Classification of regions according to the dominant innovation barriers – The characteristics and stability of regional archetypes in Germany

02.21

Tobias Johannes Hertrich and Thomas Brenner

Philipps Universität Marburg

Imprint:

Working Papers on Innovation and Space
Philipps-Universität Marburg

Herausgeber:

Prof. Dr. Dr. Thomas Brenner
Deutschhausstraße 10
35032 Marburg
E-Mail: thomas.brenner@staff.uni-marburg.de

Published in: 2021

Classification of regions according to the dominant innovation barriers – The characteristics and stability of regional archetypes in Germany

Tobias Johannes Hertrich[1], Thomas Brenner[1]

[1] Department of Economic Geography and Location Research, Philipps-University Marburg

Correspondence: Tobias Johannes Hertrich, Department of Economic Geography and Location Research, Philipps-University Marburg, Deutschhausstraße 10, 35037 Marburg, Germany, tobias.hetrich@geo.uni-marburg.de

The research project on which this report is based was funded by the German Federal Ministry of Education and Research under the funding code 03IS01. The responsibility for the content of this publication lies with the authors.

Abstract:

Lagging regions differ in their characteristics, implying a need for tailor-made policy measures to improve the economic situation in these regions. However, while there are differences between these regions, certain "archetypes" of regions might exist that share the same obstacles to innovations, allowing for taking similar political measures. This paper analyses whether such archetypes can be identified in Germany, what characteristics they possess, and how stable they are. For this purpose, regional characteristics that are related to innovation barriers are identified and operationalized. Then, a cluster analysis is conducted for the German labor market area. Based on these characteristics six archetypes are identified. These archetypes are found to be relatively stable over time, confirming that such a classification can be considered a good basis for policy measures. Furthermore, this classification allows to identify trends that might lead to problems in the future and require policy attention.

Keywords: classification of regions, innovation barriers, cluster analysis, lagging regions.

JEL Classifications: R11, R58, O38

1 Introduction

The difference between lagging regions and economically successful regions has been a predominant problem in Germany and most other countries. Despite the good economic situation in recent years, economic differences between strong and weak municipalities are still growing in Germany (Boettcher et al., 2019). Under Section 2(2)(1) of the Spatial Planning Act, policy in Germany is required, inter alia, to ensure balanced social and economic conditions. Politics aims to counteract this inequality through many different programs and measures.

Lagging regions are characterized by comparatively high unemployment, low income, and low economic growth as well as stagnating population development, bad tangible and intangible infrastructure and poor accessibility (Brown et al., 2017). Furthermore, lagging regions often also show low innovation activities. Studies show a correlation between regional structure weakness and low innovation activity (Koschatzky, 2018). A high level of innovation activity is one way of improving the economic structure of a region and achieving a more dynamic economy (Brenner & Pudelko, 2019; Ulrich et al., 2007). Therefore, the fostering of innovation activity can and should be a crucial part of regional policy and structural funding.

The literature provides an extensive analysis of the various innovation barriers (Coad et al., 2016; D'Este et al., 2011; Hadjimanolis, 2003; McAdam et al., 2004) but the connection between innovation barriers and the characteristics of (lagging) regions is rarely examined. Some papers examine regional aspects regarding regional innovation systems (Arnold et al., 2014; B. Asheim et al., 2019; B. T. Asheim & Gertler, 2011; Autio, 1998; Cooke, 1992, 1996; Morgan & Cooke, 1994), focusing on identifying institutional thinness, fragmentation, and lock-ins as typical regional barriers to innovation (Martin & Trippl, 2014; Tödtling & Trippl, 2005).

We extend this literature in the following two ways: First, we connect literature on regional innovation barriers and the more firm-oriented literature on barriers of innovations that so far have been unconnected. This provides a better understanding of how regional characteristics cause reduced innovation activities. Second, we believe that lagging regions differ in their characteristics and the relevant barriers to innovation. This is supported by the literature arguing for tailor-made policy activities designed for each region separately (Brenner & Niebuhr, 2021). Such region-specific policy measures are antipodal to general region-independent measures. The question that we aim to answer is whether an approach between these polar approaches is possible. We intend to formulate a policy measure that can be applied to many regions with similar characteristics. Such an approach needs to be systemic by combining various policy measures and requires the existence of regions with similar characteristics. In more detail, it requires regions that face the same combination of innovation barriers so that the same bundle of measures can serve the regions adequately. This paper examines whether such "archetypes" of regions exist in Germany that face specific sets of innovation barriers.

In this paper, we classify German regions using characteristics that are connected to innovation barriers and examine the identified types and their stability. So far, such an analysis has not been conducted. With the help of cluster analyses, six archetypes of regions were identified. These six types of lagging regions are relatively stable over time and differ in terms of their characteristics and barriers to innovation studied. At the same time, regions frequently change cluster affiliation over the study period. These changes provide relevant information on the dynamics of lagging regions. For the study period, we find that many lagging regions are less affected by the increasing shortage of skilled workers due to the low need for such workers. Furthermore, we find deterioration of founding activity in many regions, especially in the urban hinterland.

The remainder of the paper proceeds as follows: In the second chapter, Regional Innovation System (chapter 2.1) and research on barriers to innovation (chapter 2.2) are linked and transferred to the regional level. Next, a region classification based on innovation barriers is theoretically derived, using the company- and region-specific characteristics described in chapter 2.3 (chapter 2.4). Based on this, a cluster analysis is conducted. After, chapter 3 describes the methodological procedure of the cluster analysis and Chapter 4 discusses the results. This chapter contains the correlations between the properties (chapter 4.1), the identified (number of) clusters based on silhouette plots (chapter 4.2), the properties of the found clusters (chapter 4.3), the change of clusters over time (chapter 4.4), and the change of cluster membership of regions in the study period (chapter 4.5). Finally, Chapter 5 concludes the paper.

2 Theoretical background

In this chapter first, we introduce the literature on regional innovation barriers within RIS research. Second, we examine the more firm-oriented literature on barriers to innovations. Third, we use the insights from these two strands of literature to identify relevant characteristics on the regional level on which we base our further research.

2.1 Regional Innovation System (RIS)

Regional innovation systems (RIS) are understood as the region-specific socio-institutional and cultural embedded setting of all private and public organizations and institutions that are involved in innovation processes (Cooke, 1992). The three core elements are actors, networks, and institutions. Actors are mainly firms (e.g. suppliers, costumers, competitors) as well as organizations and institutions that belong to the knowledge infrastructure (e.g. universities, knowledge transfer and research institutes). Networks between the aforementioned actors generate knowledge transfer and joint learning. The socio-cultural embedded institutional setting of networks, regulations, informal norms, and beliefs are considered crucial for the innovation process taking place in a region (Isaksen et al., 2018; Scott, 2008).

The theoretically-derived concept has been statistically examined in many studies. For example, studies of Research & Development (R&D) expenditures show that the innovativeness of the RIS depends significantly on existing firms and their innovation efforts (e.g. Czarnitzki et al., 2009). In addition, a positive influence of existing universities and research institutions (e.g. Anselin et al., 1997), population density (Broekel et al., 2015), FDI (Li et al., 2020), human capital (Charlot et al., 2015), social capital (Hauser et al., 2007), gross domestic product, and local market size (Li et al., 2020) is found.

While the literature on regional innovation systems generally focuses on factors that support innovation processes, some also define circumstances that hinder innovation processes, which is the more relevant part considering the context of this paper. Tödtling and Trippl (2005) identify three aspects that hinder innovation from a system perspective: organizational thinness, negative lock-in, and fragmentation. In organizationally thin RIS, crucial elements of the system are missing or insufficiently developed. Frequent examples of such missing elements are the lack of a critical mass of innovative firms, a low level of clustering or a weak endowment with key institutions and organizations. Although combinations of RIS shortages are often observed, some system failures are more important than others in specific types of regions. Organizational thinness hinders innovation especially in peripheral areas (Trippl et al., 2016), which often contain less R&D and innovation activities, small and medium-sized enterprises (SME) operating in traditional industries, low knowledge uptake from extra-regional sources, and a weak structure of organizations (Doloreux & Dionne, 2008). Complementary, Zukauskaite et al. (2017) distinguish further between organizational and institutional thinness/thickness. Under organizational thinness, Zukauskaite et al. (2017) understand the missing of a critical mass of companies, research and scientific institutions, organizations, and associations. Institutional thinness, on the other hand, is understood as the missing of formal (e.g. written law and rules) and informal (e.g. informal cooperation culture and mindset) institutions.

RIS with a negative lock-in show an "over-embeddedness and over-specialization in mature sectors and outdated technologies" (Trippl et al., 2016, p. 27). These regions contain strong spatial concentrations of capital-intensive industries (e.g. steel, coal-mining). Therefore, RIS with negative regional lock-ins occur often in old industrial areas that suffer from de-industrialization (Hassink, 2010; Tödtling & Trippl, 2005). Grabher (1994) differentiates between functional, cognitive, and political lock-ins. Functional lock-ins are characterized by a hierarchical and close inter-firm relationship that hinders firms the development of boundary-spanning functions (e.g. own R&D). Firms that struggle with a cognitive lock-in have a mindset that hinders them to recognize secular trends and technological developments. A political lock-in is an institutional set-up that preserves existing traditional industrial structures, thus unnecessarily slowing down industrial restructuring and indirectly hindering the development of regional potential (Hassink, 2010).

Fragmented RIS are RIS with insufficient interaction between the elements. This lack of connectivity and networking leads to reduced or inexistent knowledge exchange and weak or insufficient interactive learning between the actors. Fragmented RIS often hinders innovations in metropolitan areas with, in principle, well-equipped actors (Martin & Trippl, 2014; Tödtling & Trippl, 2005; Trippl et al., 2016).

2.2 Firm-level innovation barriers

While research on RIS has identified important problems of systemic nature, there are also many obstacles to innovation that unfold on the level of companies, which are the main generators of innovations. Companies are confronted with several challenges in the innovation process, which are called innovation barriers in the literature (e.g., D'Este et al., 2008, 2011; Galia & Legros, 2004; Hadfield, 2008; Hadjimanolis, 2003; Iammarino et al., 2009; Iammarino et al., 2021; Piatier, 1984). Despite their regular occurrence, companies often pay too little attention to them (Storey, 2000). Many barriers are not properly addressed before they occur in the company and consequently impact innovation. From a short-term perspective, barriers in the innovation process lead to innovation change, delay or complete prevention of innovation. In the long term, barriers and the innovation projects that are not realized lead to profit and productivity losses and possibly to a loss of value for the company (Coad et al., 2016; Mirow, 2010). Furthermore, it is the case that more innovative companies face innovation barriers more often (Baldwin & Lin, 2002; Iammarino et al., 2009).

Barriers to innovation can be structured in different ways. For example, Mirow et al. (2007) argue for a division of barriers into symptom and cause. Schültz (2014) sees an interplay of three areas: technical/content, organizational, and social complexity. Other authors structure barriers based on their occurrence in the phase in the innovation process (e.g., Hauschildt & Salomo, 2012). Additionally, D'Este et al. (2011) divide innovation barriers into two types: revealed barriers and deterring barriers.

Often, the different barriers to innovation are divided according to their origin into barriers external to the firm (also exogenous) and barriers internal to the firm (also endogenous) (Goepel, 2014; Hadjimanolis, 2003; Piatier, 1984). External barriers can only be influenced marginally by the company and arise in the environment and surroundings of the company. Internal barriers arise within the firm and are therefore easier for the firm to change (Hadjimanolis, 2003). To connect innovation barriers to region types such a classification is helpful. We use the classification by Hadjimalonis (2003) into external (market-related, government-related, other) and internal (people related, structure related and strategy related) barriers and complemented it by distinguishing further subcategories using insights from the literature. The result is presented in Table 1.

Table 1: Overview of internal and external barriers to innovation (modified illustration based on Hadjimanolis (2003)).

Internal barriers		External barriers	
Group	**Barriers (B)**	**Group**	**Barriers (B)**
I. Strategic & management-based barriers	B1. Leadership shortcomings in management B2. Lack of risk-taking and commitment B3. Company goals and/or strategy are missing, unclear or hinder innovation B4. Conflicts of interest and priority B5. Poor marketing and sales management	**IV. Market and industry barriers**	B15. Shortage of skilled workers (within the branch) B16. Barriers to market entry B17. Market uncertainty/lack of information B18. High return target (especially for PLC) B19. Capital market access restrictions
II. Structural barriers	B6. Lack of resources & information (e.g. Human capital deficiencies) B7. Poor organizational structure and organizational inertia B8. Lack of process relevance of innovations B9. Insufficient internal cooperation and information flow B10. Unclear or too little decision-making authority B11. Corporate and learning culture that inhibits innovation	**V. Regulatory institutional barriers**	B20. Standards, regulations & laws B21. Bureaucracy & bad/slow communication channels and procedures B22. Barriers to trade and tax systems B23.Legal uncertainty B24. Lack of support from political institutions for business and innovation B25. More difficult access to intellectual property rights B26. Political power and interest conflicts
III. Individual barriers (employee level)	B12. Barriers to motivation B13. Barriers to competence B14. Capacity problems (time)	**VI. Social Barriers**	B27. Climate hostile to innovation (e.g. sceptical attitude towards socio-economic change) B28. Static school and education system B29. Lack of entrepreneurial spirit in society
		VII. Barriers to Cooperation	B30. Resistance to external ideas ("Not invented here") B31. Too few external connections & knowledge transfer a. Lack of cooperation with other companies (vertical, horizontal and diagonal) b. Insufficient cooperation with institutions (universities, research institutes and intermediaries) B32. Lack of trust and prejudices

The different company-internal barriers are often interrelated. Strategic and management-based barriers, for example, are anchored at the top management level of the company and concern the strategic orientation of the company. However, an orientation of the company that hinders innovation or inadequate strategic objectives at the highest management level often leads to structural barriers, such as insufficient human capital or a lack of financial R&D resources in the company. These problems often cause an innovation-inhibiting (and often sluggish) company structure with long information and decision-making paths (D'Este et al., 2011; Hadjimanolis, 2003; Mirow, 2010). The individual employees of the company act within a given framework and according to the instructions of the management, so that they are also influenced by the fundamental orientation of the company and structural barriers. At the individual employee level, knowledge and willpower barriers (Hauschildt & Salomo, 2012) are the most important barriers to innovation.

Barriers to innovation that are external to the company originate in the company's environment, implying some concordance with the insights from RIS research. External barriers can only be insufficiently influenced by the company itself (Hadjimanolis, 2003). Firms often face certain market and industry constraints that can act as barriers to innovation (Pellegrino & Savona, 2017; Tang & Yeo, 2003). Political institutions set important standards, rules, norms, and frameworks covering almost all areas of entrepreneurial activity. Such regulations and standards are often restrictive and can act as barriers to innovation (Palmer et al., 1995). The influence of such regulations on a firm's innovativeness is relatively small (Cooper, 1975) and depends additonally on the market situation (Blind et al., 2017; Sainio et al., 2012). The education and training system play an important role in providing innovative employees to firms. If society tends to be sceptical to socioeconomic change and science and is strongly status quo afflicted, then these might represent societal barriers to innovation (Büttner et al., 2004; Hadjimanolis, 2003; Tang & Yeo, 2003). Barriers to cooperation arise primarily when companies do not cooperate or cooperate insufficiently with other actors for various reasons (e.g., resistance to external ideas, lack of adequate (nearby) partners, lack of trust, and prejudice) (Lewandowska & Danik, 2016). As a consequence, innovation is hindered or event prevented. This applies to horizontal and vertical cooperation as well as to all other forms of cooperation (Hadjimanolis, 2003). Cooperation is also seen as one way to overcome obstacles to innovation (Antonioli et al., 2017; Faria et al., 2010).

2.3 Regional characteristics

Some of the innovation barriers can be related to the regional level. Nevertheless, besides the above-mentioned literature on RIS, the connection between regional characteristics and innovation barriers is rarely mentioned in the literature on the innovation barriers. Therefore, we will develop a comprehensive and structured link between regional characteristics and the various innovation barriers in this paper.

Companies that do not innovate are on average smaller (have fewer employees) than innovative firms (D'Este et al., 2011). The occurrence and importance of barriers to innovation are therefore often linked to the size of the company (Piatier, 1984; Rosa & Mohnen, 2000). Large firms are expected to face mainly internal barriers to innovation (**e.g., B1; B2; B7; B9; and B10** in Table 1). Small firms have some advantages when it comes to internal barriers (e.g., simpler structures, direct communication channels) but often tend to be influenced by external barriers where large firms usually have the advantage of possessing the expertise and resources to overcome these external barriers (Vossen, 1998).

SMEs and young firms are more affected by both internal and external financial barriers (**B6b and B19** in Table 1) (Coad et al., 2016; Freel, 2000; Madrid-Guijarro et al., 2009; Savignac, 2008) and are more likely to be discouraged from innovating than large companies (Arza & López, 2021). Arza and López (2021) highlight that cost obstacles in particular deter SMEs from investing than large companies. Access to bank capital and venture capital or investors is more difficult for SMEs than for older and larger firms as well as firms belonging to a company groups (Mohnen et al., 2008; Storey, 1994). Ylinenpää (1996) states that within a cohort of SMEs, "micro-firms" suffer most from insufficient venture capital. Savignac (2008) examines differences between individual sectors. Accordingly, firms in the electrical and electronic equipment sector suffer disproportionately from financial barriers. The riskier and newer an industry or sector is, the more it struggles with financial barriers (Canepa & Stoneman, 2002). Additionally, Engel (2002) observes that in Germany high-density regions benefit more from venture capital activities.

These high-density regions tend to be regions with a high "technological potential" (Engel, 2002, p. 17) in the form of a strong presence of non-university, university, and industrial R&D facilities. In rural regions, it is rare to find companies (especially in the software sector) with VC funding. Significantly less venture capital also flows into structurally weak regions. These dependencies of innovation barriers on the size of firms imply regional issues if regions are dominated by smaller or larger firms causing the respective innovation barriers to be more prevalent in these regions.

Furthermore, SMEs have disadvantages compared to larger companies in employing skilled workers (**B6c and B15** in Table 1) due to lack of time (**B6a** in Table 1) (Hadjimanolis, 1999; Piatier, 1984). Also, Strobel and Kratzer (2017) find that the internal barriers, lack of expertise and capacity overload are main obstacles to innovation for SMEs. Small firms typically cannot offer their employees as attractive wage terms, job security, education, training, and career opportunities as larger firms. Training suitable skilled employees also often requires greater effort for small firms (Hadjimanolis, 1999). Coad et al. (2016) find that the lack of qualified workers can hinder a high productivity. Furthermore, they find that exporting firms struggle less with the lack of qualified workers, financial barriers, and regulatory barriers. In peripheral regions, external innovation infrastructure is often less developed than in central regions. This is particularly evident in the decreased availability of skilled labor and know-how (Anderson et al., 2001). Nerlinger (1998) highlights that for young high-tech companies, the availability of skilled labor and regional know-how are the most significant location factors, along with proximity to customers. Peripheral regions may thus even be considered "hostile environments" for new, small, and innovative firms (Anderson et al., 2001). Major and Cordey-Hayes (2003) examine that SMEs in particular have a lower propensity to interact and cooperate with other players in the region such as universities (**B6d; B30; and B31** in Table 1). The authors attribute this to a lack of time, management, knowledge resources, and experience. From a regional perspective, spatial proximity favors informal collaboration, human capital formation, and business spin-offs. Most R&D institutions are located in large agglomerations, exhibiting greater clustering, variety, and commercialization of new knowledge. As a result, cooperation takes place predominantly within or between these agglomerations (Bathelt & Glückler, 2018; Engel, 2002).

In the case of SMEs, it is primarily up to the company owner(s) to perceive market signals, information, and innovation opportunities (Vossen, 1998). They are also significantly more affected by market uncertainty and ignorance (**B17** in Table 1). At the same time, they can often afford to spend only fewer resources on R&D compared to large firms and due to the market power of large firms they also often have more difficulties to access and enter markets (**B16** in Table 1) (Levin, 1978). Moreover, it is more challenging for SMEs to become a part of successful commodity chains and export goods (McAdam et al., 2004). Therefore, small firms' innovation strategies tend to focus on flexibility and market niches (Vossen, 1998). Firms in peripheral regions have poorer market access compared to firms in well-connected, urban areas. Anderson et al. (2001) describe the disadvantages of peripheral areas in terms of limited customer base, larger distances to markets and suppliers, and a limited pool of well-educated workforce. According to Porter (2014), distinctive economies of scale, distinctive product differentiation, high capital requirements at market entry, difficult access to distribution channels, size-independent cost advantages (through e.g. location advantages or subsidies), and political measures (e.g. tariff barriers) act as causes for a hindered market entry of companies.

Bureaucratic hurdles and lack of support from political institutions particularly affect SMEs (Hadjimanolis, 1999; Strobel & Kratzer, 2017). Political disinterest at the local level is also linked to the lack of relevance and often presence of large companies (**B24; B21** in Table 1). SMEs also have less influence on technical standards and policy regulations because of their low market power and public presence (Piatier, 1984) (**B20** in Table 1). SMEs also hindered in their access to property rights (**B25** in Table 1). Furthermore, they face greater obstacles in protecting intellectual property and in searching and applying for patents. According to Hadjimanolis (2003), this is linked with a lack of suitable skilled workers and associated high costs.

Because of differences in regional characteristics and social attitudes there are regional disparities in the propensity to start a business (**B29** in table 1). Bergmann and Volery (2006) find for Switzerland that more startups are created in economically successful regions, which are characterized by a high start-up rate, high purchasing power, self-employment rates, and low unemployment rate. Engel (2002) emphasizes the prominent position of the industry as an incubator for innovative start-ups. There are thus regional disadvantages in the probability of start-ups in economically and structurally weak regions.

The dependencies of innovation barriers on the company and regional characteristics are summarized in Table 2. It is shown that SMEs, economically lagging, and rural regions are affected the strongest by innovation barriers.

Table 2: List of innovation barriers and their dependence on regional and enterprise characteristics.

Barriers to innovation		Enterprise differences	Regional differences
Esp. B1, B2, B5, B7, B9, B10	Internal barriers	Larger companies are more affected	
B6b	Lack of internal financial resources	- Smaller & young companies are more affected - There are sector differences - Companies that belong to a group of companies are less affected	
B6c, B6a, B15	Lack of skilled workers & time	- Smaller companies are more affected because of attractiveness - Firms with higher productivity are more effected - Exporting firms are less effected	Rural and lagging regions are more affected due to attractiveness (skilled workers)
B6d, B30, B31	Insufficient cooperation	Smaller companies are more affected by a lack of resources	- Lagging regions are more affected due to a lack of partners - Regions without research institutions and universities are more affected due to a lack of partners
B16	Barriers to market entry	- Small companies are more affected because of market power - There are sector differences	Companies in peripheral regions have disadvantages in market access
B17	Market uncertainty and ignorance	Smaller companies are more affected because of resources and market access	
B19	Lack of external financial resources	Smaller companies are more affected due to higher dependence on external funds and poorer access to credit	Rural and lagging regions are more affected by the lack of VC companies
B29	Lack of start-up and foundation activities	There are sector differences	Low firm foundation activities might be caused by many different regional characteristics, such as low economic attractiveness and remote location but also culture and alternative job opportunities
B20; B21; B24	Regulatory institutional barriers	- SMEs have less influence on technical standards and regulations - SMEs are more affected by bureaucratic hurdles - SMEs suffer more often from a lack of political support -Exporting firms are less effected	
B25	More difficult access to intellectual property rights	SMEs are more affected	

2.4 Classification of regions based on dominant innovation barriers

This subsection aims to classify regions with low innovation activity according to the dominant innovation barriers based on the insights documented above. Such a classification does not yet exist in the literature. Previous classifications of lagging regions have been based on identifying and measuring structural weakness. As key indicators the gross domestic product (GDP) per inhabitant and the unemployment rate are used (BMWi, 2016; European Commission, 2017; Koschatzky & Kroll, 2019).

The starting point of our classification of innovation weak regions is the above-identified relationships between innovation barriers, regional, and company characteristics. The relationships of company characteristics need to be transferred to the regional scale. This is done by assuming that regions that are dominated by companies with corresponding characteristics are also particularly affected by the corresponding innovation barriers. Table 3 lists the various regional characteristics and the particularly relevant innovation barriers connected to them and results from resorting the information in Table 2 from a regional perspective.

We identify six types of regions that are relevant in our context. R1 and R2 reflect firm characteristics, R3 and R4 are based on regional characteristics that occur in connection with many innovation barriers in Table 2, R5 is specific to a lack of cooperation, and R6 representing a low firm foundation rate. R6 received a separate since it might be influenced by culture and history besides being related to many of the other characteristics (R6).

Table 3: List of regional characteristics, the especially relevant barriers to innovation and the operationalization used in the empirical approach below.

Region characteristics		Barriers to innovation	Operationalization / Variables
R1	SME-dominated economic structure	Lack of financial resources (B6b, B19), market access problems (B16, B17), skills shortages (B6c, B15), insufficient cooperation (B6c, B30), regulatory barriers (B20, B21, B24)	- Share of large firms (firms with more than 250 employees); source: INKAR database
R2	Dominance of large weakly innovative companies	Internal Barriers (B2, B7, B10, B12)	- Share of employees with a university degree; source: IAB
R3	Rural regions	Lack of skilled workers (B6c, B15), market access problems (B16), lack of external financial resources (B19)	- Spatially weighted population density; source: Statistical Office of Germany (Statistisches Bundesamt) and own calculations based on travelling distances - Transport infrastructure: Average driving time to next highway, airport and inter-regional train station; source: INKAR database
R4	Lagging regions (hardly any activities in dynamic, innovative industries)	Lack of skilled workers (B6c, B15), insufficient cooperation (B6c, B30), lack of external financial resources (B19), lack of propensity to start a business (B29)	- GDP; source: INKAR - Structural strength: industry shares according to Brenner&Pudelko (2019); source: IAB - Shortage of skilled workers: time to fill qualified job vacancies; source: IAB
R5	Cooperation-weak regions (research-weak regions)	Insufficient cooperation (B6c, B30)	- Number of publications; source: WoS
R6	Low founding activity	Missing foundation inclination (B29)	- Number of foundations; source: ZEW

The types of regions also partially match the insights from the RIS literature. Three types have been declared in Tödtling & Trippl 2005, namely organizational thinness, negative lock-in, and fragmentation. The negative lock-in situation matches our case R2 with a dominance of large, weakly innovative firms, especially in the case of functional and cognitive lock-ins. Fragmentation is strongly connected to insufficient cooperation (R5). In the empirical approach, we narrow this down to research-weak regions because spatially inclusive and comprehensive information about the cooperation activity in regions is not available and the lack of research facilities has been identified above as part of the problem. Organizational thinness is related to some of our regional characteristics such as low economic activity (lagging regions) and missing science institutions (research-weak regions). Institutional thinness can be defined as a seventh type of region but is missing in Table 3. We decided against listing this type because it would not follow the same logic that was applied to the other types (deducing it from Table 2) and it also would have difficulties to operationalize institutions (Rodríguez-Pose, 2013; Trippl et al., 2016; Zhu et al., 2019).

Several of the region properties listed in Table 3 often occur together. For example, rural regions are often also weak in a structurally and research sense and the economic structure is characterized by many small firms. Likewise, many regions in eastern Germany, not only rural regions, are characterized by structural weakness and the absence of large firms. For this reason, in the next section we aim to assess whether typical sets of regional characteristics exist.

3 Empirical approach

The empirical analysis aims to classify the German regions concerning characteristics connected to innovation barriers. Therefore, the regional level and the characteristics used must first be determined.

The central variable is the innovativeness of regions (***INNO***). In the literature, the usual measure for this are patents. The shortcomings of choosing the number of patents as a measure of innovativeness are the following: not all inventions are technically patentable, different firm inclinations to patent their inventions, different patent restrictions (costs, time, protection) among countries (Archibugi & Pianta, 1996). But despite these shortcomings, patent data is widely available and can be simply assigned to regions with the help of inventor addresses. Therefore, we decided to implement the latter approach. The use of inventor addresses from patent data makes labor market areas (LMAs) the adequate regional analysis unit. LMAs are based on the idea that most people work and also live in that region. In this respect, the private addresses of inventors often fall into the associated LMA in which the invention took place.

3.1 Regional characteristics and their operationalization

Above, we identified regional characteristics that are connected to innovation barriers and, thus, lead to lower innovation activities. We operationalize all characteristics in a way that higher values are connected to higher innovation activities. The operationalizations are listed in Table 3 and are discussed in the following paragraphs.

According to aforementioned arguments, SME-dominated economic structures (**R1**) as well as large sluggish companies (**R2**) can lead to lower innovation activity. Hence, both regions with many small firms and regions with many large firms, might be more innovative. The empirical data shows that, on average, regions with predominantly large firms are more innovative. The disadvantage of lagging (financial) means in the innovation process seems to be a more determining barrier than the various internal barriers in large firms. Therefore, we use as a measure for both arguments, namely the share of large firms (above 250 employees) in a region (***LARGE***), which reflects the missing of powerful actors. This data is available from 2006 till 2015 (INKAR database).

To reflect the sluggishness of (large) companies, we use the share of all employees in a region that have graduated (***QUAL***). The assumption behind this is that firms with a lower rate of highly qualified employees are, in general, less innovative. The data is obtained from the Institute for Employment Research (IAB) for the years 2002 until 2019.

Rural regions (**R3**) are operationalized by population density. One approach is to use the population density which is calculated for each LMA by dividing the population by area. But this is only part of the story since the arguments above are also related to the distance to agglomerations or the belonging to metropolitan areas. Therefore, we use the spatially weighted average of the population density (***spDENS***). For each municipality *i* a weighted average of the population density of all surrounding municipalities is calculated using the following distance decay function (see Brenner 2017):

$$spDENS_i = \sum \left(w_{ij} \cdot DENS_j \right)$$

$$w_{ij} = \frac{1}{1+\left(\frac{d_{ij}}{r}\right)^{-s}},$$

where w_{ij} is the used weights, d_{ij} denotes the driving time from municipality *i* to municipality *j* (based on the street map from the year 2012), *r* and *s* are parameters determining the exact shape of the decay function (Brenner 2017), which are set to r=45 minutes and s=7 here (as used and discussed in Brenner & Pudelko 2019). The value for each labor market area is calculated as the weighted average of the $spDENS_i$ of all contained municipalities weighted by the number of their inhabitants. By applying this procedure, rural areas near big cities obtain higher values than rural areas in the periphery. The data covers official inhabitant numbers for all years from 2002 till 2019.

As a second measure for the remoteness of the regions (**R3**) we use the driving time to the next highway, the next airport, and the next inter-regional train station (with IC/ICE trains). To condense the number of variables, we build the average of these three driving times for each labor market area (***TRANS***). The data is only available for the year 2012 (INKAR database).

To operationalize lagging regions (**R4**), three variables are used: gross domestic product, structural strength, and skill shortage. First, to represent the economic activity in the regions, we use the gross domestic product of each region (***GDP***). This data is available from 2002 until 2017 (INKAR database). Second, lagging regions have besides a low overall economic activity also a disadvantageous industry structure. We use the measure of structural strength developed by Brenner & Pudelko (2019). This measure assigns a value to each industry based on its employment dynamics, qualification, and innovativeness and calculates its weighted average for each region based on the industries' shares in the region (***STRUCT***). The data necessary for the calculation of the share of industries has been obtained from the IAB for the years 2007 until 2019. Third, lagging regions also have issues attracting skilled workers. However, this also holds true for rural regions. Hence, the measure for skill shortage (***SKILL***) can be seen as a characteristic of economically lagging as well as rural regions. In this paper it is measured by the average time (in days) to fill a qualified position (qualification level 2 and higher in the IAB classification, containing workers with, at least, 2 to 3 years of job qualification). To obtain a measure that is positively related to innovativeness, we use the negative value of the average vacancy duration. The data was obtained from the IAB for the years 2007 until 2019.

To operationalize research-weak regions (**R5**), we use the number of paper publications (***SCIENC***). This aims to represent the presence of scientific activity in the region that might support the innovation activity of firms in the region. The data is taken from the Web of Science with all author addresses assigned to the LMA and fractional counting. The data is available for the years 2002 until 2019.

Finally, regions with a lack of start-up activity (**R6**) are identified with the help of the number of firm foundations in the region (***FOUND***). The data has been obtained from the Leibniz Centre for European Economic Research (ZEW) for 3-year periods from 2002 until 2019.

3.2 Statistical approach

Besides a simple correlation analysis, the main part of our approach is a cluster analysis. We use a simple k-means clustering based on Euclidean distances and the Hartigan-Wong algorithm (Hartigan & Wong 1979). The number of clusters k is determined by a silhouette analysis (Rousseeuw, 1987). To prepare the data for the cluster analysis, the usual standardizing approach is applied (Romesburg, 2004). This includes subtracting from each value the average value of this variable and dividing the result by the variables' standard deviation. We apply this procedure to each period separately. This implies two characteristics of our data. First, time trends that apply to all German regions are eliminated. Second, all values are distributed around zero with positive values signifying above-average characteristics.

The data is available on a yearly basis, covering a long period (most variables from 2002 till 2019). Due to fluctuations, it is not adequate to use data for each year separately. Furthermore, some variables are not available for the whole period. At the same time, one of our aims is to check whether the profiles of regions remain stable over time. Therefore, we build three periods: 2002-2007, 2008-2013 and 2014-2019. For each variable, the average of all available values is assessed for each period. For all variables, except the transport infrastructure, at least one value is available in each period. In the case of the transport infrastructure, only values for the year 2012 are available. Assuming that the transport infrastructure does not change much, we use this value for all periods.

There are two options for the cluster analysis: Applying it to each time period separately or pooling the data in the three periods and conducting one overall cluster analysis. The former approach is better suited to examine whether the regional characteristics that jointly define typical innovation-weak regions change over time. The latter approach is better suited to examine whether regions change their characteristics and, thus, their type including the main barriers to innovation. Consequently, we decided to apply both approaches.

4 Results

In this chapter, we present the results of the cluster analysis. First, we show the correlations found between the characteristics used. Second, we illustrate the identified (number of) clusters based on silhouette plots. Third, we describe the characteristics of the six cluster archetypes. Fourth, we analyze the change of clusters over time. Fifth, we have a look at the changes in cluster membership of the regions over the study period.

4.1 Correlation analysis

As a first step, we analyze which of the regional characteristics that might signal barriers to innovation occur together. Table 4 shows the results of the simple correlation analysis.

*Table 4: Correlations between the variables (***: p<.001; **: p<.01; *: p<.05).*

Variable	INNO	SCIENC	spDENS	TRANS	QUAL	STRUCT	GDP	LARGE	FOUND	SKILL
INNO	1.00***	.25***	.22***	.29***	.29***	.63***	.57***	.26***	.22***	.42***
SCIENC		1.00***	.86***	.57***	.50***	.28***	.30***	.20***	.38***	.06
spDENS			1.00***	.57***	.34***	.28***	.24***	.25***	.30***	.11***
TRANS				1.00***	.50***	.30***	.38***	.32***	.37***	.06
QUAL					1.00***	.44***	.37***	.23***	.32***	-.06
STRUCT						1.00***	.55***	.46***	.13***	.37***
GDP							1.00***	.50***	.34***	.32***
LARGE								1.00***	.00	.16***
FOUND									1.00***	.08*

SKILL	1.00***

The variable *INNO* is significantly positively correlated to all other variables, confirming the assumption that all used variables represent regional characteristics that might hinder innovation activities. Most correlations are rather weak and of similar size (between .2 and .3) except the correlations with the industrial structure (*STRUCT*), the economic strength (*GDP*), and the availability of skilled labor (*SKILL*). Since industrial structure measures, among other aspects, the presence of innovative industries, the high correlation of *INNO* with this variable is not surprising. The strong correlation between *GDP* and *INNO* confirms that innovation and economic development are strongly connected. Although skill shortage is an innovation barrier, the strong correlation between *SKILL* and *INNO* is surprising. However, the finding only signals a connection, not a causal relation.

Most of our regional characteristics are also significantly positively correlated with each other, which shows that indeed various barriers are likely to occur together on a regional level. Most strongly correlated are the population density (*spDENS*) and the presence of scientific research (*SCIENC*). Of course, scientific institutions are rarely present in rural areas. Further correlations above .5 are found between the transport infrastructure (TRANS) and both, population density and scientific activity. Population density and transport infrastructure have both been chosen as indicators for rural areas. The correlations suggest that the innovation barriers connected to the rural regions and research-weak regions might occur often together. Another correlation above .5 is found between GDP and industry structure, which have both been declared as measures for lagging regions.

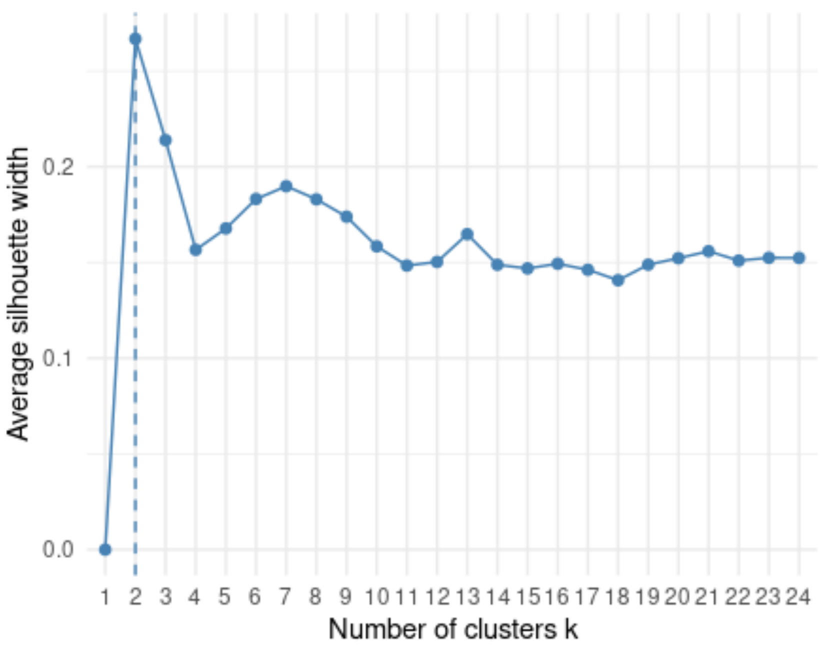
Additionally, the availability of skilled labor is the only variable that is not significantly correlated to several other variables. Correlation coefficients of above .3 are found only with *GDP* and *STRUCT*, confirming our use of these variables as an indicator for lagging regions. Nevertheless, the lack of skilled labor seems to be an independent factor.

Hence, the correlation analysis shows that population density (*spDENS*) and transport infrastructure (*TRANS*) measure similar things, so that we add the respective (normated) values together forming a new variable *URBAN*. The same holds true for GDP and industrial structure (*STRUCT*), which are combined to a new variable *ECON*. Although the scientific activity is also strongly correlated to population density and transport infrastructure, we keep it separate because it represents a different factor according to our theoretical considerations. As a robustness test, all analyses are also conducted using all variables leading to similar results and especially the same classes of regions.

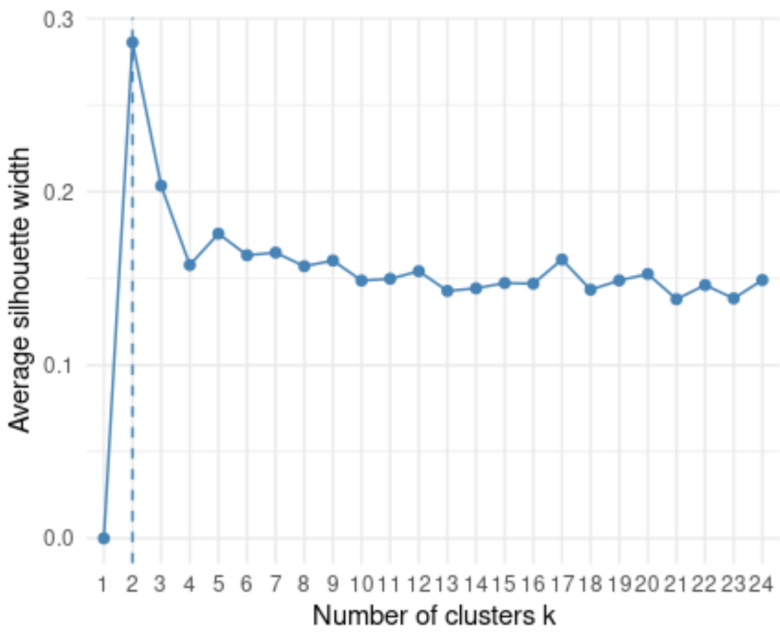
4.2 Identified clusters

Independent of whether the periods are pooled or analyzed separately, the silhouette plots indicate the existence of two clusters. Building these two clusters leads in all cases to one cluster of regions for which all characteristics are positive (above German average) and one cluster of regions for which all characteristics are negative (below German average). This shows that a clear difference exists between economically and structurally well-endowed regions and rather lagging regions in Germany. However, this separation is not relevant for our research context.

a)



b)



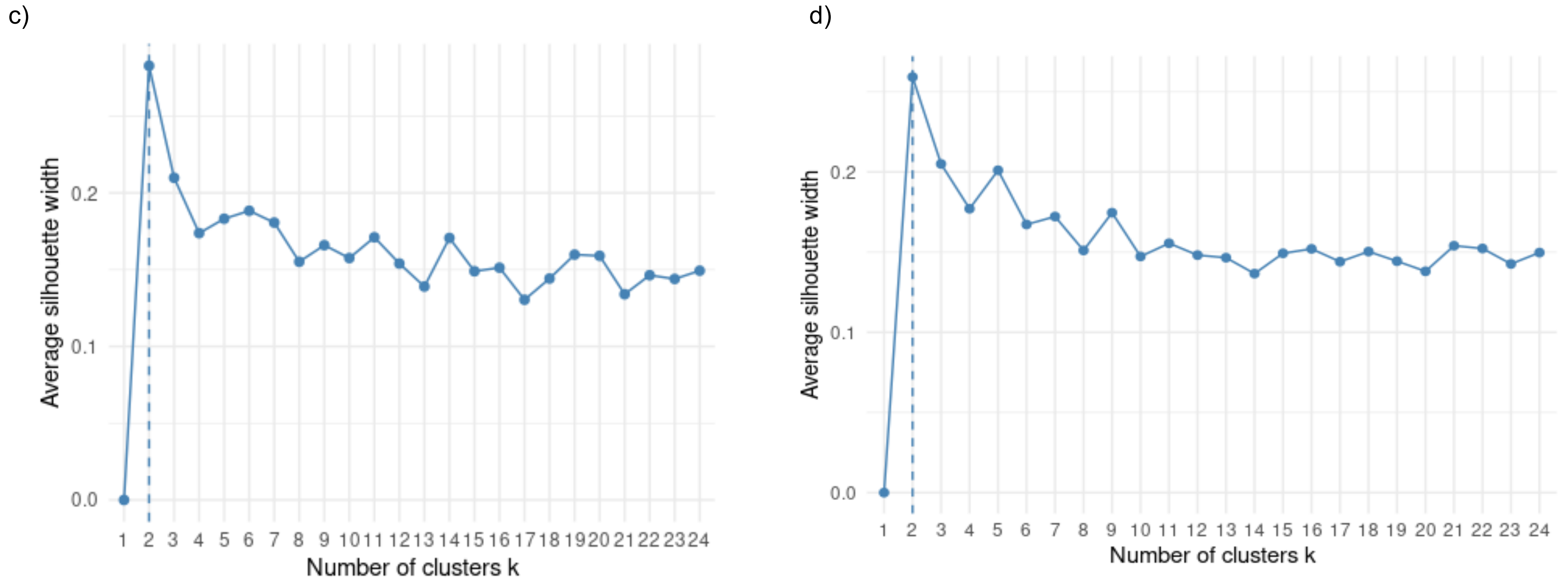


Figure 1: Silhouette plots for a) all periods pooled, b) the period 2002-2007, c) the period 2008-2013, and d) the period 2014-2019.

Therefore, we use a partition into more than two clusters. Most relevant for our analysis is the pooling of all periods and the latest period. The silhouette plot for the pooled data (Figure 1a) shows that besides two clusters, 7 or 13 clusters are also a good choice. The silhouette plot for the latest period (Figure 1d) signifies 5 or 9 clusters as good choices.

We tested the different possibilities and found out that choosing 9 clusters for the latest period serves our aim the best. Choosing 5 clusters leads to a lower stability of the clusters over and a separation of the interesting lagging regions into only two clusters, which provides less information. In the case of the pooled data, 7 and 13 clusters are used. The resulting assignments of the labor market areas are depicted in Figure 2.

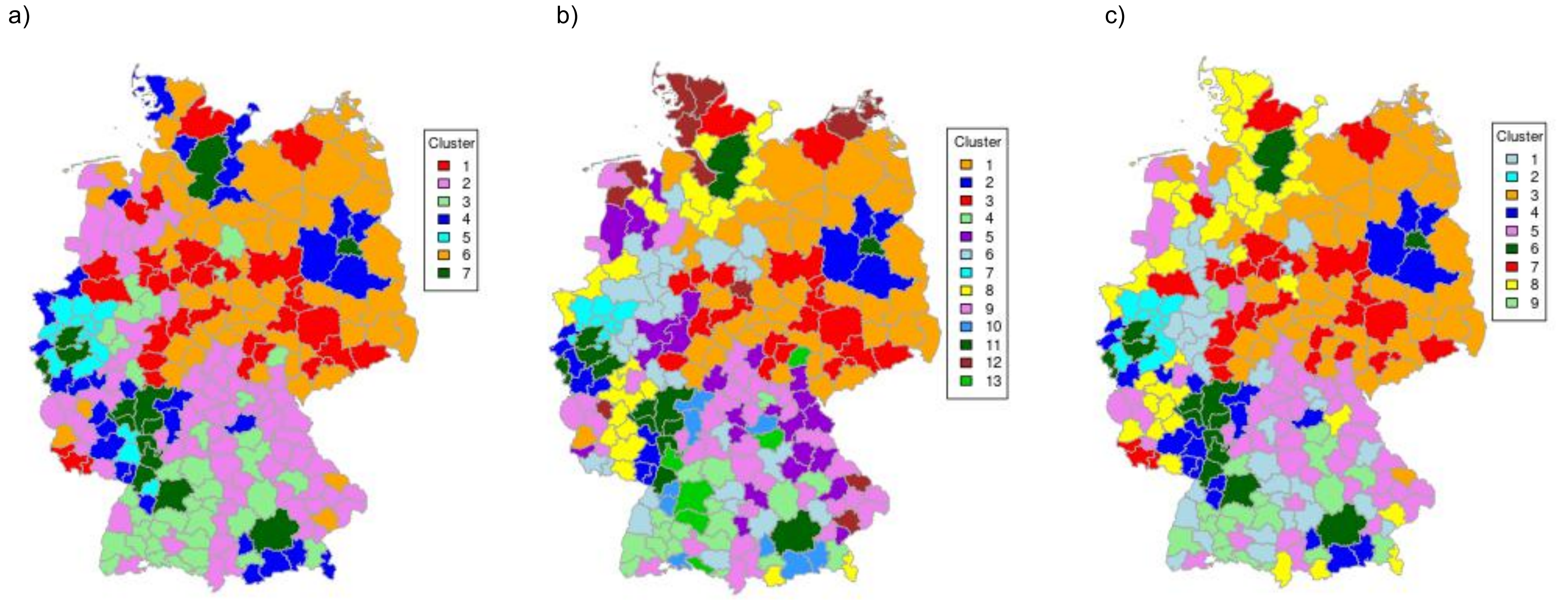


Figure 2: Cluster assignment of the labor market regions in 2014-2019 for the clustering including all periods identifying a) 7 clusters and b) 13 clusters and for c) the separate clustering of period 2014-2019.

The maps of the clusters (Figure 2) show some similarities in the classification of regions, although different periods and different numbers of clusters are used. This is further examined in the next subsection.

4.3 Related characteristics in clusters

Our main interest is to examine whether certain regional characteristics related to innovation barriers occur frequently together. The above correlation analysis has shown that there is a positive but relatively weak correlation between all characteristics (between 0.2 and 0.3 in most cases), which reflects the finding of a clear difference between more urban/central, economically strong regions and more rural/peripheral, economically weak regions. Now we analyze whether there are groups of regions that show specific co-occurring characteristics. Next, the clusters identified above are analyzed separately.

The basis for this analysis is the three clustering results presented above: 7 clusters including all periods, 13 clusters including all periods and 9 clusters for the most recent period 2014-2019. The three different clustering approaches are used to also examine whether the identified "archetype" clusters are robust concerning their exact setting. The analysis is based on the centroids of the clusters, which represent the average values of the characteristics for each cluster.

Several clusters show average innovation activities above the German average (these are the dark green, green, lighter green, and lighter blue clusters in Figure 2). These are not of further interest for this paper since we focus on innovation barriers in innovation-weak regions. Therefore, we discuss all other clusters in the order of decreasing average innovation activities.

Cluster A (Urban hinterland, dark blue clusters in Figure 2):

In this cluster, most characteristics are nearly average. Three weaknesses appear together: low share of large firms, low economic activity, and low share of qualified employees. This implies that firms are missing a good basis for innovations due to the lack of financial means in small firms and the presence of less dynamic industries (low qualification rate of employees). The respective map shows that most regions of this type are near to larger cities. Therefore, we call them urban hinterlands. The innovation activities in these regions might be overestimated by our approach because many inventors might live in these regions but work in the nearby centers.

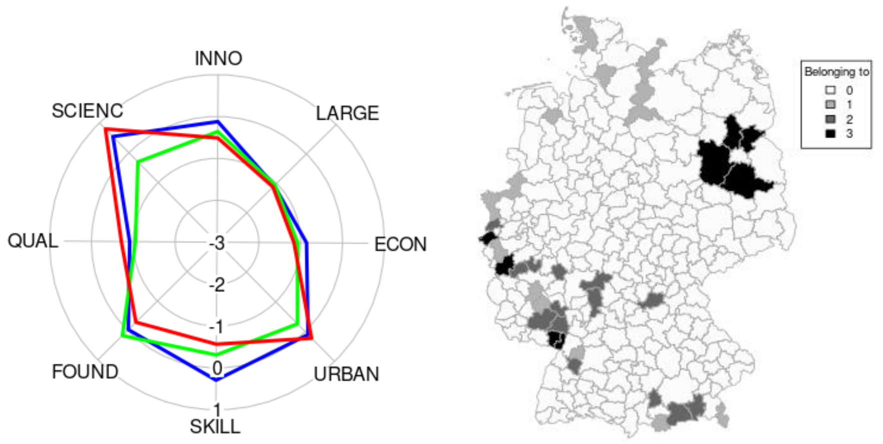


Figure 3: Average characteristics of Cluster A (blue: 2014-2019; green: 7 clusters all periods; red: 13 clusters all periods) and localization of regions belonging to cluster A (light grey: region falls into cluster A in only one cluster variant of figure 2; grey: two cluster variants of figure 2; dark grey: all three cluster variants of figure 2).

Cluster B (Old-industrialised regions, cyan clusters in Figure 2):

In this cluster scientific activity, share of large firms, and urbanity are above the German average while economic strength and qualification are slightly below average and founding activity is well below the average. This kind of region is found in Germany mainly in the Ruhr area.

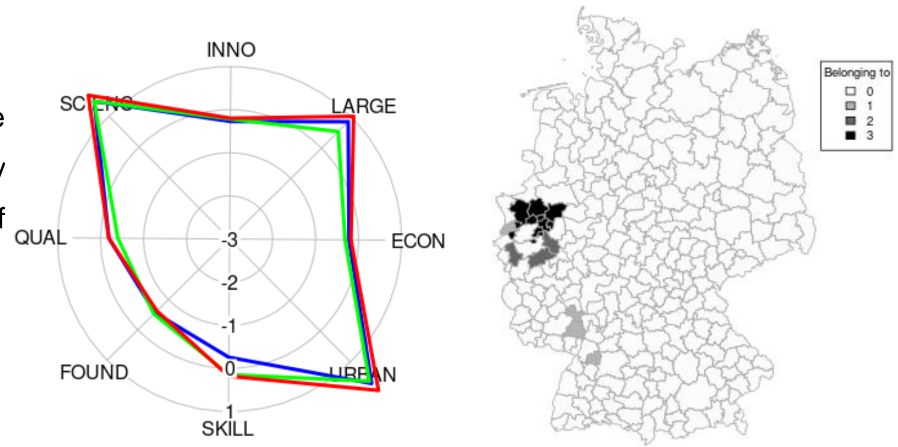


Figure 4: Average characteristics of Cluster B (blue: 2014-2019; green: 7 clusters all periods; red: 13 clusters all periods) and localization of regions belonging to cluster B (light grey: region falls into cluster B in only one cluster variant of figure 2; grey: two cluster variants of figure 2; dark grey: all three cluster variants of figure 2).

Cluster C (Attractive periphery, (dark) violet clusters in Figure 2):

In this cluster, almost all parameters are below average, except the skill availability. The shortage of skilled workers is a lower issue than in other regions. Furthermore, the number of large companies is roughly in line with the average for Germany as a whole. The regions in this cluster are characterized by a relatively low qualification of the workforce, low research activity, and a below-average propensity to start new businesses. The regions in this cluster are located in peripheral areas. Nevertheless, they contain some economic and innovative activity and seem to have less of a problem acquiring skilled labor.

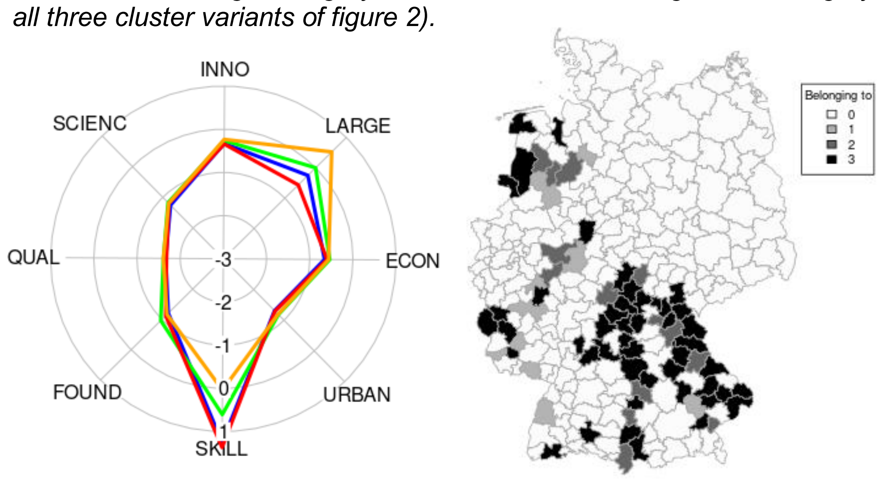


Figure 5: Average characteristics of Cluster C (blue: 2014-2019; green: 7 clusters all periods; red/orange: 13 clusters all periods) and localization of regions belonging to cluster C (light grey: region falls into cluster C in only one cluster variant of figure 2; grey: two cluster variants of figure 2; dark grey: all three cluster variants of figure 2).

Cluster D (skill-shortage regions, red clusters in Figure 2):

In this cluster, the most negative characteristics are the shortage of skilled workers and the propensity to start new businesses. The qualification of the workforce and the share of large companies are average. Hence, these regions are attractive for large firms and qualified production. However, they are not similarly attractive for workers and founders, which hinders development. Many medium-large cities fall into this cluster, suggesting that these regions, which have been rather average economically, could falling behind.

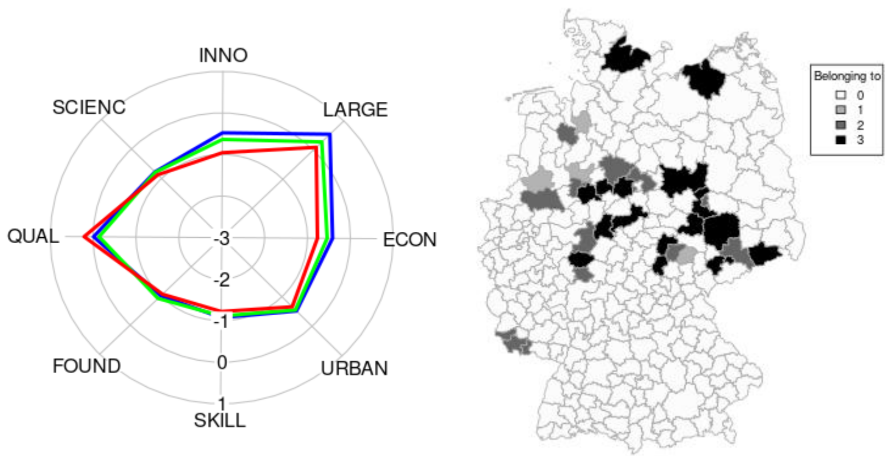


Figure 6: Average characteristics of Cluster D (blue: 2014-2019; green: 7 clusters all periods; red: 13 clusters all periods) and localization of regions belonging to cluster D (light grey: region falls into cluster D in only one cluster variant of figure 2; grey: two cluster variants of figure 2; dark grey: all three cluster variants of figure 2).

Cluster E (Peripheral hinterland, yellow clusters in Figure 2):

In the 7-cluster classification for all periods, this cluster of regions does not exist. The respective regions fall mainly into Cluster A but also into Cluster C, D, and F. This means that the regions have some similarities with those from other clusters, especially those of Cluster A. The proportion of qualified employees is even lower than in Cluster A and represents the most negative aspect. There are also a few large companies and an overall weak economy as well as a lack of scientific institutions. The propensity to start a business, on the other hand, is only slightly below average. Most of these regions are near big cities but slightly farther away than those in Cluster A.

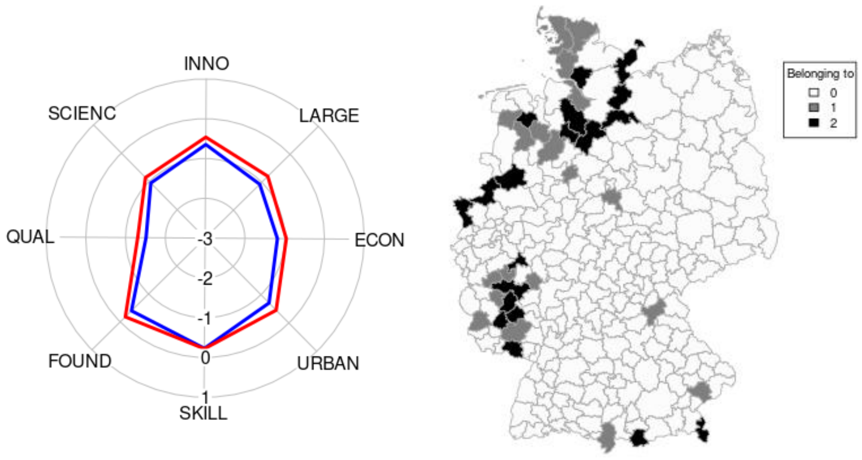


Figure 7: Average characteristics of Cluster E (blue: 2014-2019; red: 13 clusters all periods) and localization of regions belonging to cluster E (light grey: region falls into cluster E in only one cluster variant of figure 2; grey: two cluster variants of figure 2; dark grey: all three cluster variants of figure 2).

Cluster F (Peripheral lagging regions, orange and brown clusters in Figure 2):

This cluster is far below average in all characteristics. Due to the lack of companies, the shortage of skilled workers seems to be a rather subordinate problem. The regions in this cluster are remote, not innovative, and distinctly economically weak. Only in part of these regions the firm founding activity might be seen as a positive sign.

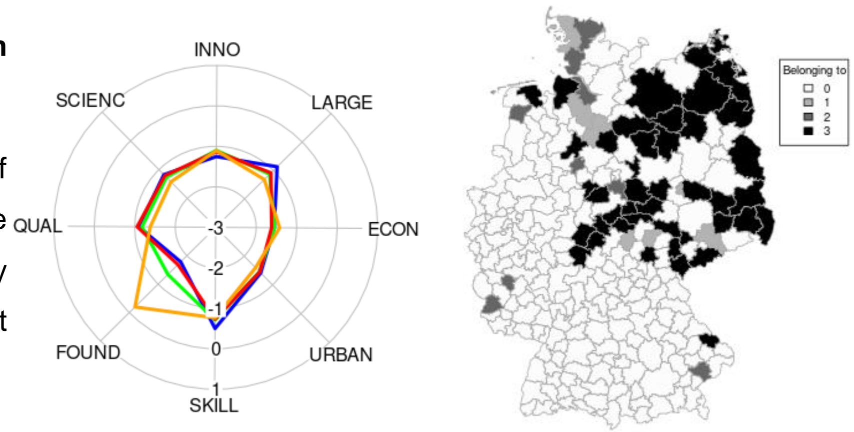


Figure 8: Average characteristics of Cluster F (blue: 2014-2019; green: 7 clusters all periods; red/orange: 13 clusters all periods) and localization of regions belonging to cluster F (light grey: region falls into cluster F in only one cluster variant of figure 2; grey: two cluster variants of figure 2; dark grey: all three cluster variants of figure 2).

Overall, the analysis shows that indeed several weak characteristics occur together, allowing for a characterization of distinct "archetypes" of innovation-weak regions. This classification is quite robust using different periods and numbers of clusters. Table 5 shows the characteristics of these "archetype" clusters.

Table 5: Average regional characteristics for the 6 low-innovation clusters (classified as ++: >.5; +: 0-.5; o: -.5-0; -: -.5- -1; --: -1- -1.5; ---: <-1.5; the defining characteristics are presented large and bold).

Cluster	Denomination	INNO	SCIENC	QUAL	FOUND	SKILL	URBAN	ECON	LARGE
A	Urban hinterland	o	+/-	**-/--**	o	+/-	o	**-/--**	**--**
B	Old-industrialised regions	o	++	**o**	**-**	o/+	++	**o**	++
C	Attractive periphery	o	**--**	**---**	**--**	+/++	**--**	-	+/-
D	Skill shortage regions	-	-	o/+	**--**	**--**	-	o/-	+
E	Peripheral hinterland	-	-/--	**--**	o	o	-	**--**	**-/--**
F	Peripheral lagging regions	--	--	--	**-/---**	-	**--/---**	**--/---**	-/--

4.4 Stability of clusters over time

We previously argued that six innovation-weak clusters are relatively robust when applying clustering approaches considering different specifications. Now we want to check whether these clusters are stable over time. To this end, we apply the cluster analyses to the three periods separately by using the fixed number of nine clusters. The spatial distribution of the clusters shows some stability but also some changes (Figure 9).

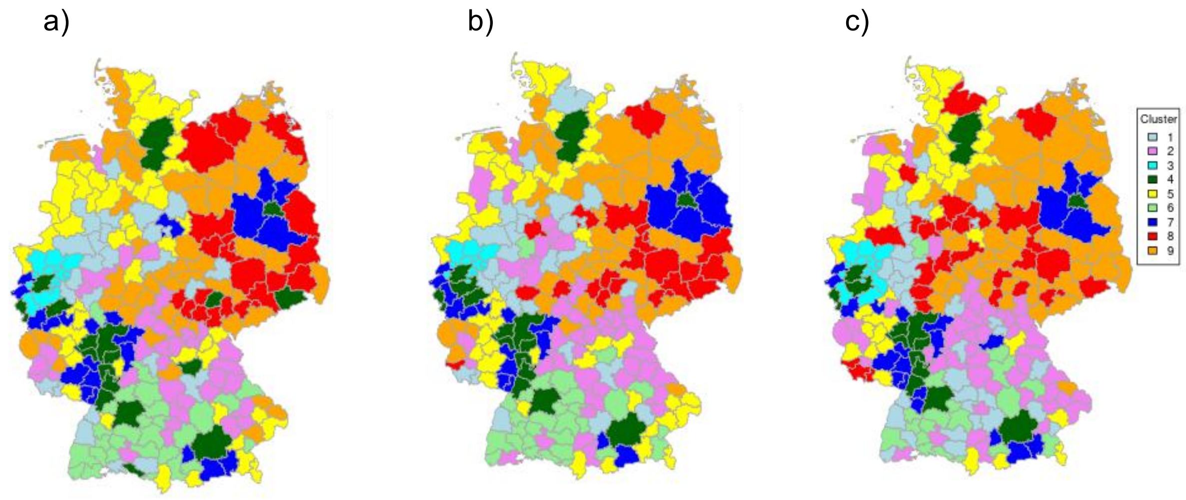


Figure 9: Cluster assignment of the labor market regions for the periods a) 2002-2007, b) 2008-2013, and c) 2014-2019.

In contrast to the changes in the assigned regions, the average cluster characteristics are stable (Figure 10). The main changes are found in skill shortage, which has increased tremendously within the considered time span and seems to have affected the regions within the same cluster differently. This is an interesting topic for further research and will be taken up also in the next subsection. Furthermore, we observe some changes in the founding activity. The only cluster with clear changes in more than these two variables is Cluster D, which shows also the most regional changes in Figure 9. The changes in the regional composition of the other clusters seem to not impact the defining characteristics of these clusters.

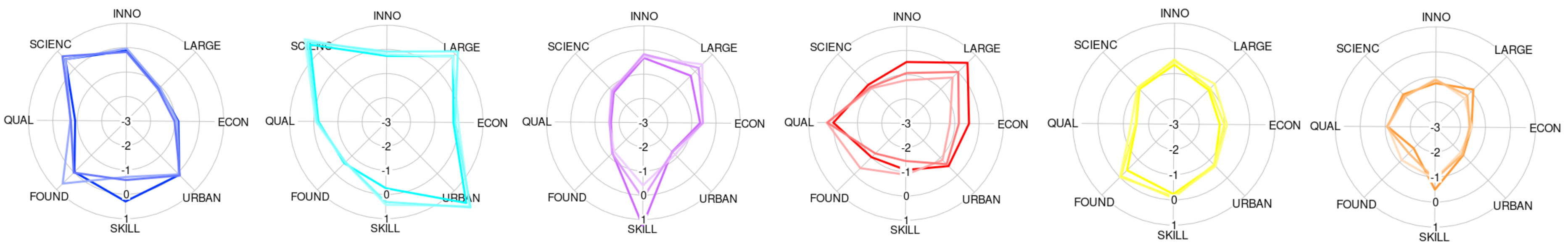


Figure 10: Average cluster characteristics for the six clusters (in order A to F) and the periods 2002-2007 (light color), 2008-2013 (medium color), and 2014-2019 (darkest color).

Consequently, the archetype clusters seem, except Cluster D, to be very stable over time, so that we can indeed assume that specific combinations of regional innovation-relevant characteristics occur frequently.

4.5 Change of cluster-assignments of regions

To study the stability of the cluster assignments of regions, we include all three periods in one clustering process. By following this approach, one set of clusters is defined and the regions are assigned to this separately for each of the three periods. Consequently, we can examine whether regions change their cluster-assignment with time and which changes in the regional characteristics are responsible for this movement between clusters. Several interesting developments are detected when pursuing this approach.

Above we detected that 7 or 13 clusters can be built considering all periods. We use the classification of 7 clusters in the following because it is sufficient to understand the occurring dynamics and reduces the number of cases to be discussed compared to the 13-clusters analysis. The assignment of the regions to these 7 clusters for the three periods is depicted in Figure 11.

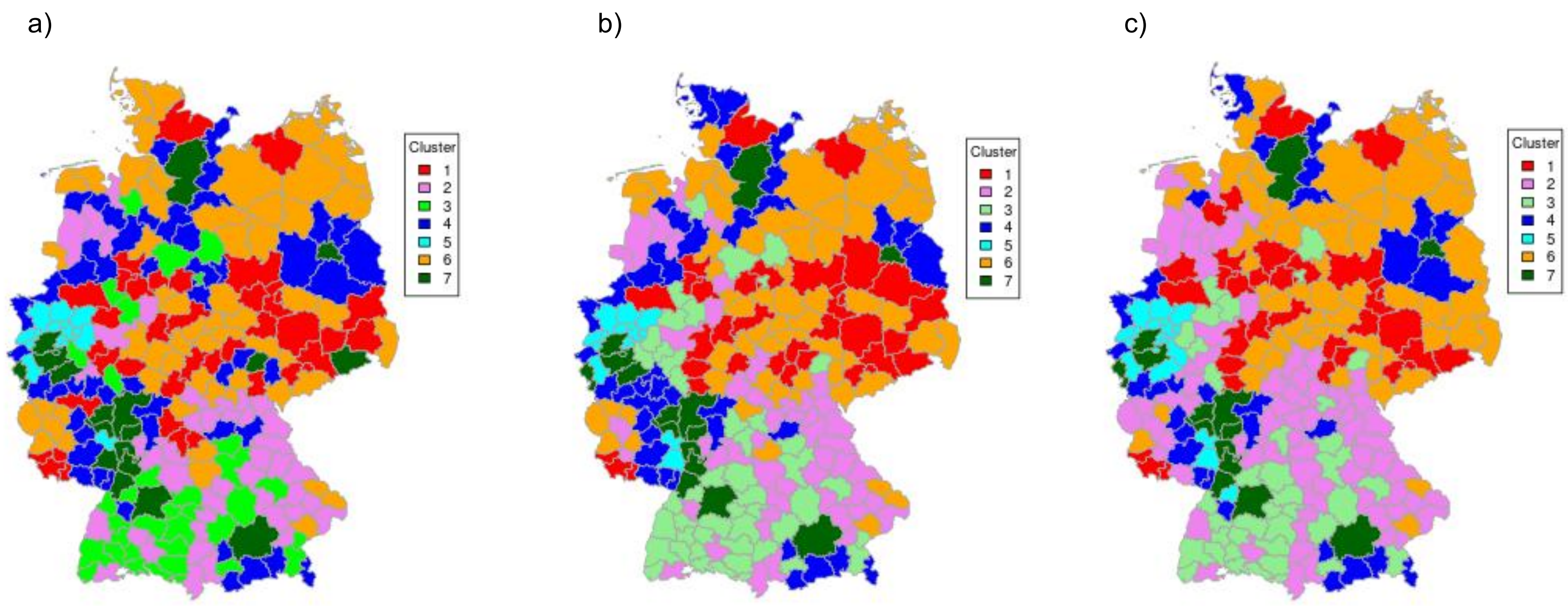
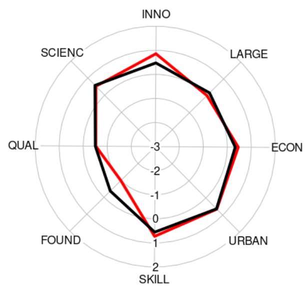
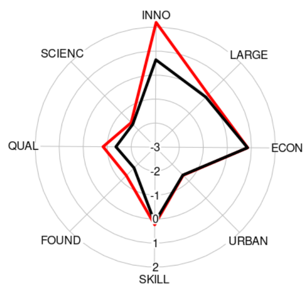
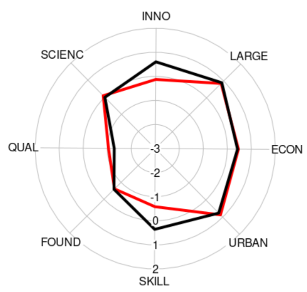
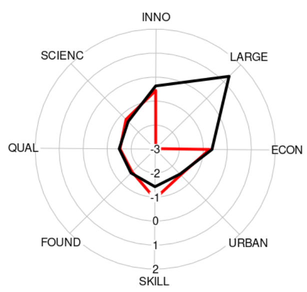


Figure 11: Cluster assignment of the labor market regions for conducting the cluster analysis on all periods together. The maps present the assignments for the periods a) 2002-2007, b) 2008-2013, and c) 2014-2019.

Figure 11 shows that over time there are some movements of regions from one cluster to another. This is in line with the finding in the last subsection (Figure 9) that applying the clustering to each period separately leads to some changes in the regional composition of the clusters. However, this contrasts with the fact that the average values of the clusters remain very stable over time. To shed light on these issues, we examine all regions that change their cluster assignment between the period 2002-2007 and the period 2014-2019. So far, we have only named and discussed the clusters with low innovativeness in detail. In the following, the high-innovation clusters also play a role. Consequently, the cluster colored in green in Figure 11 is denoted as Cluster G and the cluster colored in dark green in Figure 11 is denoted as Cluster H in the following.

65 of the 257 regions change their classification from the first to the last period. Tables 6-9 group these changes according to clusters between which the regions switch. Furthermore, these three tables also present the average values of the regional characteristics for each changing group and the two periods. For the discussion, we build four tables and discuss them separately. We find that many moves are related only to changes in skill availability with all other characteristics remaining stable, except for some smaller changes in the founding activity. All these cases are presented in Table 7. Similarly, many moves are triggered by a strong decrease in the founding activity, connected to changes in skill availability and partly in qualification. These cases are presented in Table 8. We also separately discuss the moves from the very innovative cluster H to the less innovative clusters (Table 9). All other cases with quite different changes in the characteristics and only one or two cases of the same movement between clusters are presented in Table 6 and are not further discussed because these cases seem to represent specific and not general developments.

Table 6: Region-specific changes in cluster assignments of regions from 2002-2007 to 2014-2019 (red and black lines in the radial plots represent the average values of the regional characteristics in 2002-2007 and 2014-2019, respectively).

Cluster change	Number of cases	Average characteristics	Regions (names)	Regions (locations)
G → B	2		Pforzheim Gummersbach	
G → C	1		Burghausen	
B → G	1		Lüdenscheid	
F → D	1		Korbach	

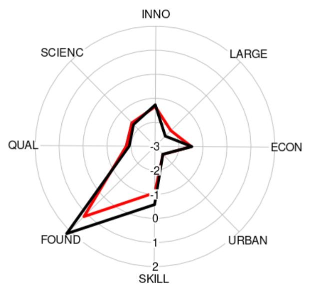
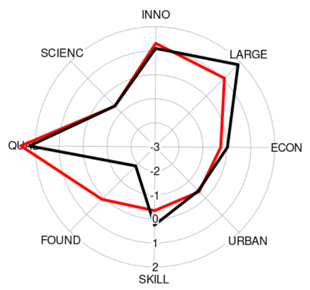
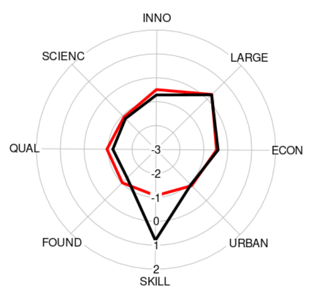
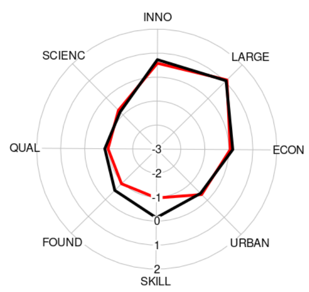
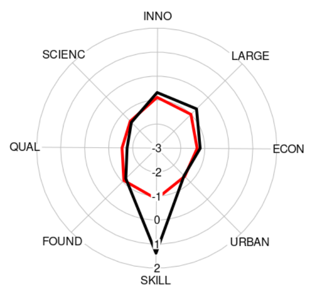
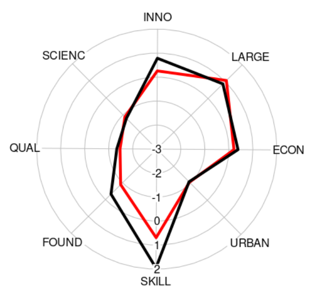
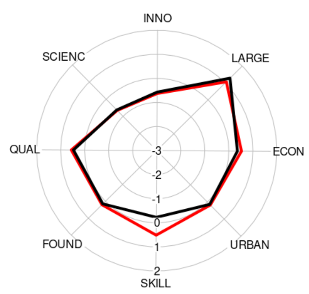
F → A	1		Husum	
H → G	1		Jena	

Table 7 presents 30 cases in which all regional characteristics remain relatively stable over time except the SKILL variable and sometimes the FOUND variable. In 28 cases the skill availability has increased strongly. The basic reason for these changes is the strong increase in skill shortage that Germany experienced within the last ten years. The number of days that it takes to fill free qualified positions increased from 65 in the first period to 75 in the second period and 102 in our third period. Since we calculated our variables relative to the average within each period, the SKILL variable varies around zero for all periods. The changes in this variable for a region results from a higher or lower increase in skill shortage relative to the German average.

Hence, the identified 28 cases of regions that change their cluster-assignment due to an increase in the SKILL variable are regions that have been less hurt by skill shortage in recent years compared to others. Many of them moved to Cluster C, which is characterised by an above-average availability of skilled labor. This also matches the strong increase in the SKILL variable that we observe for Cluster C when clustering each period separately (Figure 10). Most regions that show this change are smaller and medium-large cities with a low share of qualified employees (Table 7). To sum up, many regions do not require a large amount of qualified labor, so that they are less hurt by skill shortage. This fits findings from Coad et al. (2016, p. 328) that companies "with more highly educated employees are more likely to face problems of 'lack of qualified personnel". Our findings cause a change in cluster assignments without clear changes in the other variables. The opposite effect is only observed in two cases (last row in Table 7).

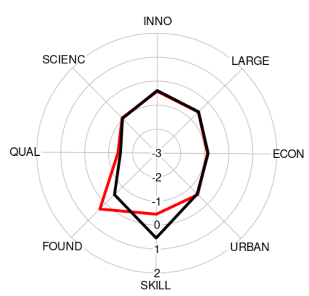
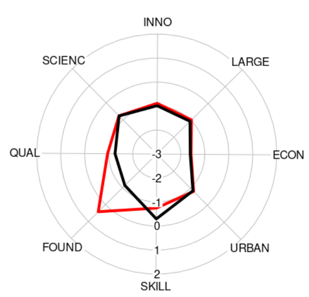
Table 7: Skill-shortage implied changes in cluster assignments of regions from 2002-2007 to 2014-2019 (red and black lines in the radial plots represent the average values of the regional characteristics in 2002-2007 and 2014-2019, respectively).

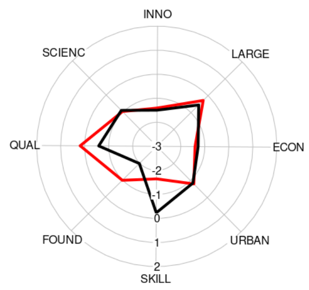
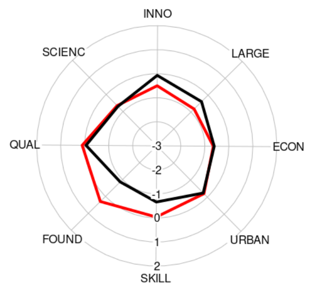
Cluster change	Number of cases	Average characteristics	Regions (names)	Regions (locations)
D → C	9		Siegen Fulda Koblenz St. Wendel Kitzingen Lohr am Main Eisenach Gotha Pößneck	
D → G	3		Olpe Soest Würzburg	

F → C	13		Wetzlar; Nordholm; Idar-Oberstein; Bernkastel-Wittlich; Daun; Bitburg; Freyung; Ansbach; Neustadt/Aisch; Bad Kissingen; Suhl; Meiningen; Sonneberg;	
C → G	3		Schwäbisch Hall Balingen Coburg	
G → D	2		Hannover Bremen	

There are additional regions that show strong changes in the relative skill availability but in these cases, there is also a strong decrease in the founding activity. Table 8 presents all cases with such a strong decrease in the FOUND variable. In 18 cases we observe the combination with an increasing skill availability, while in six cases skill availability decreases. Four of the former cases also display a strong decrease in qualification and the other eight cases show a smaller but still visible decrease in qualification. We can conclude that in these 24 regions the economic dynamics (founding activity) have decreased, partly combined with lower qualification requirements. Most of these regions have been classified as urban hinterlands in the first period and developed during the observed time into regions with peripheral characteristics. These regions have already been before the more peripheral regions within the urban hinterland group (including also medium-sized cities outside or at the edge of metropolitan areas). However, the findings suggest that these regions continue losing attractivity, especially regarding founding activities. Since new firms are an important engine for future economic development, these regions are likely to fall further behind. This will lead to increases the inequality between the economically successful and lagging regions.

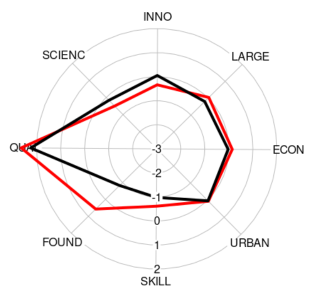
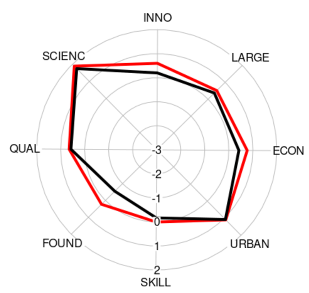
Table 8: Founding-induced changes in cluster assignments of regions from 2002-2007 to 2014-2019 (red and black lines in the radial plots represent the average values of the regional characteristics in 2002-2007 and 2014-2019, respectively)

Cluster change	Number of cases	Average characteristics	Regions (names)	Regions (location)
A → C	6		Sulingen Verden Osnabrück Montabaur Pirmasens Bayreuth	
A → F	8		Goslar Helmstedt Stadthagen Celle Soltau Leer Frankfurt/Oder Gera	

D → F	4		Cottbus Bautzen Meißen Salzlandkreis	
A → D	6		Braunschweig Oldenburg Steinfurt Gießen Weimar Arnstadt	

Finally, there are four cases in which regions that have been classified into the highly innovative cluster H move to one of the less innovative clusters (Table 9). Again, a reduction in founding activities is, on average, the most important change. This adds to the aforementioned discussion since several relatively urban regions have experienced a strong decrease in founding activities, despite the strong support of start-ups in Germany. It can be expected that this will have negative impacts on the future economic development in these regions.

Table 9: Changes from Cluster H to low-innovate clusters of regions from 2002-2007 to 2014-2019 (red and black lines in the radial plots represent the average values of the regional characteristics in 2002-2007 and 2014-2019, respectively)

Cluster change	Number of cases	Average characteristics	Regions (names)	Regions (location)
H → D	1		Dresden	
H → B	3		Leverkusen Bonn Ludwigshafen	

5 Conclusions

The paper aimed to classify German regions according to present innovation barriers. We identified and used several regional characteristics that are related to barriers in the innovation process. The results of several statistical clustering approaches applied to different periods show that indeed, distinct types of regions can be identified. While the assignment of regions shows some dynamics, the identified types are found to be relatively independent of the studied period and variations in the number of clusters. Hence, we can claim that at least in Germany, various types of regions exist that are less innovative for different reasons.

This finding has consequences for region-specific policy. We argue that policy programs that can be formulated which are not only region-specific but can also be applied to many other lagging regions. For example, cluster B (old-industrialised regions) contains regions that mainly lack economic dynamics in the form of new firms. Hence, politicians should focus on generating new economic activity in these regions. In contrast, regions in clusters A (urban hinterland) and E (peripheral hinterland) are predominantly lacking economically strong, large firms that employ qualified labor. The smaller firms in these regions usually need support in their innovation activity due to limited resources and capacities. Another case are the regions in cluster D (skill-shortage regions). Although, many characteristics of these regions are average or only slightly below average, skill shortage is a big issue and consequently founding activity is relatively low. The findings suggest that policy must focus on investing and attracting skilled people to the region and motivating them to found new firms. A special case is cluster C (attractive periphery). These regions seem to be attractive for firms and skilled workers but are lacking science institutions and founding activity. Politicians should focus on building research and education facilities in these regions or connect the firms with such institutions. Less clear is the policy situation in regions of cluster F (peripheral lagging regions) because these are comparably weak in all studied aspects.

Additionally, the classification has proven itself to be helpful in identifying crucial dynamics. While the characteristics of the identified classes of regions do change relatively little over time, many regions change their class assignment. Examining these changes revealed two interesting dynamics. First, many lagging regions in Germany are less affected by the recent increase in skill shortage. This is caused by the low requirement of skilled labor in these regions. While this might look like a positive relationship, it rather signals that these regions are not economically dynamic, decreasing their economic development expectations for the future.

Second, and most importantly, many regions experienced a clear decrease in founding activity. These are often regions in the urban hinterland that have not been economically strong in the past. The increase of policy support for start-ups seems to have fallen on the fruitful ground mainly in the economically strong regions. The economically weak as well as many regions in the middle have not benefitted and especially those in the middle have lost their relative position as a consequence. Since future developments are strongly influenced by start-ups, the question of how founding activity can be supported and increased in the economically not so strong regions is an important policy question identified by our analysis. This is also related to the low presence of skilled people in these regions.

While our approach has provided relevant and interesting results, our study region was limited to Germany. It would be interesting to see whether similar types of less innovative regions exist in other countries as well. Furthermore, it would be interesting to know whether the dynamics found and described in this paper are also present in other countries. Consequently, future research should pursue the same approach in other countries to test its feasibility and to gain more insights. Hence, this paper can be seen as a first step towards establishing a classification of regions on which policy measures can be based upon.

References

Anderson, A., Jack, S., & McAuley, A. (2001). “Periphery? What periphery? Marketing to a state of mind”. *Marketing Review*, *14*(1), 26–34.

Anselin, L., Varga, A., & Acs, Z. (1997). Local Geographic Spillovers between University Research and High Technology Innovations. *Journal of Urban Economics*, *42*(3), 422–448. https://doi.org/10.1006/juec.1997.2032

Antonioli, D., Marzucchi, A., & Savona, M. (2017). Pain shared, pain halved? Cooperation as a coping strategy for innovation barriers. *The Journal of Technology Transfer*, *42*(4), 841–864. https://doi.org/10.1007/s10961-016-9545-9

Archibugi, D., & Pianta, M. (1996). Measuring technological chance through patents and innovation surveys. *Technovation*, *16*(9), 451–468.

Arnold, M., Mattes, A., & Sandner, P. (2014). Regionale Innovationssysteme im Vergleich. *DIW Wochenbericht*(5), 79–88. https://www.diw.de/documents/publikationen/73/diw_01.c.436185.de/14-5-3.pdf

Arza, V., & López, E. (2021). Obstacles affecting innovation in small and medium enterprises: Quantitative analysis of the Argentinean manufacturing sector. *Research Policy*, *50*(9), 104324. https://doi.org/10.1016/j.respol.2021.104324

Asheim, B., Grillitsch, M., & Trippl, M. (2019). Regional innovation systems: Past, present and future. *Revista Galega De Economía*, *28*(2), 4–22. https://doi.org/10.15304/rge.28.2.6190

Asheim, B. T., & Gertler, M. S. (2011). The Geography of Innovation: Regional Innovation Systems. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The Oxford Handbook of Innovation* (pp. 291–317). Oxford Univ. Press.

Autio, E. (1998). Evaluation of RTD in regional systems of innovation. *European Planning Studies*, *6*(2), 131–140. https://doi.org/10.1080/09654319808720451

Baldwin, J. R., & Lin, Z. (2002). Impediments to advanced technology adoption for Canadian manufacturers. *Research Policy*, *31*, 1–18.

Bathelt, H., & Glückler, J. (2018). *Wirtschaftsgeographie: Ökonomische Beziehungen in räumlicher Perspektive* (4., vollständig überarbeitete und erweiterte Auflage). *UTB: Vol. 8217*. UTB; Verlag Eugen Ulmer.

Bergmann, H., & Volery, R. (2006). Regionale Unterschiede von Unternehmensgründungen in der Schweiz. *Die Volkswirtschaft Das Magazin Für Wirtschaftspolitik*(6), 43-46. https://www.researchgate.net/publication/36381930_Regionale_Unterschiede_von_Unternehmensgrundungen_in_der_Schweiz/link/55269e220cf2d000c7fc4a73/download

Blind, K., Petersen, S. S., & Riillo, C. A. (2017). The impact of standards and regulation on innovation in uncertain markets. *Research Policy*, *46*(1), 249–264. https://doi.org/10.1016/j.respol.2016.11.003

BMWi. (2016). *Wirtschaft in den Regionen stärken*. https://www.bmwi.de/Redaktion/DE/Dossier/regionalpolitik.html

Boettcher, F., Freier, F., Geißler, R., & Stollhoff, R. (2019). *Kommunaler Finanzreport 2019*. https://www.bertelsmann-stiftung.de/de/publikationen/publikation/did/kommunaler-finanzreport-2019 https://doi.org/10.11586/2019045

Brenner, T., & Niebuhr, A. (2021). Policy options for lagging regions - effects, new approaches and emerging challenges: introduction to the special issue. *Review of Regional Research*, *41*(2), 125–130. https://doi.org/10.1007/s10037-021-00162-x

Brenner, T., & Pudelko, F. (2019). The effects of public research and subsidies on regional structural strength. *Journal of Evolutionary Economics*, *29*(5), 1433–1458. https://doi.org/10.1007/s00191-019-00626-x

Broekel, T., Brachert, M., Duschl, M., & Brenner, T. (2015). Joint R&D Subsidies, Related Variety, and Regional Innovation. *International Regional Science Review*, *40*(3), 297–326. https://ideas.repec.org/a/sae/inrsre/v40y2017i3p297-326.html

Brown, A., Fornoni, R., Gardiner, B., Greunz, L., Jestl, S., Rabemiafara, N., Römisch, R., Stenning, J., & Ward, T. (2017). *Economic challenges of lagging regions: Final report*. Publications Office of the European Union.

Büttner, T., Cleff, T., Egeln, J., Licht, G., Metzger, G., Overesch, M., Rammer, C., Belitz, H., Edler, D., Engerer, Hella, Geishecker, Ingo, Schrooten, M., Trabold, H., Werwatz, A., & Wey, C. (2004). Innovationsbarrieren und internationale Standortmobilität. *ZEW Zentrum Für Europäische Wirtschaftsforschung GmbH*, *06-05*. ftp://ftp.zew.de/pub/zew-docs/docus/dokumentation0605.pdf

Canepa, A., & Stoneman, P. (2002). *Financial Constraints in Innovations: A European Cross Country Study* (Working Paper no 02-11). Kiel.

Charlot, S., Crescenzi, R., & Musolesi, A. (2015). Econometric modelling of the regional knowledge production function in Europe. *Journal of Economic Geography*, *15*(6), 1227–1259. https://doi.org/10.1093/jeg/lbu035

Coad, A., Pellegrino, G., & Savona, M. (2016). Barriers to innovation and firm productivity. *Economics of Innovation and New Technology*, *25*(3), 321–334. https://doi.org/10.1080/10438599.2015.1076193

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

Cooke, P. (1996). The new wave of regional innovation networks: analysis, characteristics and strategy. *Small Business Economics*, *8*(4), 475–491.

Cooper, R. G. (1975). Why New Industrial Products Fail. *Industrial Marketing Management*(4), 315–326.

Czarnitzki, D., Kraft, K., & Thorwarth, S. (2009). The knowledge production of ‘R’ and ‘D’. *Economics Letters*, *105*(1), 141–143. https://doi.org/10.1016/j.econlet.2009.06.020

D’Este, P., Iammarino, S., Savona, M., & Tunzelmann, N. von (2008, February). What hampers innovation? Evidence from the UK CIS4. *SPRU Electronic Working Paper Series*(168).

D’Este, P., Iammarino, S., Savona, M., & Tunzelmann, N. von (2011). What hampers innovation? Revealed barriers versus deterring barriers. *Research Policy*, *41*(2), 482–488. https://doi.org/10.1016/j.respol.2011.09.008

Doloreux, D., & Dionne, S. (2008). Is regional innovation system development possible in peripheral regions? Some evidence from the case of La Pocatière, Canada. *Entrepreneurship & Regional Development*, *20*(3), 259–283. https://doi.org/10.1080/08985620701795525

Engel, D. (Mai 2002). *Welche Regionen profitieren von Venture Capital-Aktivitäten?* (Discussion Paper 02-37).

European Commission. (2017, April 10). *Competitiveness in low-income and low-growth regions: The lagging regions report*. Brusseles.

Faria, P. de, Lima, F., & Santos, R. (2010). Cooperation in innovation activities: The importance of partners. *Research Policy*, *39*(8), 1082–1092. https://doi.org/10.1016/j.respol.2010.05.003

Freel, M. S. (2000). Barriers to Product Innovation in Small Manufacturing Firms. *International Small Business Journal*, *18*(2), 60–81.

Galia, F., & Legros, D. (2004). Complementarities between obstacles to innovation: evidence from France. *Research Policy*, *33*(8), 1185–1199. https://doi.org/10.1016/j.respol.2004.06.004

Goepel, M. (2014). Organisationale Rahmenfaktoren für erfolgreiche Innovationsprozesse. In B. Schültz, P. Strothmann, C. T. Schmitt, & L. Laux (Eds.), *SpringerLink. Innovationsorientierte Personalentwicklung: Konzepte, Methoden und Fallbeispiele für die Praxis* (pp. 56–72). Springer Gabler.

Grabher, G. (1994). The Embedded Firm: On the Socioeconomics of Industrial Networks. In G. Grabher (Ed.), *The embedded firm: On the socioeconomics of industrial networks* (pp. 255–277). Routledge.

Hadfield, G. K. (2008). Legal Barriers to Innovation. *Regulation*, *31*(3), 14–21.

Hadjimanolis, A. (1999). Barriers to innovation for SMEs in a small less developed country (Cyprus). *Technovation*, *19*(9), 561–570.

Hadjimanolis, A. (2003). The Barriers Approach to Innovation. In L. V. Shavinina (Ed.), *The international handbook on innovation* (pp. 559–574). Elsevier.

Hassink, R. (2010). Locked in Decline? On the Role of Regional Lock-ins in Old Insudstrial Areas. In R. Boschma & R. Martin (Eds.), *The Handbook of Evolutionary Economic Geography* (pp. 450–468). Edward Elgar Pub.

Hauschildt, J., & Salomo, S. (2012). *Innovationsmanagement* (4., überarb., erg. und aktualisierte Aufl.). *Vahlens Handbücher der Wirtschafts- und Sozialwissenschaften*. Vahlen. http://sub-hh.ciando.com/book/?bok_id=19586

Hauser, C., Tappeiner, G., & Walde, J. (2007). The Learning Region: The Impact of Social Capital and Weak Ties on Innovation. *Journal of Economic Geography*, *41*(1), 75–88. https://doi.org/10.1080/00343400600928368

Iammarino, S., Sanna-Randaccio, F., & Savona, M. (2009). The perception of obstacles to innovation. Foreign multinationals and domestic firms in Italy. *Revue D’économie Industrielle*(125), 75–104. https://doi.org/10.4000/rei.3953

Iammarino, S., Sodano, T., & Vittorino, G. (2021). Firms’ Perceptions of Barriers to Innovation and Resilience: The Italian Region of Friuli Venezia Giulia during the Crisis. *Scienze Regionali*(1), 25–54. https://doi.org/10.14650/97448

Isaksen, A., Martin, R [R.], & Trippl, M. (2018). New Avenues for Regional Inovation Systems and Policy. In A. Isaksen, R. Martin, & M. Trippl (Eds.), *New Avenues for Regional Innovation Systems - Theoretical Advances, Empirical Cases and Policy Lessons* (pp. 1–22). Springer International Publishing.

Koschatzky, K. (2018). *Innovation-based regional structural change –Theoretical reflections, empirical findings and political implications* (Working Paper R1). Karlsruhe. https://www.econstor.eu/bitstream/10419/177445/1/1018328793.pdf

Koschatzky, K., & Kroll, H. (2019). Innovationsbasierter regionaler Strukturwandel: Strukturschwache Regionen in Deutschland. *Arbeitspapiere Unternehmen Und Region (ISI)*(R1).

Levin, R. C. (1978). Technical Change, Barriers to Entry, and Market Structure. *Economica*, *45*(180), 347. https://doi.org/10.2307/2553450

Lewandowska, M., & Danik, L. (2016). Motives and Barriers in the Field of Cooperation between Companies. Research Outcomes Based on the Polish Engineering Industry. *Journal of Economic & Management*(14).

Li, Q., Lee, S., & Park, S. W. (2020). The Effect of Inward and Outward Foreign Direct Investment on Regional Innovation Performance: Evidence from China. *GLOBAL BUSINESS FINANCE REVIEW*, *25*(1), 65–88. https://doi.org/10.17549/gbfr.2020.25.1.65

Madrid-Guijarro, A., Garcia, D., & van Auken, H. (2009). Barriers to Innovation among Spanish Manufacturing SMEs. *Journal of Small Business Management*, *47*(4), 465–488.

Major, E., & Cordey-Hayes, M. (2003). Encouraging Innovation in Small Firms Through Externally Generated Knowledge. In L. V. Shavinina (Ed.), *The international handbook on innovation* (pp. 667–680). Elsevier.

Martin, R [R.], & Trippl, M. (2014). System Failures, Knowledge Bases and Regional Innovation Policies. *DisP - the Planning Review*, *50*(1), 24–32. https://doi.org/10.1080/02513625.2014.926722

McAdam, R., McConvery, T., & Armstrong, G. (2004). Barriers to innovation within small firms in a peripheral location. *International Journal of Entrepreneurial Behavior & Research*, *10*(3), 206–221. https://doi.org/10.1108/13552550410536780

Mirow, C. (2010). *Innovationsbarrieren*. Zugl.: Berlin, Techn. Univ., Diss., 2009. *Betriebswirtschaftliche Studien in forschungsintensiven Industrien*. Gabler Verlag / Springer Fachmedien Wiesbaden GmbH Wiesbaden. http://dx.doi.org/10.1007/978-3-8349-6100-6 https://doi.org/10.1007/978-3-8349-6100-6

Mirow, C., Hölzle, K., & Gemünden, H. G. (2007). Systematisierung, Erklärungsbeiträge und Effekte von Innovationsbarrieren. *Journal Für Betriebswirtschaft*, *57*(2), 101–134. https://doi.org/10.1007/s11301-007-0023-1

Mohnen, P., Palm, F. C., van der Loeff, S. S., & Tiwari, A. (2008). Financial Constraints and Other Obstacles: are they a Threat to Innovation Activity? *De Economist*, *156*(2), 201–214. https://doi.org/10.1007/s10645-008-9089-y

Morgan, K., & Cooke, P. (1994). The regional innovation system in Baden-Württemberg. *International Journal of Technology Management*, *9*(3/4), 394–429.

Nerlinger, E. A. (1998). *Standorte und Entwicklungen junger innovativer Unternehmen: Empirische Ergebnisse für West-Deutschland* (Wirtschaftsanalysen 27). Baden-Baden.

Palmer, K., Oates, W. E., & Portney, P. R. (1995). Tightening environmental standards: the benefit-cost or the no-cost paradigm? *Journal Economic Perspectives*, *9*(4), 119–132.

Pellegrino, G., & Savona, M. (2017). No money, no honey? Financial versus knowledge and demand constraints on innovation. *Research Policy*, *46*(2), 510–521. https://doi.org/10.1016/j.respol.2017.01.001

Piatier, A. (1984). *Barriers to innovation*. Frances Printer Publishers Ltd.

Porter, M. E. (2014). *Wettbewerbsstrategien: Methoden zur Analyse von Branchen und Konkurrenten* ((A. Jaeger & M. Schickerling, Trans.)) (8. Auflage). *Campus Strategie*. Campus.

Rodríguez-Pose, A. (2013). Do Institutions Matter for Regional Development? *Journal of Economic Geography*, *47*(7), 1034–1047. https://doi.org/10.1080/00343404.2012.748978

Romesburg, H. C. (2004). *Cluster analysis for researchers*. Lulu Press.

Rosa, J., & Mohnen, P. (2000). *Les obstacles a l'innovation dans les industries de service au Canada: Working paper 2000 s-14.* Montreal. CIRANO.

Rousseeuw, P. J. (1987). Silhouettes: A graphical aid to the interpretation and validation of cluster analysis. *Journal of Computational and Applied Mathematics*, *20*, 53–65. https://doi.org/10.1016/0377-0427(87)90125-7

Sainio, L.-M., Ritala, P., & Hurmelinna-Laukkanen, P. (2012). Constituents of radical innovation—exploring the role of strategic orientations and market uncertainty. *Technovation*, *32*(11), 591–599. https://doi.org/10.1016/j.technovation.2012.06.006

Savignac, F. (2008). Impact of financial constraints on innovation:What can be learned from a direct measure? *Economics of Innovation and New Technology*, *17*(6), 553–569. https://doi.org/10.1080/10438590701538432

Schültz, B. (2014). Führen im Projekt - Ein Kompetenzentwicklungsprogramm für Prozessmanager in Innovationsvorhaben. In B. Schültz, P. Strothmann, C. T. Schmitt, & L. Laux (Eds.), *SpringerLink. Innovationsorientierte Personalentwicklung: Konzepte, Methoden und Fallbeispiele für die Praxis* (pp. 86–101). Springer Gabler.

Scott, W. R. (2008). *Institutions and organizations: Ideas, interests and identities*. Sage.

Storey, J. (1994). *Understanding the small business sector*. Routledge.

Storey, J. (2000). The Management of Innovation Problem. *International Journal of Innovation Management*, *04*(03), 347–369. https://doi.org/10.1142/S1363919600000196

Strobel, N., & Kratzer, J. (2017). Obstacles to Innovation for SMEs: Evidence from Germany. *International Journal of Innovation Management*, *21*(03), 1750030. https://doi.org/10.1142/S136391961750030X

Tang, H.-K., & Yeo, K.-T. (2003). Innovation under Constraints: The Case of Singapore. In L. V. Shavinina (Ed.), *The international handbook on innovation* (pp. 873–882). Elsevier.

Tödtling, F., & Trippl, M. (2005). One size fits all? Towards a differentiated regional innovation policy approach. *Research Policy*, *34*(8), 1203–1219. https://doi.org/10.1016/j.respol.2005.01.018

Trippl, M., Asheim, B., & Miörner, B. (2016). Identifification of regions with less-developed research and innovation system. In M. D. Parrilli, R. Dahl Fitjar, & A. Rodriguez-Pose (Eds.), *Routledge studies in innovation, organization and technology: Vol. 40. Innovation Drivers and Regional Innovation Strategies* (pp. 23–44). Taylor and Francis.

Ulrich, A., Breitenfelder, M., Job, H., Kleinhenz, G., Maier, J., Mayer, M., Odewald, C., Ruppert, K., & Weber, J. (2007). *10 Thesen zu Entwicklungen, Strukturen, Problemenund Lösungsstrategien peripherer, strukturschwacherRegionen in Bayern* (Positionspapier aus der ARL No. 72). Hannover. https://www.econstor.eu/bitstream/10419/102780/1/pospaper_72.pdf

Vossen, R. (1998). Relative strengths and weaknesses of small firms in innovation. *International Small Business Journal*, *16*(3), 88–94.

Ylinenpää, H. (September 1996). *Barriers to Innovation in Swedish SMEs.* Vaasa, Finland. Paper presented to EFMDs 26th European Small Business Seminar.

Zhu, S., He, C., & Luo, Q. (2019). Good neighbors, bad neighbors: local knowledge spillovers, regional institutions and firm performance in China. *Small Business Economics*, *52*(3), 617–632. https://doi.org/10.1007/s11187-017-9975-2

Zukauskaite, E., Trippl, M., & Plechero, M. (2017). Institutional Thickness Revisited. *Economic Geography*, *93*(4), 325–345. https://doi.org/10.1080/00130095.2017.1331703