Measuring Regional Innovative Capability – Development of an Extended Set of Indicators

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Abstract Regional innovative capability is described through a complex interaction of the dimensions human, organization and technology, which needs to be measured in a differentiated manner. The objective of this paper is the development and testing of an extended set of indicators as the basis of a measuring instrument for regional innovative capability. Therefore, three existing approaches provide the basis for the compilation of this extended set. Influenced by fundamental and formal requirements, key indicators as well as certain add-on indicators are identified, which are verified on the example of the Aachen region in Germany (This paper represents the working process and the results of an unpublished master's thesis by the first author. The full validation of the extended set of indicators on the example of the Aachen region can be provided by the author). The Aachen region shows many distinct characteristics of indicators allowing a reflection of regional innovative capability. This developed set of indicators represents the basis for a further development towards a measurement and management tool that enables the more precise evaluation of the innovation capability of a region, as well as statements on sensitive control factors of regional development.

Keywords Regional Innovative Capability · Hexagon Model · Operationalization · Indicators · Measurement · Regional Development

1 Introduction and Problem Statement

In today's complex and dynamic world economy the ability of a country or a region to innovate continuously is crucial for its competitiveness. Also at the regional level, innovative capability has recently been identified as a crucial determinant of social stability and economic growth [1]. Targeting the development and modelling of innovative capability, suitable measuring instruments at the regional level are

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required. Previous spatial scientific measurement approaches do not adequately consider that innovative capability substantially diverges at the regional level due to certain location factors.

To foster a country's sustainable competitiveness, regional innovation potentials have to be detected at an early stage and they have to be systematically exploited to finally increase the innovative capability [2]. Existing approaches and models are built primarily to measure the innovative capability of enterprises, networks or countries (e. g. *European Commission - Innovation Union Scoreboard, Deutsche Telekom Stiftung & Bundesverband der deutschen Industrie e. V. – Innovationsindikator*). Especially with regard to a smaller scale of measuring regional innovative capability, fewer approaches are available and applicable (e. g. *European Commission - Regional Innovation Scoreboard*). The aim of this paper is to develop a wider, regional small-scale, spatially differentiated and precise set of indicators for measuring and modelling regional innovative capability.

2 Operationalizing Regional Innovative Capability

Innovations are an important factor of economic growth and regional development [3]. In the early twentieth century Schumpeter already emphasized the importance of innovation as the driving force of economic development and structural change [4]. The challenge is that innovations are fraught with uncertainty and risk, and so the failure rate of technical innovation projects is 50 % [5]. Therefore, it is of great interest to identify innovative capabilities and the critical factors for innovation success more accurately [6]. For defining the term regional innovative capability, it is broken down into single components. Innovative capability is being defined, before spatial and regional aspects are involved.

Contemporary research mainly focuses on success factors, characteristics and criteria of successful innovations. However, innovative capability is rarely a subject of theoretical and empirically grounded research literature [6]. Basically, it means the ability of individuals, groups, institutions or networks to continuously innovate [7]. A system-oriented approach towards innovative capability is crucial: Cantner [8] points out the importance of interaction and collaboration of the elements of a system, which is based on the exchange of knowledge and experience. System's elements e. g. can be stakeholders like individuals or small and medium-sized enterprises (SME). Trantow et al. [7] have a similar system-oriented understanding of innovative capability: the ability to bring forth innovation requires a complex interaction of the dimensions human, organization and technology. Here, every innovation is always a result of the far-reaching inter-relations of these dimensions and interdependent processes that arise from it [7].

In the Oslo Manual (2005) the complex understanding of innovative capability is extended to a spatial and regional perspective [9]. Here, region-specific location factors crucially influence the creation of innovations. Accordingly, regional disparities are precisely examined and main characteristics identified in order to gain a better understanding of innovation processes: "*The notion that regional factors can influence the innovative capacity of firms has led to increasing interest in analyzing innovation at the regional level. Regional differences in levels of innovation activity can be substantial, and identifying the main characteristics and factors that promote innovation activity and the development of specific sectors at regional level can help in understanding innovation processes and be valuable for the elaboration of policy*" [9].

The challenge is to operationalize regional innovative capability. Basically, innovative capability is being operationalized analogous to innovations with input and output or process factors [10]. However, the significance of quantitative output-oriented indicators (e. g. patents) or input-based indicators (e. g. Research & Development (R&D) expenditure and employees) is not sufficient. In order to accomplish a more precise operationalization, the spatial- and the content-related dimensions of the complex system of regional innovative capability are defined in more detail during the following sections.

2.1 Spatial Dimension: Spatial Planning Region

Innovative capability as well as innovation and development processes are influenced by the respective region. But what distinguishes a region more closely and which scale is reasonable for the proposed set of indicators for measuring regional innovative capability? In economic geography the terminus *region* is defined very broadly, it is considered as a contiguous space section [11].

The German Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) defines spaces on the one hand by administrative, on the other hand by functional criteria [1]. Here, counties[1] as authorities and holders of public tasks (especially in the function of lower state administrative bodies) constitute the administrative basis for the functional and spatial delineation of Spatial Planning Regions (SPRs). Therefore, SPRs are agglomerations of counties into functional units, which are characterized by commuters' relations towards a major regional centre [12].

In the German Federal Spatial Planning SPRs are applied to analyze large-scale disparities and developments and therefore they are of great interest for this work. On the one hand this spatial delineation is used if the county level is too fragmented, too spatially small or if the (federal) state level is too coarse. On the other hand SPRs are used to analyze and highlight intertwining relationships between major regional centers and surrounding areas [12]. The advantage of SPRs is that these are defined functionally and not purely in an administrative way, but at the same time statistically detectable, since they are based on the agglomerations of counties.

[1] European equivalent: NUTS-3 Regions. To harmonize the regional statistical reporting, the European Union has introduced a common classification of territorial units for statistics in the 1970 s (Nomenclature of Territorial Units for Statistics, NUTS) [12].

For example, besides commuting, also interactions and innovation links between peripheral enterprises and a university as a gravity core can be measured [12].

2.2 Content-related Dimension: Knowledge Region

Models of innovation-oriented regional development are used to operationalize the content-related dimension of regional innovative capability. These models are primarily used to establish an ideal state of the development objectives that have to be regionally pursued [13]. In the context of this study, concepts of regional development are considered to examine regions concerning their potentials and capabilities in terms of generating innovation. Finally, using these concepts, regional innovative capability can be operationalized.

Models of innovation-oriented regional development capture different conceptual facets of knowledge-based regional development [14]. By comparing five different models namely clusters, innovative or creative milieus, regional innovation systems, learning regions and knowledge regions (KR) [15–18], the KR turns out as a suitable model of regional development to finally develop a set of indicators for measuring regional innovative capability. The innovation-oriented regional development model of the KR by Fromhold-Eisebith [13] represents an overarching, linking framework of the compared, all previously pre-established regional development models. This model provides more of a regional development tool, which pursues strategic intentions, as a descriptive or analytical tool [13, 19]. The term KR emphasizes the importance of knowledge for the economic and social future of a region [20]. Furthermore, the operationalization of knowledge as the basis of innovation, offers an adequate approach towards the identification of regional innovative capability.

Fromhold-Eisebith [13] uses the clarification of knowledge in order to illustrate the advantages of the terminus KR over other regional development models. Due to the broad and socially accepted knowledge concept (e. g. explicit and tacit knowledge [21]), which refers to various areas of expertise, such as science, economy and society, the model of the KR activates and involves a wider range of stakeholders and competence-fields accordingly. This in turn promotes a greater information-sharing, more interactions and collaborations for knowledge generation and finally an increase of regional innovative capability. The concept of the KR with its large bandwidth for example also captures peripheral, rural areas [13]. To summarize, (regional) knowledge has a direct impact on the development process of a region and serve as a key factor for identifying specific regional capabilities which also determines the long-term position in the region.

The KR is characterized by flexible network-structures and a high degree of cross-linking. This implies a high grade of interaction and cooperation between internal and external stakeholders. Due to spatial proximity, social-cultural relations also play an important role. To understand these structures, the hexagon model portrays basic structure of the KR concept (cf. Fig. 1).

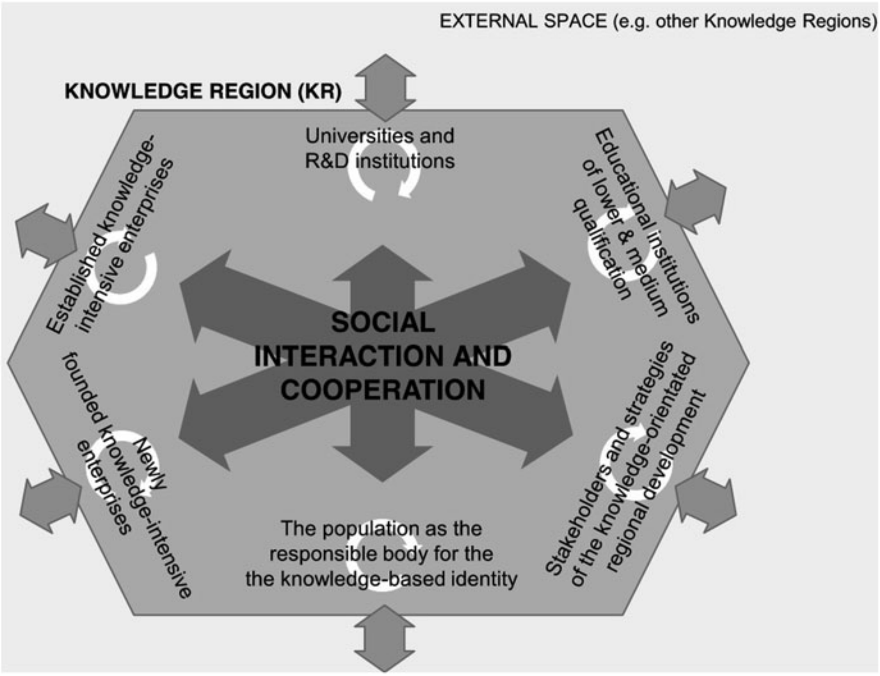

Fig. 1 The hexagon model of the KR. (Source: own representation based on Fromhold-Eisebith [13])

This model outlines the demand for a modern knowledge-based regional development in form of an ideal image on the one hand, and strategy-based, regionally appropriate statements on the other hand [13]. Hence, the hexagon model represents stakeholders of knowledge-related processes. A KR can be exemplary captured by R&D intensity, by the number of R&D institutions or R&D employees, but also by the existence funding strategies or the knowledge-related self-image of the population [22].

To conclude, the concept of KR is suitable for the identification of the innovative capability of regions. Demands of a modern knowledge-based regional development in the means of social interaction and cooperation as well as strategy statements relating to the development of a region are pointed out in this concept. Furthermore, it provides content-related requirements for the development of an extended set of indicators to measure regional innovative capability.

Table 1 Comparison of three different existing approaches measuring (regional) innovative capability. (Source: own representation)

	BAKBASEL Innovations-Benchmarking	Regional Innovation Scoreboard	Innovationsindikator
N° OF INDICATORS	7	12	38
INTERNATIONAL FRAMEWORK	-	24 countries	28 countries
SPATIAL DIMENSION	NUTS 1, Planningregions	NUTS 2	State
CONTENT RELATED DIMENSION	Regional Innovationsystems	-	National Innovationsystems

Table 2 Set of indicators - *Regional Innovation Scoreboard*. (Source: European Commission [23])

Indicator	Dimension
Population with tertiary education per 100 population aged 25-64	Enablers
Public R&D expenditures (% of GDP)	Enablers
Business R&D expenditures (% of GDP)	Firm Activities
Non-R&D innovation expenditures (% of total turnover)	Firm Activities
SMEs innovating in-house (% of all SMEs)	Firm Activities
Innovative SMEs collaborating with others (% of all SMEs)	Firm Activities
Public-private co-publications	Firm Activities
EPO patent applications per billion GDP (in PPP€)	Firm Activities
Technological (product or process) innovators (% of all SMEs)	Outputs
Non-technological (marketing or organisational) innovators (% of all SMEs)	Outputs
Employment in knowledge-intensive services / medium-high and high-tech manufacturing	Outputs
Sales of new-to-market and new-to-firm products (% of total turnover)	Outputs

2.3 State of the Art: Sets of Indicators for Measuring Innovative Capability

To initiate the development of an expanded set of indicators three existing approaches are used in a literature study (cf. Table 1). The consideration focuses on the quantification and qualification of the contained sets of indicators. It examines how innovation capability is operationalized at different spatial dimensions. Further actions such as index calculations or other additional procedures are not considered. The selection of these three approaches founded on one certain criterion: The measurement of innovative capability of countries or regions, and not the measurement of the innovative capability of enterprises.

The *Regional Innovation Scoreboard* by the European Commisson refers on the comparability of the NUTS-2 regions of 24 European countries [23]. Such an extensive comparative study requires corresponding data sources, which have to be accompanied by statistical estimates. The challenge here is the nationwide regional data availability. Innovative capability is described by 12 indicators, which refer to three dimensions. “Enablers” capture the main drivers of innovation performance external to the firm, “firm activities” refer to the innovation efforts at the level of the firm and “outputs” imply further effects of firm-based innovation activities [cf. Table 2] [23]. Concerning the content related dimension, no more specifications in the meaning of models of regional development are made.

Table 3 Set of indicators - *Innovationsindikator*. (Source: DTS/BDI [24])

Indicator	Dimension
Foreign students as a percentage of all tertiary enrolment	Education
Share of employees with at least secondary (non tertiary) education	Education
Population with ISCED 6 level education in mathematics, sciences, and engineering	Education
Tertiary graduates per 55+ year old academic employees	Education
Share of employees with tertiary education	Education
Annual education expenses per student	Education/State
Quality of education system	Education/State
Quality of the mathematical and natural science education	Education/State
Index of PISA results in sciences, reading, mathematics	Education/State
E-readiness indicator	Society
Risk-taking behavior	Society
Number of PCs per 100 inhabitants	Society
Share of post materialists	Society
Public demand for advanced technologies	State
Demand of companies for technological products	Enterprises
Early-stage venture capital relative to GDP	Enterprises
Importance of Marketing	Enterprises
Share of international co-patents	Enterprises
Share of value added in high-tech sectors in total value added	Enterprises
Share of employees in knowledge intensive services	Enterprises
Intensity of competition	Enterprises
GDP per capita	Enterprises
Transnational patents per capita	Enterprises
USPTO patent applications per capita	Enterprises
Value added per hour worked	Enterprises
Trade balance in high-tech goods per capita	Enterprises
Share of university R&D financed by enterprises	Enterprises
Internal business R&D expenditures as share of GDP	Enterprises
B-index for tax-based funding of business R&D	Enterprises/State
Publicly funded R&D in enterprises as a share of GDP	Enterprises/State
Number of researchers in FTE per 1,000 employees	Public Research
Number of SCI publications relative to population	Public Research
Quality of research institutions	Public Research
Field-specific expected impact rate of SCI-publications	Public Research
Public science sector patents per inhabitant	Public Research
Share of international SCI co-publications	Public Research
R&D share in Public Research Institutions and Universities	Public Research
Country share among the top 10% of most highly cited publications	Public Research

The *Innovationsindikator* reflects the most detailed portray of innovative capability [24]. With using 38 indicators different dimensions like education, society, enterprises and public research are operationalized. In comparison to the other approaches the understanding of innovative capability is wider and includes more certain aspects, like the quality of the education system or the Index of PISA (cf. Table 3). Nevertheless, the focus is on the dimension enterprises, which is described by almost 15 indicators. Some qualitative indicators of this approach are based on expert interviews, which significantly imply more effort for the survey, since no pure query of available data is possible. The content-related dimension of the *Innovationsindikator* is described by national innovation systems as a model of regional

Table 4 Set of indicators - *BAKBASEL Innovations-Benchmarking*. (Source: BAKBASEL [25])

Indicator	Dimension
R&D expenditures	INPUT
R&D intensity	INPUT
Papers in scientific publications	INPUT
Shanghai-Index	INPUT
Students	INPUT
Patens	OUTPUT
Size of the knowledge-intensive business sector	OUTPUT

development (cf. Table 1). Considering the international framework, the *Innovationsindikator* refers to the comparison of 28 industrialized countries. Any further regional specifications are not made.

The approach of *BAKBASEL Innovations-Benchmarking* covers different phases and aspects of an innovation process using 7 indicators [25]. These are divided into the input and output dimension of an innovation process. In comparison to the other two approaches, the description and identification of innovative capability relies on a few core indicators, such as patents, R&D expenditures or papers in scientific publications (cf. Table 4). Considering the spatial framework, the *BAKBASEL Innovations-Benchmarking* only focuses on the German federal state of Baden-Württemberg as well as on smaller-scale planning regions, thereby the view is much more limited and focused. The content-related dimension of the *BAKBASEL Innovations-Benchmarking* is described respectively by models of regional development – in this case regional innovation systems (cf. Table 1). A special feature is the combination of a spatially and functionally defined region (Planningregions) on the hand and an innovation-orientated model of regional development on the other hand. This combination approaches the intended procedures of this work already quite closely.

Reflecting Table 1 it becomes obvious that innovation is described by manifold indicators and in very different degrees. Based on this cross-sectional choice of different approaches, it has been highlighted, which sets of indicators are used to measure innovative capability and what selection of indicators is necessary for determining the innovative capability of SPRs regarding the development of the proposed set of indicators.

3 Development of an Extended Set of Indicators

An extended approach is derived from the previously highlighted indicators of the three sets of indicators described. This derivation happens in a compaction process under influence of formal requirements based on the Grounded Theory Methodology[2]. Thus, a compressed data corpus is generated through encoding. The encoding

[2] Grounded theory describes a curriculum related theory-formation, which has been described by the sociologists GLASER and STRAUSS 1967 in the book "The Discovery of Grounded Theory" first time fundamentally [26].

Table 5 Fundamental and formal requirements. (Source: own representation)

Fundamental requirements	Formal requirements		
Universities and R&D institutions	(Regional) Data availability	Clear assesment	Operating efficiency
Established knowledge-intensive enterprises			
Newly founded knowledge-intensive enterprises			
The population as the responsible body for the knowledge-based identity			
Stakeholders and strategies of the knowledge-oriented regional development			
Educational institutions of lower & medium qualification			

process represents the core of Grounded Theory. In order to enable a systemic analysis, collected data is abstracted, categorized and put into an interdependent context. During the open coding, categories are identified and described hypothetical. Existing data is coded accordingly towards its conceptual content. The resulting codes can be construed as preliminary concept names. The previously developed concepts are then further refined during axial coding. Thus, the differentiation rotates at a certain point around the axis of a concept or a category. During the axial coding, categories are related to each other and further sub-categories are analyzed. Finally, key categories (=indicators) are identified [26].

3.1 Requirements

The fundamental requirements for the proposed set of indicators are given by the six edges of the hexagon model (cf. Fig. 1), which represent the stakeholders of knowledge-based processes. These stakeholders are required in sufficient availability and quality for the creation, the use and the transfer of knowledge in order to strengthen innovative capability (cf. Table 5).

In addition to these fundamental requirements for the justification of the proposed set of indicators, more formal requirements are needed, such as (regional) data availability, clear assessment and operating efficiency. Clear assessment implies the definition of explicit parameters or key figures and operating efficiency involves a proportionally cost/benefit ratio concerning the data collection. For the identification of the extended set of indicators all formal requirements have to be equally respected. However, the availability and quality of data at the regional planning level is decisive.

3.2 Identification of Key Indicators

In comparison of the three sets of indicators, a data corpus of 57 codes emerged through open coding which generally describes regional innovative capability[3].

[3] Full tables can be provided by the author.

Table 6 Overview of the extended set of indicators. (Source: own representation)

Input	Output
GDP	Patents
R&D expenditures of the business sector	
R&D employees in the business sector	
Publications	
Ten percent of the most cited scientific and technical publications	Size of the knowledge-intensive & medium- / high-tech-business sector
Excellent Research	
Foreign Students	
Students	International interrelations of the knowledge-intensive & medium- / high-tech-business sector
Population with tertiary education	
Public R&D expenditures *	
Venture-Capital*	Enterprises innovating in-house **
Knowledge-regional initiatives**	Home institutions of enterprises of the knowledge-intensive business & medium- / high-tech-business sector **
Technology and business incubator-centres**	
Regional cluster and network initiatives**	
* Add-on-A-Indicator, ** Add-on-B-Indicator	

Through axial coding, the previously open encoded codes were again compressed to twelve codes and through selective coding into two categories (cf. Table 6). After this, the extended set of indicators has been compacted and derived in accordance with the given requirements. This allowed a justification and validation in accordance with the requirements of the KR.

3.3 Identification of Additional Indicators

In accordance with the introduced fundamental and formal requirements, key indicators were identified and additional indicators could be developed. Here, a distinction is made between Add-on-A-Indicators and Add-on-B-indicators (cf. Tables 6 and 7): Add-on-A-indicators have also been raised from the above-described compression step from the existing indicator sets. However these do not meet the formal requirements i. e. that they are either difficult or impossible to collect. This is why these indicators cannot be counted among the key indicators. Nevertheless, the Add-on-A-indicators meet the fundamental requirements. Despite the non-fulfillment of formal requirements they contribute to the validity of the set of indicators regarding the portraiture of regional innovative capability.

Definitions of the Add-on-A-indicators can be found, as well as those of the key indicators, in the different considered indicator sets. Add-on-B-indicators are indicators that cannot be found in the considered indicators sets, however, they are additionally required to describe regional innovative capability and KRs. Accordingly, Add-on B-indicators fulfill fundamental and formal requirements, but due to their new construction they also cannot be counted among the key indicators. Table 6

Table 7 Specification of the extended set of indicators. (Source: own representation)

	Fundamental requirements	Formal requirements	Derived	Newly developed
Key indicators (12)	☑	☑	☑	
Add-On-A-Indicators (3)	☑		☑	
Add-On-B-Indicators (4)	☑	☑		☑

shows the complete and extended set of indicators in a summarizing, conceptional overview. In the entire academic work all indicators are fully defined, justified and explicitly described by parameters or key figures.

4 Evaluation and Application-oriented Outlook

The extended set of indicators has been tested for its functionality in the context of the Aachen region. Observations are that e. g. scientific clusters of excellence contribute to increase the innovative capability in the region of Aachen or that a high density of technology-, start-up- and service-centers promote innovation. Furthermore, the Aachen region is strong in the area of knowledge-intensive as well as medium- and high-tech enterprises without being characterized by a strong urban-rural gradient. In addition, the region is characterized by a functioning transfer between scientists and citizens [27].

Overall the Aachen region shows many distinctive characteristics of indicators that suggest being an innovative capable region. Regional innovative capability can therefore be portrayed with the developed broader approach, although more precise statements about the innovative capability of a region are not possible here: The interpretability of these collected data is restricted due to missing observation spaces, data series and a further consideration of comparable regions.

5 Summary and Outlook

The example of the Aachen Region shows that the extended set of indicators is able to reflect regional innovative capability. As a spatial dimension, SPRs serve to capture regional innovative capability, which are suitable for large-scale analyzes, regional forecasting as well as large regional surveys to detect interactions and innovation links. In addition, the model of KR delineates the content-related dimension of the proposed set of indicators, not at least because this model links many existing models of regional development.

An option is the development of this extended set of indicators towards a full measurement and control tool of knowledge-regional development by considering these missing aspects and by weighting the individual indicators. So, for example, even sensitive control variables can be identified. Finally, an index value of all indicators can also be formed in such a way whereby a direct comparison of different regions is allowed. A comparable index is e. g. shown by the *Regional Innovation Scoreboard* or by the *Innovationsindex*. Another further step is the ongoing evaluation of this set of indicators on other regions in the meaning of long-term studies. The development of this set of indicators towards a measurement and management tool will allow more accurate statements about the innovative capability of a region.

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References

1. Backhaus, Angela. 2000. *Öffentliche Forschungseinrichtungen im regionalen Innovationsystem - Verflechtungen und Wissenstransfer - Empirische Ergebnisse aus der Region Südostniedersachsen*. 55 vols. Münster: LIT. (*Hannoversche Geographische Arbeiten*).
2. Brenner, Thomas. 2008. Messbarkeit und Standorteffekte regionaler Innovationsysteme. Presentation. Köln.
3. Bathelt, Harald and Johannes Glückler. 2012. *Wirtschaftsgeographie*. Stuttgart: Verlag Eugen Ulmer.
4. Schumpeter, Joseph. 1964. *Theorie der wirtschaftlichen Entwicklung - Eine Untersuchung über Unternehmergewinn, Kapital, Kredit, Zins und den Konjunkturzyklus (1911)*. Berlin: Duncker & Humblot.
5. Giese, Ernst and Reinhard v. Stoutz. 1998. Indikatorfunktion von Patentanmeldungen für regionalanalytische Zwecke in der Bundesrepublik Deutschland. *Raumforschung und Raumordnung* 56 (5–6): 414–420.
6. Sammerl, Nadine. 2006. *Innovationsfähigkeit und nachhaltiger Wettbewerbsvorteil: Messung - Determinanten - Wirkungen. (Marktorientierte Unternehmensführung und Internetmanagement)*. Wiesbaden: Deutscher Universitäts-Verlag.
7. Trantow, Sven, Frank Hees, and Sabina Jeschke. 2011. Die Fähigkeit zur Innovation - Einleitung in den Sammelband. In *Enabling Innovation - Innovationsfähigkeit – Deutsche und internationale Perspektiven*, ed. Sabina Jeschke, Ingrid Isenhardt, Frank Hees, and Sven Trantow, 1–14. Berlin Heidelberg: Springer.
8. Cantner, Uwe. 2000. Die Bedeutung von Innovationssystemen für die internationale Wettbewerbsfähigkeit. In *Innovation als Schlüsselfaktor eines erfolgreichen Wirtschaftsstandortes - Nationale und regionale Innovationssysteme im globalen Wettbewerb*, ed. Uwe Staroske, Maren Wiegand-Kottisch, and Karl Wohlmuth, 77–110. Münster: LIT.
9. OECD (Organisation for Economic Co-Operation and Development) and EUROSTAT (Statistical Office of the European Communities), eds. 2005. *Oslo Manual - Guidelines for collecting and interpreting innovation data*.
10. Busch, Sigrid, Christoph Lammert, Sylvia Sparschuh, and Frank Hees. 2011. *Innovationsfähigkeit im Gespräch*. 7 vols. Berlin: Aachen. (*Innovationsfähigkeit im Gespräch*).
11. Sinz, Manfred. 2005. Region. In *Handwörterbuch der Raumordnung*. ed. Akademie für Raumforschung und Landesplanung, 919–923. Hannover: Akademie für Raumforschung und Landesplanung.
12. Stadt-und Raumforschung BBSR (Bundesinstitut für Bau), ed. 2012. *Raumabgrenzungen und Raumtypen des BBSR*. 6 vols. Bonn. (*Analysen Bau, Stadt, Raum*).

13. Martina Fromhold-Eisebith. 2009. Die “Wissensregion” als Chance der Neukonzeption eines zukunftsfähigen Leitbilds der Regionalentwicklung. *Raumforschung und Raumordnung* 67 (3): 215–217.
14. Moulaert, Frank and Farid Sekia. 2003. Territorial Innovation Models: A Critical Survey. *Regional Studies* 37 (3): 289–302.
15. Porter, Michael E. 1990. The Competitive Advantage of Nations. *Harvard Business Review* (03/04):73–91.
16. Camagni, Roberto. 1991. Introduction: From the local ‘milieu’ to innovation through cooperation networks. In *Innovation Networks - Spatial Perspectives*, ed. Roberto Camagni, 1–9. London, New York: Belhaven.
17. Cooke, Philip. 1998. Introduction. Origins of the concept. In *Regional Innovation Systems. The role of governances in a globalized world*, ed. Hans-Joachim Braczyk, P. Cooke, M. Heidenreich, and G. Krauss, 2–25. London: UCL.
18. Hassink, Robert. 1997. Die Bedeutung der Lernenden Region für die regionale Innovationsförderung. *Geographische Zeitschrift* 85 (2/3): 159–173.
19. Martina Fromhold-Eisebith. 2009. Space(s) of Innovation: Regional Knowledge Economies. In *Milieus of Creativity - An Interdisciplinary Approach to Spatiality of Creativity*, ed. Peter Meusburger, Joachim Funke, and Edgar Wunder, 201–218. Heidelberg: Springer.
20. Buschmann, Birgit. 2005. Positionspapier: Regionales Prozess- und Wissensmanagement, Bedeutung von Wissen für Regionen. 2013-02-20, http://www.bmfsfj.de/doku/Publikationen/perspektiven/3-Arbeitsgruppen/Arbeitsgruppe-regionales-prozess-und-wissensmanagement/positionspapier-dr-birgit-buschmann.html.
21. Nonaka, Ikojiro. 1994. A dynamic theory of organizational knowledge creation. *Organization Science* 5 (1): 14–37.
22. Martina Fromhold-Eisebith. 2008. Von der Technologie- zur Wissensregion: Neukonzeption anhand des Beispiels der Region Aachen. Presentation.
23. European Commission. 2012. Regional Innovation Scoreboard 2012. http://ec.europa.eu/enterprise/policies/innovation/files/ris-2012-methodology-report_en.pdf.
24. DTS (Deutsche Telekom Stiftung) and BDI (Bundesverband der deutschen Industrie e. V.). 2012. Innovationsindikator 2012. http://www.telekom-stiftung.de/dtag/cms/contentblob/Telekom-Stiftung/de/2145384/blobBinary/Innovationsindikator+2012.pdf.
25. BAKBASEL BAK (Basel Economics AG), ed. 2011. *Innovationskraft Baden-Württemberg: Erfassung in Teilregionen des Landes und Beitrag zum Wirtschaftswachstum*. Basel.
26. Glaser, Barney and Anselm Strauss. 2005. *Grounded Theory. Strategien qualitativer Forschung*. Bern: Hans Huber.
27. Stiehm, Sebastian. 2013. Innovationsfähigkeit von Regionen - Entwicklung eines erweiterten Indikatorensatzes am Beispiel der Region Aachen. Master’s thesis, Unpublished.