romer-externalities*) or diversity (*Jacobs-externalities*) of economic structures in the empirical analysis. This circle approach based on postcode information maps the regional economic environment of an individual establishment more precise than regional variables based on NUTS3-regions (German "Kreise" and "Kreisfreie Städte") as these administrative borders are, to a large degree, arbitrary with respect to economic activity.[14]

3.3.2 Knowledge Production Function of innovation in KIBS

In the following, the Knowledge Production Function (KPF) used to investigate the data is presented together with variables used in the analyses. Moreover, the identification of the empirical model in order to reduce endogeneity is indicated.

Knowledge Production Function and innovation types

The hypotheses are tested using a Knowledge Production Function (KPF) that relates innovational output to the presence and volume of innovative resources

[13] $d = acos(sin\phi 1 * sin\phi 2 + cos\phi 1 * cos\phi 2 * cos\Delta\lambda) * R$, with d=distance, ϕ=latitude, λ=longitude, R=radius

[14] Note that distance is defined as purely spatial phenomenon. See, for example, Boschma (2005) on other forms of distance.

(Griliches 1979) and which has been widely applied as a theoretical basis for innovative processes. It takes the following form:

$$I_{ij} = CON_i^{b1} * ENV_{ir}^{b2} * CIT_i^{b3} * LOC_i^{b4}, \tag{3.1}$$

where I denotes the innovative output of establishment i regarding innovation type j, CON a vector of control variables including establishment-specific internal resources for innovative processes, ENV the structure of the economic environment in region r – subsuming variables that depict economic activities of other firms that are assumed to induce knowledge spillovers (*Marshall-Arrow-Romer-externalities* and *Jacobs-externalities*) and hence foster innovative activity of establishment i – and CIT the variables indicating the minimum distance and to the nearest city of establishment i. Finally, variable vector LOC represents the location of establishment i relative to the nearest city. The KPF includes both internal and external knowledge resources for innovation. For each innovation type the KPF is estimated by maximum likelihood using the probit approach to account for the binary dependent variables.

Table 3.1 describes innovation types I_j pursued by KIBS establishment i during the last year. While technological forms of innovation are represented by product improvement, product introduction and process innovation, non-technological innovation is indicated by organizational innovation that is a summary variable encompassing various organizational changes. Innovation is defined as being new to the firm.

Table 3.1: Dependent variables – Innovation types pursued by KIBS

I = Innovation Type	Scale Level	Description
Product Improvement	Binary	Improvement of product
Product Introduction	Binary	Introduction of a product new to the firm
Process Innovation	Binary	Improvement of process
Organizational Innovation	Binary	Insourcing or outsourcing of services, Restructuring of supplier and customer relationships, Restructuring of competences and responsibilities within the establishment, Introduction of working groups that act independently, Introduction of units with own cost-benefit analysis, Ecological organizational innovation, Improvement of quality management

Explanatory variables

Control variables CON in *Table 3.2* reflect various features of a KIBS establishment that might influence its innovative activity. Productivity is measured as turnover per employee subject to social insurance contributions. It is calculated as annual day average per full time equivalent workforce. In accordance with the literature on productivity and innovation, we expect a positive relation between both.[15] Establishment size is represented by the number of employees subject to social insurance contributions measured in full time equivalents. According to the meta-study by Camisón-Zornoza et al. (2004) a positive impact of establishment size on innovation is expected. In order to control for non-linearities, establishment size is categorized with an establishment size of 20 to 49 employees being the reference category. Human capital is defined as the share of high-skilled employees among the establishment's workforce following a task based definition (Brunow and Blien 2015).[16] It aims to control for the internal resources of innovation and is expected to exert a positive effect on innovation. To reduce the impact of endogeneity, the variable enters with a one year time-lag. Further control variables consider the legal form of the establishment, its embedment in a company structure – i.e. branch office, headquarter or single-site company –, and foreign ownership. The age of the establishment and its capital stock are also controlled for. Time-fixed effects are taken into account by means of annual dummy variables.

Vector ENV is introduced in order to control for agglomeration externalities stemming from sectoral economic structures and thus captures potential spillover effects induced by other establishments. It encompasses both measures for specialization (*Marshall-Arrow-Romer-externalities*) and for diversity (*Jacobs-externalities*) of economic environments around KIBS establishments. Economic specialization is modeled as share of employees in the own KIBS-industry with respect to overall employment in region r. Regional diversity is computed as inverse Hirschman-Herfindahl Index for region r, such that the index augments with rising diversity. Both measures are based on 2-digit industry levels and exclude the contribution of establishment i to avoid simultaneity. Another possible source of simultaneity regarding the variables included in ENV relates to the location decision of the establishment under consideration. If, in general, a firm settles down in a par-

[15] See Mohnen (2013) for a recent overview on the topic.

[16] The task-based definition of human capital applies the following criteria in order to identify low and high skilled employees: average time spent with analytical work relative to analytical and manual work, share of non-routine work relative to routine and non-routine work and proportion of human capital in the occupation based on formal qualification.

Table 3.2: Explanatory variables for innovation in KIBS

Variable	Scale Level	Description
CON = Control Variables		
Productivity	Interval	Turnover per employee
Establishment Size	Binary	Categories: 1 to 4, 5 to 9, 10 to 19, 20 to 49 [reference category], 50 to 99, 100 to 149, 150 to 199, 200 to 249, 250 to 499, 500 to 999, 1000 and more employees
Human Capital	Interval	Share of high skilled employees among establishment workforce
Sole Trader	Binary	Legal form of the establishment: Sole trader
Private Company	Binary	Legal form of the establishment: Private company
Limited Liability	Binary	Legal form of the establishment: Limited liability company [reference category]
Single-site Company	Binary	Embedment in company structure: Single-site company [reference category]
Branch Office	Binary	Embedment in company structure: Branch office
Headquarter	Binary	Embedment in company structure: Headquarter
Foreign Ownership	Binary	Establishment is foreign owned
Age: 0-4	Binary	Age of establishment: 0 to 4 years [reference category]
Age: 5-14	Binary	Age of establishment: 5 to 14 years
Age: 15+	Binary	Age of establishment: 15 years and more
Newest Equipment	Binary	Capital stock of the establishment: newest [reference category]
New Equipment	Binary	Capital stock of the establishment: new
Older Equipment	Binary	Capital stock of the establishment: older
Out-of-date Equipment	Binary	Capital stock of the establishment: out-of-date
Time Dummy	Binary	Time dummy variables of each survey year [1999, 2000, 2003, 2006, 2007, 2008, 2009]
ENV = Economic Environment		
Diversity	Interval	Inverse Hirschman-Herfindahl Index of industries; 2-digit-level
Specialization	Interval	Share of employees in own KIBS industry; 2-digit-level
CIT = Distance to nearest City		
Any City	Interval	Minimum distance in 100 km to the next city [50,000 or more inhabitants]
Metropolis	Interval	Minimum distance in 100 km to a Metropolis [500,000 or more inhabitants]
Large City	Interval	Minimum distance in 100 km to a Large City [100,000 to less than 500,000 inhabitants]
Small City	Interval	Minimum distance in 100 km to a Small City [50,000 to less than 100,000 inhabitants]
LOC = Location		
Closest City	Binary	Dummy for the closest city type: Metropolis, Large City, Small City [reference category]

ticular location due to the economic structures at place, it potentially strengthens the agglomeration forces and thus the measure becomes endogenous. However, meta-analytical evidence provided by Melo et al. (2009) suggests that estimates of agglomeration measures are only little biased by this kind of endogeneity. Modeling the local environment covers a radius of 17km around the centroid of the postcode associated with establishment i. This radius has been chosen as the average distance between centroids of German NUTS3-regions is about 34km. Thus, the regions modeled for the analysis are comparable to NUTS3-regions in size but do not rest on administrative boarders allowing for a more precise mapping of the local economic environment. In the following, when referring to the term region, we refer to all centroids of postcodes that are in a 17km circle around the centroid of the postcode associated with establishment i.

The variables subsumed in vector CIT are used to model distance decay effects of knowledge flows and thus *urbanization economies* as described in *Sections 1.1* and *3.2*. Whereas vector ENV aims to cover agglomeration externalities potentially stemming from local economic structures, CIT explicitly considers distance effects. In order to take into account presumed effects connected to city sizes, three city types are defined according to their population size – metropolises with 500,000 or more inhabitants, large cities with 100,000 to less than 500,000 inhabitants and small cities with 50,000 to less than 100,000 inhabitants. Distances are calculated as minimum distance to each of the city types as well as to any city. A complete list of cities included and their classification in terms of city types is provided in *Appendix B* (*Tables B.1.1*, *B.1.2* and *B.1.3*).

Identification

In the empirical analyses distance decay effects on innovation serve as a measure of *urbanization economies*. In order to statistically identify these effects, distance measures need to be exogenous and consequently all sources of endogeneity have to be taken into account. The main source of endogeneity relates to the location of each establishment. This is coped with in two ways. First, by introducing variable vector LOC that takes into account the urban environment of each establishment. Second, by treating each city as uniform spatial entity.

Vector LOC is introduced to reduce the omitted variable bias on distance decay effects. Distance decay effects might be also affected by the location decisions of the KIBS establishments themselves. They might locate explicitly in or in close distance to a metropolis, a large or a small city – depending on their needs connected to city size characteristics. For instance, if an establishment seeks to be innovative and knows about possible *urbanization economies* stemming from being located in or near a metropolis, it would locate accordingly. Then observable distance decay patterns are biased by the location decision related to cities and expected knowledge flows. In order to reduce this form of endogeneity, dummy variables that reflect the closest city type are introduced. They absorb between-city-type variation and related potentially differing distance decay patterns between city types. Binary variables "Closest to Metropolis" and "Closest to Large City" are set to one if the location of the establishment is closest to a metropolis or a large city, respectively. Thus, reference category is being located closest to a small city.

While LOC covers possible endogeneity due to location choices of KIBS establishments depending on city sizes, location choices within cities or close to certain areas of a city might constitute another source of endogeneity: selectivity in space within a city type. To illustrate this, assume that an establishment might locate somewhere in a city where it expects the best benefit from potential economies and spillovers. For example, if there is a specific technology park at the city border that provides all KIBS requirements best, it will locate there and not somewhere else in the city. In that case, defining a central point in a city as reference for distance calculations – such as the city hall, a central business district or the train station – would not control for endogeneity of location choices depending on varying spatial characteristics within cities themselves. This problem is overcome by relating the distance of a KIBS establishment to the centroid of the closest postcode area belonging to the respective city. Thus, each city is implicitly treated as uniform spatial entity. However, this shaping of cities implies that the results regarding distance decay effects and thus concentric location patterns for different types of innovation are not related – as implied by the modeling of McCann (2007) – to a central point in a city but to its outer boundaries.

3.4 Effects of distances to cities on innovation probabilities in KIBS

Section 3.4 presents the empirical results. As hypothesized, varying *urbanization economies* for all types of innovation are found. Differentiating between city types according to their population reveals that distance decay effects are stronger with growing city sizes, i.e. that *urbanization economies* are strongest for KIBS establishments that are located closest to a metropolis. However, these size effects and their significance levels vary according to the type of innovation pursued by the KIBS establishments.

3.4.1 Descriptive results

The total number of KIBS establishments observed in the analysis is 7,073 (*Table 3.4*). However, as not each type of innovation has been surveyed each year and because of missing values in the dependent variables, the number of observations varies between 4,264 and 6,199 regarding innovation types. An overview is given in *Table 3.3*. 11.0% of the KIBS establishments in the sample indicate that they have introduced new products or services. Regarding the improvement of products, the share of innovators is substantially higher with 44.8% of all KIBS. Nearly one fourth (22.3%) of the KIBS establishments has improved internal processes. Organizational innovation has been pursued by nearly half (47.4%) of the KIBS establishments. The descriptive statistics of variables and the correlation matrix of control variables can be found in *Appendix B* (*Tables B.2.1*, *B.2.2* and *B.2.3*).

Table 3.3: Innovation types, number of observations and share of innovators

Innovation Type	Number of observations [N]	Share of innovators [%]
Product Improvement	6,199	44.8
Product Introduction	6,189	11.0
Process Innovation	4,264	22.3
Organizational Innovation	4,937	47.4

The spatial location of the KIBS establishments in the sample and the city types in Germany are presented in *Figure 3.1*. Although, in international comparison, the German city system is quite polycentric due to a relative high degree of federalization of political power, the location pattern of KIBS seems to confirm the tendency of KIBS establishments to locate near or in cities and towards the top of the urban hierarchy. A considerable concentration of KIBS in and around the capital Berlin and the federal state capital Hamburg, which with around 3.5 and 1.7 Million inhabitants are the biggest cities in Germany, is observable.

The average distance of a KIBS establishment to the next postcode associated with a city with 50,000 or more inhabitants is 8.5km. Distinguishing between city types reveals that the average distance to a metropolis is about 3.1km, to a large city slightly more than 9km and to a small city almost 15km – always on condition that these city types are the closest city type to a KIBS establishment. The maximum distance to the next city is 91.8km, which relates to a small city. For metropolises and large cities the maximum distance is around 70km.

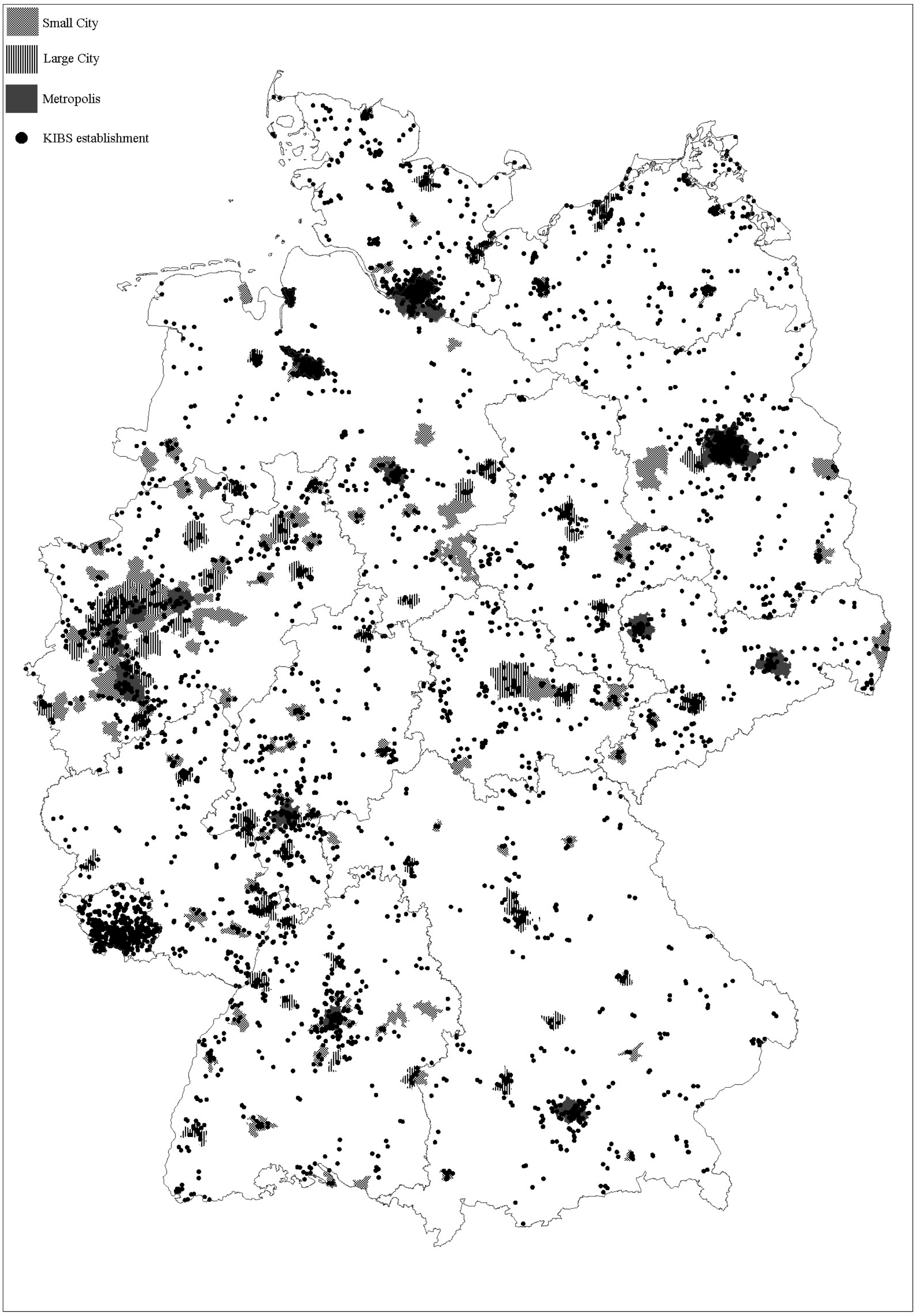


Figure 3.1: Location of KIBS establishments and city types in Germany

Differentiating relative locations of establishments between city sizes in *Table 3.4*, shows that 36.1% of the KIBS establishments in the data used for the empirical analysis are closest to a metropolis. The majority of KIBS (37.3%) are closest to a large city. Further 26.6% are closest to a small city. As the ES covers all KIBS in Germany, it is possible to compare the location pattern in the data set to the overall location pattern of KIBS in Germany in order to evaluate its spatial representativeness. The proportional values for KIBS in Germany show that the data set slightly over-represents KIBS establishments closest to a metropolis and closest to a large city. However, the deviations are quite small leading to the conclusion that the German-wide pattern of KIBS location is represented by the data set.

Table 3.4: Spatial distribution of KIBS establishments relative to closest city type

Closest City Type	Sample	KIBS in Germany*
Closest to Metropolis [%]	36.1	33.4
Closest to Large City [%]	37.3	36.0
Closest to Small City [%]	26.6	30.5
N	7,073	296,154

* Notes: Includes all KIBS with at least one employee subject to social insurance. Calculations are based on averages for the survey years 1999, 2000, 2003, 2006, 2007, 2008 and 2009.

In order to gain some first insights on the relationship between innovative activities of KIBS and their spatial location, *Table 3.5* depicts the share of innovators and their respective location separated for the various types of innovation. The spatial information captures two things: the closest city type and the distance to the closest city type separated by distance percentiles. Thus, two findings for each type of innovation can be derived. First, rows indicate differences in innovation behavior in relation to the closest city type. For instance, the first data row reports the share of KIBS establishments that have improved their products and are located within the first percentile of distance to their respective closest city type. The share of establishments that have improved their products in this category varies between 39.1%, if they are closest to a large city, and 52.8%, if they are closest to a metropolis. Second, columns show how the shares of innovators vary with increasing distance. For example, the column heading "Closest to Metropolis" indicates that the shares of KIBS located closest to a metropolis that have improved their products decrease from 52.8% for the first percentile of distance to 27.9% for the fourth percentile of distance; i.e. we can observe decreasing shares of KIBS establishments that have improved their products with growing distances

Table 3.5: Cross table of relative KIBS location and innovative activity

Percentiles of distance	Closest to Metropolis [%]	Closest to Large City [%]	Closest to Small City [%]	Any City* [%]
Establishments with Product Improvement				
1	52.8	39.1	48.5	50.6
2	56.3	51.4	44.0	51.8
3	42.5	40.6	47.0	43.3
4	27.9	35.3	34.6	34.3
Total	50.6	42.3	40.9	44.8
N	2,159	2,353	1,687	6,199
Establishments with Product Introduction				
1	11.6	9.8	25.0	11.9
2	10.6	10.3	9.5	10.2
3	10.5	10.3	10.8	10.5
4	10.2	11.3	11.4	11.3
Total	11.1	10.5	11.4	11.0
N	2,156	2,344	1,689	6,189
Establishments with Process Innovation				
1	25.1	23.3	35.9	25.4
2	29.1	27.2	17.6	26.0
3	24.8	18.5	21.9	20.9
4	11.8	19.8	17.4	17.9
Total	25.0	22.0	19.7	22.3
N	1,399	1,634	1,231	4,264
Establishments with Organizational Innovation				
1	54.5	52.4	48.1	54.0
2	51.3	49.1	45.9	49.4
3	45.4	44.7	47.1	45.7
4	46.0	41.7	37.1	39.9
Total	52.2	46.0	42.4	47.4
N	1,850	1,820	1,267	4,937

*Independent of city size.

Notes: Distances according to percentiles are 0km to 0.9km (1), >0.9km to 1.6km (2), >1.6km to 12.3km (3) and >12.3km (4)

to metropolises.

Regarding the hierarchy of city sizes, as *Table 3.5* shows, no clear picture emerges. Systematically lower or higher shares of innovators within the same percentile depending on the closest city type are not observable. However, there are remarkable distance-based variations for product improvement and organizational innovation. In total, for these innovation types the share of innovators decreases by approximately 15 percentage points[17] with growing distance to any city. There

[17]For product improvement we observe a decrease from 50.6% to 34.3%. The corresponding shares for organizational innovation are 54.0% and 39.9%.

is no such pattern for product introduction and an inverse u-shaped pattern for process innovation. The data provides first indications that distance decay effects might differ depending on the closest city type.

The descriptive examination of the relationship between innovative activities of KIBS and their spatial location indicates, as hypothesized, positive effects of proximity to cities on the innovation probability of KIBS establishments. However, differentiating among innovation and closest city types delivers first findings of complex relations between both. In order to validate and to deepen the understanding of these relations, multivariate probit-regressions are introduced in *Section 3.4.2*.

3.4.2 Multivariate analyses of urbanization economies

The KPF is estimated using probit-regressions to identify both the effects of cities on different types of KIBS innovation in general as well as the effects of city sizes on these types of innovation. Having this agenda, *Model 1* introduces the distance to any city with 50,000 or more inhabitants. The augmented *Model 2* additionally differentiates between the three city types metropolis, large city and small city that represent city sizes according to inhabitants. As we intend to concentrate on the distance variables, for both models the values of control variables CON and variables representing the specialization and diversity of the economic environment ENV as well as their Average Marginal Effects (AME) are depicted in *Appendix B* (*Tables B.3.1*, *B.3.2*, *B.3.3* and *B.3.4*). The results presented in the following are therefore conditional on other explanations such as productivity and employment size at the level of KIBS establishments as well as their economic environment. Also because of the inclusion of location-specific dummy variables LOC – i.e. closest to metropolis, large city or small city – endogeneity connected to the location decisions of KIBS establishments is controlled for.

In both models presented a joint significance test of all variables included is performed and always indicates the joint relevance of these variables. It is further tested whether the inclusion of the distance related variables CIT improves model fit relative to the basic model containing variable vectors CON, ENV and LOC only. The tests depicted in line "All variables" indicate that the inclusion of these variables has explanatory power for all innovation types in both models.

Table 3.6: Results for *Model 1* – Distance decay patterns for Any City

	Product Improvement	Product Introduction	Process Innovation	Organizational Innovation
Distance decay pattern for Any City				
Minimum distance	-2.508***	-0.641	-1.507***	-0.505
	(0.30)	(0.45)	(0.15)	(0.35)
Squared minimum distance	2.243***	0.880**	1.510***	0.491
	(0.35)	(0.43)	(0.48)	(0.50)
Joint significance tests [Chi-Square]				
Distance decay variables	749.8***	88.7***	95.1***	5.6*
All variables	1,085.6***	427.8***	522.2***	742.3***
Model Fit				
Pseudo R2	0.127	0.100	0.115	0.109
N	6,199	6,189	4,264	4,937

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level
Note: Cluster robust s.e. in (), control variables included.

Model 1 – Distance decay patterns of innovation for Any City

As described, *Model 1* aims at identifying general distance decay effects for innovation types related to cities. Distance to any city is defined as distance to the next city with 50,000 or more inhabitants.

Non-linear gradients of distance patterns are allowed for, as distance is modeled as minimum distance and squared minimum distance. Because both variables are highly correlated and this correlation is likely to affect significance levels of variables, a joint significance test is performed. As depicted in *Table 3.6*, the non-linear distance pattern is jointly significant for each type of innovation. In probit-regression models, the quantitative interpretation of variable values is somewhat cumbersome as they are only directly interpretable for a latent, i.e. unobservable, dependent variable. Thus, the effects of distance to the next city with 50,000 or more inhabitants on innovation probabilities are evaluated by averaged probability plots. *Figure 3.2* shows that the distance effect on the probability of innovation decreases for all types of innovation with growing distance to the closest city.[18]

In the light of the theoretical reflections outlined in *Section 3.2* the results indicate that proximity to cities matters for innovation and KIBS benefit from *urbanization economies*. For all types of innovation KIBS establishments profit from

[18]The slope of the probability functions depicted in *Figure 3.2* relates to the Average Marginal Effects (AME) of distance on innovation probabilities.

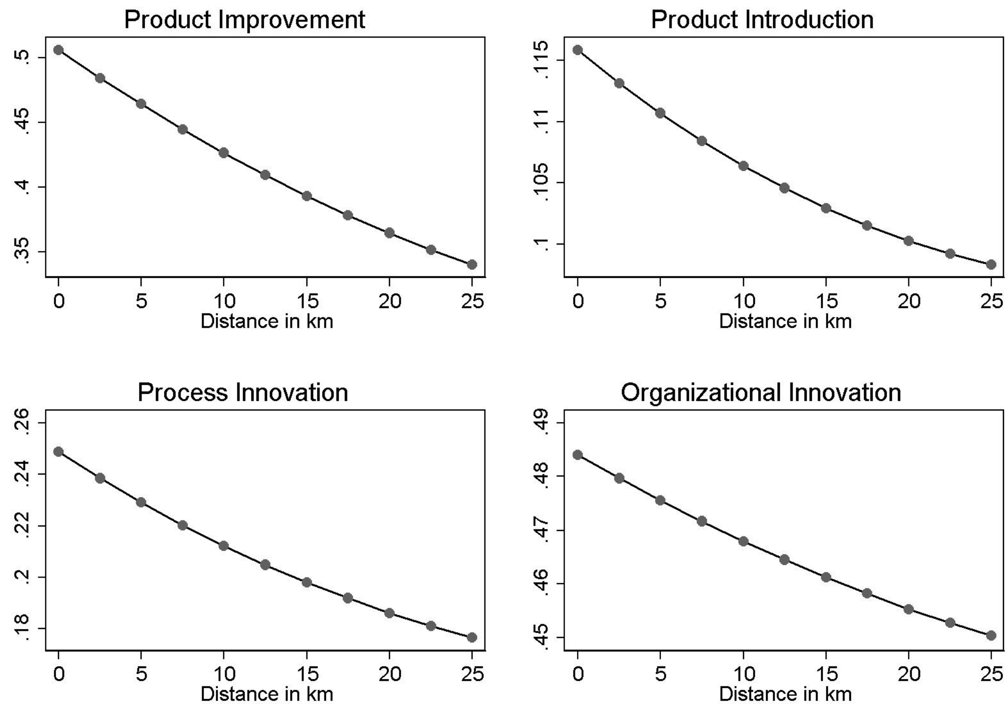


Figure 3.2: Probabilities of innovation with growing distance to Any City

increased face-to-face interaction and thus the absorption of (tacit) external knowledge that is offered in proximate cities more easily relative to a situation when the KIBS establishment is located rather remote. Because the location specific economic environment ENV is controlled for, the distance effect captures *urbanization economies*. As suggested by the theoretical reflections and the descriptive analyses, distance decay effects vary according to the type of innovation pursued by the KIBS establishments. These variations are presumably due to different interaction needs connected to innovation types. Comparing the distance decay effects in terms of a percentage reduction of innovation probabilities with increasing minimum distances in the range of 0km to 25km[19], leads to the conclusion that the strongest distance decay effect of innovation probabilities is observable for product improvement (-32.8%), followed by process innovation (-29.3%), product introduction (-15.5%) and organizational innovation (-7.0%). Compared to the descriptive results in *Section 3.4.1*, distance decay effects of product introduction are stronger and distance decay effects of organizational innovation are weaker than

[19]The threshold of 25km minimum distance is chosen as it covers 90% of all KIBS establishments. Differentiating according to the closest city type, it covers more than 95% of all KIBS establishments located closest to a metropolis, 60% of those closest to a large city and slightly more than 75% of those closest to a small city.

one might expect. Thus, variables included in the multivariate model substantially change distance decay patterns compared to the purely descriptive results which do not account for further explanations of innovation in KIBS. In general, *Model 1* leads to conclude that geographical proximity to a city and interaction with multiple contacts seems of bigger importance for technological types of innovation and that KIBS profit strongest from *urbanization economies* connected to these types of innovation. However, there might be distinct patterns between city sizes which further explain the observed distance decay effects. These size effects of cities are analyzed in *Model 2*.

Model 2 – Distance decay patterns of innovation for Metropolises, Large Cities and Small Cities

Model 2 differentiates between city types and depicts distance decay patterns depending on the closest city type, i.e. metropolis, large city and small city. The estimates are presented in *Table 3.7* and are reported without reference category; i.e. they relate to the city specific distance decay functions. As it was the case in *Model 1*, minimum distance as well as squared minimum distance to control for non-linearity in distance decay patterns are introduced. Joint significance tests for each pair of distances are conducted. Interpretation of distance decay patterns is only feasible if the distance variables are jointly significant. While significant results for distance decay patterns of all three city types for product improvement and process improvement are found, distance effects are only significant for metropolises regarding product introduction and for large cities when organizational innovation is considered. As the estimated differences in slopes between city types might be random, difference in parameter tests are performed to evaluate whether the spatial patterns differ significantly between city types. For process innovation all distance patterns are significantly different from each other. However, regarding product improvement, significant differences in the curves of metropolises and large or small cities are detectable but not between the curves for large and small cities. Thus, metropolises exhibit a different distance decay function than large and small cities. For product introduction and organizational innovation the difference in parameter tests are of less relevance as in each case significant distance decay patterns are found for one type of city only.

Again, the gradients of innovation probabilities are illustrated in order to interpret the results. Curve progressions are depicted in *Figure 3.3*. Apparently, given significant distance decay patterns, the distance decay effects differ between city sizes

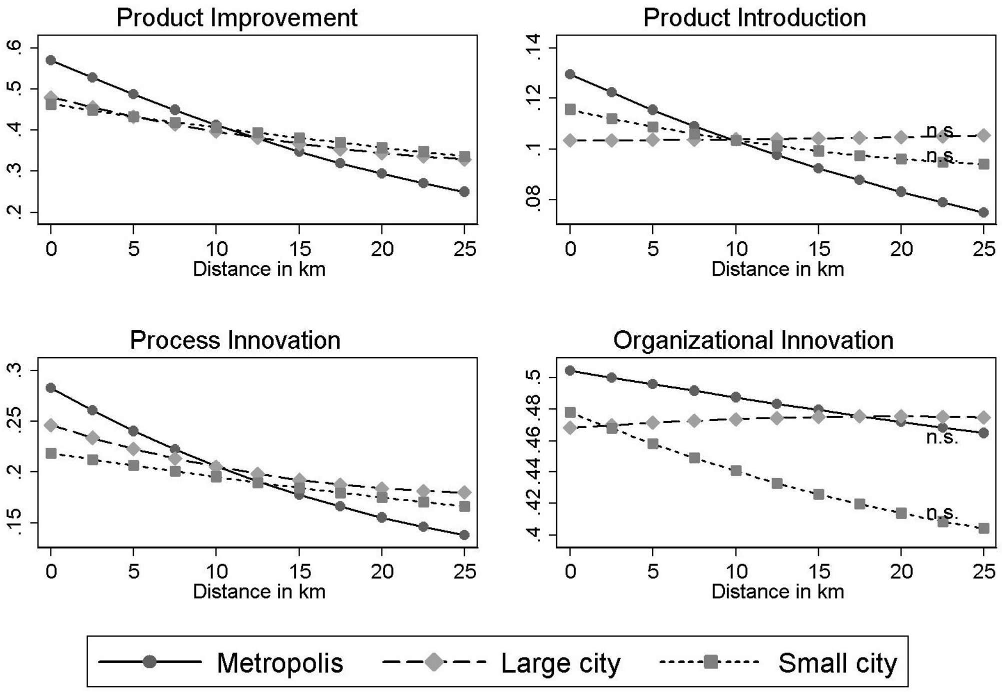
Table 3.7: Results for *Model 2* – Distance decay patterns for Metropolises, Large Cities and Small Cities

	Product Improvement	Product Introduction	Process Innovation	Organizational Innovation
Distance decay pattern if closest city is a Metropolis				
Minimum distance	-4.948***	-1.577	-3.086***	-0.500
	(1.7)	(1.28)	(0.98)	(0.85)
Squared minimum distance	4.194	0.776	3.056	0.201
	(3.19)	(2.35)	(1.97)	(1.37)
Distance decay pattern if closest city is a Large City				
Minimum distance	-2.818***	0.003	-1.886***	0.217
	(0.51)	(0.60)	(0.28)	(0.58)
Squared minimum distance	4.153***	0.176	3.424**	-0.559
	(1.12)	(0.76)	(1.41)	(1.12)
Distance decay pattern if closest city is a Small City				
Minimum distance	-1.766***	-0.847	-0.963	-1.200**
	(0.56)	(0.89)	(0.76)	(0.55)
Squared minimum distance	1.059	1.277	0.368	1.430**
	(0.78)	(1.02)	(1.43)	(0.66)
Joint significance tests [Chi-Square]				
Distance decay variables for Metropolis	14,5421.7***	4,900.5***	89.7***	2.5
Distance decay variables for Large City	49.2***	0.5	633,361.0***	4, 013.3***
Distance decay variables for Small City	12.0***	3.3	6.9**	0.3
All variables	1,112.5***	433.4***	529.0***	745.7***
Difference in parameter tests [Chi-Square]				
Metropolis vs. Large City	159.1***	256.6***	28.3***	1.6°°
Metropolis vs. Small City	33.4***	20.6***,°°	108.7***	7.2**
Large City vs. Small City	3.5	29.9***,°°	11.7***	3.0°°
Model Fit				
Pseudo R2	0.130	0.101	0.117	0.109
N	6,199	6,189	4,264	4,937

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level
°° Joint significance test for distance decay variables is not significant.
Note: Cluster robust s.e. in (), control variables included.

as hypothesized. However, as was presented in *Table 3.7*, the differences are not significant in every case. *Table 3.8* reports the alteration in average probabilities of innovation for 0km and 25km distance to the closest city.

For product improvement and for process innovation considerably stronger distance decay effects for metropolises than for large and small cities are found. Relating to the theoretical reflections this leads to the conclusion that for these two types of innovation the distance decay effects – i.e. *urbanization economies* –



Note: Average predicted probabilities of *Model 2*; n.s. = not significant based on joint significance test

Figure 3.3: Probabilities of innovation with growing distances to Metropolises, Large Cities and Small Cities

are closely connected to city sizes. As large and small cities offer a lower degree of interaction possibilities compared to metropolises, the negative effect of being located further away is weaker. Additionally, as depicted in *Appendix B*, *Table B.1.3*, most of the metropolises do have capital functions which might indicate connections to their qualitative aspects. However, in the empirical analyses, these aspects of cities are not explicitly tested for.[20] Due to the flatter shape of the probability curves regarding distances to small and large cities for both types of innovation, we observe a cut value of about 12km where the innovation probability is higher for establishments that are located closest to a small or large city relative to establishments closest to a metropolis.

For product introduction only a significant decrease of innovation probabilities with increasing distance to metropolises is detectable. Thus, KIBS establishments introducing new products may be located closest to small or large cities and their innovation probability is unaffected by that location characteristic. For organizational innovation the distance decay pattern even shows a slight increase of innovation probabilities with growing distance to large cities, while distance patterns

[20]In robustness checks distances to federal state capitals and the capital city Berlin were introduced. These measures always turned out to be insignificant while the results so far remained. This implies that the distance measure does not serve as a proxy for governmental institutions.

Table 3.8: Alteration in average innovation probabilities according to city types

	Product Improvement [%]	**Product Introduction [%]**	**Process Innovation [%]**	**Organizational Innovation [%]**
Metropolis	-56.2	-42.3	-51.3	-7.9°°
Large City	-31.2	1.9°°	-26.9	1.5
Small City	-27.2	-18.7°°	-24.1	-15.4°°

°° Joint significance test for distance decay variables is not significant.

Notes: Estimates based on *Model 2*. Alterations in probabilities for being located 0km and 25km away from the respective city type.

in relation to small cities and metropolises are insignificant. This picture is incongruent with the descriptive findings in *Section 3.4.1* where the share of innovators decreases with growing distance to all three city types. Therefore, the additional variables included in the probit regressions take over the variation among innovative processes and absorb the effects from distance measures.

To summarize the results regarding product improvement, product introduction and process innovation in KIBS, it is found that innovation probabilities decrease considerably with growing distance to metropolises and that decreases in innovation probabilities for distances from large and small cities, if significant, occur to a lesser extent. For all three types of innovation this leads to the conclusion that establishments located closest to large or small cities benefit less from external resources provided by nearby urbanity in order to innovate. This conclusion is in accordance with O'Farrell et al. (1996) who show that firms in less urban regions face narrower local knowledge supply bases when conducting innovation and with Doloreux and Shearmur (2012) who derive that firms in peripheral regions may compensate for narrower local knowledge supply bases by attempting to 'internalize' some of the benefits which are external to firms in cities. Moreover, given the definition of the dependent variables enables a rough comparison of results regarding the spatial patterns of product innovation (improvement and introduction) and process innovation to the patterns found for basic product and basic process innovation in Doloreux and Shearmur (2012) for Canada: They also find distance decay effects for basic product innovations with respect to major metropolitan cores, while they even find negative effects of proximity to small metropolitan areas for both basic process and basic product innovation. This confirms the notion of distance decay effects varying to a considerable degree with city sizes and the finding that *urbanization economies* are positively connected to city sizes.

According to the theoretical reflections of McCann (2007) set out in *Section 3.2.2*, innovation types pursued by KIBS are assumed to settle in concentric circles around cities depending on innovation specific opportunity costs induced by less than continuous face-to-face interaction. As we have seen from our previous analysis, *urbanization economies* for innovation types vary considerably according to city sizes. For analyzing potential concentric patterns of innovations, we again differentiate between city types and compute relative odds ratios. Formally, the relative odds ratio $\Omega_{A,B}(d)$ at distance d for any two distinct types i of innovation I_i is computed as

$$\Omega_{A,B}(d) = \frac{\left(\frac{p(I_A(d)=1)}{p(I_A(d)=0)}\right)}{\left(\frac{p(I_B(d)=1)}{p(I_B(d)=0)}\right)}. \tag{3.2}$$

The nominator (and denominator) of that equation represents the odds depending on distance d to perform a specific innovation type $p(I_i(d) = 1)$ relative to the probability of not performing this type of innovation $p(I_i(d) = 0)$. The ratio of any two odds describes the relative odds ratio which represents the relative incentives to innovate in one of the two types. For $\Omega_{A,B}(d) > 1$, innovation type A is performed with a higher relative probability than innovation type B and for $\Omega_{A,B}(d) < 1$ vice versa. For $\Omega_{A,B}(d) = 1$ relative innovation probabilities are identical. Therefore, concentric patterns of innovation are determined if $\Omega_{A,B}(d)$ crosses the value of 1 in the distance interval from 0km to 25km. However, if there is no such change in the incentives to innovate, still the change in odds ratios depending on distance provides evidence on the relative importance of any two types of innovation due to the relative location of the establishment in space. Because for some types of innovation there was no significant effect of distance on the innovation probabilities, the odds ratios for these types of innovation are computed as the average predicted probabilities over all distances $d \in [0, 25]$ and thus are kept constant for any distance $d \in [0, 25]$.

Figure 3.4 depicts the relative odds ratios for any two combinations of innovation separated by city types. For metropolises, a concentric pattern between organizational innovation and product improvement is found. At a distance of around 5km from a metropolis, the relative odds ratio of organizational innovation on product improvement becomes greater 1 indicating that organizational innovation becomes relatively more likely. It is worth mentioning that the distance pattern for organizational innovation is independent of distance to metropolises and small cities, as the joint significance tests depicted in *Table 3.7* indicate insignificance. Consequently its odds ratio is kept constant. The effect on the relative odds ratio is therefore driven by the decreasing probabilities of product improvement when the establishment is located relatively remote. A similar pattern as for metropolises is found for large cities where the relative odds ratio of organizational innovation on product improvement becomes greater than 1 at around 1km distance from a large city. This leads to the same implications regarding concentric innovation patterns between these two types of innovation: The requirement of face-to-face contacts as they are provided by metropolises and large cities is stronger for product improvement than for organizational innovation.

Apart from the findings of concentric patterns between organizational innovation and product improvement for metropolises and large cities, the hierarchical order of innovation types remains constant. However, there are three further points to make. First, the relative odds ratios related to product introduction are always larger than 1. This indicates that product introduction is always less likely than the other types of innovation, but – especially regarding process innovation and product improvement – with decreasing odds ratios. This observation is in line with the notion of "hidden champions", where firms located in peripheral regions are highly innovative in the field of radical innovation, i.e. product introduction. Second, we observe relatively flat curves of relative odds ratios for small cities compared to curve progressions with respect to metropolises and large cities. This indicates that KIBS located closest to a small city benefit to a smaller degree from external resources of knowledge that are connected to and provided by the nearest city. Third, the scarce evidence on concentric patterns of innovation might be due to the modeling of cities applied in our analyses.

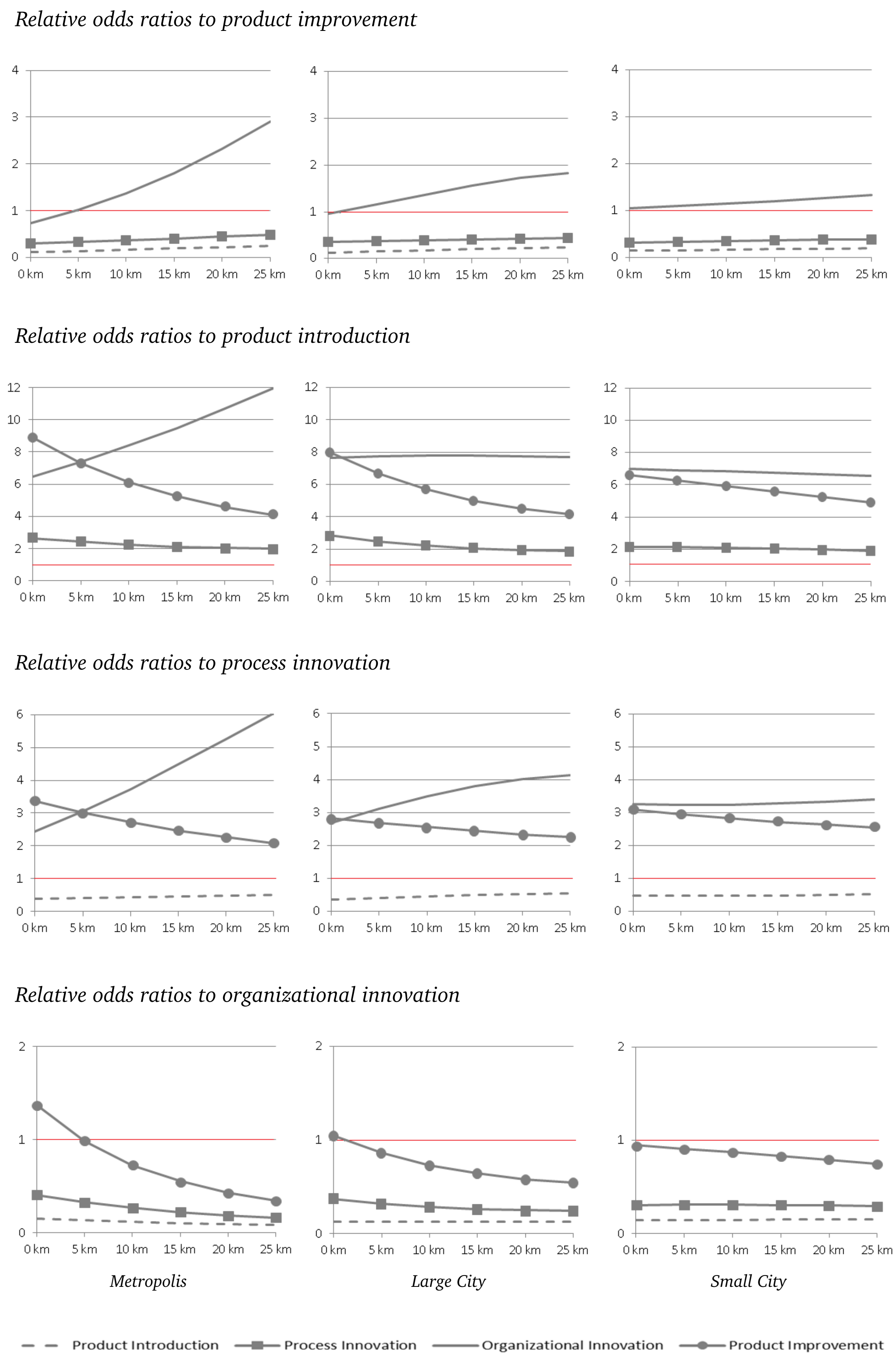


Figure 3.4: Relative odds ratios for innovation types

3.5 Discussion

In the analysis three data sets representing internal resources and external resources of innovation as well as micro-geographic data were combined in order to detect and quantify *urbanization economies* in German KIBS. Comparatively analyzing distance decay effects induced by growing distance to cities for four types of innovation, a state-of-the-art synthesis approach to innovation in services is applied. The empirical results show varying distance decay effects not only connected to the type of innovation pursued by KIBS establishments but also to city sizes.

In general, we observe that innovation probabilities in KIBS decrease with growing distances to cities. However, the negative effects of being located further away from a city vary according to innovation types. *Urbanization economies* are strongest for product improvement, followed by process innovation, product introduction and organizational innovation. Refining the analysis according to city sizes reveals that metropolises exert the strongest distance decay effects leading to the conclusion that *urbanization economies* augment with city size. Especially innovation opportunities connected to metropolises might act as centripetal forces for KIBS allocation.

We do not want to gloss over limitations of the analysis due to limited data availability on the one hand and methodological issues on the other hand. Regarding data availability the analyses are subject to two major restrictions. First, although *urbanization economies* in their pure form exclusively relate to size effects of cities, quantitative and qualitative aspects of cities are interconnected. However, due to lacking harmonized qualitative data on cities in Germany, disentangling both aspects was not possible in the analyses. Second, external knowledge resources are considered by incorporating the local economic environment – as possible source of knowledge spillovers resulting from specialization (*Marshall-Arrow-Romer-externalities*) or diversity (*Jacobs-externalities*) of proximate firm structures – and distance to cities in the analyses. This omits other, non-local external knowledge resources for KIBS innovation as they are for example considered in Doloreux and Shearmur (2012). From a methodological point of view, the modelling of distance to cities allows for non-linear curve progressions of distance decay effects but does not take into account the wider spatial patterns of urbanity. For example, distance measures do not cover the relative density of cities in the Ruhr Area or the relative city scarcity in parts of Lower Saxony. Nevertheless, as the interpretation of data resulting from binomial regressions is somewhat cumbersome to interpret and requires simulation techniques, the measure of geographic distance to cities was kept relatively simple.

This chapter seeks to contribute to the under-explored debate on innovation in KIBS and their connection to geography. To the best of our knowledge, empirical evidence based on micro-geographic spatial patterns addressing this field of research is limited to the case of Canada. The chapter contributes to the research on spatial innovation patterns of KIBS in two ways. First, using micro-geographic data allows to detect distance-based distance decay effects on a relatively fine-grained geographical level compared to analysis on NUTS2 or NUTS3 levels (see, for example, Meliciani and Savona 2015 and Herstad and Ebersberger 2015 for analyses on EU level). Second, it is the first to provide differentiated evidence on *urbanization economies* with respect to different types of innovation in a polycentric city system as it is represented by Germany.

The advantageous position of cities and especially metropolises as sources of *urbanization economies* and hence possible attractors for KIBS together with the increased relevance of KIBS as (co-)producers of innovation and economic growth raises questions regarding the need of policy intervention due to a possible polarization of regional development. This is particularly relevant for EU policy aiming at regional convergence. Not only rural areas but also locations quite close to cities as well as relatively small cities feature spatial disadvantages for KIBS innovation resulting in reduced innovation and economic growth in these areas. In accordance with Herstad and Ebersberger (2015) this leads to conclude that governmental initiatives in and for these regions should focus on supporting the build-up of internal competences of KIBS and strengthening their supra-local external linkages. Moreover, as substantial distance decay effects in a radius not larger than 25km from cities are detected, strengthening the connections between cities and their local environment seems a further adequate measure to reduce regional disparity in KIBS innovation. Nonetheless dependence of KIBS on local conditions suggests that their potential for growth in non-urban regions and relatively small cities is limited.

The results call for further investigations. While it is observable that innovation in KIBS plays out continuously in geographical space, the underlying mechanisms need further exploration. First, the modeling does not take into account distances within cities but solely distances to the next postcode with city characteristics, implying that within city dynamics of location and innovation do not enter the results. Recent case studies on Milan, Amsterdam and the Jönköping city region indicate that location patterns of KIBS within cities are not arbitrary but deviate significantly from randomness (Antonietti et al. 2013, Jacobs et al. 2014) and might also be connected to their innovativeness (Klaesson and Norman 2015). In the light of the results in this chapter that indicate strong distance decay effects especially between metropolitan and non-metropolitan areas, it would be of interest to evaluate whether and to which degree the observable patterns sustain within cities or are rather connected to the distinction between the urban and the non-urban. Second, in order to disentangle quantitative *urbanization economies* from effects related to qualitative aspects of cities, i.e. their endowment with various assets that might foster innovation, further empirical work is required. However, the main challenge lies in lacking availability of comparative data sets on cities that represent these endowments. Third, the incorporation of supra-local external knowledge resources for innovation in KIBS, e.g. trade fairs, international customers etc., in empirical analysis might add additional explanatory power to the results.

Chapter 4

Urban innovation systems – Case study on Knowledge Intensive Services (KIS) in Karlsruhe

An earlier version of this chapter has been published as a working paper in the KIT Working Paper Series in Economics (Hammer 2014).

4.1 Introduction

This study aims at investigating which local infrastructures and knowledge resources foster innovation of city-located Knowledge Intensive Services (KIS). KIS comprise firms that are primarily engaged in service activities in which human capital is the major input (Miles 2008). A majority of the output of KIS is information in the form of technical and management consultancy as well as diverse specialist activities – e.g. financial management, marketing and advertising, staff recruitment and development, property acquisition and management (Wood 2002).[1] Turning attention to the spatial distribution of KIS in advanced economies

[1] According to NACE classifications, divisions of the sections 'Information and communications', 'Financial and insurance activities', 'Professional, scientific and technical activities' and the divisions 'Human health services', 'Creative, arts and entertainment activities', 'Libraries, archives, museums and other cultural activities' are defined as KIS (Gehrke et al. 2010). Note that KIBS are a subset of KIS. While KIBS mostly serve corporate clients, KIS serve both corporate clients and private customers.

shows that they not only exhibit a tendency to concentrate in space; their location pattern also reveals a strong preference towards being located in cities (Ó hUallacháin and Reid 1991, Cooke et al. 2002, Keeble et al. 2006, Krätke 2007, Shearmur and Doloreux 2008, Gornig and Mundelius 2012). Moreover, being located in cities positively affects innovation in KIS (see *Chapter 3* and *Chapter 4* of this dissertation).

In order to further investigate the effects of cities on KIS innovation, this study applies the concept of *Urban Innovation Systems (UIS)*. It contributes to research in three ways. First, it extends the manufacturing-focused approach of empirical applications of *UIS* to services by focusing on innovation output of KIS and expanding the scope of innovation types to technological *and* non-technological forms. Second, it delivers insights in the spatial dimension of KIS innovation that has been rarely addressed and hence is under-researched in KIS literature (Muller and Doloreux 2009). Third, it contributes to the discussion on the interaction between local, i.e. city-based, and supra-local spatial contexts for innovation. This interaction is object of research in both literature on *UIS* and on the spatial implications of KIS innovation. By varying the spatial scope of cooperation partners of KIS firms, this study empirically investigates the interplay between local and supra-local resources in order to generate innovation.

The data set that is used in the analyses originates from a company survey conducted by the city of Karlsruhe, the second largest city in the German federal state of Baden-Württemberg. As KIS are relatively strongly concentrated in Karlsruhe, the city constitutes a suitable research subject. The effects of city-specific infrastructures and knowledge resources on KIS innovation are analyzed by applying identical Knowledge Production Functions (KPF) on four types of innovation pursued by KIS: product innovation, process innovation, organizational innovation and business model innovation. Independent variables are modeled as input vectors representing city-specific innovation support infrastructure, i.e. finance and support services by industrial and governmental organizations, and city-based cooperation partners.

In general, the analyses show positive effects of both city-based innovation support infrastructures and cooperation partners in the city itself (i.e. on the local level) on innovation in KIS. However, these beneficial effects vary with respect to the type of innovation pursued. Process innovation in KIS is positively affected by cooperation activities with local customers and suppliers as well as higher education organizations situated in Karlsruhe. Product innovation is neither positively influenced by city-specific innovation support infrastructures nor by cooperation with city-based partners. Contrary, for organizational innovation positive effects of the usage of city-specific financial resources and cooperation with local suppliers and customers are detectable. Finally, business model innovation is positively affected by city-specific innovation support services as they are for example provided by the Steinbeis Association. City-based cooperation activities alone appear to be insufficient in order to foster that type of innovation in KIS as positive effects of horizontal and value chain oriented cooperation activities are only detectable when analyses are expanded to all spatial levels.

While KIS and their innovation activities concentrate in cities, cities themselves become more important from a political perspective, as – especially in advanced economies – national governments have chosen to give up some of their powers in favor of cities. Hence, the balance of power, responsibility, and decision making authority between the national and the city levels of government changes to the advantage of cities (Kresl and Proulx 2000). This development successively enhances the importance of regional, respectively city, policy with respect to KIS as growth and development of urban economies depend on local abilities to generate and attract activities of KIS firms.

This chapter is organized as follows. *Section 4.2* presents the theoretical framework and the hypotheses derived. *Section 4.3* presents the survey data and develops a KPF that is used in order to test the hypotheses. The results are presented and discussed in *Section 4.4*. *Section 4.5* discusses further empirical applications and policy implications, together with concluding comments.

4.2 KIS innovation as output of urban innovation systems

In this section a theoretical framework for analyzing the effects of city-specific infrastructures and knowledge resources on KIS innovation is derived. First, the *UIS* approach is introduced and organizations that are involved in innovation processes and shape the city-specific framework conducive to innovation are presented. Second, innovation in KIS and its spatial implications are discussed together with resulting hypotheses.

4.2.1 Urban innovation systems

In order to take into account local specificities and individual path-dependent trajectories that might be beneficial for innovation in KIS, the concept of *Urban Innovation Systems* (*UIS*) is applied. Since the early 1990s research about innovation processes is increasingly directed towards systems of innovation. Initially, the concept of innovation being a systemic process was applied to the national level (Freeman 1987, Lundvall 1992, Edquist 1997). However, since the mid 1990s, the concept of Regional Innovation Systems (RIS), with *UIS* constituting a special form by defining a city as region to be analyzed, has gained increasing popularity.

An innovation system is constituted by organizations which interact in the production, diffusion and use of economically useful knowledge underpinned by an institutional framework (Lundvall 1992, Edquist 1997). Innovation thus is a result of continuous interaction of firms with each other and other knowledge generating private and public sector organizations. This reasoning relates to two notions about firm innovation. First, it is a process that relies on a variety of factors that are internal and external to a firm (Doloreux 2002). Moreover, the interdependencies and feedback loops internal and external to the firm go beyond market relations and occur in networks giving innovation a team-like character (Tödtling and Kaufmann 1999, Asheim and Gertler 2005). Second, innovation is an evolutionary process contrasting the traditional chain linkage models of innovation that oversimplify innovation processes (Feldman 1994). This implies that, besides research and development, various starting points of innovation are possible.

Being based on two strands of scientific work, namely Regional Science and National Innovation Systems (NIS), the RIS approach adopts the systemic notion of innovation but also emphasizes the role of *regional* or *local* interactions and infrastructures in order to generate innovation (Cooke et al. 1997, Cooke 2001, Doloreux and Parto 2005, Asheim et al. 2011). RIS thus takes the region as a "...lens through which to observe the ways in which different sectors or even clusters interact with the regional governance and innovation support infrastructures as well as the national and global levels." (Cooke et al. 1997, 476). It is also worth noting that the RIS approach thus implicitly relates to the idea that innovation occurs more easily when geographical concentration and proximity are present as the exchange of tacit knowledge[2] requires intensive personal contacts which in

[2]The conception of tacit knowledge was introduced by Polanyi (1967).

turn are facilitated by geographical proximity (Storper 1997, Morgan 2004).[3]

Research on the spatial distribution of innovation has impressively demonstrated that cities are the main locus of innovation.[4] Analyzing product announcements, Audretsch and Feldman (1996) find that world-first new products tend to be introduced in large cities. Duranton and Puga (2001) demonstrate that new industries emerge in large cities and then relocate within the urban hierarchy – from diversified to specialized cities in terms of economic structures – once production processes become more standardized. Other contributions show that cities tend to concentrate creative talent (Florida 2002a, for Germany see Fritsch and Stützer 2007) and highly skilled individuals (Glaeser 2000a,b) both constituting major input factors for invention and innovation. Consequently, the concept of RIS has been applied to analyze the underlying factors of innovation in cities. There are two broad categories of studies on *UIS*: City-based case studies on specific industries or types of firms[5] and comparative studies on innovation systems in different cities[6]. Two further points have to be made regarding these studies on *UIS*. First, as it is also the case with the majority of studies on RIS, the industries analyzed are in the manufacturing sector and the underlying notion of innovation mostly is technological and thus product and process oriented. Second, apart from emphasizing the role of local, city-based resources, they also point out to the relevance of supra-urban linkages for innovation. However, the questions to which degree which spatial resource contributes to innovation and if city-based resources also might be sufficient to generate innovation are left open as analyses are mostly descriptive.[7]

Theoretical and empirical evidence on RIS as well as *UIS* identifies organizations that act as cooperation partners and that shape the city-specific infrastructure con-

[3]For large-scale empirical applications of the RIS approach see, for example, ERIS (Koschatzky and Sternberg 2000, Sternberg 2000), REGIS (Tödtling and Kaufmann 1999, Cooke et al. 2000) and SMEPOL (Tödtling and Kaufmann 2001).

[4]In general, patents and R&D tend to concentrate in cities (OECD 2013).

[5]See, for example, Doloreux (2004) for SMEs in Ottawa, Blažek and Žižalová (2010) for biotechnology firms in Prague and Trippl (2011) for the food industry in Vienna.

[6]See, for example, Revilla Diez (2000) and Fischer et al. (2001) on Barcelona, Stockholm and Vienna and Simmie et al. (2002) on Amsterdam, London, Milan, Paris and Stuttgart.

[7]This point is illustrated by the following conclusion drawn by Simmie et al. (2002) in their comparative study on Amsterdam, London, Milan, Paris and Stuttgart:"The innovative and competitive advantages of the five cities are therefore based on a complex mixture of local, national and international factors. These are combined on the one hand to form their distinctive local innovation systems. No two of these systems are exactly the same. On the other hand, all five cities are major or important nodes in the international economy." (Simmie et al. 2002, 63).

ducive to innovation. These are firms, non-university research and development organizations, higher education organizations, industrial organizations, governmental organizations and finance providers.

Firms: Within a city, firms generate and diffuse knowledge. They may be regarded as learning organizations which cooperate with other organizations that share their environment in order to innovate. Within the innovation system they take up different roles: beneath being collaborators, they also act as users, producers and competitors (Doloreux 2002). As pointed out by Revilla Diez (2000) and Simmie et al. (2002) especially cooperation partners along the value chain that are located in the same city support firm-level innovation processes.

Higher education organizations and *non-university research and development organizations*: Higher education organizations (e.g. universities) are sources of academic knowledge. Regarding this role, their content of research might be directed to areas that underpin the city's economic base and thus turn them into valuable cooperation partners with respect to local innovation processes (Gunasekara 2006). However, apart from being sources of academic knowledge, higher education organizations also act as providers of academic education and local innovation system builders, thus shaping the local institutional framework (Caniëls and van den Bosch 2011). In their role as providers of academic education, higher education organizations act as educators, attractors and retainers of students, building the knowledge base for a city's economy (Boucher et al. 2003). Acting as local innovation system builders, they consult the local economy and local policy makers, create spin-offs and participate in public debates (Benneworth et al. 2009). Following the reasoning of innovation systems, non-university research and development organizations (e.g. laboratories, non-university research facilities) function as local knowledge providers and cooperation partners providing mainly research and development-based knowledge to firms. Moreover, Blažek and Žižalová (2010) find that both higher education organizations and non-university research and development organizations within an *UIS* offer indirect international knowledge resources-connections to local firms.

Industrial organizations and governmental organizations: Industrial organizations (e.g. chambers of commerce) as well as governmental organizations (e.g. business development agencies) are engaged in local governance for innovation aiming to facilitate cooperation between organizations (Cooke 2001). They provide mainly innovation support services that promote technology diffusion or are oriented towards developing new and profitable economic activities at the city level (Doloreux 2002). Examples for the innovation support services generated mainly by industrial and governmental organizations are science parks, technology transfer centres and innovation advisory agencies. For example, Simmie et al. (2002) find that technology transfer institutions play an important role in the *UIS* of Milan and Stuttgart.

Finance providers: The activities undertaken by the different organizations introduced above are supported by local financial competence, encompassing private and public finance as well as a local credit-based system (Cooke 2001).

4.2.2 Innovation in KIS and its spatial implications

Being among the most rapidly growing sectors in advanced economies, research on innovation in KIS has increased considerably since the late 1990s. However, studies differ regarding the conceptions of both KIS[8] and innovation in services[9]. Notwithstanding, three general statements on innovation in KIS can be derived. First, innovation in KIS takes different forms than in manufacturing. As described by Gallouj (2002), innovation in KIS is often intangible in the sense that it is not technology-based or embodied in material products. Thus, innovative output in KIS is often described as non-technological and manifests itself in organizational changes (Tether and Tajar 2008). Second, innovation in KIS is cooperative, as it

[8]For example, Freel (2006) distinguishes between technology-based KIBS (t-KIBS) and professional KIBS (p-KIBS) while Hipp and Grupp (2005) define KIS as services that, in a survey, depict customers and universities or non-university research institutes as important or very important sources of external knowledge.

[9]The definition and analysis of service innovation distinguish three approaches, namely the assimilation, the demarcation and the synthesis approach (Coombs and Miles 2000). The basic idea of the assimilation approach is that service innovation is similar to innovation in manufacturing industries. This approach equates innovation in services to technologically oriented product and process innovation. Regarding the analytical framework this implies that empirical indicators that were originally developed with manufacturing in mind are equally applicable to services (Gallouj and Windrum 2009). In contrast to the assimilation approach, the demarcation approach stresses the differences between innovation in services and manufacturing, seeking to establish distinctive definitions and measurement methods for service innovation (see, for example, den Hertog 2000, Preissl 2000). The synthesis approach is based on the assumption that service innovation unveils hitherto barely noticed aspects of innovation that are distributed across the economy. Even as they are primarily observable in service firms, they also occur in manufacturing firms. The approach thus is based on the insights of demarcation writers and integrates them within a neo-Schumpetarian framework, addressing technological and non-technological modes of innovation. According to Gallouj and Savona (2009), the synthesis approach currently is in an emerging and expanding phase, while the demarcation and assimilation approaches are in mature or even declining phases.

involves a considerable degree of interaction both within the firm and with external partners. As R&D departments in service firms are often absent, internal innovation processes are mostly organized in project-specific teams involving actors from various departments (Gallouj 2002, Hipp and Grupp 2005). Compared to manufacturing firms, access to external knowledge resources seems to be more important for innovating KIS (Koschatzky 1999). These external knowledge resources are mostly firms along the value chain of KIS, i.e. their customers and suppliers (Gallouj 2002, Hipp and Grupp 2005, Freel 2006, Amara et al. 2009). These supply-chain based cooperative practices for innovation seem to be more common than research-based cooperation with universities or non-university research institutes (Tether and Tajar 2008, Amara et al. 2009). However, as pointed out by Amara et al. (2009) different forms of innovation, i.e. technological and non-technological forms, pursued by KIS rely on different knowledge resources internal and external to the KIS firm. Third, being knowledge providers for a large number of economic actors, KIS are not only innovative themselves, but play an important role fostering innovation processes of their clients (Gallouj 2002, Hipp and Grupp 2005).

The importance of external knowledge resources for KIS innovation has considerable spatial implications. As already described, in order to manage their innovation processes successfully, KIS need to interact with external resources, especially firms along their value chain. In large cities, KIS can benefit from both density of and proximity to potential cooperation partners in innovation processes (Aslesen and Isaksen 2007). Empirical evidence presented in *Chapter 2* and *Chapter 3* of this dissertation demonstrates that consequently KIS tend to agglomerate their innovation input in cities and that their innovative performance is maximized in cities. However, as pointed out by studies on the market extension of KIS, their innovativeness is not only associated with access to the local, mostly city-based knowledge base, but also with the spatial expansion of their markets.[10]

In the context of RIS or *UIS*, research on KIS follows two main strands. In the first strand, KIS form an own category of economic actors on the firm-level occupying a specific role within the system of innovation. Indeed, they are portrayed as 'bridges of innovation' as they not only develop their own knowledge but stimulate the acquisition and production of knowledge in their client firms (Strambach 1998, Muller and Zenker 2001, Thomi and Böhn 2003, Corrocher and Cusmano 2014). They thus contribute both indirectly and directly to the performance of innovation

[10] See, for example, Aguilera (2003) for Lyon, Aslesen and Isaksen (2007) for Oslo, Koch and Stahlecker (2006) for Bremen, Munich and Stuttgart and Bettiol et al. (2013) for the Veneto region.

systems. The second strand of research analyzes RIS as contexts that foster the creation and growth of KIS. These analyses often refer to *UIS* as the emergence of KIS in the first place is an urban phenomenon. Within that strand of research, several theoretical and empirical analyses have shown that *UIS* provide favorable conditions for both the emergence and growth of KIS, in terms of supply and demand, i.e. market size (Egeln et al. 2004, Koch and Stahlecker 2006, Andersson and Hellerstedt 2009). However, both strands of research do not focus on KIS innovation resulting from city-specific characteristics of an *UIS*.

Hypotheses on innovation in KIS and its connection to cities

At its core, the approach of *UIS* demonstrates that a firm's innovative output to a considerable degree is shaped by local, city-specific conditions that are external to the innovating firm. These conditions encompass local cooperation activities with a variety of organizations – including other firms, higher education organizations, non-university research and development organizations – and the usage of local innovation support services as well as financial support. Innovation in KIS is a highly interactive process that requires external knowledge resources. These external knowledge resources, i.e. firms along the value chain, are concentrated in cities and being located in a city hence facilitates innovation in KIS. Integrating the reasoning of *UIS* and the spatial implications of KIS innovation into a common framework leads to three hypothesis. While *Hypothesis 1* relates to the innovation behavior of KIS firms in general, *Hypothesis 2* and *Hypothesis 3* refer to the effects of the city-specific framework on innovation activities of KIS firms.

Hypothesis 1: KIS firm innovation depends positively on internal resources and cooperation with organizations external to the firm
It is assumed that KIS firm innovation is positively affected by internal resources and cooperation activities with external organizations. Internal resources encompass knowledge embedded in KIS firms as well as research and development activities. Cooperation activities with external organizations cover other firms, higher education organizations and non-university research and development organizations. However, the positive effects of internal resources and cooperation activities with organizations external to the firm are supposed to differ according to the type of innovation pursued by the individual KIS firm. In accordance with the findings of Tether and Tajar (2008) it is assumed that technological forms of innovation involve internal research and development activities, cooperation activities with

higher education organizations and non-university research and development organizations, while non-technological forms of innovation mostly rely on cooperation activities along a KIS firm's value chain.

Hypothesis 2: KIS firm innovation depends positively on the utilization of city-specific infrastructures supporting innovative activities at the firm level
City-specific innovation support infrastructures, consisting of local financial competence and innovation support services provided mainly by industrial and governmental organizations, are assumed to foster technological and non-technological forms of innovation within KIS firms.

Hypothesis 3: KIS firm innovation is positively influenced by cooperation with city-based organizations
As *UIS* relies on the notion of regionally embedded knowledge, cooperation with *local*, city-based organizations external to the firm – other firms, higher education organizations and non-university research and development organizations – is assumed to have a positive influence on both, technological and non-technological types of KIS firm innovation.

4.3 Data and empirical model

This section presents the company survey conducted by the city of Karlsruhe and introduces a Knowledge Production Function (KPF) depicting that KIS firm innovation depends on internal resources, (city-based) external resources and city-specific innovation support infrastructures.

4.3.1 Company survey of Karlsruhe

Karlsruhe is situated in the German Federal State of Baden-Württemberg. With 298,542 inhabitants in 2013, it is the second largest city in Baden-Württemberg after the capital Stuttgart with 602,811 inhabitants (Statistical Office of the Federal State of Baden-Württemberg 2014b). The economic structure of Karlsruhe is coined by service firms that contributed 74.3% to the city's gross value added in 2011 (Statistical Office of the Federal State of Baden-Württemberg 2014a). *Figure*

4.1 shows the location of Karlsruhe, which is the geographic center of the Karlsruhe Technology Region (KTR). The KTR is made up by regional political actors encompassing 11 cities – including Karlsruhe –, four rural districts and a regional association[11] aiming to optimize regional cooperation in several areas, including economic issues (Karlsruhe Technology Region 2014).

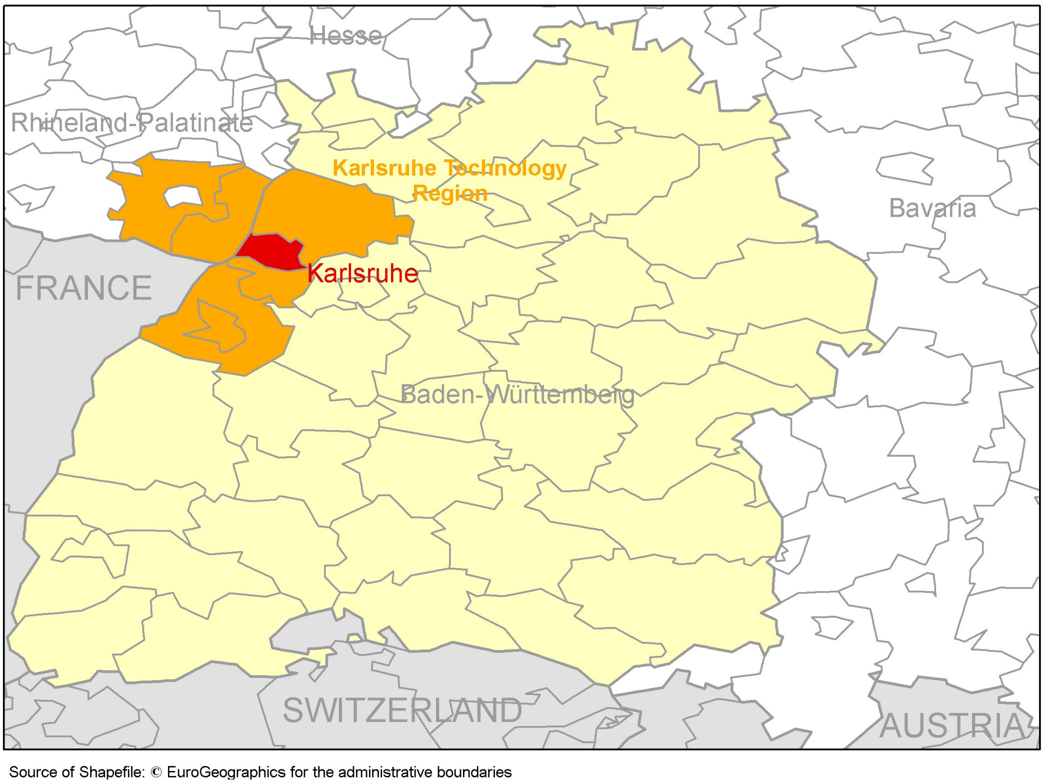


Figure 4.1: Geographic Position of Karlsruhe, Karlsruhe Technology Region and Baden-Württemberg

In 2012, 30.2% of the employees in Karlsruhe worked in KIS firms (Statistical Office of the Federal State of Baden-Württemberg 2014c). *Appendix C.1.1* depicts the location quotients of KIS sections and divisions based on NACE industry classifications with respect to the federal state of Baden-Württemberg and Germany. The city-data indicates a relative concentration of KIS with respect to the state levels: The NACE sections J 'Information and Communication', K 'Financial and Insurance Activities' and M 'Professional, Scientific and Technical Activities' show

[11]The individual actors are: Karlsruhe (city), Baden-Baden (city), Bretten (city), Bruchsal (city), Bühl (city), Ettlingen (city), Gaggenau (city), Rastatt (city), Rheinstetten (city), Stutensee (city), Waghäusel (city), Germersheim (rural district), Karlsruhe (rural district), Rastatt (rural district), Südliche Weinstraße (rural district), Regionalverband Mittlerer Oberrhein (regional association).

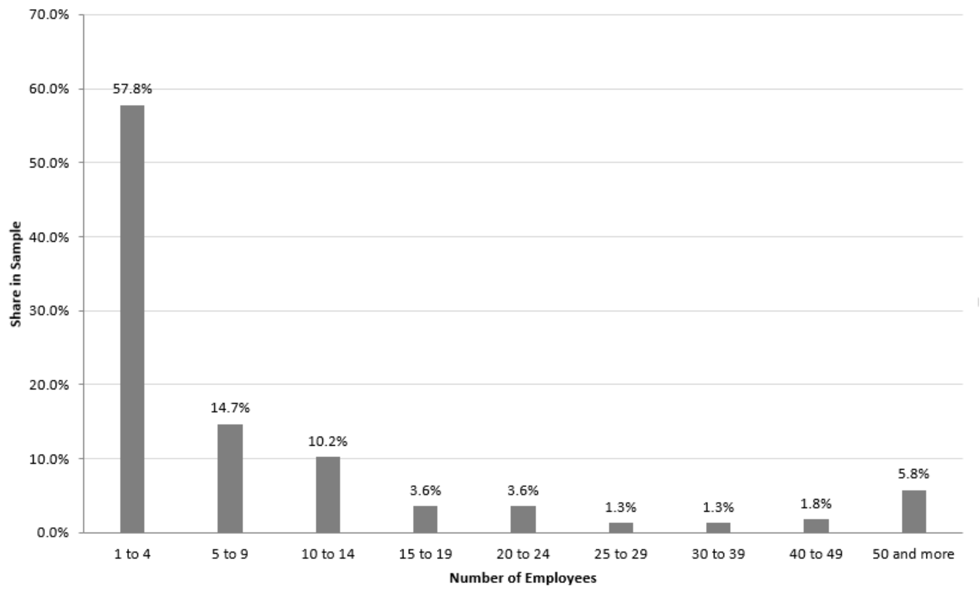


Figure 4.2: Firm size distribution of KIS in the sample

location quotients between 1.2 and 2.6, demonstrating a relatively strong concentration of KIS in Karlsruhe.

The data used in order to test the hypotheses originates from a company survey conducted by the city of Karlsruhe in August and September 2013. 2,656 firms were invited to the online survey. With 478 firms participating, the response rate was 18%. As the survey was intended to serve as a base for a city-intern competence field analysis, it was designed as a complete survey. The choice of industries considered was in accordance with the Community Innovation Survey (CIS) of the European Union[12] that is conducted every two years. However, in contrast to the CIS, the company survey of Karlsruhe does not have a lower threshold concerning firm size, thus including micro-sized companies in the data set. Furthermore, the data set contains information about innovative activities, internal resources, the spatial dimension of value chains and of external organizations cooperated with as well as on the usage of city-specific innovation support infrastructures.

As missing data was not imputed, 225 complete questionnaires of KIS firms are available for analyses. *Figure 4.2* shows the distribution of KIS firm size in the sample. The majority of firms has between 1 and 4 employees, followed by firms with

[12]The CIS excludes KIS divisions that are likely to be subject to specific provisions or provided by public institutions. These are 86 'Human health services', 90 'Creative, arts and entertainment activities' and 91 'Libraries, archives, museums and other cultural activities'. *Table C.1.1* in the *Appendix* provides an overview of all divisions defined as KIS.

5 to 9 employees. Thus, microfirms with less than 10 employees account for 72.5% of the firms participating in the survey. However, as the share of microfirms in Germany ranges between 91.8% and 94.8% in the NACE sections J 'Information and Communication', K 'Financial and Insurance Activities' and M 'Professional, Scientific and Technical Activities', KIS microfirms are presumably under-represented in the sample (Statistisches Bundesamt 2011).

4.3.2 Knowledge Production Function of KIS in Karlsruhe

The hypotheses are tested using a KPF. Initially developed by Griliches (1979), the KPF relates innovational output to the presence and volume of innovative resources. Since its emergence, the KPF has been widely applied in empirical works analyzing innovation patterns of firms.[13] The KPF that is used in order to analyze the survey data takes the following form:

$$I_{ij} = CV_i^{b_1} * INT_i^{b_2} * EXT_{ik}^{b_3} * CIT_i^{b_4},$$

where *I* denotes the innovative output of KIS firm *i* regarding innovation type *j*, *CV* a vector of control variables, *INT* the internal resources, *EXT* the cooperation activities with external organizations in region *k* and *CIT* the usage of city-based innovation support infrastructures. The coefficients b_1 to b_4 will be estimated in the analyses.

An overview on the variables and the descriptive data is given in *Tables 4.1* and *4.2*. Furthermore, an extract of the questionnaire is available in *Appendix C.3*. Innovation *I* is a binary variable, indicating if a KIS firm has introduced at least one innovation within the last three years. The types of innovation considered in the analyses refer to technological – product and process – and non-technological – organizational and business model – innovations. Regarding the degree of novelty, the notion of innovation encompasses innovations 'new to the firm'.

Control variables *A* and *S* indicate age and size of a KIS firm. *A* is measured in years since the foundation of the firm, independent of the current legal form. *S* refers to the number of employees including the proprietor of the firm.[14] Regarding the effects of *A* and *S*, no assumptions are made.

The vector of internal resources *INT* includes variables *KI* and *RD*. *KI* relates to the knowledge intensity of a KIS firm that is depicted by the percentage of employees with a graduate degree ranging from 0% to 100%. *RD* is defined as a binary,

[13] For an application within the RIS approach see Fritsch (2002).

[14] The data refers to the number of persons and not to full-time equivalents.

Table 4.1: Variables of the KPF for KIS innovation

Variable	Scale Level	Description
Dependent Variables		
I	Binary	Type of innovation; product, process, organizational or business model innovation
Independent Variables		
1. Control Variables [CV]		
A	Interval	Age of firm in years
S	Interval	Size of firm, number of employees
2. Internal Resources [INT]		
KI	Interval	Knowledge intensity, share of employees with graduate degree
RD	Binary	Research and development activities
3. External Organizations [EXT]		
VC	Binary	Vertical cooperation with other firms
HC	Binary	Horizontal cooperation with other firms
HEC	Binary	Cooperation with higher education organizations
RDC	Binary	Cooperation with non-university research and development organizations
4. City-specific Innovation Support Infrastructures [CIT]		
AIS	Binary	Usage of any city-specific innovation support service
FIN	Binary	Usage of services of the L-Bank

indicating if a KIS firm has pursued any research and development activities, occasional or continuous, within the last three years. In accordance with *Hypothesis 1*, it is assumed that *KI* and *RD* both have a positive impact on technological and non-technological forms of innovation.

Vector *EXT* denotes cooperation activities with organizations external to the firm in the last three years. Variables *VC* and *HC* refer to cooperation with other firms. While *VC* relates to vertical cooperation with suppliers or customers along a KIS firm's value chain, *HC* covers horizontal cooperation with firms that are not part of the value chain. *HEC* and *RDC* indicate any cooperation with higher education organizations or non-university research and development organizations. The conception of cooperation is broad, as it encompasses any form of knowledge exchange regarding *HC*, *HEC* and *RDC* and any exchange of knowledge that goes beyond a commercial relationship regarding *VC*. As derived in *Hypothesis 1*, the variables *VC*, *HC*, *HEC* and *RDC* should have a positive influence on innovation depending on the type of innovation. Moreover, it is assumed that cooperation with *local*, city-based organizations – in geographical proximity to a KIS firm – does have a positive impact on innovation (see *Hypothesis 3*).

Vector *CIT* represents the usage of city-specific innovation support infrastructures covered by variables *AIS* and *FIN*. *AIS* indicates the usage of any innovation sup-

Table 4.2: Descriptive statistics on variables

	Min	Max	Mean	Standard Deviation	N
Dependent Variables					
Product Introduction	0	1	0.44	0.498	225
Process Innovation	0	1	0.07	0.250	225
Organizational Innovation	0	1	0.39	0.488	225
Business Model Innovation	0	1	0.18	0.387	225
Independent Variables					
1. Control Variables [CV]					
A	0	117	16.52	14.798	225
S	1	1,500	17.48	101.461	225
2. Internal Resources [INT]					
KI	0	100	64.44	34.926	225
RD	0	1	0.44	0.498	225
3. External Organizations [EXT]					
VC	0	1	0.48	0.501	225
HC	0	1	0.33	0.471	225
HEC	0	1	0.25	0.433	225
RDC	0	1	0.06	0.242	225
4. City-specific Innovation Support Infrastructure [CIT]					
AIS	0	1	0.08	0.279	225
FIN	0	1	0.11	0.315	225

port service located in the city. These are services provided by the Steinbeis Association, the 'Innovationsallianz TechnologieRegion Karlsruhe', the 'Wirtschaftsstiftung Südwest, Gesellschaft für Beratungen und Beteiligungen' and the 'House of Living Labs'. The Steinbeis Association, headquartered in Stuttgart, aims to support knowledge and technology transfer (Steinbeis Association 2014a). Steinbeis is present in Karlsruhe with transfer centers at several higher education organizations and with transfer entrepreneurs (Steinbeis Association 2014b). Local industrial, higher education and non-university research and development organizations are partners of the 'Innovationsallianz TechnologieRegion Karlsruhe' that aims to impart research partners to local firms (Innovationsallianz TechnologieRegion Karlsruhe 2014). A local governmental organization, namely the business development agency of Karlsruhe, as well as local finance providers are founders of the 'Wirtschaftsstiftung Südwest, Gesellschaft für Beratungen und Beteiligungen'. The aim of these facilities is to promote local entrepreneurship, offering consulting services especially for small and medium-sized enterprises (Gesellschaft für Beratungen und Beteiligungen mbH 2014). The 'House of Living Labs', operated by the FZI Research Center for Information Technology – a non-profit institution for applied research in information technology and technology transfer –, serves as research environment for small and medium-sized companies supporting innovation in the domain of information technologies (FZI House of Living Labs 2014). As the city-based innovation support services are assumed to be quite specific regarding their services and target groups, they are introduced using the summarized variable *AIS*. Variable *FIN* indicates the usage of city-based finance represented by the services provided by the L-Bank in Karlsruhe. The L-Bank Karlsruhe is the local branch of the state bank of Baden-Württemberg that has the objective to promote activities of small and medium-sized enterprises.

As formulated in *Hypothesis 2*, city-specific innovation support services and finance are assumed to foster innovation within KIS firms. It is hence expected that variables *AIS* and *FIN* positively affect technological and non-technological innovation of KIS firms.

4.4 Analyses of the urban innovation system in Karlsruhe

This section applies multivariate logit regressions in order to estimate the KPF using the survey data on KIS firms collected by the city of Karlsruhe. The results indicate that KIS firm innovation is positively affected by internal resources, cooperation with external organizations and the usage of city-specific innovation support infrastructures. However, the effects vary according to the type of innovation pursued by the individual KIS firm. Furthermore, the benefits from cooperation activities with external organizations are sensitive to distance.

4.4.1 Effects of internal resources, cooperation activities and city-specific innovation support infrastructures on KIS Innovation

In what follows *Hypothesis 1* and *2* – assuming that innovation of KIS firms depends positively on internal resources *INT*, cooperation activities with external organizations *EXT* and the usage of city-specific innovation support infrastructure *CIT* – are evaluated. *Table 4.3* indicates the logit regressions for technological and non-technological forms of innovation. According to Chi-square tests all models are significant with respect to a constant only model.

Table 4.3: Effects of internal resources, cooperation activities and city-specific innovation support infrastructures on innovation in KIS

	Type of Innovation			
	Product	**Process**	**Organi-zational**	**Business Model**
1. Control Variables [CV]				
A	-0.016	-0.008	0.002	-0.027
S	0.021*	-0.001	0.040***	-0.007
2. Internal Resources [INT]				
KI	-0.001	-0.007	-0.009**	-0.005
RD	1.986***	1.321*	0.683*	0.612
3. External Organizations [EXT]				
VC	0.400	1.249*	0.600*	0.968**
HC	0.087	-0.147	0.332	0.701*
HEC	-0.074	1.178*	-0.544	-0.136
RDC	-0.870	-19.928	-0.551	-0.171
4. City-specific Innovation Support Infrastructures [CIT]				
AIS	-0.688	-0.500	-0.517	1.288**
FIN	-0.532	0.077	0.842*	-0.168
Model Fit				
-2LL	236.997	89.807	256.262	187.028
Chi-Square	72.136***	20.412**	43.993***	26.608***
N	225	225	225	225

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level

The control variables *CV* used in the logit regression are firm size *S*, depicting the number of employees including the owner, and age *A*. While *A* does not significantly affect the probability of any type of innovation pursued by the KIS firms, *S* has a significant positive effect on the probabilities of product and organizational innovation. The positive coefficients indicate that the propensities of product and organizational innovations augment with the number of employees of a KIS firm.

Hypothesis 1: Effects of internal resources and cooperation with external organizations

Hypothesis 1 assumes a positive effect of internal resources *INT*, encompassing knowledge intensity *KI* and research and development activities *RD*, on the innovation probability of KIS firms. However, *KI* shows a negative influence on the propensity of organizational innovation. This negative influence is counterintuitive and not in accordance with the assumption that knowledge is conducive to any type of innovation. A possible explanation for this finding is that the sample is characterized by microfirms. Indivisibilities regarding the workforce are likely to be more evident within small firms, where hiring an additional non-graduate employee for auxiliary works substantially decreases the degree of knowledge intensity. Thus, for samples containing a substantial share of microfirms the degree of knowledge intensity is not a reliable predictor for innovation and seems a misspecified variable. *RD* does have a significant positive impact on the probabilities of product, process and organizational innovation. Z-standardizing the coefficients[15] shows that – in accordance with *Hypothesis 1* – the impact of *RD* is especially high for product and process related forms of innovation and is of minor relevance for organizational innovation (*Table C.1.2*).

Regarding external resources *EXT*, *Hypothesis 1* suggests that KIS firm innovation is positively affected by cooperation activities with customers or suppliers (*VC*), other firms (*HC*), higher education organizations (*HEC*) and non-university research and development organizations (*RDC*). As depicted in *Table 4.3*, *VC* has a positive effect on the probabilities of process, organizational and business model innovation, thus supporting technological and non-technological modes of KIS firm innovation. Z-standardizing the coefficients (*Table C.1.2*) demonstrates that the effect of *VC* on the propensity to innovate is highest regarding business model innovation. Cooperation with other firms (*HC*) positively affects the probability of business model innovation. This finding suggests that KIS firms learn from other firms that are not part of their value chain, e.g. competitors, with respect to this specific type of non-technological innovation. Furthermore, cooperation with higher education organizations (*HEC*) positively affects the probability of an introduction of processes new to the KIS firms in the sample. Cooperation activities with non-university research and development organizations do not exert any significant influence on the propensity of product, process, organizational or business model innovation.

The results regarding the usage of internal and external resources show that KIS firms rely on different resources in order to innovate – according to the type of innovation pursued. Concerning technological forms of innovation, product introduction of KIS firms depends exclusively on internal resources while process innovation also relies on external resources, namely vertical cooperation and co-

[15]Logit regressions are based on the assumption of a latent, non-observable variable z^* that leads to states which can be observed as dichotomous variable z. As z^* is not empirically observable and therefore the error variance is not measurable, a constant error variance $\mathrm{var}(\varepsilon)=\pi^2/3$ of z^* is assumed. As the error variance of z^* is fixed, total variance of z^* differs depending on the variance explained. Thus coefficients are only comparable when they are standardized with regards to the standard deviation of z^* (Best and Wolf 2012).

operation with higher education organizations. Both non-technological types of innovation rely on cooperation with suppliers and customers. However, while organizational innovation still involves internal research and development activities besides vertical cooperation, business model innovation relies exclusively on external cooperation partners, vertical and horizontal, in order to innovate. Different forms of innovation within KIS firms hence require different knowledge inputs: While product introduction relies exclusively on internal resources and business model innovation uses solely external resources, process and organizational innovation require a mix of both, internal and external resources, for innovation.

***Hypothesis 2*: Effects of city-specific innovation support infrastructures**

Hypothesis 2 predicts a positive impact of the usage of city-specific innovation support infrastructures, comprising city-specific innovation support services *AIS* and city-based finance *FIN*, on technological and non-technological forms of innovation within KIS firms. The logit analyses show significant positive effects of *AIS* on business model innovation and of *FIN* on organizational innovation. These results indicate that city-specific innovation support infrastructures do have positive effects on innovation activities of KIS firms. The effects, however, depend upon the type of innovation pursued by the individual KIS firm. While technological forms of KIS innovation are not positively affected by the city-specific innovation support infrastructures considered in the analysis, non-technological are found to be positively influenced.

4.4.2 Localness of cooperation effects

As demonstrated, KIS firms rely on internal and external resources in order to innovate. However, the usage of internal resources and the cooperation activities with external organizations vary according to the type of innovation pursued by the individual KIS firm. Regarding cooperation with organizations external to a KIS firm, *Hypothesis 3* states that cooperation with *local*, city-specific organizations is sufficient in order to induce a positive effect on innovation. To verify this hypothesis, it is hence necessary to geographically adapt the KPF for process, organizational and business model innovation as these types of innovation rely, to a different degree, on cooperation activities with organizations external to the firm. In order to adjust the model regarding the geographical position of cooperating organizations, six multivariate logit regressions are performed, integrating the different geographic positions of cooperation partners (*Table 4.4*). While the City Models allow for cooperation partners in Karlsruhe only, the Urban Models take into account cooperation partners in Karlsruhe and the KTR thus describing a concentric extension of the region considered in the analysis.

Table 4.4: Localness of cooperation effects

	Type of Innovation and local Model					
	Process		**Organizational**		**Business Model**	
	City	**Urban**	**City**	**Urban**	**City**	**Urban**
1. Control Variables [CV]						
A	-0.006	-0.008	0.001	0.001	-0.029	-0.029
S	-0.001	-0.001	0.043***	0.043***	-0.005	-0.005
2. Internal Resources [INT]						
KI	-0.008	-0.008	-0.010**	-0.010**	-0.006	-0.006
RD	1.377*	1.296*	0.848**	0.835**	0.876**	0.863**
3. External Resources [EXT]						
VC	0.869	1.026*	0.751**	0.572	0.676	0.617
HC	-0.466	-0.482	0.508	0.594	0.330	0.427
HEC	1.392**	1.337**	-0.476	-0.475	0.029	0.015
RDC	-19.826	-19.845	-1.898	-1.759	-0.537	-0.488
4. City-specific Innovation Support Infrastructures [CIT]						
AIS	-0.823	-0.697	-0.474	-0.468	1.251**	1.274**
FIN	-0.047	0.066	0.728	0.765	-0.372	-0.327
Model Fit						
-2LL	92.452	91.299	252.985	254.025	193.119	192.919
Chi-Square	17.767*	18.919**	47.270***	46.230***	20.517**	20.717**
N	225	225	225	225	225	225

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level

According to Chi-Square tests, all local models are significant with respect to a constant only model. Before referring to the geographic patterns of external cooperation of KIS firms, it has to be pointed out that the coefficients of *RD* vary with expanding regional cooperation. However, controlling for interaction effects between internal research and development activities and external resources does not show significant results.

***Hypothesis 3*: *Local*, city-based effects of vertical cooperation, horizontal cooperation and cooperation with higher education organizations**

The logit regressions in *Table 4.4* show that effects of cooperation activities with external organizations are sensitive to distance depending on the type of innovation pursued and external organization cooperated with. Cooperation with customers and suppliers (*VC*) induces significant positive effects on the local levels regarding the probabilities of process and organizational innovation. However, there is no local effect of *VC* on the propensity of business model innovation. Cooperation with other firms (*HC*), that also is expected to have a local effect on business model innovation, does not induce significant positive effects on the propensity to innovate in the geographically adjusted model. Collaborative activities with higher education organizations (*HEC*) positively influence the probability of process innovation in the City as well as Urban Model.

These results lead to four central conclusions regarding innovation types and cooperation partners. Firstly, cooperation along local, city-based value chains and thus the usage of local knowledge embedded in suppliers and customers is sufficient in order to generate process and organizational innovation within KIS firms. Note that this holds although the majority of suppliers and customers of KIS is situated outside Karlsruhe and the KTR (*Table 4.5*). However, local knowledge embedded in value chains alone does not induce business model innovation. Secondly, as it was the case for vertical cooperation, horizontal cooperation on the city level is not sufficient in order to sustain firm level innovativeness regarding business model innovation. These findings concerning business model innovation are in accordance with Oinas and Malecki (1999, 2002) who state that local connections of firms are insufficient for sustaining firm-level innovativeness and that extra-regional contacts are of key importance, as they provide access to ideas, knowledge and technologies that are not available within the limited context of the region. Thirdly, the positive impacts of cooperation with higher education organizations on process innovation in the City and Urban Model indicate that – in accordance with the reasoning of *UIS* – the local higher education organizations underpin the region's economic base by their content of research regarding process innovation and thus constitute key centripetal forces with respect to this type of innovation. Fourthly, cooperation activities leading to specific types of innovation are unevenly distributed in geographical space. While for process innovation – constituting a form of technological innovation – cooperation with local external resources is sufficient in order to generate innovation, especially business model innovation relies on a combination of local and supra-local external resources. This uneven distribution of cooperation necessities in space according to the type of innovation pursued is probably due to different contact intensities required depending on the innovation type (McCann 2007) or to the combination of knowledge types, codified or tacit, necessary to induce innovation.

Table 4.5: Spatial vertical cooperation potential of KIS

Region	% of Suppliers [Mean]	% of Customers [Mean]
City	29	25
Urban	41	40
State	60	61
National	94	92
International	100	100
N	225	225

4.5 Discussion

Research on the location patterns of KIS and their innovative performance has demonstrated that KIS tend to concentrate in cities and that being located in cities fosters innovation in KIS. This study applies the approach of *UIS* in order to investigate the underlying mechanisms of innovation in city-located KIS. It is argued that due to the cooperative nature of KIS innovation, being located in a city offers innovation advantages to KIS resulting from both density of and proximity to potential cooperation partners.

The empirical results lead to three central conclusions. First, in accordance with other studies on innovation in KIS, the analyses underline that cooperation along the value chain, i.e. with customers and suppliers, is of major importance for innovation in KIS. However, differentiating for innovation types demonstrates that the positive effect holds for business model innovation, organizational innovation and process innovation, but not for the introduction of new products or services. Second, city-specific innovation support infrastructures foster innovation in KIS. Again, differentiating for innovation types reveals that this holds only for non-technological types of innovation which in turn are of special relevance for KIS. Third, the analyses demonstrate that cooperation along *local* value chains is sufficient in order to generate process and organizational innovation in KIS. The same holds for *local* cooperation with higher education organizations to foster process innovation. However, analyzing the *local* effects on business model innovation, reveals that only the combination of *local and supra-local* cooperation activities along the value chain and with horizontal partners generate innovation.

Policy implications with respect to the strengthening of innovation opportunities for KIS firms in order to attract knowledge-intensive service activities to cities refer to two key levers. First, the city-specific cooperation potential provided by customers, suppliers and higher education organizations plays a key role in attracting KIS firms. Thus, fostering the agglomeration of vertically interconnected firms that provide sufficient vertical cooperation potential is of crucial importance in order to attract KIS firms. Furthermore, higher education organizations play an important role as they support process innovation within KIS firms. Promoting activities of higher education organizations that underpin a city's economic base renders cities attractive for economic activities of KIS firms. Second, city-specific infrastructures do have the potential to enhance innovative activities of KIS firms with regards to specific innovation types. It is hence advisable to generate infrastructures conducive to KIS firm innovation with regards to the type of innovation bearing in mind a presumably high specificity of city-based innovation support infrastructures encompassing innovation support services and finance. As the existing city-specific innovation support services show low usage rates among KIS firms, it is recommended to policy makers to pay more attention to policies supporting innovation within KIS. This policy recommendation is in close accordance with Green et al. (2001) showing that service firms – compared with manufacturing firms – are less often the assumed targets of innovation policies and thus tend to be overlooked in activities aimed at promoting innovation.

In order to gain a deeper understanding of the underlying mechanisms of KIS innovation in cities and to derive further policy implications, additional empirical applications are necessary. There are manifold indications that KIS are not a homogeneous group as they are diverse with respect to their activities and their innovation behavior (see, for example, Evangelista 2000, Tether 2003, Hollenstein 2003, Camacho and Rodríguez 2005). Thus, further research should incorporate the diversity of KIS. Additionally, the present contribution focuses on higher education organizations as providers of academic knowledge to local firms. However, as described before, the role of higher education organizations within *UIS* also expands to the provision of academic education and their role as innovation system builders. Especially their impact on the local labor market – shaping the city-specific knowledge base – should be addressed in additional studies. Furthermore, literature that deals with the notion of cities as environments fostering creativity often refers to subcultural scenes and a city underground in order to explain local innovation opportunities (see, for example, Cohendet and Zapata 2009). Taking this reasoning into account – which encompasses a broader notion of institutions – might also enhance the understanding of KIS agglomeration in cities. Finally, the uneven distribution of cooperation necessities regarding different types of innovation calls for further research incorporating contact intensities required for and knowledge typologies involved in innovation.

Chapter 5

Conclusion

The studies presented in this dissertation contribute in several ways to the current scientific discussion addressing the effects of cities on firm-level innovation. Directions of research conducted are based on empirical and conceptual evidence on the beneficial effects of cities on innovation introduced in *Chapter 1*. The study in *Chapter 2* analyzes industry-specific location patterns of R&D in Germany. It contributes to research on empirical evidence of spatial R&D distribution in three ways. First, it is the first study that applies measures of continuous space to the geographical distribution of corporate R&D activity for a whole economy. Second, by differentiating between industries, the analyses demonstrate if and how spatial R&D patterns of specific industries significantly deviate from the overall location pattern of corporate R&D. Third, and most important, it develops measures in order to assess effects of cities on industry-specific spatial R&D organization. These measures allow to demonstrate if and how spatial corporate R&D patterns of specific industries significantly deviate from the general location pattern of corporate R&D in relation to cities. The studies in *Chapter 3* and *Chapter 4* are based on the empirical evidence that innovative activities in general tend to concentrate in cities and on the observation that it is primarily economic and innovative activities of knowledge-intensive services exhibiting this spatial organization pattern. They add to research by addressing the under-explored connection between innovation in knowledge-intensive (business) services and geography applying the concepts of *urbanization economies* and *Urban Innovation Systems (UIS)*.

This chapter is organized as follows. *Section 5.1* presents and discusses the central findings of the studies in *Chapter 2, Chapter 3* and *Chapter 4*. Moreover, it brings together the findings regarding innovation types. Policy implications and prospects for future research are depicted in *Section 5.2*.

5.1 Results and discussion

Chapter 2 relates to two perspectives on the spatial patterns of firm-level R&D activity by analyzing *(a)* industry location patterns of R&D and *(b)* industry location patterns of R&D in relation to cities. The results indicate if and how spatial patterns of R&D in industries deviate from the overall spatial distribution of R&D in Germany. Analyzing these location patterns on a 3-digit industry-level reveals that 40.8% of industries deviate significantly from random spatial location patterns and thus are localized or dispersed. Looking at industry sectors, the share of localized industries in production is higher than in services. Knowledge creation in production industries hence tends to be more localized than in services. In service industries dispersion occurs more often than localization. Especially research-intensive service industries exhibit strong cross-distance indices of dispersion.

Taking into account distances where localization occurs, reveals that industry-specific R&D is clustered over relatively long distances of about 100km. Shifting the perspective from R&D establishments to the individual researcher even increases that relatively long distance of clustering to an interval from 260km to 350km. In total, the results indicate that taking into account the size of R&D establishments in terms of researchers employed there, either leads to dispersion or random distribution at distances from 0km to 200km. This implies that at this distance interval the number of researchers in an industry either follows the general distribution of R&D workforce or is even less than one would expect from taking the general spatial distribution of researchers as a reference.

Overall, the evidence on industry-specific spatial concentration of R&D is relatively weak. Localization of both R&D establishments and researchers, if it occurs, mainly is observable for production industries over relatively long distances. However, this observation does not contradict the notion of R&D itself being concentrated. It rather suggests that clustering of R&D establishments or researchers at short distances is not, or only weakly, connected to the 3-digit industries in which innovative activities are performed.

The picture of the sector-specific spatial distribution of R&D changes radically when cities are integrated in the analyses. For production industries, if R&D activities are urban localized – in the sense that they locate above-average in or near to cities –, they tend to cluster at a certain radius *around* a city's external borders. For service industries, spatial dispersion found in industry-specific patterns of R&D activities is connected to urban localization. Especially research-intensive service industries exhibiting dispersion are localized in relation to cities. Moreover, above average concentration of service R&D directly *in* cities is depicted.

While the analyses in *Chapter 2* explicitly step back from theoretical concerns and aim to contribute to the empirical examination of industry-specific agglomeration patterns of innovative activity, they nevertheless implicitly relate to the continuing debate on *Marshall-Arrow-Romer-externalities*, *urbanization economies* and *Jacobs-externalities* as introduced in *Chapter 1*. Assuming that the expected returns to R&D activities are taken into account when companies decide where to locate them, as for example demonstrated in Duranton and Puga (2005), the location of R&D and thus knowledge potential in space hints to anticipated knowledge spillover mechanisms. In the light of that reasoning, localization, as identified in *Section 2.3*, might be defined as industry-specific spatial specialization in R&D activities. It indicates that industries with localized R&D activities profit or expect to profit from above-average spatial proximity of their R&D activities, i.e. an R&D-related intra-industry transmission of knowledge (*Marshall-Arrow-Romer-externalities*). Consequently, urban localization as identified in *Section 2.4*, hints to above-average industry-specific beneficial effects of cities on R&D (*urbanization economies* and/or *Jacobs-externalities*). Note that these effects are not mutually exclusive as industries might simultaneously exhibit localization and urban localization.

Relating the results indicated above to theoretical reflections leads to further conclusions. First, interpreting industry-specific localization as indicator for *Marshall-Arrow-Romer-externalities* suggests that they are either of minor relevance for R&D activities or occur over relatively long distances. It thus appears likely that spatial clustering of R&D establishments and researchers is only weakly connected to the industry in which the innovative activities are performed. Moreover, as the data reveals a strong concentration of R&D activities themselves, especially in the researcher-weighted approach, R&D appears to attract R&D rather on a general than on an industry-specific level. Second, taking urban localization as indicator for *urbanization economies* and/or *Jacobs-externalities* reveals that industries in both sectors, production and services, benefit from innovation advantages emanating from cities – however, at different spatial scales. Especially research-intensive services tend to concentrate their knowledge potential as well as their 'absorptive capacity' directly in cities. R&D in these industries thus benefits above-average from knowledge spillovers originating from urbanity. However, these findings leave open the questions to which extent *urbanization economies* or *Jacobs-externalities* are at work and which city-specific endowments attract firm-level

R&D.

Chapter 3 analyses to which degree innovative activities in Knowledge Intensive Business Services (KIBS) benefit from *urbanization economies* differentiating between the four innovation types product introduction, product improvement, process innovation and organizational innovation new to the firm.[1] The concept of *urbanization economies* relates to knowledge spillovers that arise from the city itself, i.e. its scale, independent from other factors like economic or sectoral structures (Glaeser et al. 1992, 1995, Henderson et al. 1992, Glaeser 1999). Like *Marshall-Arrow-Romer-externalities* and *Jacobs-externalities* – both relating to economic structures – the idea of *urbanization economies* relates to the logic of face-to-face contact fostering knowledge transmission and hence innovation. In order to disentangle the effects of these various sources of potential knowledge spillovers, economic structures are controlled for in the empirical model. To account for city sizes in the analyses, cities in Germany are grouped in small cities (50,000 to less than 100,000 inhabitants), large cities (100,000 to less than 500,000 inhabitants) and metropolises (500,000 and more inhabitants).

The results of the empirical analyses indicate that *urbanization economies* – which are modeled as decreasing innovation probabilities of KIBS establishments with growing distance to the nearest city type – vary in relation to both city sizes and innovation types. Overall, the results suggest that, for the majority of innovation types, *urbanization economies* increase with augmenting city size. The bigger a city, the stronger the decrease in innovation probabilities with growing distance from the city. This observation holds for product improvement, process innovation and product introduction in KIBS where the reduction in innovation probabilities is significantly stronger with growing distances to metropolises than to large or small cities. An exception from this general observation is found for organizational innovation: Probabilities of innovation even exhibit a slight increase with growing distance from large cities.

The strengths of the proximity-based beneficial effects of especially metropolises on innovation in KIBS vary between innovation types. Increasing the distance of a KIBS establishment to a metropolis from 0km, i.e. being directly located in the metropolis, to 25km leads to a decrease of 56.2% in average innovation probabilities of product improvement. The corresponding decreases in average innovation probabilities for process improvement and product introduction are 51.3% and

[1] The survey-based identification of innovation types is inspired by the definitions and procedures as depicted in the *Oslo Manual* (OECD 2005).

42.3%. This hierarchy in the relative decreases of average innovation probabilities also holds for large and small cities where distance-effects for product introduction even become insignificant.

The results of the analysis verify the existence of *urbanization economies*. They demonstrate knowledge spillovers originating from cities, especially metropolises, which exert positive effects on product improvement, product introduction and process improvement in KIBS. In the light of the conceptual descriptions in the introduction to this dissertation, this leads to the conclusion that the openness of innovation processes in KIBS together with the concept of knowledge tacitness has severe implications regarding the relationship between location of and innovation in KIBS establishments. The results indicate that "being there", i.e. near or in a city that provides maximum face-to-face contact as approximated by population, indeed effectively enhances knowledge transmission and hence innovation in KIBS. This conclusion regarding the usage of proximate city-based knowledge resources for innovation is in accordance with O'Farrell et al. (1996) who show that firms in less urban regions face narrower local knowledge supply bases when conducting innovation and with Doloreux and Shearmur (2012) who derive that firms in peripheral regions may compensate for narrower local knowledge supply bases by attempting to 'internalize' some of the benefits which are external to firms in urban regions. However, the beneficial effect of "being there" is limited regarding organizational innovation and is varying in strengths for the other three innovation types. Thus, the necessity of face-to-face interaction and knowledge transmission provided by a proximate city varies with the type of innovation pursued in KIBS. Regarding location decisions of KIBS establishments or KIBS R&D activities, the results on the existence and strengths of *urbanization economies* indicate that they constitute centripetal forces fostering KIBS agglomeration in cities. Moreover, the larger a city, the stronger are its centripetal forces.

The analyses of the effects of cities on innovation in *Chapter 4* step back from modeling the city in terms of its scale and economic structures (i.e. industry specialization and diversity) as potential sources of knowledge spillovers. Instead, they turn to the question which city-specific assets foster the innovativeness of Knowledge Intensive Service (KIS) firms. As a city's assets most likely are highly specific due to individual, path dependent trajectories (Iammarino 2011), the study is designed as a case study focusing on one city – Karlsruhe. In order to derive the effects of city-specific assets on firm-level innovation the concept of *Urban Innovation Systems (UIS)* serves as theoretical base. At its core, it puts an emphasis on interactions between agents encompassing both private and public sectors to engender and diffuse knowledge and hence innovation in city-specific environments (Asheim et al. 2011). It is worth noting that these actors have a dual function as they might act as cooperation partners and shape city-specific infrastructures conducive to innovation. Similarly to the study in *Chapter 3*, the analyses relate to four types of innovation: product or service introduction, process innovation, organizational innovation and business model innovation.[2]

Generally, the results demonstrate positive effects of both the utilization of Karlsruhe-specific innovation support infrastructures (i.e. finance and support services by industrial and governmental organizations) and cooperation activities with public and private agents within the city on innovation in KIS. The beneficial effects of these Karlsruhe-specific assets vary with the type of innovation pursued by KIS located in the city. Process innovation is positively affected by cooperation with customers and suppliers as well as higher education organizations in the city. Organizational innovation is also fostered by local vertical cooperation and additionally profits from financial resources provided by actors located in Karlsruhe. Business model innovation is not positively affected by cooperation activities on the city level but profits from innovation support services provided by industrial and governmental organizations in Karlsruhe.

However, two further points concerning the beneficial effects of cities have to be made. First, for product or service introduction in KIS, the utilization of city-specific innovation support infrastructures as well as cooperation activities with local, i.e. city-based, and supra-local resources shows no significant effects. KIS in Karlsruhe exclusively rely on R&D activities in order to introduce new services and products. Thus, the idea of open innovation processes in KIS does not hold and "being there" potentially is of no relevance for the introduction of new products or services. Second, on a global level business model innovation is fostered by both vertical and horizontal cooperation activities. Exclusively city-oriented cooperation activities are not sufficient in order to exert a positive effect on innovation. Business model innovation is thus only positively affected by cooperation activities on both local *and* supra-local levels. It is hence not only local face-to-face interaction but also its combination with supra-local contact with other firms that is conducive to this type of innovation, whereas process innovation and organizational innovation are already induced by local cooperation.

The results in *Chapter 4* lead to the conclusion that KIS benefit from local city-

[2]As before, the survey-based identification of innovation types is inspired by the definitions and procedures as depicted in the *Oslo Manual* (OECD 2005).

specific assets in order to innovate. The analyses depict a city-based system that fosters innovation. However, differentiating between types of innovation reveals that resources provided within the system exert different effects and are not necessarily sufficient in order to induce beneficial effects on innovation.

The comparison of the empirical results in *Chapter 3* and *Chapter 4* suggests itself, although it is subject to reasonable reservations that should not be glossed over. First, being a case study based on individual city-specific assets, the results derived in *Chapter 4* are not readily transferable to other cities in Germany. Second, KIBS and KIS both encompass knowledge-intensive service industries. However, being a subset of KIS, KIBS mostly serve corporate clients while KIS serve both corporate clients and private customers. Third, although both data sets used in the studies are survey-based and inspired by the *Oslo Manual*, the definitions applied to innovation types are not congruent. These different definitions can be accounted for by only directly comparing results regarding product or service introduction and process innovation. Additionally, it is advisable to jointly compare the results on organizational and business model innovation in *Chapter 4* to the results on organizational innovation in *Chapter 3*.

Keeping these reservations in mind, the following – admittedly rough – holistic conclusions regarding the effects of cities on innovation types can be drawn. For process innovation indicating at least a significantly improved production or delivery method, both studies depict beneficial effects of being located in or near to a city. The case study reveals that *urbanization economies* detected in *Chapter 3* might be connected to within-city cooperation activities with suppliers and customers as well as higher education organizations. Consequently, these partners are likely to hold a prominent position as sources of knowledge spillovers fostering that type of innovation in knowledge-intensive service firms. For product introduction, i.e. the introduction of a service or product new to the firm, *urbanization economies* are exclusively found for metropolises. KIS in the case study for a large city with approximately 300,000 inhabitants solely rely on internal resources in order to introduce new products. These findings suggest that knowledge-intensive service firms adjust their usage of nearby external resources for innovation depending on the local resources available. For organizational innovation, no beneficial effects of cities are detected in *Chapter 3*. This is in line with the findings in *Chapter 4* indicating that only the interaction of local, city-based *and* supra-local vertical and horizontal partners exerts a significant positive effect on innovation.

5.2 Policy implications and research prospects

The prime focus of the studies in this dissertation is the connection between firm-level innovation and cities. This has direct policy implications since the concepts introduced in *Chapter 1* and referred to in the studies feed into innovation policy on all state levels. As found in *Chapter 2*, the evidence for industry-specific localization of R&D is relatively weak since it occurs over long distances. Clustering of R&D establishments or researchers at short distances seems not or only weakly connected to the 3-digit industries in which R&D is conducted. Since this observation changes radically when cities are integrated in the analysis, there is quite some indication that, for innovative activities on the firm level, *urbanization economies* and/or *Jacobs-externalities* in R&D prevail over *Marshall-Arrow-Romer-externalities* and the *Cluster* approach.

The results may thus yield some implications for the ongoing debate on German cluster policy. Numerous cluster initiatives have been launched in Germany at both federal and state levels during the last 20 years. Evaluations of these cluster policies have revealed several positive influences.[3] For instance, an analysis on the impact of the Leading-Edge Cluster Competition on the formation of innovation networks showed a significant effect on the network structure in terms of density, centralisation and geographical reach.[4] On average, more than half of the existing linkages were either initiated or intensified by the cluster policy, leading to an increased density of the network.

However, it is crucial to know that most policies follow Porter's *Cluster* approach defining a cluster as geographic concentration of interrelated companies and institutions in a particular field (Porter 1998). Thus, the aim of cluster policies is to encourage the spatial agglomeration of firms and other organisations belonging to a particular sectoral, industrial or technological field in order to foster innovation. Contrary to this industry-related approach to regional innovation policy, the results in *Chapter 2* indicate that knowledge spillover-caused incentives for technologically related knowledge-producers – reflected by their common industry affiliation – to spatially agglomerate are likely to be rather weak. Instead, the provision of resources, skills, infrastructure and services outside of the firm's in-

[3]For a detailed overview of the varying implementations and effects of German cluster policies and initiatives, see EFI (2015).

[4]The Leading-Edge Cluster Competition was launched by the Federal Ministry of Education and Research in 2007 as part of the High-Tech Strategy. It addressed high-performance clusters formed by business and science. For an evaluation see Rothgang et al. (2014).

dustry specific knowledge sphere – as they are provided by cities – appear to be more important for the settlement of innovative activity. The implications for policy are twofold: First, *Marshall-Arrow-Romer-externalities* – if at all – only secondarily affect location decisions regarding R&D. Instruments aimed at stimulating R&D agglomeration need to be designed accordingly. Second, if for some industries *Jacobs-externalities* have a higher impact on R&D clustering and the locational benefits of cities and industrial heterogeneity in R&D potentially outweigh the benefits of intra-industry knowledge transfer, one may have to question the paramount aim and political support of attracting "more of the same" – at least in terms of R&D activities.

Being sources of *urbanization economies* and providers of other innovation enhancing assets, cities – especially metropolises – do have a self-reinforcing advantageous position over other types of geographical space for attracting service industries that rely to an above-average degree on knowledge and knowledge-creation. The observable spatial concentration of both economic and innovative activities of knowledge-intensive services in cities together with their increased relevance as contributors to (regional) economic growth – by own innovation activities and the enhancement of innovation capacities in client firms (Muller and Zenker 2001) – raises questions regarding the need of policy intervention. This is particularly relevant for policy aiming at regional convergence.[5]

Policy initiatives for regional convergence can relate to two key strategies. First, they should target knowledge-intensive services in non-urban regions by supporting build-up of internal competencies and supra-local linkages in order to compensate for lacking proximate city-based resources conducive to innovation. However – as indicated by Miles (2005), Herstad and Ebersberger (2015) as well as the studies in *Chapter 3* and *Chapter 4* – the beneficial effect of cities on innovation in knowledge-intensive services suggests that their potential for growth in non-urban regions is limited. This results in two factors leading to lower growth prospects in non-urban regions. On the one hand, as knowledge-intensive services enhance innovation capacities in (spatially proximate) client firms, firms in non-urban regions are less likely to profit from proximity to knowledge-intensive services. On the other hand, being major innovators themselves and under-represented in non-urban regions, the direct contribution to innovation and growth of knowledge-intensive services is potentially lower in these regions. Taking this reasoning into account, a second strategy for policy initiatives lies in the strengthening of links

[5]For an overview on policy initiatives addressing knowledge-intensive (business) services on the level of the EU and and its member states, see Schricke et al. (2012).

between city-located knowledge-intensive services and potential client firms in non-urban regions. These links could be initiated and established by intermediaries working in both directions, i.e. towards KIBS and client firms.

As the studies depicted in *Chapter 2* and *Chapter 3* apply continuous measures of space, they allow to specify the above statements in terms of distance. Research-intensive services locate their innovative activities directly *in* cities and substantial distance decay effects in innovation probabilities of KIBS are already observable at a radius of 25km from cities. This indicates a relatively sharp divide between cities and non-urban areas in terms of allocation of innovative activities and benefits from cities.

However, differentiating between innovation types reveals different effects that might alter policy implications. There are several findings in the studies which therefore deserve attention in future research. First, the study in *Chapter 2* finds that R&D activities in urban localized service industries tend to allocate *in* cities, while R&D activities in manufacturing industries tend to allocate *around* large cities. Second, as demonstrated in *Chapter 3, urbanization economies* are not verifiable for organizational innovation and solely significant for metropolitan areas regarding product introduction. Additionally, the calculation of relative odds ratios reveals concentric allocation patterns of organizational innovation and process innovation with growing distances to cities. Third, the analyses of the *UIS* in Karlsruhe in *Chapter 4* indicate that business model innovation is fostered by both vertical and horizontal cooperation activities. However, exclusively city oriented cooperation activities are not sufficient in order to exert a positive effect on business-model innovation. Only the combination of urban face-to-face interaction and supra-local contact with other firms is conducive to this type of innovation.

These findings set an agenda for future research evolving around the following questions:

1. *Which within-city variations are observable in innovation patterns and how are they connected to a city's spatial structure?*
   The modeling of cities in the studies does not take into account distances within cities but solely distances to postcodes with city characteristics. This implies that within-city dynamics of location and innovation do not enter the analysis. Recent case studies on Milan, Amsterdam and the Jönköping city region indicate that location patterns of establishments within cities are not arbitrary but deviate significantly from randomness (Antonietti et al.

2013, Jacobs et al. 2014) and might also be connected to their innovativeness (Klaesson and Norman 2015). In the light of the results that indicate distance-based innovation patterns, it would be of interest to evaluate in a systemic approach whether and to which degree the observable patterns sustain within cities or are rather connected to the distinction between the urban and the non-urban.

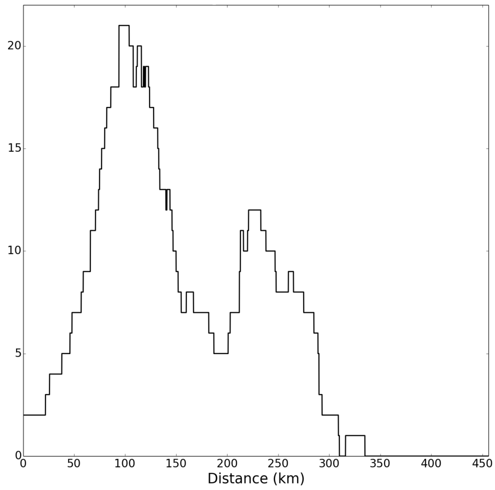
2. *What type of innovation is more likely to occur in cities, and what type occurs in non-urban settings?*
   So far, our understanding of how different technological and non-technological innovation types are allocated in relation to cities is very limited. Apart from conceptual evidence, as indicated by the model of McCann (2007) and empirical work for Canada (Shearmur 2010, 2011, Doloreux and Shearmur 2012) and for Germany (*Chapter 3* of this dissertation), spatial-analytic distance-based work on this issue is scarce. In general, empirical evidence indicates a geography of innovation in relation to cities that plays out in a continuous fashion across space. This geography varies with respect to industries and innovation types. In order to better depict and understand the various spatial patterns, more research using micro-geographic data sets is required.

3. *To what extent do firms rely on proximate city-based interactions in order to innovate, and to what extent do they rely on supra-local interactions?*
   The results on the *UIS* of KIS in Karlsruhe (*Chapter 4*) indicate that it is likely that a combination of local, city-specific and supra-local external knowledge resources constitutes a necessary condition for innovation. This finding relates to the literature on 'global pipelines' that stresses the importance of establishing supra-local national and international communication channels for innovation in addition to local ones (Bathelt et al. 2004, Gertler and Wolfe 2006, Isaksen 2009, Fitjar and Rodríguez-Posé 2011, Fitjar and Huber 2014, Herstad and Ebersberger 2015). The consensus emerging from this strand of research is that local and global interaction operate together in fostering firm-level innovation and are complementary. However, empirical evidence is limited regarding innovation types and industries and thus requires further investigation.

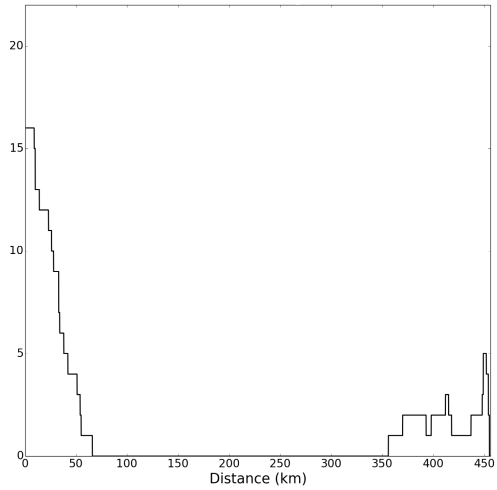
Appendix A

Appendix to Chapter 2

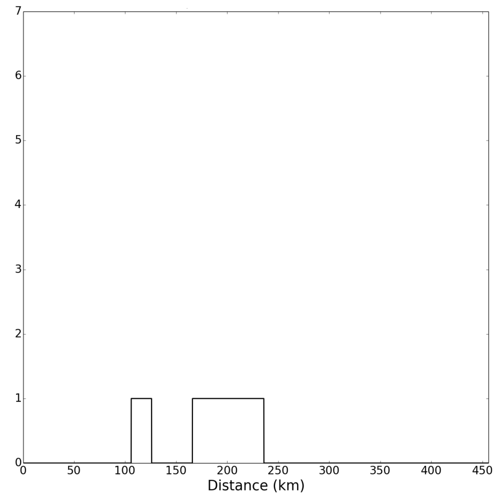
A.1 Distance-based sectoral location patterns



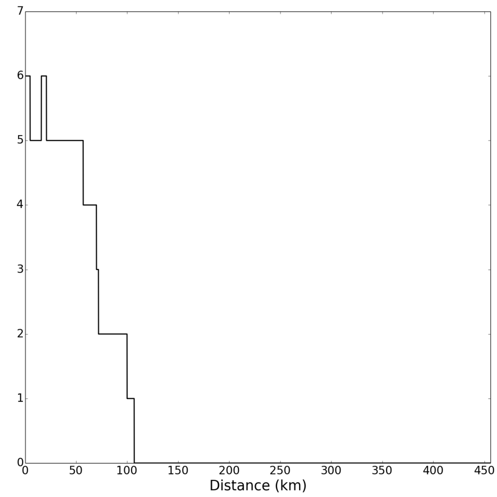
(a) Localization production



(b) Dispersion production

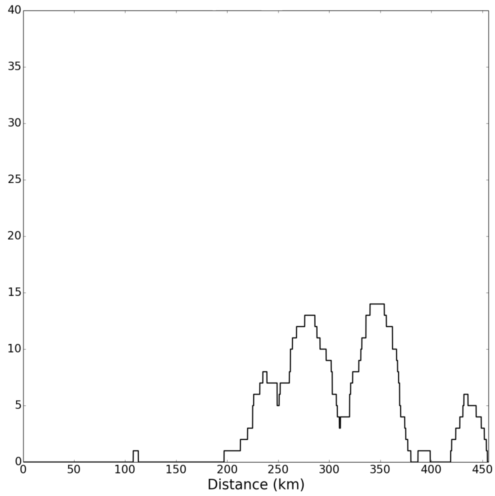


(c) Localization services

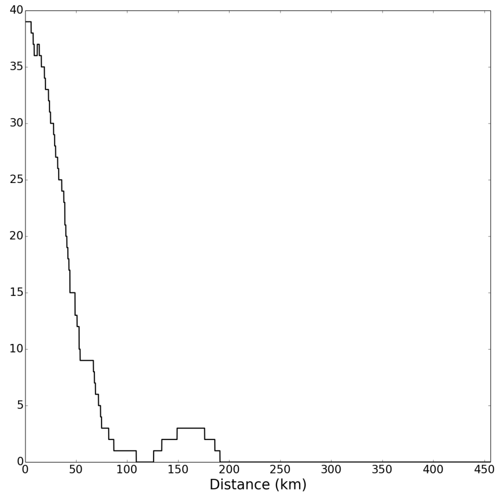


(d) Dispersion services

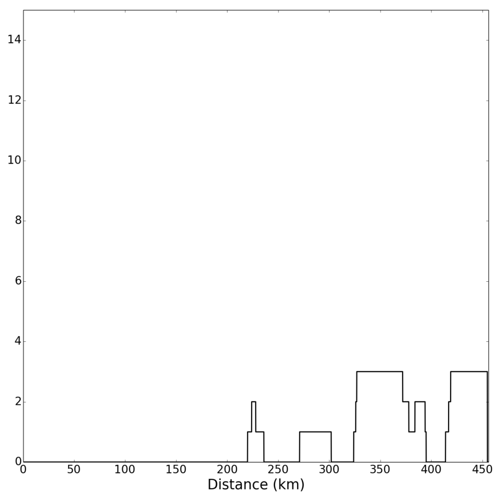
Figure A.1.1: Sectoral distance patterns of industries exhibiting localization and dispersion of R&D



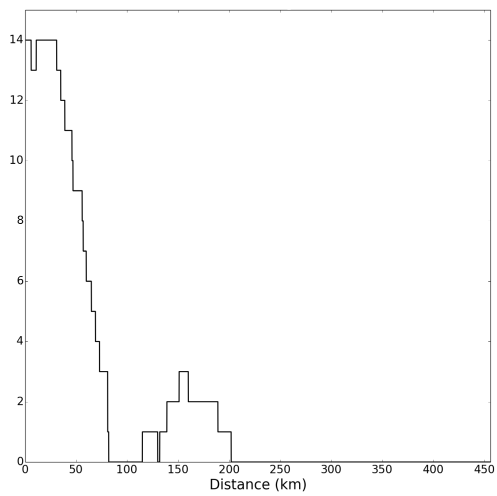
(a) Localization production



(b) Dispersion production



(c) Localization services



(d) Dispersion services

Figure A.1.2: Sectoral researcher-weighted distance patterns of industries exhibiting localization and dispersion of R&D

A.2 Research-intensive 3-digit industries in Germany

Table A.2.1: List of research-intensive 3-digit production industries in Germany

3-digit production industry	
202	Manufacture of pesticides and other agrochemical products
211	Manufacture of basic pharmaceutical products
212	Manufacture of pharmaceutical preparations
254	Manufacture of weapons and ammunition
261	Manufacture of electronic components and boards
262	Manufacture of computers and peripheral equipment
263	Manufacture of communication equipment
265	Manufacture of instruments and appliances for measuring, testing and navigation
266	Manufacture of irradiation, electromedical and electrotherapeutic equipment
267	Manufacture of optical instruments and photographic equipment
303	Manufacture of air and spacecraft and related machinery
304	Manufacture of military fighting vehicles
201	Manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms
205	Manufacture of other chemical products
221	Manufacture of rubber products
264	Manufacture of consumer electronics
271	Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus
272	Manufacture of batteries and accumulators
274	Manufacture of electric lighting equipment
275	Manufacture of domestic appliances
279	Manufacture of other electrical equipment
281	Manufacture of general-purpose machinery
283	Manufacture of agricultural and forestry machinery
284	Manufacture of metal forming machinery and machine tools
289	Manufacture of other special-purpose machinery
291	Manufacture of motor vehicles
293	Manufacture of parts and accessories for motor vehicles
302	Manufacture of railway locomotives and rolling stock
325	Manufacture of medical and dental instruments and supplies

Source: Gehrke et al. (2013)

Table A.2.2: List of research-intensive 3-digit service industries in Germany

3-digit service industry	
620	Computer programming, consultancy and related activities
631	Data processing, hosting and related activities
712	Technical testing and analysis
721	Research and experimental development on natural sciences and engineering
722	Research and experimental development on social sciences and humanities

Source: Gehrke et al. (2010)

A.3 List of large cities and descriptive statistics on distances

Table A.3.1: List of large cities in Germany

City	Federal State	Capital Function
Aachen	North Rhine-Westphalia	
Augsburg	Bavaria	
Bergisch Gladbach	North Rhine-Westphalia	
Berlin	Berlin	Federal Capital, Federal State Capital
Bielefeld	North Rhine-Westphalia	
Bochum	North Rhine-Westphalia	
Bonn	North Rhine-Westphalia	
Bottrop	North Rhine-Westphalia	
Braunschweig	Lower Saxony	
Bremen	Bremen	
Bremerhaven	Bremen	Federal State Capital
Chemnitz	Sachsen	
Darmstadt	Hesse	
Dortmund	North Rhine-Westphalia	
Dresden	Saxony	Federal State Capital
Duisburg	North Rhine-Westphalia	
Düsseldorf	North Rhine-Westphalia	Federal State Capital
Erfurt	Thuringia	Federal State Capital
Erlangen	Bavaria	
Essen	North Rhine-Westphalia	
Frankfurt am Main	Hesse	
Freiburg im Breisgau	Baden-Wrttemberg	
Fürth	Bavaria	
Gelsenkirchen	North Rhine-Westphalia	
Göttingen	Lower Saxony	
Hagen	North Rhine-Westphalia	
Halle/ Saale	Saxony-Anhalt	
Hamburg	Hamburg	Federal State Capital
Hamm	North Rhine-Westphalia	
Hannover	Lower Saxony	Federal State Capital
Heidelberg	Baden-Württemberg	
Heilbronn	Baden-Württemberg	
Herne	North Rhine-Westphalia	
Ingolstadt	Bavaria	
Jena	Thuringia	
Karlsruhe	Baden-Württemberg	
Kassel	Hesse	
Kiel	Schleswig-Holstein	Federal State Capital
Koblenz	Rhineland-Palatinate	
Köln	North Rhine-Westphalia	
Krefeld	North Rhine-Westphalia	
Leipzig	Sachsen	
Leverkusen	North Rhine-Westphalia	
Lübeck	Schleswig-Holstein	
Ludwigshafen am Rhein	Rhineland-Palatinate	
Magdeburg	Saxony-Anhalt	Federal State Capital
Mainz	Rhineland-Palatinate	Federal State Capital
Mannheim	Baden-Württemberg	
Moers	North Rhine-Westphalia	

Reference date: 31.03.2014.

Table A.3.1: List of large cities in Germany – continued

City	Federal State	Capital Function
Mönchengladbach	North Rhine-Westphalia	
Mülheim an der Ruhr	North Rhine-Westphalia	
München	Bavaria	Federal State Capital
Münster	North Rhine-Westphalia	
Neuss	North Rhine-Westphalia	
Nürnberg	Bavaria	
Oberhausen	North Rhine-Westphalia	
Offenbach am Main	Hesse	
Oldenburg (Oldenburg)	Lower Saxony	
Osnabrück	Lower Saxony	
Paderborn	North Rhine-Westphalia	
Pforzheim	Baden-Württemberg	
Potsdam	Brandenburg	Federal State Capital
Recklinghausen	North Rhine-Westphalia	
Regensburg	Bavaria	
Remscheid	North Rhine-Westphalia	
Reutlingen	Baden-Württemberg	
Rostock	Mecklenburg-Western Pomerania	
Saarbrücken	Saarland	Federal State Capital
Solingen	North Rhine-Westphalia	
Stuttgart	Baden-Württemberg	Federal State Capital
Trier	Rhineland-Palatinate	
Ulm	Baden-Württemberg	
Wiesbaden	Hesse	Federal State Capital
Wolfsburg	Lower Saxony	
Wuppertal	North Rhine-Westphalia	
Würzburg	Bavaria	

Reference date: 31.03.2014.

Table A.3.2: Descriptive Statistics on distances to large cities in Germany in km

Industry division		Min	Max	Mean	Standard Deviation
Agriculture					
01	Crop and animal production, hunting and related service activities	0.0	109.6	25.1	23.7
02	Forestry and logging	.	.	.	.
Production Industry					
05	Mining of coal and lignite	.	.	.	.
06	Extraction of crude petroleum and natural gas	.	.	.	.
07	Mining of metal ores	.	.	.	.
08	Other mining and quarrying	0.0	115.4	31.2	24.6
09	Mining support service activities	0.0	78.9	31.3	25.8
10	Manufacture of food products	0.0	104.8	21.2	23.8
11	Manufacture of beverages	0.0	75.4	24.3	21.7
12	Manufacture of tobacco products	.	.	.	.
13	Manufacture of textiles	0.0	99.8	32.5	24.5
14	Manufacture of wearing apparel	0.0	93.2	24.2	23.5
15	Manufacture of leather and related products	0.0	117.3	27.4	27.9
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0.0	103.7	33.7	19.7
17	Manufacture of paper and paper products	0.0	90.1	30.0	23.2
18	Printing and reproduction of recorded media	0.0	75.6	15.8	19.2
19	Manufacture of coke and refined petroleum products	0.0	45.9	10.5	16.0
20	Manufacture of chemicals and chemical products	0.0	128.1	18.0	20.8
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.0	94.6	13.3	20.0
22	Manufacture of rubber and plastic products	0.0	100.6	24.6	21.7
23	Manufacture of other non-metallic mineral products	0.0	120.5	26.6	24.5
24	Manufacture of basic metals	0.0	115.6	19.0	22.1
25	Manufacture of fabricated metal products, except machinery and equipment	0.0	128.1	24.2	21.9
26	Manufacture of computer, electronic and optical products	0.0	111.5	16.0	20.9
27	Manufacture of electrical equipment	0.0	117.3	21.3	22.3
28	Manufacture of machinery and equipment n.e.c.	0.0	104.5	21.7	21.5
29	Manufacture of motor vehicles, trailers and semi-trailers	0.0	116.6	22.2	22.5
30	Manufacture of other transport equipment	0.0	103.7	20.8	24.9
31	Manufacture of furniture	0.0	129.7	31.5	23.9
32	Other manufacturing	0.0	88.4	21.2	23.1
33	Repair and installation of machinery and equipment	0.0	103.9	19.4	22.5
35	Electricity, gas, steam and air conditioning supply	0.0	115.6	20.1	29.1
36	Water collection, treatment and supply	0.0	58.8	11.8	16.6
37	Sewerage	0.0	40.8	19.8	14.6
38	Waste collection, treatment and disposal activities; materials recovery	0.0	80.4	20.1	19.8
39	Remediation activities and other waste management services	0.0	53.2	14.7	18.1
41	Construction of buildings	0.0	79.5	19.8	22.1
42	Civil engineering	0.0	92.9	23.9	23.1
43	Specialized construction activities	0.0	117.4	24.7	24.6

(.) Statistical confidentiality because of 3 or less R&D establishments in the industry

Table A.3.2: Descriptive Statistics on distances to large cities in Germany in km – continued

Industry division		Min	Max	Mean	Standard Deviation
Services					
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	0.0	85.9	22.5	22.3
46	Wholesale trade, except of motor vehicles and motorcycles	0.0	93.3	18.5	21.7
47	Retail trade, except of motor vehicles and motorcycles	0.0	115.6	21.7	24.3
49	Land transport and transport via pipelines	0.0	75.7	13.4	21.8
50	Water transport	0.0	74.2	18.5	32.1
51	Air transport	0.0	10.0	2.5	4.3
52	Warehousing and support activities for transportation	0.0	80.8	6.3	14.6
53	Postal and courier activities	.	.	.	.
56	Food and beverage service activities	0.0	28.6	8.4	11.9
58	Publishing activities	0.0	95.7	6.5	16.4
59	Motion picture, video and television programme production, sound recording and music publishing activities	0.0	7.7	2.1	3.4
60	Programming and broadcasting activities	.	.	.	.
61	Telecommunications	0.0	27.1	2.6	6.5
62	Computer programming, consultancy and related activities	0.0	111.8	11.6	20.2
63	Information service activities	0.0	87.7	12.2	21.5
64	Financial service activities, except insurance and pension funding	0.0	5.2	0.3	1.3
65	Insurance, reinsurance and pension funding, except compulsory social security	0.0	49.8	5.0	12.1
66	Activities auxiliary to financial services and insurance activities	0.0	7.5	4.3	2.9
68	Real estate activities	0.0	55.9	12.2	15.6
69	Legal and accounting activities	.	.	.	.
70	Activities of head offices; management consultancy activities	0.0	97.3	10.3	19.2
71	Architectural and engineering activities; technical testing and analysis	0.0	115.4	14.7	21.5
72	Scientific research and development	0.0	107.6	9.4	17.3
73	Advertising and market research	0.0	47.1	6.3	12.6
74	Other professional, scientific and technical activities	0.0	78.1	9.5	17.2
75	Veterinary activities	0.0	42.5	15.3	17.5
77	Rental and leasing activities	0.0	84.4	18.0	22.3
78	Employment activities	0.0	19.4	5.7	8.0
79	Travel agency, tour operator and other reservation service and related activities	.	.	.	.
80	Security and investigation activities	.	.	.	.
81	Services to buildings and landscape activities	0.0	48.1	11.7	13.0
82	Office administrative, office support and other business support activities	0.0	87.5	11.6	18.8
84	Public administration and defence; compulsory social security	.	.	.	.
85	Education	0.0	33.0	10.1	12.8
86	Human health activities	0.0	88.1	10.6	19.9
87	Residential care activities	.	.	.	.
88	Social work activities without accommodation	.	.	.	.
90	Creative, arts and entertainment activities	0.0	8.6	2.1	3.7
93	Sports activities and amusement and recreation activities	0.0	61.6	21.7	25.2
94	Activities of membership organisations	0.0	37.6	5.8	13.0
95	Repair of computers and personal and household goods	0.0	76.0	19.4	26.4
96	Other personal service activities	0.0	101.7	16.2	23.4

(.) Statistical confidentiality because of 3 or less R&D establishments in the industry

A.4 Model of city-related dynamic distances

A reader might wonder why the threshold in the analyses regarding effects of urbanity is firmly set as average distance to a large city and does not depend on city-size. Indeed, the larger a city, the higher should be the distance over which its influence spreads. Since in the analyses in *Chapter 2* first exploratory steps in studying the effects of urbanity on R&D are taken, it relates to a simple model with a fixed threshold. The following description sketches a model of dynamic distances that accounts for city size.

Suppose that every city has a certain distance up to which industry-specific location patterns of R&D activities are influenced. For example, assume four classes of city size (S_1, S_2, S_3, S_4) with respective distances (D_1, D_2, D_3, D_4) as indicated in *Figure A.4.1*. Distances over which influence is exerted might be calculated as average distance to a city of this size and bigger. In this example given distances are: D_1=38.0 km, D_2=18.8 km, D_3=10.4 km, D_4=6.2 km. In order to detect location patterns, intervals are normalized to one size. From a spatial perspective, this can be interpreted as scaling or stretching space in such a way that the values of all distances match (*Figure A.4.2*). Afterwards, the analyses as described in *Section 2.4.1* can be performed.

A drawback of applying a dynamic threshold is that distance patterns of urban localization or dispersion become more difficult to interpret. However, instead it allows to estimate whether location patterns deviating from randomness fall into the influence area of cities of various size. Thus, it leads to conclusions whether R&D activity in a particular industry is attracted or pushed away from cities accounting for their size. An even more comprehensive measure of city influence could be obtained by measuring not only the minimum distance to the next city but analysing distances to all cities and thus account for overall urban structures. However, this approach requires careful development of an indicator of city influence that is beyond the scope of this study.

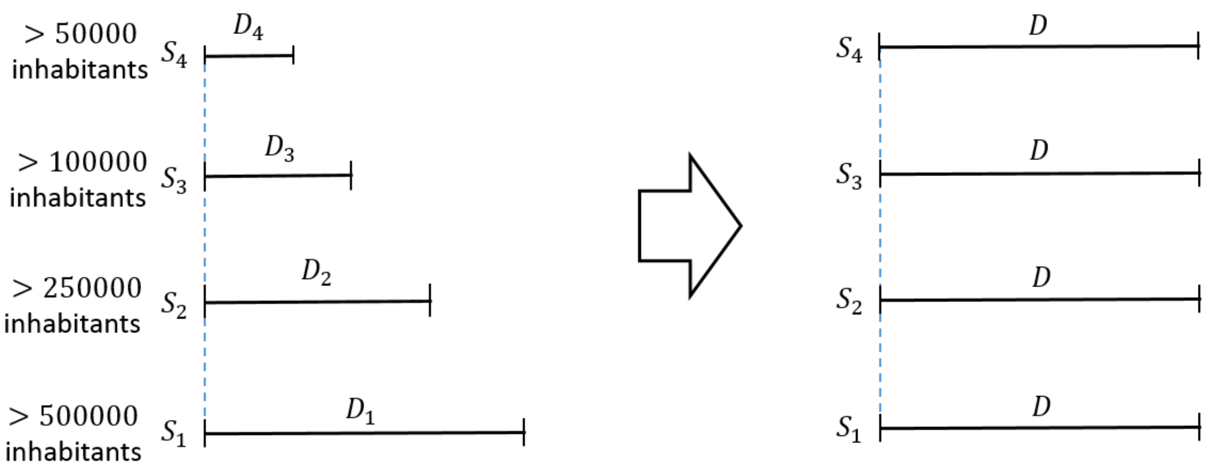


Figure A.4.1: Normalization of distances to the nearest city

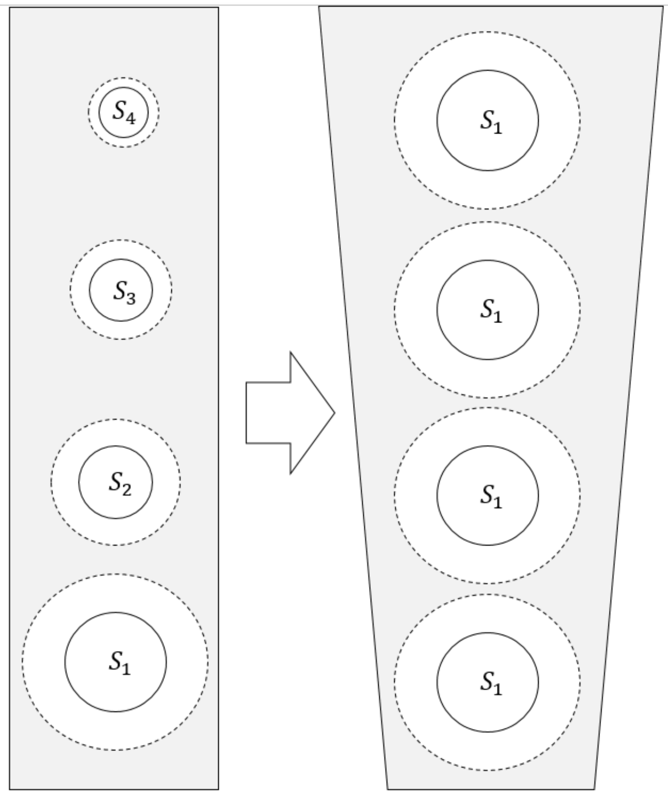


Figure A.4.2: Space stretch in order to bring all influence intervals to one value

A.5 Industrial scope of the researcher-weighted location patterns in relation to cities

Table A.5.1: Industrial scope of the researcher-weighted location patterns in relation to cities

Industry division		No. of 3-digit industries	Urban localization [%]	Urban dispersion [%]	Random distribution [%]
Agriculture					
01	Crop and animal production. hunting and related service activities	3		33.3	66.7
Production industries					
08	Other mining and quarrying	2		50.0	50.0
10	Manufacture of food products	7		28.6	71.4
11	Manufacture of beverages	1			100.0
13	Manufacture of textiles	4		50.0	50.0
14	Manufacture of wearing apparel	2			100.0
15	Manufacture of leather and related products	1			100.0
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	2		100.0	
17	Manufacture of paper and paper products	2		100.0	
18	Printing and reproduction of recorded media	1			100.0
19	Manufacture of coke and refined petroleum products	1			100.0
20	Manufacture of chemicals and chemical products	6			100.0
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	2	50.0		50.0
22	Manufacture of rubber and plastic products	2	50.0		50.0
23	Manufacture of other non-metallic mineral products	8		37.5	62.5
24	Manufacture of basic metals	5			100.0
25	Manufacture of fabricated metal products. except machinery and equipment	8	25.0	37.5	37.5
26	Manufacture of computer, electronic and optical products	7	28.6		71.4
27	Manufacture of electrical equipment	6	16.7		83.3
28	Manufacture of machinery and equipment n.e.c.	5	80.0		20.0
29	Manufacture of motor vehicles, trailers and semi-trailers	3		33.3	66.7
30	Manufacture of other transport equipment	4			100.0
31	Manufacture of furniture	1		100.0	
32	Other manufacturing	5		20.0	80.0
33	Repair and installation of machinery and equipment	2			100.0
35	Electricity, gas, steam and air conditioning supply	2			100.0
36	Water collection, treatment and supply	1			100.0
38	Waste collection, treatment and disposal activities; materials recovery	2			100.0
41	Construction of buildings	1			100.0
42	Civil engineering	3			100.0
43	Specialized construction activities	4		25.0	75.0

Table A.5.1: Industrial scope of the researcher-weighted location patterns in relation to cities – continued

Industry division		No. of 3-digit industries	Urban localization [%]	Urban dispersion [%]	Random distribution [%]
Service industries					
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	2		50.0	50.0
46	Wholesale trade, except of motor vehicles and motorcycles	8	12.5		87.5
47	Retail trade, except of motor vehicles and motorcycles	3			100.0
49	Land transport and transport via pipelines	1			100.0
52	Warehousing and support activities for transportation	1	100.0		
58	Publishing activities	2	100.0		
61	Telecommunications	1	100.0		
62	Computer programming, consultancy and related activities	1	100.0		
63	Information service activities	2	100.0		
64	Financial service activities, except insurance and pension funding	1			100.0
65	Insurance, reinsurance and pension funding, except compulsory social security	1	100.0		
68	Real estate activities	1			100.0
70	Activities of head offices; management consultancy activities	2	50.0		50.0
71	Architectural and engineering activities; technical testing and analysis	2	100.0		
72	Scientific research and development	2	100.0		
73	Advertising and market research	2			100.0
74	Other professional, scientific and technical activities	1		100.0	
77	Rental and leasing activities	1			100.0
82	Office administrative, office support and other business support activities	1	100.0		
86	Human health activities	1			100.0
96	Other personal service activities	1			100.0

A.6 Cross-distance indices of localization and dispersion

Table A.6.1: Cross-distance indices of localization and dispersion

3-digit industry		Location		Urban Location	
		R&D establishm.	Researchers	R&D establishm.	Researchers
Agriculture					
011	Growing of non-perennial crops		Ψ_m^r=0.0017		
015	Mixed farming			Ψ_m^u=0.0192	$\Psi_m^{u,r}$=0.0131
016	Support activities to agriculture and post-harvest crop activities				
Production industries					
081	Quarrying of stone, sand and clay				
089	Mining and quarrying n.e.c.			Ψ_m^u=0.0071	$\Psi_m^{u,r}$=0.0072
101	Processing and preserving of meat and production of meat products				
103	Processing and preserving of fruit and vegetables	Ψ_m=0.0000	Ψ_m^r=0.0023		
105	Manufacture of dairy products		Ψ_m^r=0.0013	Ψ_m^u=0.0027	$\Psi_m^{u,r}$=0.0254
106	Manufacture of grain, mill products starches and starch products		Ψ_m^r=0.0000		
107	Manufacture of bakery and farinaceous products				
108	Manufacture of other food products	Ψ_m=0.0010	Ψ_m^r=0.0117		
109	Manufacture of prepared animal feeds			Ψ_m^u=0.0293	$\Psi_m^{u,r}$=0.0090
110	Manufacture of beverages				
131	Preparation and spinning of textile fibres				
132	Weaving of textiles			Ψ_m^u=0.1408	
133	Finishing of textiles				$\Psi_m^{u,r}$=0.0105
139	Manufacture of other textiles	Γ_m=0.0122	Ψ_m^r=0.0007	Ψ_m^u=0.2597	$\Gamma_m^{u,r}$=0.0013
141	Manufacture of wearing apparel, except fur apparel		Ψ_m^r=0.0003		
143	Manufacture of knitted and crocheted apparel	Γ_m=0.0114			
151	Tanning and dressing of leather				
161	Sawmilling and planing of wood			Ψ_m^u=0.0468	$\Psi_m^{u,r}$=0.0372
162	Manufacture of products of wood, cork, straw and plaiting materials	Ψ_m=0.0001	Ψ_m^r=0.0043	Ψ_m^u=0.2654	$\Psi_m^{u,r}$=0.1758
171	Manufacture of pulp, paper and paperboard		Ψ_m^r=0.0007	Ψ_m^u=0.0664	$\Psi_m^{u,r}$=0.1017
172	Manufacture of articles of paper and paperboard		Ψ_m^r=0.0025	Ψ_m^u=0.0025	$\Psi_m^{u,r}$=0.0291
181	Printing and service activities related to printing		Ψ_m^r=0.0017		
192	Manufacture of refined petroleum products				
201	Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms	Γ_m=0.0013	Γ_m^r=0.0011		$\Gamma_m^{u,r}$=0.0137
202	Manufacture of pesticides and other agrochemical products		Ψ_m^r=0.0007		
203	Manufacture of paints, varnishes and similar coatings, printing ink and mastics	Γ_m=0.0020	Γ_m^r=0.0008		
204	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	Ψ_m=0.0000	Ψ_m^r=0.0042		
205	Manufacture of other chemical products	Ψ_m=0.0007	Γ_m^r=0.0009		
206	Manufacture of man-made fibres				
211	Manufacture of basic pharmaceutical products		Ψ_m^r=0.0018		
212	Manufacture of pharmaceutical preparations	Ψ_m=0.0023	Ψ_m^r=0.0137	Γ_m^u=0.2061	

Note: Γ_m=Cross-distance index of localization, Ψ_m=Cross-distance index of dispersion

Table A.6.1: Cross-distance indices of localization and dispersion – continued

3-digit industry		**Location**		**Urban Location**	
		R&D establishm.	Researchers	R&D establishm.	Researchers
Production industries – continued					
221	Manufacture of rubber products	Γ_m=0.0010	Ψ^r_m=0.0025		$\Gamma^{u,r}_m$=0.0005
222	Manufacture of plastic products	Γ_m=0.0226	Γ^r_m=0.0083	Γ^u_m=0.0231	$\Gamma^{u,r}_m$=0.0490
231	Manufacture of glass and glass products	Γ_m=0.0163	Γ^r_m=0.0012	Ψ^u_m=0.0883	$\Psi^{u,r}_m$=0.0913
232	Manufacture of refractory products		Ψ^r_m=0.0000		
233	Manufacture of clay building materials				
234	Manufacture of other porcelain and ceramic products	Γ_m=0.0021	Ψ^r_m=0.0002	Ψ^u_m=0.0287	$\Gamma^{u,r}_m$=0.0006
235	Manufacture of cement, lime and plaster				
236	Manufacture of articles of concrete, cement and plaster	Ψ_m=0.0007	Ψ^r_m=0.0059	Ψ^u_m=0.0582	$\Gamma^{u,r}_m$=0.0082
237	Cutting, shaping and finishing of stone				
239	Manufacture of abrasive products and non-metallic mineral products n.e.c.	Γ_m=0.0000	Ψ^r_m=0.0004		
241	Manufacture of basic iron and steel and of ferro-alloys	Γ_m=0.0100			
242	Manufacture of tubes, pipes, hollow profiles and related fittings of steel				
243	Manufacture of other products of first processing of steel	Γ_m=0.1044			
244	Manufacture of basic precious and other non-ferrous metals	Γ_m=0.0085	Ψ^r_m=0.0012		
245	Casting of metals		Ψ^r_m=0.0008		$\Psi^{u,r}_m$=0.0362
251	Manufacture of structural metal products	Ψ_m=0.0015	Ψ^r_m=0.0004	Ψ^u_m=0.1200	$\Gamma^{u,r}_m$=0.0016
252	Manufacture of tanks, reservoirs and containers of metal		Ψ^r_m=0.0010	Ψ^u_m=0.0792	$\Psi^{u,r}_m$=0.0731
253	Manufacture of steam generators, except central heating hot water boilers				
254	Manufacture of weapons and ammunition				
255	Forging, pressing, stamping and roll-forming of metal	Γ_m=0.0463	Γ^r_m=0.0001		$\Gamma^{u,r}_m$=0.0012
256	Treatment and coating of metals	Γ_m=0.0003	Γ^r_m=0.0090	Γ^u_m=0.0010	$\Gamma^{u,r}_m$=0.0182
257	Manufacture of cutlery, tools and general hardware	Γ_m=0.0107	Γ^r_m=0.0083	Ψ^u_m=0.0038	$\Gamma^{u,r}_m$=0.0251
259	Manufacture of other fabricated metal products	Γ_m=0.0127	Γ^r_m=0.0017	Γ^u_m=0.0021	$\Gamma^{u,r}_m$=0.0360
261	Manufacture of electronic components and boards	Γ_m=0.0016	Γ^r_m=0.0057		
262	Manufacture of computers and peripheral equipment	Ψ_m=0.0001	Γ^r_m=0.0002		
263	Manufacture of communication equipment	Ψ_m=0.0006	Ψ^r_m=0.0105		
264	Manufacture of consumer electronics	Ψ_m=0.0003	Ψ^r_m=0.0038		
265	Manufacture of instruments and appliances for measuring, testing and navigation	Γ_m=0.0001	Γ^r_m=0.0098	Γ^u_m=0.0720	$\Gamma^{u,r}_m$=0.0004
266	Manufacture of irradiation, electromedical and electrotherapeutic equipment	Ψ_m=0.0022	Ψ^r_m=0.0058		
267	Manufacture of optical instruments and photographic equipment	Γ_m=0.0005	Ψ^r_m=0.0105	Γ^u_m=0.0011	
271	Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus	Ψ_m=0.0017	Γ^r_m=0.0033		$\Gamma^{u,r}_m$=0.0065
272	Manufacture of batteries and accumulators				
273	Manufacture of wiring and wiring devices		Ψ^r_m=0.0010		$\Psi^{u,r}_m$=0.0075
274	Manufacture of electric lighting equipment		Ψ^r_m=0.0004	Γ^u_m=0.0051	$\Gamma^{u,r}_m$=0.0291
275	Manufacture of domestic appliances		Ψ^r_m=0.0001		
279	Manufacture of other electrical equipment	Ψ_m=0.0014	Ψ^r_m=0.0168		$\Gamma^{u,r}_m$=0.0146
281	Manufacture of general-purpose machinery	Γ_m=0.0047	Γ^r_m=0.0012		$\Gamma^{u,r}_m$=0.0098
282	Manufacture of other general-purpose machinery	Γ_m=0.0003	Γ^r_m=0.0083	Γ^u_m=0.0039	$\Gamma^{u,r}_m$=0.0423
283	Manufacture of agricultural and forestry machinery		Ψ^r_m=0.0014	Γ^u_m=0.0003	$\Gamma^{u,r}_m$=0.0281
284	Manufacture of metal forming machinery and machine tools	Γ_m=0.0148	Γ^r_m=0.0119	Γ^u_m=0.0006	$\Gamma^{u,r}_m$=0.0320
289	Manufacture of other special-purpose machinery	Γ_m=0.0086	Γ^r_m=0.0086	Γ^u_m=0.0007	$\Gamma^{u,r}_m$=0.0399

Note: Γ_m=Cross-distance index of localization, Ψ_m=Cross-distance index of dispersion

Table A.6.1: Cross-distance indices of localization and dispersion – continued

3-digit industry		Location		Urban Location	
		R&D establishm.	Researchers	R&D establishm.	Researchers
Production industries – continued					
291	Manufacture of motor vehicles	Γ_m=0.0003			
292	Manufacture of bodies (coachwork) for motor vehicles		Ψ_m^r=0.0021	Ψ_m^u=0.0028	$\Psi_m^{u,r}$=0.0473
293	Manufacture of parts and accessories for motor vehicles	Γ_m=0.0395	Γ_m^r=0.0141		$\Gamma_m^{u,r}$=0.0145
301	Building of ships and boats	Γ_m=0.0001			$\Psi_m^{u,r}$=0.0116
302	Manufacture of railway locomotives and rolling stock				
303	Manufacture of air and spacecraft and related machinery	Ψ_m=0.0011	Ψ_m^r=0.0014		$\Gamma_m^{u,r}$=0.0000
309	Manufacture of transport equipment n.e.c.	Γ_m=0.0027			$\Gamma_m^{u,r}$=0.0111
310	Manufacture of furniture	Γ_m=0.0010	Ψ_m^r=0.0037	Ψ_m^u=0.1446	$\Gamma_m^{u,r}$=0.0003
322	Manufacture of musical instruments			Ψ_m^u=0.1802	$\Psi_m^{u,r}$=0.0329
323	Manufacture of sports goods				
324	Manufacture of games and toys	Ψ_m=0.0001			
325	Manufacture of medical and dental instruments and supplies	Ψ_m=0.0028	Γ_m^r=0.0028		$\Gamma_m^{u,r}$=0.0005
329	Manufacturing n.e.c.	Γ_m=0.0003	Ψ_m^r=0.0048		$\Psi_m^{u,r}$=0.0488
331	Repair of fabricated metal products, machinery and equipment		Ψ_m^r=0.0022		
332	Installation of industrial machinery and equipment	Ψ_m=0.0003	Ψ_m^r=0.0069		$\Gamma_m^{u,r}$=0.0116
351	Electric power generation, transmission and distribution	Ψ_m=0.0006	Ψ_m^r=0.0096		
353	Steam and air conditioning supply				
360	Water collection, treatment and supply				
382	Waste treatment and disposal				
383	Materials recovery		Ψ_m^r=0.0004		
412	Construction of residential and non-residential buildings	Γ_m=0.0005	Γ_m^r=0.0008		
421	Construction of roads and railways				
422	Construction of utility projects				
429	Construction of other civil engineering projects				
431	Demolition and site preparation				$\Gamma_m^{u,r}$=0.0020
432	Electrical, plumbing and other construction installation activities	Ψ_m=0.0001	Ψ_m^r=0.0050	Ψ_m^u=0.0364	$\Psi_m^{u,r}$=0.0764
433	Building completion and finishing		Ψ_m^r=0.0026		$\Psi_m^{u,r}$=0.0015
439	Other specialised construction activities		Ψ_m^r=0.0032		

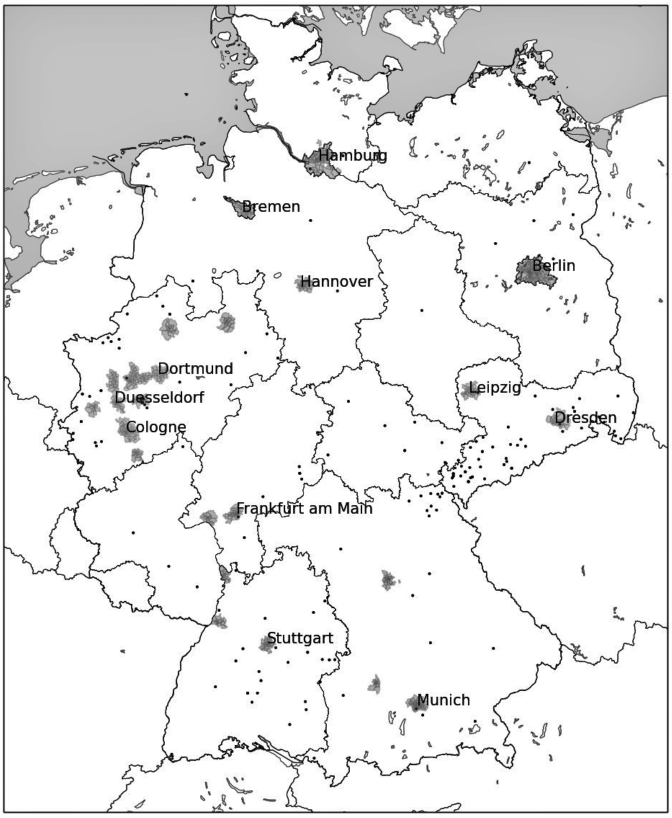
Note: Γ_m=Cross-distance index of localization, Ψ_m=Cross-distance index of dispersion

Table A.6.1: Cross-distance indices of localization and dispersion – continued

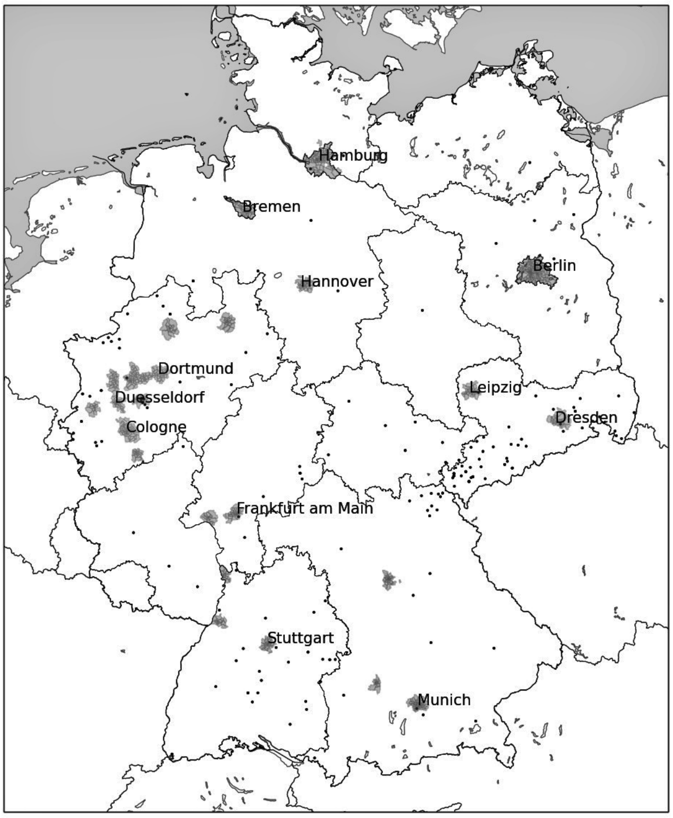
3-digit industry		Location		Urban Location	
		R&D establishm.	Researchers	R&D establishm.	Researchers
Service industries					
452	Maintenance and repair of motor vehicles			Ψ_m^u=0.0021	$\Psi_m^{u,r}$=0.0008
453	Sale of motor vehicle parts and accessories				
461	Wholesale on a fee or contract basis		Ψ_m^r=0.0062	Γ_m^u=0.0091	$\Gamma_m^{u,r}$=0.0246
462	Wholesale of agricultural raw materials and live animals				
463	Wholesale of food, beverages and tobacco				
464	Wholesale of household goods		Ψ_m^r=0.0079		
465	Wholesale of information and communication equipment		Ψ_m^r=0.0000		
466	Wholesale of other machinery, equipment and supplies		Ψ_m^r=0.0066		$\Gamma_m^{u,r}$=0.0042
467	Other specialised wholesale	Γ_m=0.0002	Ψ_m^r=0.0032		
469	Non-specialised wholesale trade				
474	Retail sale of information and communication equipment in specialised stores		Ψ_m^r=0.0016		
475	Retail sale of other household equipment in specialised stores				
477	Retail sale of other goods in specialised stores				
493	Other passenger land transport				
522	Support activities for transportation		Ψ_m^r=0.0006	Γ_m^u=0.8911	$\Gamma_m^{u,r}$=0.1696
581	Publishing of books, periodicals and other publishing activities			Γ_m^u=0.2522	
582	Software publishing		Ψ_m^r=0.0079	Γ_m^u=0.7868	$\Gamma_m^{u,r}$=0.4605
619	Other telecommunications activities			Γ_m^u=0.0026	$\Gamma_m^{u,r}$=0.0023
620	Computer programming, consultancy and related activities	Ψ_m=0.0061	Γ_m^r=0.0095	Γ_m^u=0.5490	$\Gamma_m^{u,r}$=0.1930
631	Data processing, hosting and related activities	Ψ_m=0.0021	Ψ_m^r=0.0111	Γ_m^u=0.1006	$\Psi_m^{u,r}$=0.0073
639	Other information service activities			Γ_m^u=0.3014	$\Psi_m^{u,r}$=0.0082
641	Monetary intermediation				
651	Insurance			Γ_m^u=0.6623	$\Gamma_m^{u,r}$=0.1620
682	Rental and operating of own or leased real estate				
701	Activities of head offices		Ψ_m^r=0.0015		
702	Management consultancy activities	Ψ_m=0.0008	Ψ_m^r=0.0178	Γ_m^u=0.6837	$\Gamma_m^{u,r}$=0.2318
711	Architectural and engineering activities and related technical consultancy	Γ_m=0.0018	Γ_m^r=0.0096	Γ_m^u=0.1651	
712	Technical testing and analysis	Ψ_m=0.0022	Ψ_m^r=0.0142	Γ_m^u=0.2502	
721	Research and experimental development on natural sciences and engineering	Ψ_m=0.0057	Γ_m^r=0.0102	Γ_m^u=0.6533	$\Gamma_m^{u,r}$=0.2634
722	Research and experimental development on social sciences and humanities			Γ_m^u=0.9704	$\Gamma_m^{u,r}$=0.0815
731	Advertising				
732	Market research and public opinion polling				
749	Other professional, scientific and technical activities n.e.c.		Ψ_m^r=0.0034	Ψ_m^u=0.0323	
773	Rental and leasing of other machinery, equipment and tangible goods				
829	Business support service activities n.e.c.		Ψ_m^r=0.0052	Γ_m^u=0.0288	
869	Other human health activities				
960	Other personal service activities		Ψ_m^r=0.0014		

Note: Γ_m=Cross-distance index of localization, Ψ_m=Cross-distance index of dispersion

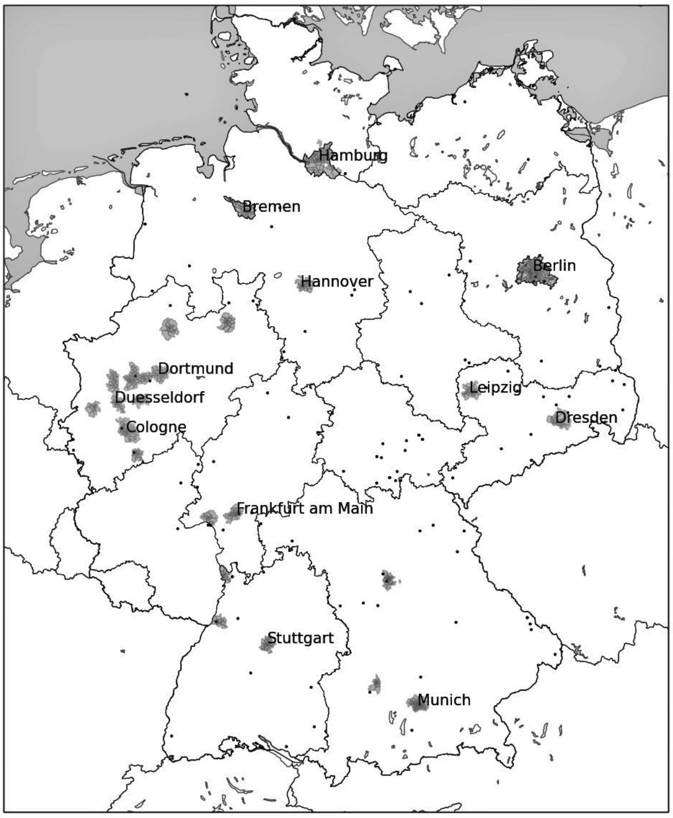
A.7 Selected maps of localized 3-digit industries



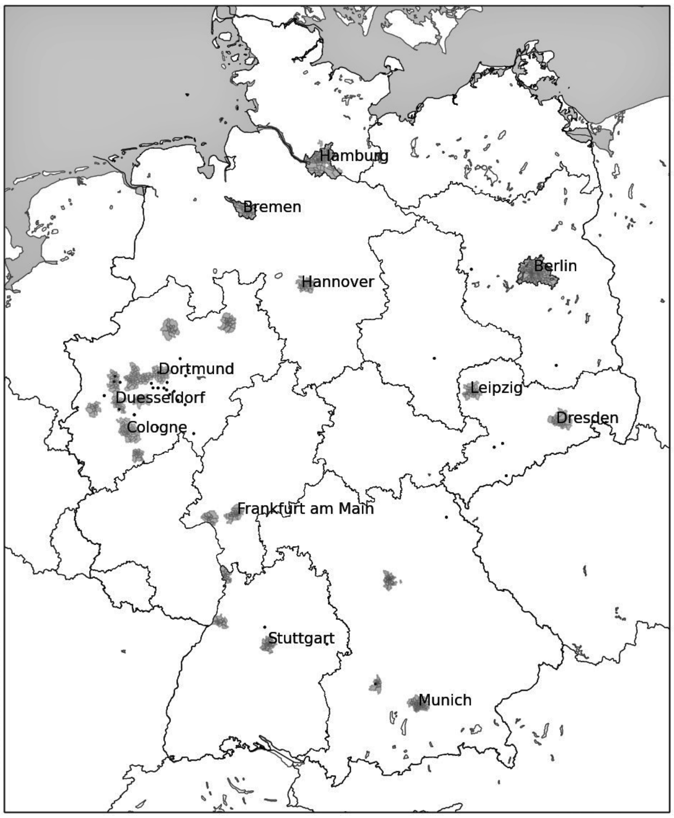
139 Manufacture of other textiles



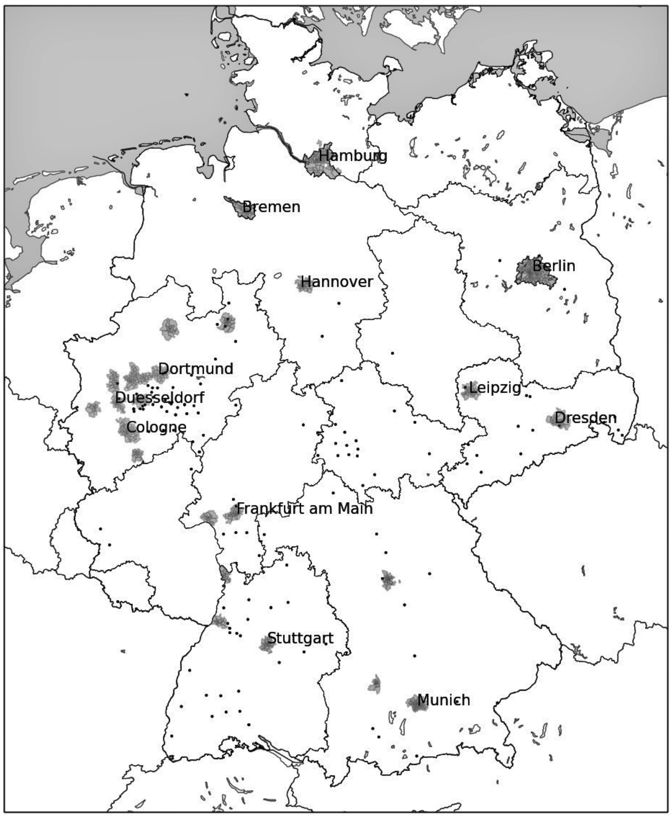
143 Manufacture of knitted and crocheted apparel



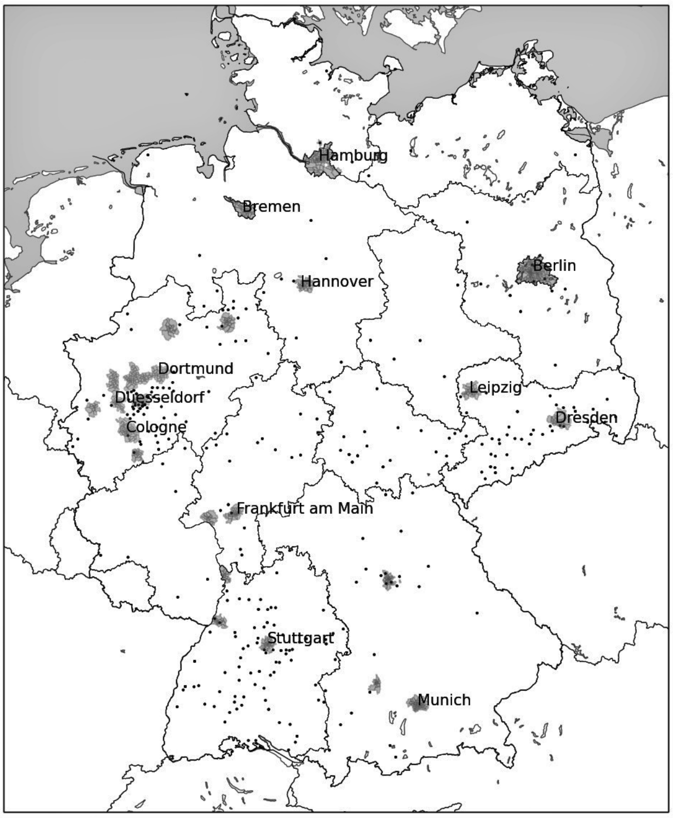
231 Manufacture of glass and glass products



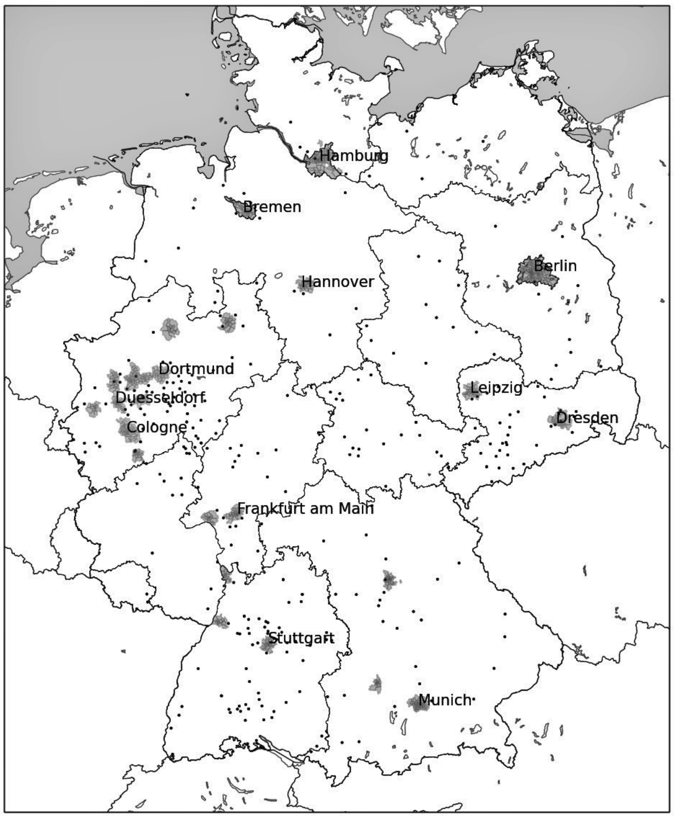
243 Manufacture of other products of first processing of steel



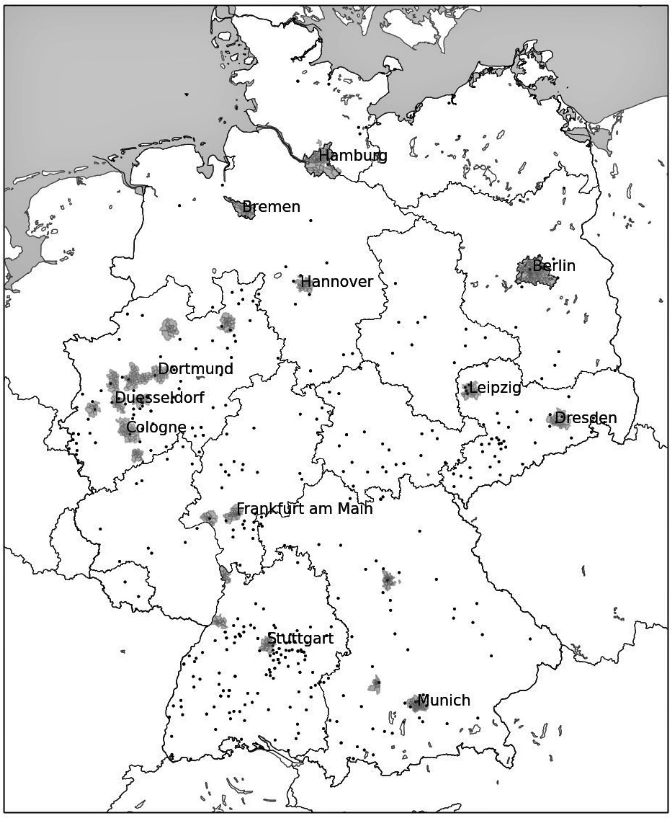
255 Forging, pressing, stamping and roll-forming of metal



257 Manufacture of cutlery, tools and general hardware

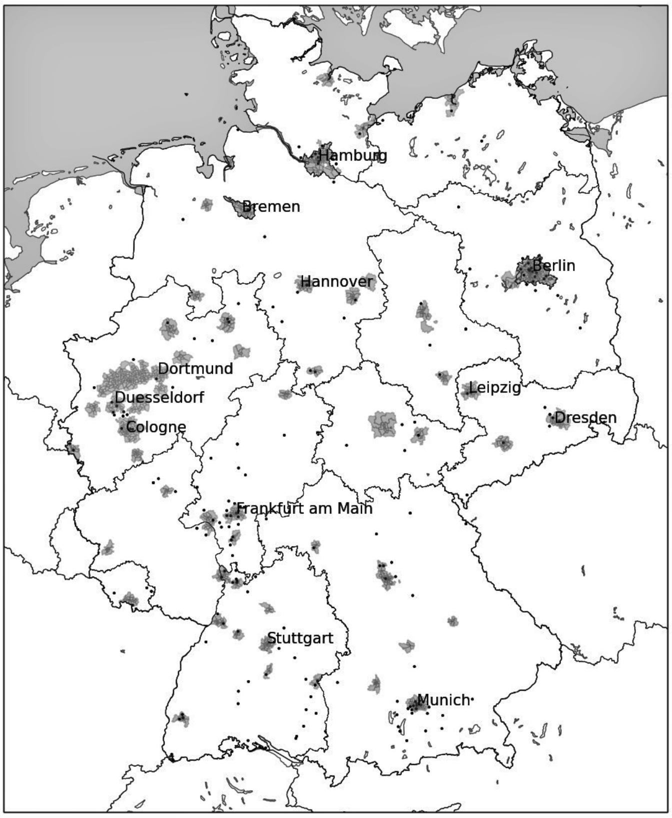


259 Manufacture of other fabricated metal products

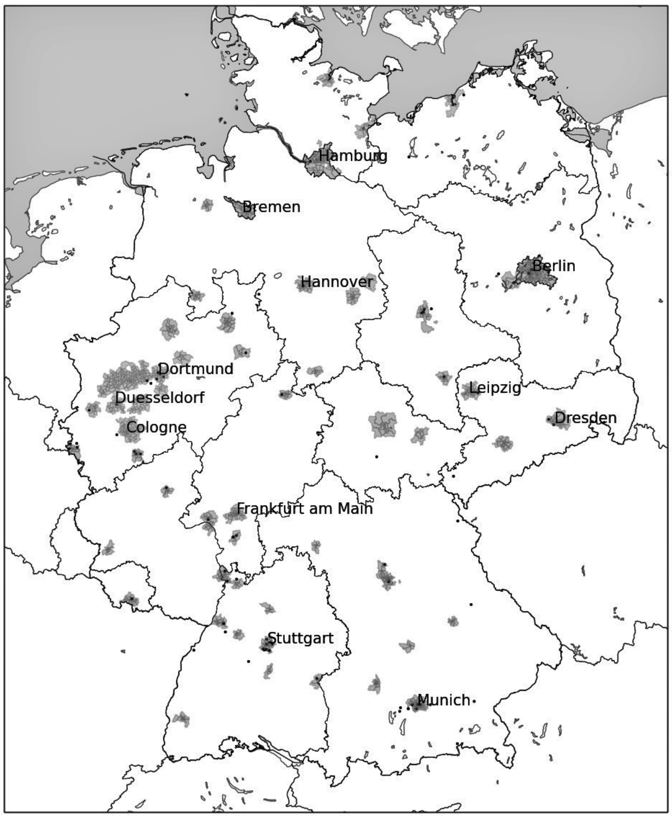


284 Manufacture of metal forming machinery and machine tools

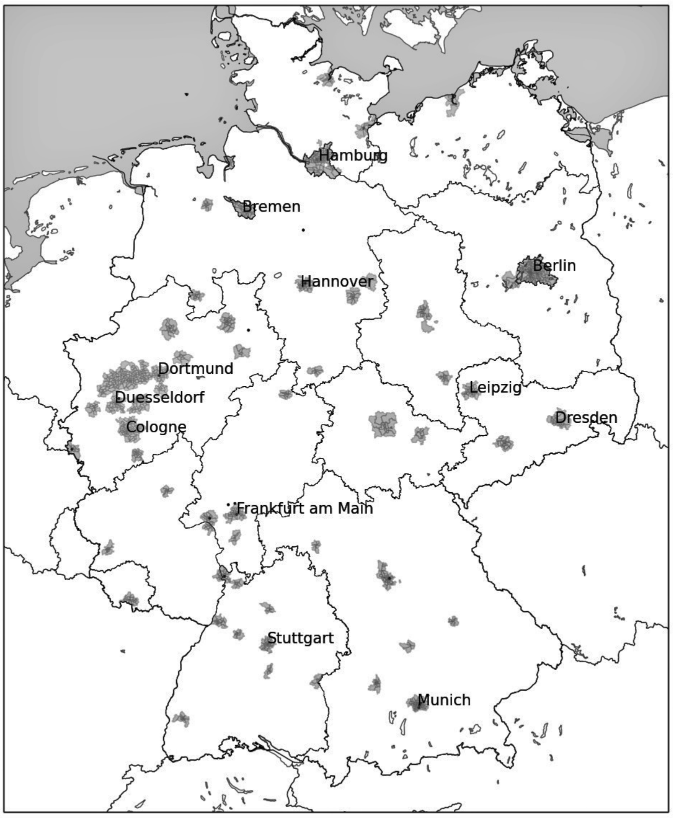
A.8 Selected maps of urban localized 3-digit industries



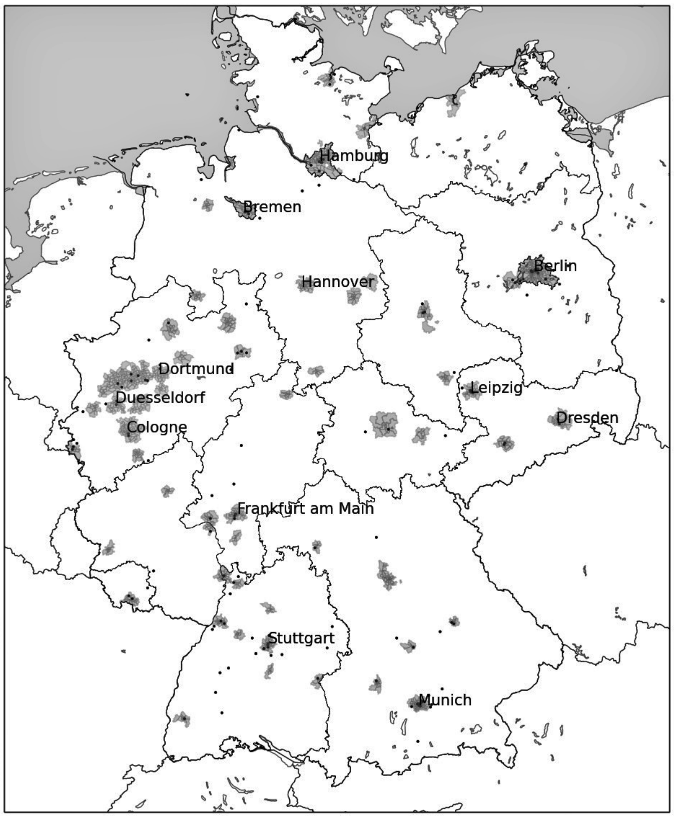
212 Manufacture of pharmaceutical preparations



582 Software publishing



651 Insurance



702 Management consultancy activities

Appendix B

Appendix to Chapter 3

B.1 Lists of cities included in the analyses

Table B.1.1: Small Cities in alphabetical order

City	Federal State	Capital Function
Aalen	Baden-Württemberg	
Ahlen	North Rhine-Westphalia	
Arnsberg	North Rhine-Westphalia	
Aschaffenburg	Bavaria	
Bad Homburg v.d. Höhe	Hesse	
Bad Salzuflen	North Rhine-Westphalia	
Baden-Baden	Baden-Württemberg	
Bamberg	Bavaria	
Bayreuth	Bavaria	
Bergheim	North Rhine-Westphalia	
Bocholt	North Rhine-Westphalia	
Brandenburg/Havel	Brandenburg	
Castrop-Rauxel	North Rhine-Westphalia	
Celle	Lower Saxony	
Cottbus	Brandenburg	
Delmenhorst	Lower Saxony	
Dessau	Saxony-Anhalt	
Detmold	North Rhine-Westphalia	
Dinslaken	North Rhine-Westphalia	
Dormagen	North Rhine-Westphalia	
Dorsten	North Rhine-Westphalia	
Düren	North Rhine-Westphalia	
Elmshorn	Schleswig-Holstein	
Eschweiler	North Rhine-Westphalia	
Esslingen am Neckar	Baden-Württemberg	
Euskirchen	North Rhine-Westphalia	
Flensburg	Schleswig-Holstein	
Frankfurt/Oder	Brandenburg	
Frechen	North Rhine-Westphalia	
Friedrichshafen	Baden-Württemberg	
Fulda	Hesse	
Garbsen	Lower Saxony	
Gera	Thuringia	
Gießen	Hesse	
Gladbeck	North Rhine-Westphalia	
Göppingen	Baden-Württemberg	
Görlitz	Saxony	
Goslar	Lower Saxony	
Greifswald	Mecklenburg-Western Pomerania	
Grevenbroich	North Rhine-Westphalia	
Gütersloh	North Rhine-Westphalia	
Hameln	Lower Saxony	
Hanau	Hesse	
Hattingen	North Rhine-Westphalia	
Herford	North Rhine-Westphalia	
Herten	North Rhine-Westphalia	
Hilden	North Rhine-Westphalia	
Hildesheim	Lower Saxony	
Hürth	North Rhine-Westphalia	
Ibbenbüren	North Rhine-Westphalia	
Iserlohn	North Rhine-Westphalia	
Kaiserslautern	Rhineland-Palatinate	
Kempten (Allgäu)	Bavaria	
Kerpen	North Rhine-Westphalia	

Reference date: 31.03.2014.

Table B.1.1: Small Cities in alphabetical order – continued

City	Federal State	Capital Function
Konstanz	Baden-Württemberg	
Landshut	Bavaria	
Langenfeld (Rheinland)	North Rhine-Westphalia	
Langenhagen	Lower Saxony	
Lingen (Ems)	Lower Saxony	
Lippstadt	North Rhine-Westphalia	
Lüdenscheid	North Rhine-Westphalia	
Ludwigsburg	Baden-Württemberg	
Lüneburg	Lower Saxony	
Lünen	North Rhine-Westphalia	
Marburg	Hesse	
Marl	North Rhine-Westphalia	
Meerbusch	North Rhine-Westphalia	
Menden (Sauerland)	North Rhine-Westphalia	
Minden	North Rhine-Westphalia	
Neubrandenburg	Mecklenburg-Western Pomerania	
Neumünster	Schleswig-Holstein	
Neustadt an der Weinstraße	Rhineland-Palatinate	
Neu-Ulm	Bavaria	
Neuwied	Rhineland-Palatinate	
Norderstedt	Schleswig-Holstein	
Nordhorn	Lower Saxony	
Offenburg	Baden-Württemberg	
Plauen	Saxony	
Pulheim	North Rhine-Westphalia	
Ratingen	North Rhine-Westphalia	
Rheine	North Rhine-Westphalia	
Rosenheim	Bavaria	
Rüsselsheim	Hesse	
Salzgitter	Lower Saxony	
Sankt Augustin	North Rhine-Westphalia	
Schwäbisch Gmünd	Baden-Württemberg	
Schweinfurt	Bavaria	
Schwerin	Mecklenburg-Western Pomerania	Federal State Capital
Siegen	North Rhine-Westphalia	
Sindelfingen	Baden-Württemberg	
Stolberg (Rhld.)	North Rhine-Westphalia	
Stralsund	Mecklenburg-Western Pomerania	
Troisdorf	North Rhine-Westphalia	
Tübingen	Baden-Württemberg	
Unna	North Rhine-Westphalia	
Velbert	North Rhine-Westphalia	
Viersen	North Rhine-Westphalia	
Villingen-Schwenningen	Baden-Württemberg	
Waiblingen	Baden-Württemberg	
Weimar	Thuringia	
Wesel	North Rhine-Westphalia	
Wetzlar	Hesse	
Wilhelmshaven	Lower Saxony	
Willich	North Rhine-Westphalia	
Witten	North Rhine-Westphalia	
Wolfenbüttel	Lower Saxony	
Worms	Rhineland-Palatinate	
Zwickau	Saxony	

Reference date: 31.03.2014.

Table B.1.2: Large Cities in alphabetical order

City	Federal State	Capital Function
Aachen	North Rhine-Westphalia	
Augsburg	Bavaria	
Bergisch Gladbach	North Rhine-Westphalia	
Bielefeld	North Rhine-Westphalia	
Bochum	North Rhine-Westphalia	
Bonn	North Rhine-Westphalia	
Bottrop	North Rhine-Westphalia	
Braunschweig	Lower Saxony	
Bremerhaven	Bremen	Federal State Capital
Chemnitz	Saxony	
Darmstadt	Hesse	
Duisburg	North Rhine-Westphalia	
Erfurt	Thuringia	Federal State Capital
Erlangen	Bavaria	
Freiburg im Breisgau	Baden-Württemberg	
Fürth	Bavaria	
Gelsenkirchen	North Rhine-Westphalia	
Göttingen	Lower Saxony	
Hagen	North Rhine-Westphalia	
Halle/Saale	Saxony-Anhalt	
Hamm	North Rhine-Westphalia	
Heidelberg	Baden-Württemberg	
Heilbronn	Baden-Württemberg	
Herne	North Rhine-Westphalia	
Ingolstadt	Bavaria	
Jena	Thuringia	
Karlsruhe	Baden-Württemberg	
Kassel	Hesse	
Kiel	Schleswig-Holstein	Federal State Capital
Koblenz	Rhineland-Palatinate	
Krefeld	North Rhine-Westphalia	
Leverkusen	North Rhine-Westphalia	
Lübeck	Schleswig-Holstein	
Ludwigshafen am Rhein	Rhineland-Palatinate	
Magdeburg	Saxony-Anhalt	Federal State Capital
Mainz	Rhineland-Palatinate	Federal State Capital
Mannheim	Baden-Württemberg	
Moers	North Rhine-Westphalia	
Mönchengladbach	North Rhine-Westphalia	
Mülheim an der Ruhr	North Rhine-Westphalia	
Münster	North Rhine-Westphalia	
Neuss	North Rhine-Westphalia	
Nürnberg	Bavaria	
Oberhausen	North Rhine-Westphalia	
Offenbach am Main	Hesse	
Oldenburg (Oldenburg)	Lower Saxony	
Osnabrück	Lower Saxony	
Paderborn	North Rhine-Westphalia	
Pforzheim	Baden-Württemberg	
Potsdam	Brandenburg	Federal State Capital
Recklinghausen	North Rhine-Westphalia	
Regensburg	Bavaria	
Remscheid	North Rhine-Westphalia	
Reutlingen	Baden-Württemberg	
Rostock	Mecklenburg-Western Pomerania	
Saarbrücken	Saarland	Federal State Capital
Solingen	North Rhine-Westphalia	
Trier	Rhineland-Palatinate	

Reference date: 31.03.2014.

Table B.1.2: Large Cities in alphabetical order – continued

City	Federal State	Capital Function
Ulm	Baden-Württemberg	
Wiesbaden	Hesse	Federal State Capital
Wolfsburg	Lower Saxony	
Wuppertal	North Rhine-Westphalia	
Würzburg	Bavaria	

Reference date: 31.03.2014.

Table B.1.3: Metropolises in alphabetical order

City	Federal State	Capital Function
Berlin	Berlin	Federal Capital, Federal State Capital
Bremen	Bremen	
Dortmund	North Rhine-Westphalia	
Dresden	Saxony	Federal State Capital
Düsseldorf	North Rhine-Westphalia	Federal State Capital
Essen	North Rhine-Westphalia	
Frankfurt am Main	Hesse	
Hamburg	Hamburg	Federal State Capital
Hannover	Lower Saxony	Federal State Capital
Köln	North Rhine-Westphalia	
Leipzig	Saxony	
München	Bavaria	Federal State Capital
Stuttgart	Baden-Württemberg	Federal State Capital

Reference date: 31.03.2014.

B.2 Descriptive statistics of variables

Table B.2.1: Descriptive statistics of dependent variables

Variable	Mean	Standard Deviation	Minimum	Maximum
I = Innovation Type				
Product Improvement	0.448	0.497	0	1
Product Introduction	0.101	0.313	0	1
Process Innovation	0.223	0.417	0	1
Organizational Innovation	0.474	0.499	0	1

Table B.2.2: Descriptive statistics of explanatory variables

Variable	Mean	Standard Deviation	Minimum	Maximum
CON = Control Variables				
Productivity [log]	5.589	0.940	-0.379	12.866
Establishment Size: 1 to 4	0.374	0.484	0	1
Establishment Size: 5 to 9	0.126	0.332	0	1
Establishment Size: 10 to 19	0.117	0.322	0	1
Establishment Size: 20 to 49	0.153	0.360	0	1
Establishment Size: 50 to 99	0.096	0.295	0	1
Establishment Size: 100 to 149	0.046	0.208	0	1
Establishment Size: 150 to 199	0.025	0.157	0	1
Establishment Size: 200 to 249	0.017	0.129	0	1
Establishment Size: 250 to 499	0.029	0.167	0	1
Establishment Size: 500 to 999	0.012	0.109	0	1
Establishment Size: 1,000 and m.	0.005	0.069	0	1
Human Capital	0.442	0.403	0	1
Sole Trader	0.283	0.451	0	1
Private Company	0.117	0.321	0	1
Limited Liability	0.600	0.490	0	1
Single-site Company	0.824	0.381	0	1
Branch Office	0.072	0.258	0	1
Headquarter	0.104	0.305	0	1
Foreign Ownership	0.042	0.201	0	1
Age: 0-4	0.187	0.390	0	1
Age: 5-14	0.290	0.454	0	1
Age: 15+	0.523	0.500	0	1
Newest Equipment	0.277	0.447	0	1
New Equipment	0.522	0.500	0	1
Older Equipment	0.186	0.389	0	1
Out-of-date Equipment	0.016	0.124	0	1
ENV = Economic Environment				
Diversity	0.908	0.037	0.426	0.946
Specialization	0.144	0.080	0.000	0.364
CIT = Distance to nearest City				
Any City [100 km]	0.085	0.127	0	0.918
Metropolis [100 km]	0.032	0.082	0	0.741
Large City [100 km]	0.091	0.117	0	0.709
Small City [100 km]	0.149	0.157	0	0.934
LOC = Location				
Closest City Metropolis	0.361	0.480	0	1
Closest City Large City	0.373	0.484	0	1
Closest City Small City	0.266	0.442	0	1

Table B.2.3: Pearson correlation matrix of establishment specific control variables

	Pro-duc-tivity	Est. Size: 1 to 4	Est. Size: 5 to 9	Est. Size: 10 to 19	Est. Size: 20 to 49	Est. Size: 50 to 99	Est. Size: 100 to 149	Est. Size: 150 to 199	Est. Size: 200 to 249	Est. Size: 250 to 499	Est. Size: 500 to 999	Est. Size: 1,000 and more	Hu-man Cap.	Sole Trader	Priv. Comp.	Ltd. Liab.	Single -site Comp.	Br. Of-fice	Head-quar-ter	Fo-reign Own.	Age: 1-4	Age: 5-14	Age: 15+	New-est Equ.	New Equ.	Older Equ.	Out-of-date Equ.
Productivity	1.00																										
Est. Size: 1 to 4	0.31	1.00																									
Est. Size: 5 to 9	0.02	-0.30	1.00																								
Est. Size: 10 to 19	-0.01	-0.30	-0.13	1.00																							
Est. Size: 20 to 49	-0.12	-0.35	-0.16	-0.15	1.00																						
Est. Size: 50 to 99	-0.16	-0.26	-0.11	-0.11	-0.13	1.00																					
Est. Size: 100 to 149	-0.13	-0.17	-0.08	-0.07	-0.09	-0.06	1.00																				
Est. Size: 150 to 199	-0.12	-0.13	-0.06	-0.06	-0.07	-0.05	-0.03	1.00																			
Est. Size: 200 to 249	-0.08	-0.10	-0.04	-0.04	-0.05	-0.04	-0.02	-0.02	1.00																		
Est. Size: 250 to 499	-0.05	-0.14	-0.06	-0.06	-0.07	-0.05	-0.04	-0.03	-0.02	1.00																	
Est. Size: 500 to 999	-0.10	-0.08	-0.04	-0.04	-0.04	-0.03	-0.02	-0.02	-0.01	-0.02	1.00																
Est. Size: 1,000 +	0.03	-0.06	-0.02	-0.02	-0.03	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	1.00															
Human Capital	0.25	0.03	0.16	0.09	-0.02	-0.11	-0.11	-0.08	-0.05	-0.08	-0.07	0.01	1.00														
Sole Trader	0.07	0.51	-0.03	-0.10	-0.23	-0.18	-0.13	-0.10	-0.07	-0.11	-0.03	-0.04	-0.00	1.00													
Private Comp.	0.08	0.03	0.03	0.05	0.03	-0.09	-0.01	-0.05	-0.04	-0.06	-0.02	-0.02	0.06	-0.21	1.00												
Limited Liability	-0.11	-0.49	0.00	0.07	0.20	0.22	0.13	0.13	0.08	0.14	0.04	0.05	-0.03	-0.80	-0.41	1.00											
Single-site Comp.	0.12	0.31	0.09	-0.00	-0.10	-0.18	-0.12	-0.11	-0.11	-0.13	-0.10	-0.10	0.05	0.27	0.07	-0.29	1.00										
Branch Office	-0.04	-0.18	-0.05	-0.00	0.04	0.09	0.10	0.02	0.10	0.11	0.11	0.07	-0.00	-0.15	0.02	0.13	-0.58	1.00									
Headquarter	-0.12	-0.23	-0.07	0.01	0.10	0.15	0.06	0.12	0.05	0.07	0.04	0.07	-0.06	-0.21	-0.01	0.26	-0.76	-0.10	1.00								
Foreign Own.	0.01	-0.15	-0.06	-0.01	0.04	0.05	0.06	0.15	-0.01	0.14	0.03	0.13	-0.02	-0.13	-0.07	0.17	-0.24	0.02	0.28	1.00							
Age: 1-4	-0.04	0.09	-0.05	-0.06	-0.00	0.03	-0.02	-0.02	-0.01	-0.04	-0.01	-0.01	-0.11	0.02	-0.05	0.01	0.08	-0.01	-0.08	-0.02	1.00						
Age: 5-14	-0.01	0.06	-0.03	-0.03	-0.01	-0.00	-0.04	0.01	0.01	-0.01	0.01	-0.01	0.02	-0.04	-0.05	0.07	-0.01	-0.03	0.04	0.03	-0.34	1.00					
Age: 15+	0.04	-0.12	0.07	0.07	0.01	-0.03	0.06	0.01	-0.00	0.04	-0.00	0.02	0.07	0.03	0.08	-0.07	-0.05	0.04	0.03	-0.02	-0.48	-0.66	1.00				
Newest Equ.	0.03	-0.08	-0.01	0.05	0.01	0.05	-0.01	0.02	0.05	0.02	0.01	0.01	0.08	-0.06	0.00	0.05	-0.02	0.02	0.01	0.02	0.04	-0.04	-0.00	1.00			
New Equ.	0.02	0.00	-0.01	-0.01	-0.02	0.01	0.04	-0.00	-0.03	0.02	0.01	0.01	0.01	-0.00	0.00	0.00	-0.02	0.03	0.00	-0.01	0.00	0.00	-0.01	-0.64	1.00		
Older Equ.	-0.05	0.07	0.03	-0.03	0.02	-0.06	-0.04	-0.02	-0.01	-0.06	-0.01	-0.03	-0.09	0.05	0.00	-0.05	0.04	-0.05	-0.01	-0.01	-0.05	0.04	0.00	-0.29	-0.51	1.00	
Out-of-date Equ.	-0.03	0.07	-0.04	-0.01	-0.01	-0.03	-0.03	0.00	-0.02	-0.00	-0.01	0.05	-0.05	0.05	-0.02	-0.03	0.03	-0.04	-0.01	-0.01	0.01	-0.02	0.01	-0.08	-0.14	-0.07	1.00

B.3 Additional results of probit regressions

Table B.3.1: Variable Vectors *CON* and *ENV* for *Model 1*

	Product Improvement	**Product Introduction**	**Process Innovation**	**Organizational Innovation**
CON = Control Variables				
Productivity	0.218***	0.130*	0.181***	0.119***
	(0.01)	(0.07)	(0.00)	(0.02)
Establishment Size: 1 to 4	-0.260***	-0.134**	-0.217***	-0.705***
	(0.04)	(0.06)	(0.06)	(0.00)
Establishment Size: 5 to 9	-0.074**	-0.026	-0.184***	-0.346***
	(0.03)	(0.10)	(0.07)	(0.09)
Establishment Size: 10 to 19	0.076	-0.011	0.074	-0.181***
	(0.08)	(0.02)	(0.07)	(0.02)
Establishment Size: 50 to 99	0.141***	-0.076	0.338***	0.189***
	(0.02)	(0.10)	(0.05)	(0.04)
Establishment Size: 100 to 149	0.399***	0.277***	0.378***	0.281***
	(0.05)	(0.06)	(0.06)	(0.05)
Establishment Size: 150 to 199	0.380***	0.490***	0.548***	0.504***
	(0.11)	(0.13)	(0.05)	(0.10)
Establishment Size: 200 to 249	0.300***	0.411**	0.312***	0.571***
	(0.04)	(0.18)	(0.08)	(0.04)
Establishment Size: 250 to 499	0.414***	0.519***	0.552***	0.433***
	(0.04)	(0.17)	(0.07)	(0.14)
Establishment Size: 500 to 999	0.624***	0.201	0.239***	0.663***
	(0.07)	(0.14)	(0.08)	(0.04)
Establishment Size: 1,000 and m.	1.167***	0.559*	0.931*	0.881***
	(0.08)	(0.31)	(0.53)	(0.17)
Human Capital	0.396***	0.262***	0.221**	0.174**
	(0.09)	(0.05)	(0.09)	(0.08)
Sole Trader	-0.351***	-0.286***	-0.326***	-0.255***
	(0.08)	(0.01)	(0.09)	(0.01)
Private Company	-0.453***	-0.420***	-0.347***	-0.243***
	(0.09)	(0.03)	(0.05)	(0.05)
Branch Office	-0.021	-0.187**	0.127	0.078
	(0.05)	(0.08)	(0.08)	(0.07)
Headquarter	-0.074	-0.168***	0.054	-0.112
	(0.05)	(0.05)	(0.06)	(0.08)
Foreign Ownership	0.064	0.113	-0.024	0.280***
	(0.13)	(0.10)	(0.14)	(0.01)
Age: 5-14	0.014	-0.048	0.021	0.075
	(0.03)	(0.05)	(0.03)	(0.10)
Age: 15+	-0.126***	-0.237***	-0.071**	-0.154
	(0.02)	(0.05)	(0.04)	(0.10)
New Equipment	-0.165***	-0.134***	-0.247***	-0.056***
	(0.02)	(0.05)	(0.02)	(0.00)
Older Equipment	-0.280***	-0.091***	-0.462***	-0.089*
	(0.06)	(0.02)	(0.04)	(0.05)
Out-of-date Equipment	-0.384***	-0.591*	-0.317***	-0.010
	(0.10)	(0.34)	(0.12)	(0.02)
ENV = Economic Environment				
Diversity	0.738	1.846*	-0.704	-1.123***
	(1.22)	(1.11)	(1.04)	(0.17)
Specialization	-3.283***	-3.191***	-2.654***	-0.784
	(1.12)	(0.56)	(0.50)	(0.64)

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level
Notes: Time-fixed effects and locational fixed effects *LOC* included.

Table B.3.2: Variable Vectors *CON* and *ENV* for *Model 1* – Average Marginal Effects

	Product Improvement	Product Introduction	Process Innovation	Organizational Innovation
CON = Control Variables				
Productivity	0.075***	0.022**	0.048***	0.042***
	(0.00)	(0.01)	(0.00)	(0.01)
Establishment Size: 1 to 4	-0.089***	-0.023**	-0.057***	-0.248***
	(0.02)	(0.01)	(0.02)	(0.00)
Establishment Size: 5 to 9	-0.025**	-0.004	-0.048***	-0.122***
	(0.01)	(0.02)	(0.02)	(0.03)
Establishment Size: 10 to 19	0.026	-0.002	0.019	-0.063***
	(0.03)	(0.00)	(0.02)	(0.01)
Establishment Size: 50 to 99	0.048***	-0.013	0.089***	0.066***
	(0.01)	(0.02)	(0.01)	(0.01)
Establishment Size: 100 to 149	0.136***	0.047***	0.099***	0.099***
	(0.01)	(0.01)	(0.02)	(0.02)
Establishment Size: 150 to 199	0.129***	0.083***	0.144***	0.177***
	(0.03)	(0.02)	(0.02)	(0.04)
Establishment Size: 200 to 249	0.103***	0.070**	0.082***	0.201***
	(0.01)	(0.03)	(0.02)	(0.02)
Establishment Size: 250 to 499	0.141***	0.088***	0.145***	0.152***
	(0.01)	(0.03)	(0.02)	(0.05)
Establishment Size: 500 to 999	0.213***	0.034	0.063***	0.233***
	(0.02)	(0.02)	(0.02)	(0.01)
Establishment Size: 1,000 and m.	0.398***	0.094*	0.244*	0.310***
	(0.02)	(0.06)	(0.14)	(0.06)
Human Capital	0.135***	0.044***	0.058**	0.061**
	(0.03)	(0.01)	(0.02)	(0.03)
Sole Trader	-0.120***	-0.048***	-0.086***	-0.090***
	(0.03)	(0.00)	(0.02)	(0.00)
Private Company	-0.154***	-0.071***	-0.091***	-0.085***
	(0.03)	(0.01)	(0.01)	(0.02)
Branch Office	-0.007	-0.032**	0.033	0.028
	(0.02)	(0.01)	(0.02)	(0.03)
Headquarter	-0.026	-0.029***	0.014	-0.039
	(0.02)	(0.01)	(0.02)	(0.03)
Foreign Ownership	0.025	0.021	-0.004	0.099***
	(0.05)	(0.02)	(0.04)	(0.00)
Age: 5-14	0.005	-0.008	0.005	0.026
	(0.01)	(0.01)	(0.01)	(0.03)
Age: 15+	-0.043***	-0.040***	-0.019**	-0.054
	(0.01)	(0.01)	(0.01)	(0.03)
New Equipment	-0.056***	-0.023***	-0.065***	-0.020***
	(0.01)	(0.01)	(0.00)	(0.00)
Older Equipment	-0.096***	-0.016***	-0.121***	-0.031*
	(0.02)	(0.00)	(0.01)	(0.02)
Out-of-date Equipment	-0.131***	-0.102*	-0.083***	-0.004
	(0.03)	(0.06)	(0.03)	(0.01)
ENV = Economic Environment				
Diversity	0.253	0.314*	-0.185	-0.395***
	(0.42)	(0.20)	(0.27)	(0.06)
Specialization	-1.121***	-0.542***	-0.698***	-0.276
	(0.36)	(0.12)	(0.14)	(0.22)

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level

Notes: Time-fixed effects and locational fixed effects *LOC* included.

Table B.3.3: Variable Vectors *CON* and *ENV* for *Model 2*

	Product Improvement	Product Introduction	Process Innovation	Organizational Innovation
CON = Control Variables				
Productivity	0.214***	0.128*	0.180***	0.119***
	(0.01)	(0.07)	(0.00)	(0.02)
Establishment Size: 1 to 4	-0.249***	-0.130**	-0.211***	-0.706***
	(0.04)	(0.06)	(0.06)	(0.01)
Establishment Size: 5 to 9	-0.059*	-0.018	-0.177**	-0.342***
	(0.03)	(0.11)	(0.07)	(0.09)
Establishment Size: 10 to 19	0.070	-0.013	0.067	-0.182***
	(0.08)	(0.02)	(0.08)	(0.02)
Establishment Size: 50 to 99	0.138***	-0.076	0.334***	0.192***
	(0.02)	(0.11)	(0.05)	(0.04)
Establishment Size: 100 to 149	0.411***	0.287***	0.386***	0.287***
	(0.04)	(0.06)	(0.06)	(0.05)
Establishment Size: 150 to 199	0.375***	0.492***	0.544***	0.514***
	(0.11)	(0.13)	(0.05)	(0.11)
Establishment Size: 200 to 249	0.303***	0.417**	0.318***	0.573***
	(0.04)	(0.18)	(0.09)	(0.04)
Establishment Size: 250 to 499	0.420***	0.527***	0.548***	0.438***
	(0.05)	(0.17)	(0.07)	(0.14)
Establishment Size: 500 to 999	0.613***	0.194	0.229***	0.662***
	(0.07)	(0.14)	(0.08)	(0.03)
Establishment Size: 1,000 and m.	1.167***	0.560*	0.922*	0.882***
	(0.08)	(0.30)	(0.54)	(0.17)
Human Capital	0.400***	0.263***	0.222**	0.176**
	(0.09)	(0.05)	(0.09)	(0.08)
Sole Trader	-0.352***	-0.288***	-0.326***	-0.255***
	(0.08)	(0.01)	(0.09)	(0.01)
Private Company	-0.453***	-0.419***	-0.348***	-0.241***
	(0.09)	(0.04)	(0.04)	(0.05)
Branch Office	-0.018	-0.184**	0.127	0.081
	(0.05)	(0.08)	(0.08)	(0.07)
Headquarter	-0.070	-0.167***	0.056	-0.112
	(0.05)	(0.05)	(0.06)	(0.08)
Foreign Ownership	0.055	0.107	-0.025	0.278***
	(0.13)	(0.10)	(0.13)	(0.01)
Age: 5-14	0.015	-0.050	0.017	0.074
	(0.02)	(0.05)	(0.03)	(0.10)
Age: 15+	-0.130***	-0.240***	-0.074**	-0.154
	(0.02)	(0.06)	(0.04)	(0.10)
New Equipment	-0.170***	-0.131***	-0.247***	-0.054***
	(0.02)	(0.05)	(0.02)	(0.01)
Older Equipment	-0.284***	-0.085***	-0.464***	-0.086*
	(0.07)	(0.02)	(0.04)	(0.05)
Out-of-date Equipment	-0.407***	-0.599*	-0.327***	-0.006
	(0.10)	(0.34)	(0.12)	(0.02)
ENV = Economic Environment				
Diversity	0.717	1.858*	-0.730	-1.154***
	(1.26)	(1.12)	(1.05)	(0.13)
Specialization	-3.399***	-3.222***	-2.703***	-0.763
	(1.06)	(0.59)	(0.49)	(0.64)

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level
Notes: Time-fixed effects and locational fixed effects *LOC* included.

Table B.3.4: Variable Vectors *CON* and *ENV* for *Model 2* – Average Marginal Effects

	Product Improvement	**Product Introduction**	**Process Innovation**	**Organizational Innovation**
CON = Control Variables				
Productivity	0.073***	0.022**	0.047***	0.042***
	(0.00)	(0.01)	(0.00)	(0.01)
Establishment Size: 1 to 4	-0.085***	-0.022**	-0.055***	-0.248***
	(0.01)	(0.01)	(0.02)	(0.00)
Establishment Size: 5 to 9	-0.020*	-0.003	-0.047**	-0.120***
	(0.01)	(0.02)	(0.02)	(0.03)
Establishment Size: 10 to 19	0.024	-0.002	0.018	-0.064***
	(0.03)	(0.00)	(0.02)	(0.01)
Establishment Size: 50 to 99	0.047***	-0.013	0.088***	0.067***
	(0.01)	(0.02)	(0.01)	(0.01)
Establishment Size: 100 to 149	0.140***	0.049***	0.101***	0.101***
	(0.01)	(0.01)	(0.02)	(0.02)
Establishment Size: 150 to 199	0.128***	0.083***	0.143***	0.181***
	(0.04)	(0.02)	(0.01)	(0.04)
Establishment Size: 200 to 249	0.103***	0.071**	0.083***	0.202***
	(0.01)	(0.03)	(0.02)	(0.02)
Establishment Size: 250 to 499	0.143***	0.089***	0.144***	0.154***
	(0.01)	(0.02)	(0.02)	(0.05)
Establishment Size: 500 to 999	0.209***	0.033	0.060***	0.233***
	(0.02)	(0.02)	(0.02)	(0.01)
Establishment Size: 1,000 and m.	0.397***	0.095*	0.242*	0.310***
	(0.02)	(0.05)	(0.14)	(0.06)
Human Capital	0.136***	0.045***	0.058**	0.062**
	(0.03)	(0.01)	(0.02)	(0.03)
Sole Trader	-0.120***	-0.049***	-0.086***	-0.090***
	(0.03)	(0.00)	(0.02)	(0.00)
Private Company	-0.154***	-0.071***	-0.091***	-0.085***
	(0.03)	(0.01)	(0.01)	(0.02)
Branch Office	-0.006	-0.031**	0.033	0.028
	(0.02)	(0.02)	(0.02)	(0.03)
Headquarter	-0.024	-0.028***	0.015	-0.040
	(0.02)	(0.01)	(0.02)	(0.03)
Foreign Ownership	0.019	0.018	-0.007	0.098***
	(0.04)	(0.02)	(0.04)	(0.00)
Age: 5-14	0.005	-0.009	0.005	0.026
	(0.01)	(0.01)	(0.01)	(0.03)
Age: 15+	-0.044***	-0.041***	-0.019**	-0.054
	(0.01)	(0.01)	(0.01)	(0.03)
New Equipment	-0.058***	-0.022**	-0.065***	-0.019***
	(0.01)	(0.01)	(0.01)	(0.00)
Older Equipment	-0.097***	-0.014***	-0.122***	-0.030*
	(0.02)	(0.00)	(0.01)	(0.02)
Out-of-date Equipment	-0.139***	-0.101	-0.086***	-0.002
	(0.03)	(0.06)	(0.03)	(0.01)
ENV = Economic Environment				
Diversity	0.244	0.315	-0.192	-0.406***
	(0.43)	(0.20)	(0.28)	(0.05)
Specialization	-1.157***	-0.546***	-0.710***	-0.268
	(0.34)	(0.13)	(0.14)	(0.23)

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level
Notes: Time-fixed effects and locational fixed effects *LOC* included.

Table B.3.5: Difference in parameter tests for city and innovation types in *Model 2*

	Product Improvement	**Product Introduction**	**Process Innovation**	**Organizational Innovation**
Chi-square difference in parameter tests if closest city is a Metropolis				
Product Improvement	—	4896.79***	73.66***	256.59***,°°
Product Introduction	4896.79***	—	42.96***	90.15***,°°
Process Innovation	73.66***	42.96***	—	22.59***,°°
Organizational Innovation	256.59***,°°	90.15***,°°	22.59***,°°	—
Chi-square difference in parameter tests if closest city is a Large City				
Product Improvement	—	31.66***,°°	11.03***	7191.17***
Product Introduction	31.66***,°°	—	34.57***,°°	5.54*,°°
Process Innovation	11.03***	34.57***,°°	—	14.74***
Organizational Innovation	7191.17***	5.54*,°°	14.74***	—
Chi-square difference in parameter tests if closest city is a Small City				
Product Improvement	—	10.28***,°°	1.03	183.65***,°°
Product Introduction	10.28***,°°	—	12.69***,°°	1.19°°
Process Innovation	1.03	12.69***,°°	—	1.17°°
Organizational Innovation	183.65***,°°	1.19°°	1.17°°	—

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level
°° Joint significance test for distance decay variables is not significant.

Appendix C

Appendix to Chapter 4

C.1 Location quotients for KIS in Karlsruhe

Table C.1.1: Concentration of Knowledge Intensive Services in Karlsruhe 2012

NACE - Sections and Divisions	Employees Karlsruhe	Location Quotient Baden-Württemberg	Location Quotient Germany
J: Information and communication	**12,127**	**2.5**	**2.6**
58 Publishing activities	2,104	2.3	2.6
59 Motion picture, video and television programme production, sound recording and music publishing act.	107	1.1	0.4
60 Programming and broadcasting activities	97	0.6	0.3
61 Telecommunications	539	1.9	1.3
62 Computer programming, consultancy and rel. act.	9,280	2.5	3.2
63 Information service activities	2,060	8.1	6.8
K: Financial and insurance activities	**11,143**	**2.0**	**2.0**
64 Financial service activities, except insurance and pension funding	5,515	1.5	1.5
65 Insurance, reinsurance and pension funding, except compulsory social security insurance	5,043	5.6	4.7
66 Activities auxiliary to financial services and insurance activities	585	0.8	0.7
M: Professional, scientific and technical act.	**12,545**	**1.2**	**1.3**
69 Legal and accounting services	2,540	1.2	1.1
70 Activities of head offices; management cons. serv.	2,943	1.0	1.1
71 Architectural and engineering activities; technical testing and analysis	4,175	1.4	1.6
72 Scientific research and development	1,776	1.5	1.6
73 Advertising and market research	807	1.5	1.2
74 Other professional, scientific and technical act.	250	1.1	0.8
75 Veterinary activities	54	0.5	0.4
Other divisions			
86 Human health services	12,039	1.1	1.0
90 Creative, arts and entertainment activities	802	2.9	2.2
91 Libraries, archives, museums and other cultural act.	649	4.1	3.3
Total Knowledge Intensive Services	**49,305**	**1.5**	**1.5**

Source: Statistical Office of the Federal State of Baden-Württemberg 2014c, Bundesagentur für Arbeit 2013, Gehrke et al. 2010; own calculations

C.2 Additional results of logit regressions

Table C.1.2: Z-standardized effects of internal resources, cooperation activities and city-specific innovation support infrastructures

	Type of Innovation			
	Product	**Process**	**Organi-zational**	**Business Model**
1. Control Variables [CV]				
A	-0.005	-0.002	0.000	-0.013
S	0.007*	0.000	0.009***	-0.003
2. Internal Resources [INT]				
KI	0.000	-0.001	-0.002**	-0.002
RD	0.645***	0.269*	0.150*	0.289
3. External Organizations [EXT]				
VC	0.130	0.254*	0.132*	0.457**
HC	0.028	-0.030	0.073	0.331*
HEC	-0.024	0.240*	-0.120	-0.064
RDC	-0.282	-4.059	-0.121	-0.081
4. City-specific Innovation Support Infrastructures [CIT]				
AIS	-0.223	-0.102	-0.114	0.609**
FIN	-0.173	0.016	0.185*	-0.079
Model Fit				
-2LL	236.997	89.807	256.262	187.028
Chi-Square	72.136***	20.412**	43.993***	26.608***
N	225	225	225	225

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level

C.3 Extract from the company survey of Karlsruhe

The survey was conducted online in German. The questions used in the multivariate logit regressions – in translation – are as follows.

C.3.1 Since when, independent of the current legal form, is your firm located in Karlsruhe? *[Year]*

C.3.2 How many employees, including the proprietor, are currently engaged at the firm location in Karlsruhe? *[Number of employees]*

C.3.3 What is the share of employees holding a degree from a higher education organization (university, university of applied sciences, university of cooperative education) in your firm? *[Share of employees with a university degree]*

C.3.4 Were any research and development activities pursued in your firm within the last three years? *[Yes / No]*

C.3.5 Which innovations were introduced in your firm within the last three years? *[Introduction of a new product or service / Introduction of a new production, manufacturing or performance method / New methods for organization and management (e.g. procedures, processes, communication channels) / Introduction of new business models]*

C.3.6 Apart from cluster and network initiatives, further initiatives support knowledge exchange and innovation activities of local firms. Which of the following services have you already used? *[Steinbeis Centers / Services of the Innovationsallianz TechnologieRegion Karlsruhe / Financial offers of the L-Bank / Forschungszentrum Informatik (House of Living Labs)]*

C.3.7 Has your firm cooperated with suppliers or customers within the last three years? Cooperation with customers or suppliers is defined as a relationship that exceeds a normal business relation (e.g. information exchange). *[Yes / No]* **C.3.8** If yes, please indicate the form of cooperation and the geographic position of your cooperation partners. *[Karlsruhe / Other KTR / Germany: Baden-Württemberg / Germany: Other federal state / Foreign country]*

C.3.9 Has your firm cooperated with other firms (Firms with which no business relationships exist, e.g. competitors, companies within the same industry, cluster) within the last three years? Cooperation with other firms is defined as any form of relationship. *[Yes / No]* **C.3.10** If yes, please indicate the form of cooperation and the geographic position of your cooperation partners. *[Karlsruhe / Other KTR / Germany: Baden-Württemberg / Germany: Other federal state / Foreign country]*

C.3.11 Has your firm cooperated with higher education organizations (universities, universities of applied sciences, universities of cooperative education) within the last three years? Cooperation with higher education organizations is defined as any form of relationship. *[Yes / No]* **C.3.12** If yes, please indicate the form of cooperation and the geographic position of your cooperation partners. *[Karlsruhe / Other KTR / Germany: Baden-Württemberg / Germany: Other federal state / Foreign country]*

C.3.13 Has your firm cooperated with non-university research and development organizations (e.g. Fraunhofer Institutes, Max-Planck-Institutes, Leibniz Association) within the last three years? Cooperation with non-university research and development organizations is defined as any form of relationship. *[Yes / No]* **C.3.14** If yes, please indicate the form of co-operation and the geographic position of your cooperation partners. *[Karlsruhe / Other KTR / Germany: Baden-Württemberg / Germany: Other federal state / Foreign country]*

Bibliography

Acs, Z., Anselin, L. and Varga, A.: 2002, Patents and innovation counts as measures of regional production of new knowledge, *Research Policy* **31**(7), 1069–1085.

Acs, Z., FitzRoy, F. and Smith, I.: 2002, High-technology employment and R&D in cities: Heterogeneity vs specialization, *The Annals of Regional Science* **36**(3), 373–386.

Aghion, P. and Howitt, P.: 1992, A model of growth through creative destruction, *Econometrica* **60**(2), 323–351.

Aguilera, A.: 2003, Service relationship, market area and the intrametropolitan location of business services, *The Service Industries Journal* **23**(1), 43–58.

Akcay, S.: 2011, Causality relationship between total R&D investment and economic growth: Evidence from United States, *The Journal of Faculty of Economics and Administrative Sciences* **16**(1), 79–92.

Albert, J., Casanoca, M. and Orts, V.: 2012, Spatial location patterns of Spanish manufacturing firms, *Papers in Regional Science* **91**(1), 107–136.

Amara, N., Landry, R. and Doloreux, D.: 2009, Patterns of innovation in knowledge-intensive business services, *The Service Industries Journal* **29**(4), 407–430.

Andersson, M. and Hellerstedt, K.: 2009, Location attributes and start-ups in knowledge-intensive business services, *Industry and Innovation* **16**(1), 103–121.

Antonietti, R., Cainelli, G. and Lupi, C.: 2013, Vertical disintegration and spatial co-localization: The case of KIBS in the metropolitan region of Milan, *Economics Letters* **118**(2), 360–363.

Arrow, K. J.: 1962, The economic implications of learning by doing, *Review of Economic Studies* **29**, 155–173.

Asheim, B. and Gertler, M.: 2005, The geography of innovation: Regional innovation systems, *in* J. Fagerberg, D. Mowery and R. Nelson (eds), *The Oxford Handbook of Innovation*, Oxford University Press, Oxford, pp. 291–317.

Asheim, B., Smith, H. and Oughton, C.: 2011, Regional innovation systems: Theory, empirics and policy, *Regional Studies* **45**(7), 875–891.

Aslesen, H. and Isaksen, A.: 2007, Knowledge intensive business services and urban industrial development, *The Service Industries Journal* **27**(3), 321–338.

Audretsch, D. and Feldman, M.: 1996, R&D spillovers and the geography of innovation and production, *The American Economic Review* **86**(3), 630–640.

Aydalot, P.: 1986, *Millieux innovateurs en Europe*, GREMI, Paris.

Bagnasco, A.: 1977, *Tre Italie, La problematica territoriale dello sviluppo italiano*, II Mulino, Bologna.

Bairoch, P.: 1988, *Cities and Economic Development: From the Dawn of History to the Present*, Univ. Chicago Press, Chicago.

Barlet, M., Briant, A. and Crusson, L.: 2013, Location patterns of service industries in France: A distance-based approach, *Regional Science and Urban Economics* **43**(2), 338–351.

Bathelt, H., Malmberg, A. and Maskell, P.: 2004, Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation, *Progress in Human Geography* **28**(1), 31–56.

Baumann, J. and Kritikos, A.: 2016, The link between R&D, innovation and productivity: Are micro firms different?, *Technical Report Discussion Paper No. 9734*, Institute for the Study of Labor (IZA), Bonn.

Beaudry, C. and Schiffauerova, A.: 2009, Who's right, Marshall or Jacobs? The localization versus urbanization debate, *Research Policy* **38**(2), 318–337.

Becattini, G.: 1979, Dal 'Settore Industriale' al 'Distretto Industriale'. Alcune considerazioni sul'uniti di indagine dell'economia industriale, *Rivista di Economia e Politica Industriale* **1**, 7–21.

Benneworth, P., Coenen, L., Moodysson, J. and Asheim, B.: 2009, Exploring the multiple roles of Lund University in strengthening Scania's regional innovation system: Towards institutional learning?, *European Planning Studies* **17**(11), 1645–1664.

Best, H. and Wolf, C.: 2012, Modellvergleich und Ergebnisinterpretation in Logit- und Probit-Regressionen, *Kölner Zeitschrift für Soziologie und Sozialpsychologie* **64**(2), 377–395.

Bettencourt, L., Lobo, J. and Strumsky, D.: 2007, Invention in the city: Increasing returns to patenting as a scaling function of metropolitan size, *Research Policy* **36**(1), 107–120.

Bettiol, M., De Marchi, V., Di Maria, E. and Grandinetti, R.: 2013, Determinants of market extension in knowledge-intensive business services: Evidence from a regional innovation system, *European Planning Studies* **21**(4), 498–515.

Blažek, J. and Žižalová, P.: 2010, The biotechnology industry in the Prague metropolitan region: A cluster within a fragmented innovation system?, *Environment and Planning C: Government and Policy* **28**(5), 887–904.

Bloch, C.: 2007, Assessing recent developments in innovation measurement: The third edition of the Oslo Manual, *Science and Public Policy* **34**(1), 23–34.

Blotevogel, H. H.: 2000, Gibt es in Deutschland Metropolen? Die Entwicklung des deutschen Städtesystems und das Raumordnungskonzept der "Europäischen Metropolregionen", *in* D. Matejovski (ed.), *Metropolen. Laboratorien der Moderne*, Schr. des Wiss. Zentrums NRW 5, Campus: Frankfurt am Main, pp. 139–167.

Boje, A., Ott, I. and Stiller, S.: 2010, Metropolitan cities under transition: The example of Hamburg/Germany, *Managing Global Transitions* **8**(4), 327–352.

Boschma, R.: 2005, Proximity and innovation: A critical assessment, *Regional Studies* **39**(1), 61–74.

Boucher, G., Conway, C. and Van der Meer, E.: 2003, Tiers of engagement by universities in their region's development, *Regional Studies* **37**(9), 887–897.

Breschi, S. and Lissoni, F.: 2001, Localised knowledge spillovers vs. innovative milieux: Knowledge 'tacitness' reconsidered, *Papers in Regional Science* **80**(3), 255–273.

Briant, A., Combes, P.-P. and Lafourcade, M.: 2010, Dots to boxes: Do the size and shape of spatial units jeopardize economic geography estimations?, *Journal of Urban Economics* **67**(3), 287–302.

Brunow, S. and Blien, U.: 2015, Agglomeration effects on labor productivity: An assessment with microdata, *REGION* **2**(1), 33–53.

Brusco, S.: 1982, The Emilian model: Productive decentralisation and social integration, *Cambridge Journal of Economics* **6**(2), 167–184.

Bryson, J., Daniels, P. and Warf, B.: 2004, *Service Worlds – People, Organisations, Technologies*, Routledge, London.

Bundesagentur für Arbeit: 2013, Sozialversicherungspflichtig Beschäftigte nach Wirtschaftszweigen (WZ 2008) – Deutschland, June 2012, Arbeitsmarkt in Zahlen – Beschäftigungsstatistik, Nürnberg.

Bundesamt für Bauwesen und Raumordnung (BBR): 2005, Raumordnungsbericht 2005, Berichte, Band 21. Bonn.

Buzard, K. and Carlino, G.: 2009, The geography of research and development activity in the U.S., *Working Papers – Research Department, Federal Reserve Bank of Philadelphia* **09-16**.

Camacho, J. and Rodríguez, M.: 2005, How innovative are services? An empirical analysis for Spain, *The Service Industries Journal* **25**(2), 253–271.

Camagni, R. P.: 1995, The concept of innovative milieu and its relevance for public policies in European lagging regions, *Papers in Regional Science* **74**(4), 317–340.

Camisón-Zornoza, C., Lapiedra-Alcamí, R., Segarra-Ciprés, M. and Boronat-Navarro, M.: 2004, Meta-analysis of innovation and organizational size, *Organization Studies* **25**(3), 331–361.

Caniëls, M. C. J. and van den Bosch, H.: 2011, The role of higher education institutions in building regional innovation systems, *Papers in Regional Science* **90**(2), 271–286.

Carlino, G., Hunt, R., Carr, J. and Smith, T.: 2012, The agglomeration of R&D labs, *Working Papers – Research Department, Federal Reserve Bank of Philadelphia* **12-22**.

Carrincazeaux, C., Lunga, Y. and Rallet, A.: 2001, Proximity and localisation of corporate R&D activities, *Research Policy* **30**(5), 777–789.

Central Intelligence Agency: 2017, Country comparison: Area, accessed: 25.01.2017.

URL: *https://www.cia.gov/Library/publications/the-world-factbook/rankorder/2147rank.html*

Chatterji, A., Glaeser, E. and Kerr, W.: 2014, Clusters of entrepreneurship and innovation, *in* J. Lerner and S. Stern (eds), *Innovation Policy and the Economy*, Vol. 14, University of Chicago Press, Chicago.

Cohen, W. and Levinthal, D.: 1990, Absorptive capacity: A new perspective on learning and innovation, *Administrative science quarterly* **35**(1), 128–152.

Cohendet, P. and Zapata, S.: 2009, Innovation and creativity: Is there economic significance to the creative city?, *Management International* **13**, 23–36.

Combes, P.-P., Duranton, G., Gobillon, L., Puga, D. and Roux, S.: 2012, The productivity advantages of large cities: Distinguishing agglomeration from firm selection, *Econometrica* **80**(6), 2543–2594.

Cooke, P.: 1992, Regional innovation systems: Competitive regulation in the new Europe, *Geoforum* **23**(3), 365–382.

Cooke, P.: 2001, Regional innovation systems, clusters, and the knowledge economy, *Industrial and Corporate Change* **10**(4), 945–974.

Cooke, P., Boekholt, P. and Tödtling, F.: 2000, *The Governance of Innovation in Europe – Regional Perspectives on Global Competitiveness*, Pinter, London and New York.

Cooke, P., Davies, C. and Wilson, R.: 2002, Innovation advantages of cities: From knowledge to equity in five basic steps, *European Planning Studies* **10**(2), 233–250.

Cooke, P., Uranga, M. G. and Etxebarria, G.: 1997, Regional innovation systems: Institutional and organisational dimensions, *Research Policy* **26**(4-5), 475–491.

Coombs, R. and Miles, I.: 2000, Innovation, measurement and services: The new problematic, *in* J. Metcalfe and I. Miles (eds), *Innovation Systems in the Service Economy. Measurement and Case Study Analysis*, Kluwer Academic Publishers, Boston, pp. 85–103.

Corrocher, N. and Cusmano, L.: 2014, The 'KIBS Engine' of regional innovation systems: Empirical evidence from European regions, *Regional Studies* **48**(7), 1212–1226.

den Hertog, P.: 2000, Knowledge-intensive business services as co-producers of innovation, *International Journal of Innovation Management* **4**(4), 491–528.

den Hertog, P.: 2002, Co-producers of innovation: On the role of knowledge-intensive business services in innovation, *in* J. Gadrey and F. Gallouj (eds), *Productivity, Innovation and Knowledge in Services: New Economic and Socio-economic Approaches*, Edward Elgar Publishing.

Desmarchelier, B., Djellal, F. and Gallouj, F.: 2013, Knowledge-intensive business services and long term growth, *Structural Change and Economic Dynamics* **25**, 188–205.

Desrochers, P.: 2001, Local diversity, human creativity, and technological innovation, *Growth & Change* **32**(3), 369–394.

Doloreux, D.: 2002, What we should know about regional systems of innovation?, *Technology in Society* **24**(3), 243–263.

Doloreux, D.: 2004, Regional networks of small and medium sized enterprises: Evidence from the metropolitan area of Ottawa in Canada, *European Planning Studies* **12**(2), 173–189.

Doloreux, D. and Parto, S.: 2005, Regional innovation systems: Current discourse and unresolved issues, *Technology in Society* **27**(2), 133–153.

Doloreux, D. and Shearmur, R.: 2012, Collaboration, information and the geography of innovation in knowledge intensive business services, *Journal of Economic Geography* **12**(1), 79–105.

Duranton, G. and Overman, H.: 2005, Testing for localization using micro-geographic data, *Review of Economic Studies* **72**(4), 1077–1106.

Duranton, G. and Overman, H.: 2008, Exploring the detailed location patterns of U.K. manufacturing industries using microgeographic data, *Journal of Regional Science* **48**(1), 213–243.

Duranton, G. and Puga, D.: 2000, Diversity and specialisation in cities: Why, where and when does it matter?, *Urban Studies* **37**(3), 533–555.

Duranton, G. and Puga, D.: 2001, Nursery cities: Urban diversity, process innovation, and the life cycle of products, *The American Economic Review* **91**(5), 1454–1477.

Duranton, G. and Puga, D.: 2005, From sectoral to functional urban specialisation, *Journal of Urban Economics* **57**(2), 343–370.

Edquist, C. (ed.): 1997, *Systems of Innovation: Technologies, Institutions and Organisations*, Pinter Publishers, London.

EFI: 2015, Gutachten zu Forschung, Innovation und technologischer Leistungsfähigkeit Deutschlands 2015, Berlin: EFI.

Egeln, J., Gottschalk, S. and Rammer, C.: 2004, Location decisions of spin-offs from public research institutions, *Industry & Innovation* **11**(3), 207–223.

Ellguth, P., Kohaut, S. and Möller, I.: 2014, The IAB Establishment Panel – Methodological essentials and data quality, *Journal for Labour Market Research* **47**(1-2), 27–41.

Ellison, G. and Glaeser, E.: 1997, Geographic concentration in US manufacturing industries: A dartboard approach, *Journal of Political Economy* **105**(5), 889–927.

Ellison, N., Lampe, C., Steinfield, C. and Vitak, J.: 2010, With a little help from my friends: How social network sites affect social capital processes, *in* Z. Papacharissi (ed.), *The networked self: Identity, community, and culture on social network sites*, Routledge, New York, pp. 124–145.

Eurostat: 2015, European cities – The EU-OECD functional urban area definition, accessed: 08.02.1017.
URL: *http://ec.europa.eu/eurostat/statistics-explained/index.php/European_cities_%E2%80%93_the_EU-OECD_functional_urban_area_definition#Definition_of_a_city*

Evangelista, R.: 2000, Sectoral patterns of technological change in services, *Economics of Innovation and New Technology* **9**(3), 183–222.

Fagerberg, J.: 2004, Innovation: A guide to the literature, *in* J. Fagerberg, D. Mowery and R. Nelson (eds), *The Oxford Handbook of Innovation*, Oxford University Press, Oxford, pp. 1–26.

Feldman, M.: 1994, *The Geography of Innovation*, Kluwer Academic, Boston.

Feldman, M. and Audretsch, D.: 1999, Innovation in cities: Science-based diversity, specialization and localized competition, *European Economic Review* **43**(2), 409–429.

Fischer, G., Janik, F., Müller, D. and Schmucker, A.: 2008, The IAB Establishment Panel – From sample to survey to projection, *Technical Report 01/2008*, FDZMethodenreport.

Fischer, M., Revilla Diez, J. and Snickars, F. Varga, A.: 2001, *Metropolitan systems of innovation – Theory and evidence from three metropolitan regions in Europe*, Springer, Berlin, Germany.

Fitjar, A. and Huber, F.: 2014, Global pipelines for innovation: Insights from the case of Norway, *Journal of Economic Geography* **16**(3), 1–23.

Fitjar, A. and Rodríguez-Posé, A.: 2011, When local interaction does not suffice: Sources of firm innovation in urban Norway, *Environment and Planning A* **43**(6), 1248–1267.

Florida, R.: 2002a, The economic geography of talent, *Annals of the Association of American Geographers* **92**(4), 743–755.

Florida, R.: 2002b, *The Rise of the Creative Class*, Basic Books, New York.

Freel, M.: 2006, Patterns of technological innovation in knowledge-intensive business services, *Industry and Innovation* **13**(3), 335–358.

Freeman, C.: 1987, *Technology Policy and Economic Performance: Lessons from Japan*, Pinter Publishers, London.

Fritsch, M.: 2002, Measuring the quality of regional innovation systems: A Knowledge Production Function approach, *International Regional Science Review* **25**(1), 86–101.

Fritsch, M. and Stützer, M.: 2007, The geography of creative people in Germany, *International Journal of Foresight and Innovation Policy* **5**(1-3), 7–23.

FZI House of Living Labs: 2014, Official website, accessed: 04.06.2014.
URL: *http://www.fzi.de/forschung/fzi-house-of-living-labs/*

Gallouj, F.: 2002, Knowledge-intensive business services: Processing knowledge and producing innovation, *in* J. Gadrey and Gallouj (eds), *Productivity, Innovation and Knowledge in Services: New Economic and Socio-economic Approaches*, Edward Elgar Publishing.

Gallouj, F. and Savona, M.: 2009, Innovation in services: A review of the debate and a research agenda, *Journal of Evolutionary Economics* **19**(2), 149–172.

Gallouj, F. and Windrum, P.: 2009, Services and services innovation, *Journal of Evolutionary Economics* **19**(2), 141–148.

Garofoli, G.: 1981, Lo sviluppo delle aree periferiche nell'economia italiana degli anni settanta, *L'Industria* **2**(3), 391–404.

Gehrke, B., Frietsch, R., Neuhäusler, P. and Rammer, C.: 2013, Re-definition of research-intensive industries and goods – NIW/ISI/ZEW-Lists 2012, *Studien zum deutschen Innovationssystem 8-2013*.

Gehrke, B., Rammer, C., Frietsch, R., Neuhäusler, P. and Leidmann, M.: 2010, Listen wissens- und technologieintensiver Güter und Wirtschaftszweige – Zwischenbericht zu den NIW/ISI/ZEW-Listen 2010/2011, *Studien zum deutschen Innovationssystem 19-2010*.

Gertler, M.: 2003, Tacit knowledge and the economic geography of context, or The undefinable tacitness of being (there), *Journal of Economic Geography* **3**(1), 75–99.

Gertler, M. and Wolfe, D.: 2006, Spaces of knowledge flows: Clusters in a global context, *in* B. Asheim, P. Cooke and R. Martin (eds), *Clusters in Regional Development*, Routledge, London, pp. 218–235.

Gesellschaft für Beratungen und Beteiligungen mbH: 2014, Official website, accessed: 04.06.2014.
URL: *http://www.gfbb-ka.de/index.php*

Glaeser, E. L.: 1999, Learning in cities, *Journal of Urban Economics* **46**(2), 254–277.

Glaeser, E. L.: 2000a, The future of urban research: Nonmarket interactions, *Brookings-Wharton Papers on Urban Affairs* pp. 101–149. Brookings Institute. Washington, DC.

Glaeser, E. L.: 2000b, The new economics of urban and regional growth, *in* C. Gordon, G. Meric and M. Feldman (eds), *The Oxford Handbook of Economic Geography*, Oxford University Press, Oxford, pp. 83–98.

Glaeser, E. L., Kallal, H., Scheinkman, J. and Shleifer, A.: 1992, Growth in cities, *Journal of Political Economy* **100**(6), 1126 –1152.

Glaeser, E. L., Scheinkman, J. and Schleifer, A.: 1995, Economic growth in a cross-section of cities, *Journal of Monetary Economics* **36**(1), 117–143.

Gornig, M. and Mundelius, M.: 2012, Reurbanisierung und wissensbasierte Ökonomie, *in* K. Brake and G. Herfert (eds), *Reurbanisierung*, VS Verlag für Sozialwissenschaften, pp. 130–150.

Green, L., Howells, J. and Miles, I.: 2001, Services and innovation: Dynamics of service innovation in the European Union, Report to the Economic Policy Committee of the European Union, PREST and CRIC, University of Manchester.

Griliches, Z.: 1979, Issues in assessing the contribution of R&D productivity growth, *Bell Journal of Economics* **10**(1), 92–116.

Griliches, Z.: 1990, Patent statistics as economic indicators: A survey, *Journal of Economic Literature* **28**(4), 1661–1707.

Grossman, M. and Helpman, E.: 1991, *Innovation and Growth in the Global Economy*, MIT Press, Cambridge, MA.

Gunasekara, C.: 2006, Reframing the role of universities in the development of regional innovation systems, *Journal of Technology Transfer* **31**(1), 101–113.

Hammer, A.: 2014, Innovation of knowledge intensive service firms in urban areas, Working Paper No. 63, *KIT Working Paper Series in Economics*, Karlsruhe.

Heineberg, H.: 2017, *Stadtgeographie*, 5 edn, Ferdinand Schöningh, Paderborn.

Henderson, J., Kuncoro, A. and Turner, M.: 1992, Industrial development in cities, *Journal of Political Economy* **103**(5), 1067–1090.

Herstad, S. and Ebersberger, B.: 2015, On the link between urban location and the involvement of knowledge-intensive business services firms in collaboration networks, *Regional Studies* **49**(7), 1160–1175.

Hipp, C. and Grupp, H.: 2005, Innovation in the service sector: The demand for service-specific innovation measurement concepts and typologies, *Research Policy* **34**(4), 517–535.

Hollenstein, H.: 2003, Innovation modes in the Swiss service sector: A cluster analysis based on firm-level data, *Research Policy* **32**(5), 845–863.

Howells, J.: 2002, Tacit knowledge, innovation and economic geography, *Urban Studies* **39**(5-6), 871–884.

Iammarino, S.: 2011, Regional innovation and diversity, *in* P. Cooke, B. Asheim, R. Boschma, R. Martin, D. Schwartz and F. Tödtling (eds), *Handbook of Regional Innovation and Growth*, Edward Elgar, Cheltenham, pp. 143–154.

Innovationsallianz TechnologieRegion Karlsruhe: 2014, Official website, accessed: 04.06.2014.
URL: *http://www.innoallianz-ka.de/*

Inoue, H., Nakajima, K. and Saito, Y.: 2013, Localization of collaborations in knowledge creation, RETI Discussion Paper Series 13-E-070.

Isaksen, A.: 2009, Innovation dynamics of global competitive regional clusters: The case of the Norwegian Centres of Expertise, *Regional Studies* **43**(9), 1155–1166.

Jacobs, J.: 1969, *The Economy of Cities*, Random House, New York.

Jacobs, W., Koster, H. and van Oort, A.: 2014, Co-agglomeration of knowledge-intensive business services and multinational enterprises, *Journal of Economic Geography* **14**(2), 443–475.

Jofre-Monseny, J., Marín-López, R. and Viladecans-Marsal, E.: 2014, The determinants of localization and urbanization economies: Evidence from the location of new firms in Spain, *Journal of Regional Science* **54**(2), 313–337.

Karlsruhe Technology Region: 2014, Official website, accessed: 05.06.2014.
URL: *http://www.technologieregion-karlsruhe.de/*

Keeble, D., Bryson, J. and Wood, P.: 2006, Small firms, business services growth and regional development in the United Kingdom: Some empirical findings, *Regional Studies* **25**(5), 439–457.

Kerr, W. and Kominers, S.: 2015, Agglomerative forces and cluster shapes, *The Review of Economics and Statistics* **97**(4), 877–899.

Klaesson, J. and Norman, T.: 2015, Market potential and the employment growth of knowledge-intensive services: Comparing different geographical resolutions, *The Annals of Regional Science* **55**(1), 157–185.

Kleinknecht, A., Van Monfort, K. and Brouwer, E.: 2002, The non-trivial choice between innovation indicators, *Economics of Innovation and New Technology* **11**(2), 109–121.

Kline, S. J. and Rosenberg, N.: 1986, An overview of innovation, *in* R. Landau and N. Rosenberg (eds), *The Positive Sum Strategy: Harnessing Technology for Economic Growth*, National Academy Press, Washington, DC, pp. 275–305.

Koch, A. and Stahlecker, T.: 2006, Regional innovation systems and the foundation of knowledge-intensive business services: A comparative study in Bremen, Munich, and Stuttgart, Germany, *European Planning Studies* **14**(2), 123–145.

Koh, H. and Riedel, N.: 2014, Assessing the localization pattern of German manufacturing and service industries: A distance-based approach, *Regional Studies* **48**(5), 823–843.

Koschatzky, K.: 1999, Innovation networks of industry and business-related services – Relations between innovation intensity of firms and regional inter-firm cooperation, *European Planning Studies* **7**(6), 737–757.

Koschatzky, K. and Sternberg, R.: 2000, R&D cooperation in innovation systems – Some lessons from the European Regional Innovation Survey (ERIS), *European Planning Studies* **8**(4), 487–501.

Krätke, S.: 2007, Metropolisation of the European economic territory as a consequence of increasing specialisation of urban agglomerations in the knowledge economy, *European Planning Studies* **15**(1), 1–26.

Kresl, P. K. and Proulx, P.-P.: 2000, Montreal's place in the North American economy, *American Review of Canadian Studies* **30**(3), 283–314.

Krugman, P.: 1991, Increasing returns and economic geography, *Journal of Political Economy* **99**(3), 483–499.

Lucas, R. J.: 1988, On the mechanics of economic development, *Journal of Monetary Economics* **22**(1), 3–42.

Lucas, R. J.: 1993, Making a miracle, *Econometrica* **61**(2), 251–272.

Lundvall, B.-Å.: 1992, *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, Pinter Publishers, London.

Maillat, D. and Lecoq, B.: 1992, New technologies and transformation of regional structures in Europe: The role of the milieu, *Entrepreneurship & Regional Development* **4**(1), 1–20.

Marshall, A.: 1920, *Principles of Economics*, Macmillan, London.

Martin, R. and Sunley, P.: 1996, Paul Krugman's geographical economics and its implications for regional development theory: A critical assessment, *Economic Geography* **72**(3), 259–292.

McCann, P.: 2007, Sketching out a model of innovation, face-to-face interaction and economic geography, *Spatial Economic Analysis* **2**(2), 117–134.

Meijers, E. and Sandberg, K.: 2008, Reducing regional disparities by means of polycentric development: Panacea or placebo?, *Scienze Regionali* **7**(2), 71–96.

Meijers, E., Waterhout, B. and Zonneveld, W.: 2005, Polycentric development policies in European countries, *Built Environment* **31**(2), 97–102.

Meliciani, V. and Savona, M.: 2015, The determinants of regional specialisation in business services: Agglomeration economies, vertical linkages and innovation, *Journal of Economic Geography* **15**(2), 387–416.

Melo, P., Graham, D. and Noland, R.: 2009, A meta-analysis of estimates of urban agglomeration economies, *Regional Science and Urban Economics* **39**(3), 332–342.

Miles, I.: 2005, Knowledge intensive business services: Prospects and policies, *Foresight* **7**(6), 39–63.

Miles, I.: 2007, Research and development (R&D) beyond manufacturing: The strange case of services R&D, *R&D Management* **37**(3), 249–268.

Miles, I.: 2008, Patterns of innovation in service industries, *IBM Systems Journal* **47**(1), 117–128.

Miles, I., Kastrinos, N., Flanagan, K., Bilderbeek, R., Den Hertog, P., Huntik, W. and Bouman, M.: 1995, Knowledge-intensive business services: Users, carriers and sources of innovation, *A report to DG13 SPRINT-EIMS*, University of Manchester.

Mohnen, P. & Hall, B.: 2013, Innovation and productivity: An update, *Eurasian Business Review* **3**(1), 47–65.

Morgan, K.: 2004, The exaggerated death of geography: Learning, proximity and territorial innovation systems, *Journal of Economic Geography* **4**(1), 3–21.

Moulaert, F. and Sekia, F.: 2003, Territorial innovation models: A critical survey, *Regional Studies* **37**(3), 289–302.

Muller, E. and Doloreux, D.: 2009, What we should know about knowledge-intensive business services, *Technology in Society* **31**(1), 64–72.

Muller, E. and Zenker, A.: 2001, Business services as actors of knowledge transformation: The role of KIBS in regional and national innovation systems, *Research Policy* **30**(9), 1501–1516.

Münter, A.: 2011, Germany's polycentric metropolitan regions in the world city network, *Raumforschung und Raumordnung* **69**(3), 187–200.

Murata, Y., Nakajima, R., Okamoto, R. and Tamura, R.: 2014, Localized knowledge spillovers and patent citations: A distance-based approach, *Review of Economics and Statistics* **96**(5), 967–985.

Nakajima, K., Saito, Y. U. and Uesugi, I.: 2012, Measuring economic localization: Evidence from Japanese firm-level data, *Journal of the Japanese and International Economies* **26**(2), 201–220.

Nelson, R. R. and Winter, S. G.: 1982, *An Evolutionary Theory of Economic Change*, The Belknap Press of Harvard, Cambridge, Massachusetts.

OECD: 2002, *Frascati Manual 2002 – Proposed Standard Practice for Surveys on Research and Experimental Development*, Paris.

OECD: 2005, *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, 3 edn, Paris.

OECD: 2013, Patent activity in metropolitan areas, *OECD Regions at a Glance 2013*, OECD Publishing, Paris.

O'Farrell, P., Wood, P. and Zheng, J.: 1996, Internationalisation of business service firms: An interregional analysis, *Regional Studies* **30**(2), 110–118.

Ó hUallacháin, B.: 1999, Patent places: Size matters, *Journal of Regional Science* **39**(4), 613–634.

Ó hUallacháin, B. and Reid, N.: 1991, The location and growth of business and professional services in American Metropolitan Areas, 1976-1986, *Annals of the Association of American Geographers* **81**(2), 254–270.

Oinas, P. and Malecki, E.: 1999, Spatial innovation systems, *in* E. Malecki and P. Oinas (eds), *Making Connections*, Ashgate, Aldershot, pp. 7–33.

Oinas, P. and Malecki, E.: 2002, The evolution of technologies in time and space: From national and regional to spatial innovation systems, *International Regional Science Review* **25**(1), 102–131.

Parr, J.: 2004, The polycentric urban region: A closer inspection, *Regional Studies* **38**(3), 231–240.

Perrin, J.-C.: 1988, New technologies, local synergies and regional policies in Europe, *in* P. Aydalot and D. Keeble (eds), *High-Technology Industry and Innovative Environments: The European Experience*, Routledge, London, New York, pp. 139–162.

Polanyi, M.: 1967, *The Tacit Dimension*, Doubleday, New York.

Polèse and Shearmur, R.: 2006, Growth and location of economic activity: The spatial dynamics of industries in Canada 1971-2001, *Growth and Change* **37**(3), 362–395.

Porter, M. E.: 1990, *The Competitive Advantage of Nations*, Free Press, New York.

Porter, M. E.: 1998, Clusters and the new economics of competition, *in* M. E. Porter (ed.), *On Competition*, Harvard Business School Press, Boston, pp. 197–287.

Preissl, B.: 2000, Service innovation: What makes it different? Empirical evidence from Germany, *in* J. Metcalfe and I. Miles (eds), *Innovation Systems in the Service Economy. Measurement and Case Study Analysis*, Kluwer Academic Publishers, Boston, pp. 125–148.

Revilla Diez, J.: 2000, The importance of public research institutes in innovative networks – empirical results from the metropolitan innovation systems Barcelona, Stockholm and Vienna, *European Planning Studies* **8**(4), 451–463.

Romer, P.: 1986, Increasing returns and long-run growth, *Journal of Political Economy* **94**(5), 1002–1037.

Romer, P.: 1990, Endogenous technological change, *Journal of Political Economy* **98**(5, Part 2), 71–102.

Rosenthal, S. S. and Strange, W. C.: 2004, Evidence on the nature and sources of agglomeration economies, *in* J. V. Henderson and J.-F. Thisse (eds), *The Handbook of Regional and Urban Economics*, Cities and Geography edn, Vol. IV, North-Holland, Amsterdam, pp. 2119–2171.

Rothgang, M., Cantner, U., Dehio, J., Engel, D., Fertig, M., Graf, H., Hinzmann, S., Linshalm, E., Ploder, M., Scholz, A. and Töpfer, S.: 2014, Begleitende Evaluierung des Förderinstruments "Spitzencluster-Wettbewerb" des BMBF. Abschlussbericht – Kurzfassung, RWI Materialien 83. Essen: RWI.

Schricke, E., Zenker, A. and Stahlecker, T.: 2012, Knowledge-intensive (business) services in Europe, Brussels: European Commission.

Schumpeter, J.: 1934, *The Theory of Economic Development*, Harvard University Press, Cambridge, Massachusetts.

Sedgley, N. and Elmslie, B.: 2011, Do we still need cities? Evidence on rates of innovation from count data models of Metropolitan Statistical Area patents, *American Journal of Economics and Sociology* **70**(1), 86–108.

Shearmur, R.: 2010, Space, place and innovation: A distance-based approach, *The Canadian Geographer* **54**(1), 46–67.

Shearmur, R.: 2011, Innovation, regions and proximity: From neo-regionalism to spatial analysis, *Regional Studies* **45**(9), 1225–1243.

Shearmur, R. and Doloreux, D.: 2008, Urban hierarchy or local buzz? High-order producer service and (or) knowledge-intensive business service location in Canada, 1991-2001, *The Professional Geographer* **60**(3), 333–355.

Silverman, B. W.: 1986, *Density Estimation for Statistics and Data Analysis*, Chapman & Hall, London – New York.

Simmie, J.: 2003, Innovation and urban regions as national and international nodes for the transfer and sharing of knowledge, *Regional Studies* **37**(6-7), 607–620.

Simmie, J., Sennett, J., Wood, P. and Hart, D.: 2002, Innovation in Europe: A tale of networks, knowledge and trade in five cities, *Regional Studies* **36**(1), 47–64.

Simmie, J. and Strambach, S.: 2006, The contribution of KIBS to innovation in cities: An evolutionary and institutional perspective, *Journal of Knowledge Management* **10**(5), 26–40.

Smith, K. H.: 2005, Measuring innovation, *in* J. Fagerberg, D. Mowery and R. Nelson (eds), *The Oxford Handbook of Innovation*, Oxford University Press, New York, pp. 148–177.

Statistical Office of the Federal State of Baden-Württemberg: 2014a, Gross value added of Karlsruhe 2011, accessed: 11.04.2014.
URL: *http://www.statistik.baden-wuerttemberg.de/SRDB/home.asp?E=GE*

Statistical Office of the Federal State of Baden-Württemberg: 2014b, Number of inhabitants in Karlsruhe and Stuttgart 2013, accessed: 11.04.2014.
URL: *http://www.statistik.baden-wuerttemberg.de/SRDB/home.asp?E=GE*

Statistical Office of the Federal State of Baden-Württemberg: 2014c, Statistics regarding employees subject to social insurance contributions, June 2012, Data request.

Statistisches Bundesamt: 2010, *Statistisches Jahrbuch 2010*, Statistisches Bundesamt, Wiesbaden.

Statistisches Bundesamt: 2011, Unternehmensregister – Unternehmen nach Beschäftigtengrößenklassen, accessed: 02.05.2014.
URL: *https://www.destatis.de/DE/ZahlenFakten/GesamtwirtschaftUmwelt/Unternehmen-Handwerk/Unternehmensregister/Tabellen/UnternehmenBeschaeftigtengroessenklassen-WZ08.html;*
jsessionid=BA27A3C07023DBEAB27613D48B504C06.cae1

Statistisches Bundesamt: 2016, Arbeistmarkt, accessed: 07.02.2017.
URL: *https://www.destatis.de/DE/ZahlenFakten/GesamtwirtschaftUmwelt/Arbeitsmarkt/Arbeitsmarkt.html*

Steinbeis Association: 2014a, Official website, accessed: 04.06.2014.
URL: *http://www.steinbeis.de/*

Steinbeis Association: 2014b, Steinbeis in Karlsruhe, accessed: 04.06.2014.
URL: *http://www.steinbeis-karlsruhe.de/*

Sternberg, R.: 2000, Innovation networks and regional development – Evidence from the European Regional Innovation Survey (ERIS): Theoretical concepts, methodological approach, empirical basis and introduction to the theme issue, *European Planning Studies* **8**(4), 389–407.

Stifterverband für die Deutsche Wissenschaft: 2015, Forschung und Entwicklung in der Wirtschaft 2013, Wissenschaftsstatisitk GmbH im Stifterverband für die Deutsche Wissenschaft, Essen.

Storper, M.: 1997, *The Regional World*, The Guilford Press, New York.

Storper, M. and Venables, A. J.: 2004, Buzz: Face-to-face contact and the urban economy, *Journal of Economic Geography* **4**(4), 351–370.

Strambach, S.: 1998, Knowledge-intensive business services (KIBS) as an element of learning regions – The case of Baden-Württemberg, *European Regional Science Association (ERSA) Conference Papers*.

Tether, B.: 2003, The sources and aims of innovation in services: Variety between and within sectors, *Economics of Innovation and New Technology* **12**(6), 481–505.

Tether, B. and Tajar, A.: 2008, The organisational-cooperation mode of innovation and its prominence amongst European service firms, *Research Policy* **37**(6-7), 720–739.

Thomi, W. and Böhn: 2003, Knowledge intensive business services in regional systems of innovation – Initial results from the case of Southeast Finland, *Paper presented at the 43rd European Congress of the Regional Science Association*.

Tödtling, F. and Kaufmann, A.: 1999, Innovation systems in regions in Europe – A comparative perspective, *European Planning Studies* **7**(6), 699–717.

Tödtling, F. and Kaufmann, A.: 2001, The role of the region for innovation activities of SMEs, *European Urban and Regional Studies* **8**(3), 203–2015.

Tödtling, F., Lehner, P. and Trippl, M.: 2006, Innovation in knowledge intensive industries: The nature and geography of knowledge links, *European Planning Studies* **14**(8), 1035–1058.

Trippl, M.: 2011, Regional innovation systems and knowledge-sourcing activities in traditional industries – Evidence from the Vienna food sector, *Environment and Planning A* **43**(7), 1599–1616.

Volgmann, K.: 2014, Entwicklung metropolitaner Funktionen im polyzentralen deutschen Städtesystem – Raummuster der Konzentration und funktionalen Spezialisierung, *Raumforschung und Raumordnung* **72**(1), 21–37.

von Thünen, J. H.: 1826, *Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie*, Perthes, Hamburg. English translation: *The Isolated State*. Oxford: Pergamon Press (1966).

Wood, P.: 2002, Knowledge-intensive services and urban innovativeness, *Urban Studies* **39**(5-6), 993–1002.