Innovation System Research: Where It Came From, and What It Is Now

– A Bibliometric Network Analysis –

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Abstract: Since its emergence in the 1980s, the concept of "Innovation Systems" (IS) has been influential in spurring research and shaping discussions in academia and policy alike, leading to a cascading development of approaches and extensions at various levels of analysis. However, the broad understanding of IS and diversity in application has resulted in blurry boundaries of the field, making its delineation as well as assessment of its progress challenging. Using a combination of data-driven techniques from bibliometrics, natural language processing, and network analysis, this paper maps and analyzes the structure of knowledge production and process of knowledge integration in the literature. We find an overall growing tendency of increasing diversity of knowledge bases the field draws from, yet accompanied by a decreasing coherence of collective research efforts. Within IS related research, we argue that the pursuit of further knowledge integration also requires equal effort to maintain internal coherence. In by nature interdisciplinary and diverse fields, we point to the crucial role institutions play in fulfilling this function.

Keywords: innovation systems, bibliometrics, networks, research area, knowledge base, diversity, coherence

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1 Introduction

The late 1980*s* of the innovation studies have been associated with the emergence of a new work concerned with a development of a more systemic understanding of innovation and diffusion. The resulting "National Innovation System" (NIS) framework[1] (Freeman, 1987; Lundvall, 1992; Nelson, 1993) have attracted much attention among both researchers and policy makers since its emergence, and propelled the larger field of Innovation Systems (IS) research into importance.

Subsequent research cascaded in the development of further frameworks of "innovation systems" differing in analytical and conceptual focus, elements and dimensions emphasized, system boundaries, and units of analysis, such as regional (Cooke, 2001; Malmberg and Maskell, 2002), sectoral (Breschi and Malerba, 1997; Malerba, 2002, 2005), technological (Bergek et al., 2008; Carlsson and Stankiewicz, 1991a; Hekkert et al., 2007), business (Whitley, 2000), social systems of innovation and production (Amable, 2000), and national systems of entrepreneurship (Acs et al., 2014).

Previous research has provided insights on the historical origin and context from which the approach emerged (Edquist, 2005; Godin, 2009; Lundvall, 2007; Sharif, 2006; Soete et al., 2010), on the system's users and role in the world of science (Fagerberg and Sapprasert, 2011; Teixeira, 2013; Uriona-Maldonado et al., 2012), as well as on the unifying elements that bind these contributions together and their role in a more narrow context of innovation studies (Fagerberg et al., 2012). However, most of these previous studies examine the origins and trace the evolution of the NIS research field starting from the contributions of the originators of the concept while not taking into account the emergence of new works. Moreover, a relative importance of what is considered the field's core literature is usually assumed to be persistent over time and homogeneous across research areas. Similarly, a review process of the trends in NIS, or IS research more broadly, has mainly focused on how the field has been institutionalized and organized in terms of intellectual structure and its change over time. However, no previous attempt has been made to employ the set of data-driven techniques adopted in this study in the context of IS related research to map and analyze the structure of knowledge production in terms of research areas.

In this article, we aim to provide a comprehensive overview on the distinct research areas advancing the literature on systemic approaches to innovation, and to identify the knowledge bases they draw from, both historically and in terms of the recent trends. We further attempt to provide insights into the process of knowledge

[1] While the terms "National Innovation System" (NIS) and "National Systems of Innovation" (NSI) in the literature are used interchangeably, we consistently use the term NIS inclusive for research on national innovation systems.

integration over time, and highlight the heterogeneity of how this process takes place across research areas. To do so, we identify and extract in an iterative process IS related publications from Thompson Reuter's "Web of Science" (WoS) database (6,370) and their cited references (162,600) for the 1980-2017 period. In a bibliographic network analysis, we map the literature's research frontier and knowledge base, and deploy clustering techniques to partition them in consistent areas. We augment this mapping by employing techniques from the field of natural language processing (NLP) to discover common topics within the publication abstracts.

We find an overall growing tendency of increasing diversity of knowledge bases the field draws from, yet accompanied by a decreasing coherence of collective research efforts. Within IS related research, we argue that the pursuit of further knowledge integration also requires equal effort to maintain internal coherence. In by nature interdisciplinary and diverse fields, we point to the crucial role institutions play in fulfilling this function.

The remainder of the paper is structured in the following manner. Section 2 presents an overview of the literature and introduces the theoretical framework. Section 3 describes data and introduces the methods used in our analysis. Section 4 presents the identified knowledge bases IS have drawn from and research areas, as well as trends in their relationship, and the overall developments in the research on IS. Section 5 concludes and discusses the implications of the analysis.

2 Theoretical Considerations

2.1 Variations and nuances in the initial conceptualization of IS as a field or research

While the intellectual foundations for the IS literature go further back in history and are broader in scope (Carlsson et al., 2002), the contributions associated with the initial conceptualizations of the NIS framework propelled the field into importance (Soete et al., 2010). These initial conceptualizations of the NIS framework are commonly attributed to three founding fathers: Christopher Freeman, Richard Nelson, and Bengt-Åke Lundvall (e.g., Fagerberg and Sapprasert, 2011). In the following, we point out the distinctiveness and commonalities between the approaches, complemented by a condensed overview in table 1.

The NIS concept introduced by Freeman (1987) refers to the network of public and private institutions whose activities and interactions are intended to initiate, import, modify, and diffuse new technologies. The main focus of the qualitative analysis is on the ways in which the resources are organized and managed at both the enterprise, the industry, and the country level, including the organization of R&D and

Table 1: Comparison Between the Original Versions of the NIS Concept

	Freeman, C. (1987)	Nelson, R. R. (1993)	Lundvall, B. Å. (1992)
Concept definition	*"The network of institutions in the public and private sectors which activities and interactions initiate, import, modify and diffuse new technologies may be described as 'the national system of innovation'."* (p. 1)	*"[...] a set of institutions whose interactions determine the innovative performance, in the sense above, of national firms."* (p. 4)	*"[...] all parts and aspects of the economic structure and the institutional set up affecting learning as well as searching and exploring - the production system, the marketing system and the system of finance present themselves as sub-systems in which learning takes place."* (p. 13)
Term "System"	Not explicitly defined	*"[...] a set of institutional actors that, together, plays the major role in influencing innovative performance."* (p. 4-5)	*"[...] a system of innovation is constituted by elements and relationships which interact in the production, diffusion and use of new and economically useful, knowledge and that a national system encompasses elements and relationships, either located within or rooted inside the boarders of a nation state."* (p. 2)
Term "Innovation"	*"[...] continuing process of technical change, involving the introduction of new and improved products and novel ways of organizing production, distribution and marketing."* (p. 1)	*"[...] the processes by which firms master and get into practice product designs and manufacturing processes that are new to them, if not to the universe or even to the nation."* (p. 4)	*"[...] on-going process of learning, searching and exploring, which result in new products, new techniques, new forms of organization and new markets."* (p. 8)
Analytical framework	• Relationship between technology, socio-economic structures, and institutions	• Linking institutional arrangements to technological and economic performances.	• Interactive learning anchored in the production structure (including "demand conditions" and "supporting industries") • Institutional set-up including "firm strategy" • Modes of cooperation and competition
Type of the analysis	• Single case study (Japan)	• Comparative case study (15 countries divided into large high-income, small high-income, and low income countries)	• Conceptual/Theoretical

production in firms, the relationships among firms, and the role of the government. The concept is seen as having the greatest importance in explaining both the emergence and the rate at which the "technological gaps" are closed between countries.

Nelson (1993) defines the system as a set of institutional actors whose interactions determine the innovative performance of national firms. The main orientation of this work is on describing the mechanisms and institutions that support technological advances, how they came to be, and relating that to the differences in countries' economic performances in such dimensions as productivity, income, income growth, export, and import performances.

The distinctiveness of the approach developed by Lundvall (1992) includes a broader understanding of the concept, including all organizations and institutions which affect production, diffusion, and exploitation of economically useful knowledge. Also, the distinctiveness of Lundvall's approach is the focus on user-producer linkages and interactive learning as a basis of innovation. The concept is seen as an analytical and policy tool or framework to link innovation to economic performance at the national level.

In sum, the differences between the approaches can be attributed to narrower or broader definitions of the concept, a main focus of the analysis, and elements of the system included in studying NIS. What is regarded as common to all three approaches is the focus on the relationship between the institutions, organizations and

their interactions on the one hand, and learning, innovation, and economic performances at the national level, on the other hand.

2.2 Survey of the literature on the development of IS studies

Attempts to review the field and developments of the NIS literature adopting a qualitative approach based on literature review include Balzat and Hanusch (2004); Godin (2009); Lundvall (2007); Sharif (2006); Soete et al. (2010). A critical assessment of the weaknesses and strengths of the approach, and the implications and suggestions for its further development are discussed in Hart (2009). Critical assessments of IS concepts more broadly are found in Carlsson et al. (2002) and Edquist (2005). Most of these studies focus on a narrower area of NIS research rather than the broader IS related literature. Typically, such studies provide an "authority based" account of the developments in the research field, and focus mainly on IS origins and intellectual heritage.

A few contributions adopt a mix of qualitative and quantitative approaches. Fagerberg and Sapprasert (2011) investigate the emergence and role of NIS within the innovation studies, based on a combination of expert assessment to identify the most important contributions (highly cited publications) and bibliometric evidence to identify the users of the literature. Similar approaches are found in mapping the field of innovation studies (Fagerberg et al., 2012), entrepreneurship (Landström et al., 2012), and science and technology studies (Martin et al., 2012). Teixeira (2013) proposes a taxonomy of the main topics and methods, the roots, and the influence of NIS literature based on a combination of qualitative assessment and bibliometric evidence. However, the main focus in these studies is more on the origins and less on the more recent research contributions. One of the conclusions in Fagerberg and Sapprasert (2011) is that research on IS might have progressed in terms of new contributions being more relevant and therefore more cited than the older works. It is these more novel contributions that are of primary interest of this paper.

More recently and relying primarily on the quantitative bibliometric approach, Uriona-Maldonado et al. (2012) and Liu et al. (2015) study the institutionalization of IS literature. Uriona-Maldonado et al. (2012) provides a descriptive account of a chronological distribution, author relevance, articles and cited references, journals, institution,s and countries of relevance based on the citation count. Liu et al. (2015) identify and visualize the intellectual structure, turning points, and dynamics of IS research based on co-word and co-citation analysis.

2.3 Conceptual framework

To understand the development of a research field, it is useful to map its' *structure of knowledge production*, its output in terms of novel knowledge generation. However, in an interdisciplinary field of research such as IS, we conceptualize this development mainly as a "process of knowledge integration", in which distinct and previously disconnected bodies of knowledge become related over time. To analyze this process of knowledge integration, we conceptually distinguish between the field's current "knowledge frontier" where new knowledge is produced (which we label "research areas"), and the historical origins and accumulated bodies of knowledge to be utilized therefore (which we label "knowledge bases").

We envision knowledge integration as a dynamic process that can be expressed by changes in pattern of how the field's distinct knowledge bases are utilized in its active areas of research. The capacity for and extent of knowledge integration within a field of research can be described by its structural coherence and diversity, and the development thereof (Porter et al., 2006).

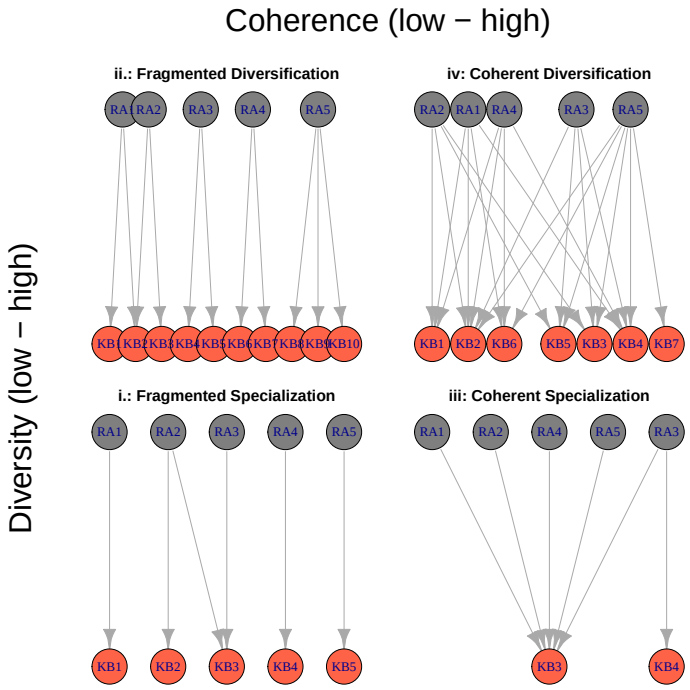
Coherence: Coherence captures the extent to which a system's elements are consistently articulated and form a meaningful constellation, hence coherence can be seen as a general system property capturing its functionality. Systems with low coherence are characterized by loosely connected or isolated elements, which are unlikely to produce meaningful collective output. Within a bibliographic analysis of a field of research, coherence can be understood as the degree to which the publications under study exhibit common citation patterns, thereby indicating higher or lesser consensus on the content of research, developed and applied theories, and methods.

Diversity: The diversity of a research field can be expressed by the number, balance, and similarity of the bodies of knowledge from the categories it comprises (Stirling, 2007). In our bibliometric analysis, we conceptualize diversity by the pattern to which the field's research areas draw from the knowledge bases, and operationalize it with the combined diversity indicator proposed by Leydesdorff (forthcoming) (cf. section 3 for details).

The combination of the two dimensions leads to four position characteristics of research, as illustrated in figure 1. It can be used to describe the static structure of knowledge production, as well as the dynamic process of knowledge integration within a field or a narrow research area:

i. **Low diversity - Low coherence:** Specialized research areas that draw from a small number of knowledge bases, without overlap. Potential indicator of a

Figure 1: Knowledge base diversity and network coherence



field's immaturity, or a temporal state in the process of internal reconfiguration and knowledge integration.

ii. **High diversity - Low coherence:** The research areas within a field are diversified and draw from a larger number of knowledge bases, yet without overlap. Indication of fragmentation or lacking consensus on theoretical foundations.

iii. **Low diversity - High coherence:** The research areas within a field are specialized and draw from a small number of knowledge bases, which are the same across areas. Indicator of strong consensus on dominant theories, or a temporal state of re-focusing.

iv. **High diversity - High coherence:** The research areas within a field are diversified and draw from a large number of knowledge bases, which are used coherently across research areas. Indicator of a successful process of knowledge integration and cross-fertilization.

The relationship between coherence and diversity should be considered to describe the dynamic process of knowledge integration within the normal progress of science, and therefore not assessed as a static state but rather in terms of a temporal derivative, i.e. a change in coherence and diversity (Rafols and Meyer, 2010). Here, it is argued that diversity and coherence should develop in the same direction, since

the increasing focus on "exploiting" a narrow knowledge base might lead to decreasing creativity and novelty generated within a field of research, while excessive but not coherent "exploration" might lead to a fragmentation of the research field and limit its ability to produce deep and meaningful insights and results (March, 2005). Generally, for research areas of fields aiming at interdisciplinary knowledge integration, a movement towards higher levels of diversity while maintaining its level of coherence suggests successful achievement of this integrative mission (Rafols and Meyer, 2010).

Applying a network perspective, further useful analogies can be drawn from insights on how individual and collective learning processes are affected by the the underlying (social) structure. The literature on social capital has featured a long-lasting debate on on the benefits of open or closed local network structures, where it is argued that open network structures provide their actors information advantages in terms of access to a diverse set of novel information (Burt, 1992, 2001), but also that closed structures facilitate the exchange of in-depth information through frequent, trust-based interaction (Uzzi, 1996, 1997). In addition, learning effects are also attributed to the composition of network (Fleming et al., 2007; Reagans and McEvily, 2003), the interaction of structure and composition (e.g., TerWal et al., 2016). Consequently, the methodological choice of applying a network analysis, and theoretical choice of accentuating the aspects of structure and composition, appears promising to gain new insights in the process of collective learning and knowledge integration.

Similar approaches have been used to describe and analyze the state and development of interdisciplinarity in research fields (e.g., Rafols et al., 2012; Rafols and Meyer, 2010). In contrast, our aim is not to analyze the integration of cross-disciplinary knowledge within a research field, but more broadly the integration of distinct bodies of knowledge (*knowledge bases*) which may have their origin within different but also the same scientific disciplines.

3 Methods, Data, and Empirical Strategy

The following section presents the methods used, and our rationales for applying them given the aim of this study. First, we delimit the field of IS research in an iterative "bottom-up" process. Second, we carry out a thematic mapping of the field of IS related research by employing techniques from the field of natural language processing (NLP) to discover common topics within the publication abstracts. Third, based on a co-citation analysis, we identify the most prominent knowledge bases IS literature has drawn from during its development. Fourth, we carry out a bibliographic coupling analysis to identify the current research frontier within IS. Lastly, we explore the development of the IS field in terms of diversity and coherence of re-

search efforts by analyzing how heterogeneous bodies of knowledge are utilized and integrated over time. We thereby emphasize the pervasive heterogeneity of knowledge within a scientific discipline, and develop delineation approach which is not dependent on predefined disciplinary categories.

3.1 Delimiting the field: Initial corpus creation

The common challenge of delineation is particularly prevalent in an interdisciplinary field such as IS, which draws from a variety of academic disciplines, such as economics, organizational studies, sociology, and psychology.

In attempts to draw the somewhat blurry boundaries of IS or related (sub-)fields, different methodologies can and have been applied. To start with, one can apply a string-search based approach, searching for publications within an academic database where title, abstract, or keywords include certain terms, for example "Systems of Innovation" (e.g, Teixeira, 2013; Uriona-Maldonado et al., 2012). Assuming all relevant publications clearly state their association to a field of research by including some related keywords in the publication's description, this approach is likely to deliver a low rate of *false positives*. However, in the case of fields with blurry boundaries and without fully coherent terminology also a high rate of *false negatives*.

Another possibility is following an authority-based approach, where the research field is delimited by the authors own (e.g., Godin, 2009; Lundvall et al., 2002) perception of the field and relevant contributions, surveyed experts (e.g., Sharif, 2006), or authoritative surveys such as handbooks (e.g., Fagerberg et al., 2012). While this approach is less dependent on the use of consistent terminology, it might still miss contributions which are less mainstream and outside the common consensus.

In case there exists a wide consensus on a field's core literature, an origin-based approach can be applied. Here, one starts with a predefined set of core contributions and then expands the corpus by all publications citing them (e.g. Meyer et al., 2004). This approach is helpful to assess the impact of core contributions independent of disciplinary associations of publications and authors, yet might miss out on later developments in the field which diverge from the original core.

Finally, more inductive "snowballing" approaches have been used, combining the identification of certain "seed" publications from previous studies and authorities in the field, and then successively identifying further related publications based on various methodologies (e.g., Jurowetzki et al., 2018; Martin, 2012a).

To leverage the main advantages of the above listed approaches jointly, we combine several of their features in a multi-step process. We first apply a string-based strategy,

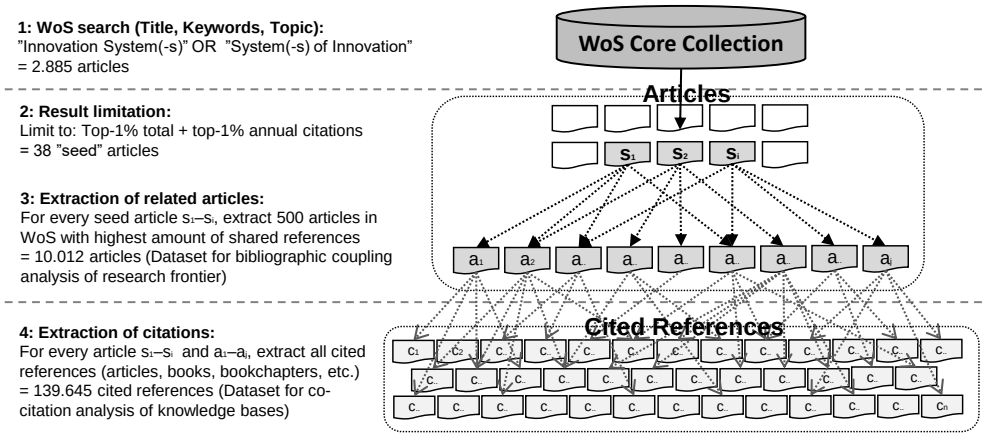
where we search WoS for publications including the terms "Innovation System(-s)" or "System(-s) of Innovation" in their title, abstracts, or keywords (2,885).[2]

To apply a first selection of significance, we reduce this list to the top-1% of publications in terms of total citations, and the top-1% in terms of average annual citations received (where the overlap is >90%). This leads to a total of 38 *seed* publications (cf. table A.1 in the Appendix), representing the most cited (journal) articles which directly associate themselves with IS.

However, the sole focus on highly cited publications might lead to an exclusion of research that has contributed to the field in a more incremental way (Macroberts and Macroberts, 1987). Therefore, in a second step, we additionally extract for every initial "seed" article the 500 publications for the 1980-2017 period with the highest bibliographical overlap (meaning, the highest number of shared references, cited by both). The intuition behind this step is that a bibliographic overlap between two publications indicates similarities in theoretical frameworks, applied methods, or context of the study.

When excluding duplicates and publications that did not receive any citation, our final corpus contains a total of 6.370 publications. We in a last step also extract for each of these publication the complete list of references (162,600 unique cited references) to be analyzed separately. This process is illustrated in figure 2.

Figure 2: Illustration: Multi-Step Literature Identification and Selection Process



The benefit of our multi-step approach is that it tends to include literature, which does not use the exact terminology required for a string-search, but deals with related topics, methods, and theories. However, this does not mean that it will provide an overview over all systemic approaches to innovation, which is also not our attempt. Centered around IS, it will by design miss out on systemic approaches

[2]Obviously, TIS, NIS, SIS, and RIS with the additional prefix are therefore also included.

without any literature and terminology overlap, such as for instance "Innovation Ecosystems" (Moore, 1993).

3.2 Topical mapping: Natural language processing

The way science progresses is to a large extent reflected in the use of language, which can indicate general research trends, but also the emergence of common consensus or dispute (Kuhn, 1971). To provide a first intuition of general themes and topics within the IS literature, we facilitate our bibliometric analysis by deploying exploratory methods from the fields of natural language processing (NLP) on the publication abstracts.

We create a *topic model* via latent Dirichlet allocation (LDA) (Blei, 2012), a graphical Bayesian probability model for discovering latent thematic structures in text document collections. Such models identify "topics" by the way words and word combinations are used within text-documents. The basic idea is that documents are represented as mixtures over latent topics, where each topic in turn is represented as a probability distribution over words in the corpus. An iterative process then generates a set of topics that describes the documents in the corpus, and assess the strength with which each document exhibits those topics. An inspection of the words with the highest assigned probability to each topic tends to provide an interpretable qualitative description of the topic's meaning and content.

3.3 Mapping the structure of research activity: Bibliometric methods

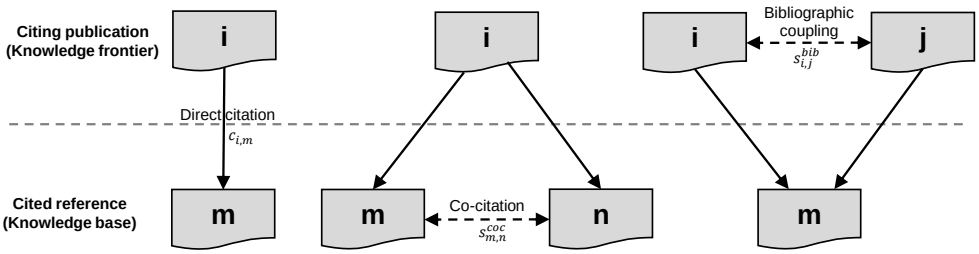
While the commonly used analysis of direct citations is useful to identify and summarize the most important publications within a scientific corpus, the dichotomous nature of this measure limits its usefulness to express the relationship between publications and thereby a structural mapping of research fields (Üsdiken and Pasadeos, 1995). Here, more nuanced methods leveraging the information found within a publication's bibliography can be utilized, such as co-citation and bibliographic coupling analysis (Boyack and Klavans, 2010).

Technically, both measures exploit the bipartite nature of the publication→references data structure common to bibliographic data,[3] and are equivalent to the projection of a 2-mode network (publication → reference) to a 1-mode network (publication ↔ publication, or reference ↔ reference). For bibliographic coupling analysis, the

[3] In bibliographic analysis, publications and the references cited in them are commonly treated as separate entities, which are consequently also analyzed in separation.

projection is done on the level of publications, and for co-citation analysis on the level of references. The logic behind each approach is illustrated in figure 3.[4]

Figure 3: Illustration: Direct citation, co-citation, and bibliographic coupling measures in a bipartite publication-reference network



3.3.1 Identifying the structure of the IS field's *knowledge base*: Co-citation analysis

Our first step to map the structure of the *knowledge base* within the IS literature is to perform a co-citation analysis, where the cited references and not the original publications are the unit of analysis. Here, the strength of the relationship between a reference pair m and n ($s^{coc}_{m,n}$) is expressed by the number of publications C which are jointly citing reference m and n, as illustrated in equation 1.

$$s^{coc}_{m,n} = \sum_{i} c_{i,m} c_{i,n} \tag{1}$$

The intuition here is that references which are frequently cited together are likely to share commonalities in theory, topic, methodology, or context. It can be interpreted as a measure of similarity as evaluated by other researchers that decide to jointly cite both references. Because the publication process is time-consuming, co-citation is a backward-looking measure, which is appropriate to map the relationship between core literature of a field (Boyack and Klavans, 2010). Co-citations between two publications tend to increase with their total number of citation. To avoid a general clustering of highly cited publications, we normalize the co-citation strength by the Jaccard similarity coefficient (cf. e.g., Hamers et al., 1989; Leydesdorff, 2008), where we weight the intercept of two publications' co-citations by their union. The resulting weight (cf. equation 2) is bounded between zero and one, where one in-

[4]We henceforth refer to the publication ↔ publication mode as the RESEARCH AREA network (formatted in SMALL CAPS), and to the reference ↔ reference mode as the *knowledge base* network (formatted in *italic*))

dicates two references to be exclusively cited together, and zero that they are never cited together.

$$S_{m,n}{}^{cocit}_{jac} = \frac{C(m \cap n)}{C(m \cup n)} = \frac{s^{cocit}_{m,n}}{c_m + c_n - s^{cocit}_{m,n}} \tag{2}$$

3.3.2 Identifying the structure of the IS field's knowledge frontier: Bibliographic coupling analysis

Similarly, we identify the IS literature's current knowledge frontier by carrying out a bibliographic coupling analysis of the publications in our corpus. This measure uses bibliographical information of publications to establish a similarity relationship between them (Kessler, 1963). This "coupling-strength" between publications is determined by the number of commonly cited references they share, assuming a common pool of references to indicate similarity in context, methods, or theory.

Formally, the strength of the relationship between a publication pair i and j ($s^{bib}_{i,j}$) is expressed by the number of commonly cited references, as illustrated in equation 3. Since our corpus contains publications which differ strongly in terms of the number of cited references, we again normalize the coupling strength by the Jaccard similarity coefficient. It is again bounded between zero and one, where one indicates the two publications to have an identical bibliography, and zero that they do not share any cited reference. Thereby, we prevent publications from having high coupling strength due to a large bibliography (e.g., literature surveys).

$$s^{bib}_{i,j} = \sum_m c_{i,m} c_{j,m} \;\Rightarrow\; S^{bib}_{i,j\ jac} = \frac{C(i \cap j)}{C(i \cup j)} = \frac{s^{bib}_{i,j}}{c_i + c_j - s^{bib}_{i,j}} \tag{3}$$

More recent articles have a higher pool of possible references to co-cite to, hence they are more likely to be coupled. Consequently, bibliographic coupling represents a forward looking measure, and the method of choice to identify the current "knowledge frontier" at the point of analysis.

The choice to represent our corpus as a similarity network of publications based on citation pattern comes with some implications and additional requirements in terms of data quality compared to a bibliometric analysis purely based on citation frequencies of publications, authors, and journals. Particularly, the resulting network structure is sensitive to false positives as well as false negatives in the edge generation. This becomes problematic when working with the WoS data on cited references since they are based on free text entries prone to inconsistent annotation (e.g., misspellings, full first name, only initials, with or without special characters). Consequently, we undertook substantial effort to homogenize the notation of references, where we first manually inspected all the most cited journals, publications,

and authors, and corrected inconsistent spelling patterns, and further developed rule-based algorithms to correct commonly made mistakes in the references.[5]

3.4 Categorizing *knowledge bases* and research areas: Clustering techniques

To summarize the knowledge structure of scientific fields, most previous research (e.g., Fagerberg et al., 2012) has done so by clustering publications according to similarity with respect to characteristics such as scientific discipline, publication outlet, and author affiliation. In contrast, we utilize the information of the corresponding bibliographic coupling or co-citation network, and cluster publications according to their pattern of connectivity with other publications or cited references.[6] In order to partition networks into components or clusters, we deploy a "community detection" technique based on the *Lovain Algorithm* (Blondel et al., 2008) on our publication network as well as on the one of cited references.[7]

3.5 Analyzing the development of the field: Diversity and Coherence

Lastly, we analyze the development of the IS field and its' research areas, focusing on the *coherence* of the structure of knowledge production, and the diversity of knowledge integration.

The coherence of the IS field here is operationalized as the aggregated coupling-strength *between* its research areas, indicating a higher or lesser consensus on important and useful bodies of knowledge. A similar approach can be applied to measure the coherence within a research area by looking at the density of the bibliographic coupling network of publications belonging to the same area.

Diversity in our context refers to the way how the corresponding research area draws from the identified IS knowledge bases. Generally, it can be measured by the variety (V), balance (B), and distance (D) of knowledge bases drawn from by the whole field or a specific research area (Stirling, 2007). We operationalize this concept using the diversity measure proposed by Leydesdorff (forthcoming):

[5] Here, we follow the advice of Raffo and Lhuillery (2009) on how to play the "Name Game". We also ran a fuzzy string matching algorithm on our list of references to match it with the most common spellings of core articles, and the official journal abbreviation scheme used in WoS.

[6] In the jargon of network science, which we will adopt throughout our analysis, a network's elements are referred to as *nodes*, and to the connections between them as *edges*.

[7] The Lovain Algorithm is a heuristic method that attempts to optimize the modularity of communities within a network by maximizing within- and minimizing between-community connectivity. Due to its proven high computational efficiency, accuracy in identification, and the ability to handle weighted networks, this algorithm appears an appropriate choice for the task at hand. In table A.6, we benchmark the results with other popular community detection algorithms for undirected weighted large-scale networks, where it for both networks leads to the highest modularity and overall most desirable characteristics.

$$Div_c = V * B * D = \frac{n_c}{N} * (1 - Gini_c) * \sum_{i=1,j=1,i\neq j}^{i=n_c,j=n_c} \frac{d_{ij}}{n_c * (n_c - 1)} \quad (4)$$

Here, N denotes the number of all existing knowledge bases, n_c the number of knowledge bases the field or area is citing, $Gini_c$ for the Gini coefficient of the distribution of knowledge bases, and d_{ij} the distance between the corresponding knowledge bases as (measured as 1 - co-citation strength between knowledge bases i, j).

4 Results and Discussion

4.1 Basic characteristics of initial "seed" and final corpus of publications

Among our seed publications, (to be found in table A.1 in the Appendix), most are published post-2010, demonstrating that indeed most seminal contributions to the IS literature pre-2010 are not to be found in journal articles but in books.[8]

The largest group of articles (16) is associated with conceptual/theoretical frameworks and their empirical application, namely: i) the "Triple Helix" model of university, industry, and government relations (Etzkowitz and Leydesdorff, 2000); ii) "Multi-level perspective on transitions" (Geels, 2004) iii) "Sectoral system of innovation and production" (Malerba, 2002); iv) "Regional systems of innovation" (Cooke et al., 1997); v) "Technological innovation systems" (Carlsson and Stankiewicz, 1991b; Hekkert et al., 2007; Jacobsson and Johnson, 2000); vi) a synthesis of "Technological innovation system" and "Multilevel framework" (Markard and Truffer, 2008); vii) "National innovation capacity" (Furman et al., 2002); viii) a functional approach to "National innovation system" (Liu and White, 2001); and ix) "National system of entrepreneurship" (Acs et al., 2014). The empirical applications include papers dealing with the typologies of: x) regional systems (Asheim and Coenen, 2005), xi) the national modes of learning (Jensen et al., 2007); xii) the modes of university industry interactions (Meyer-Krahmer and Schmoch, 1998); xiii) the role of knowledge intensive business services (Muller and Zenker, 2001); and xiv) regulation in Regional innovation system (Cooke, 1992). Another group of articles (6) is associated with a historical account of NIS (Freeman, 1995), and a synthesis of research on networks of innovators (Freeman, 1991b), or a survey of a single or various systems concepts (Carlsson et al., 2002; Lundvall et al., 2002; Markard et al., 2012; Morgan, 2004). Only one article is concerned with the data used for measuring innovation (Acs et al., 2002a), while another three articles include policy contributions (Acs et al., 2014;

[8]However, since the seed publications are mainly used to identify the current research frontier, this should not impact the results severely. Since the cited references of these publications, which we use to construct our knowledge bases, are not limited to journal articles, the intellectual origins of the field should be captured correctly.

Asheim et al., 2011; Bergek et al., 2008). Overall, the seed publications appear to capture the variety of research within the IS field.

Table 2: Final Corpus Characteristics

Institutional Affiliation			Most Occurring Journals			Most Cited References	
Institution	N	%	Journals	N	%	Reference Name	Cit
Utrecht	104	2	Res. Policy	655	10	Cohen W, 1990	1014
Sussex	91	1	Eur. Plan. Stud.	224	4	Nelson R, 1982	869
Lund	85	1	Reg. Stud.	221	4	Lundvall B, 1992	654
Manchester	73	1	Tech. Forecast. Soc. Ch.	195	3	Audretsch D, 1996	530
Toronto	56	1	J. Int. Bus. Stud.	135	2	Nelson R, 1993	491
Eindhoven	52	1	Technovation	121	2	Jaffe A, 1993	445
Erasmus	51	1	Tech. Anal. Strg. Mng.	120	2	Porter M, 1990	440
Amsterdam	46	1	Strateg. Manage. J.	118	2	Barney J, 1991	413
Cambridge	45	1	Small Bus. Econ. Group	116	2	Edquist C, 1997	409
Uppsala	41	1	Ind. Corp. Change	110	2	Cohen W, 1989	393
Wageningen	40	1	Scientometrics	109	2	Granovetter M, 1985	382
Cardiff	38	1	J. Econ. Geogr.	104	2	Powell W, 1996	376
Harvard	37	1	Int. Bus. Rev.	89	1	Bathelt H, 2004	368
LSE	36	1	J. Evol. Econ.	83	1	Burt R, 1992	361
PennState	35	0	J. Technol. Transf.	82	1	Dosi G, 1982	359
Delft	34	0	Int. J. Technol. Manage.	66	1	Boschma R, 2005	355
Leuven	34	0	Ind. Innov.	65	1	Schumpeter J, 1934	345
Bocconi	32	0	Organ Sci.	64	1	Saxenian A, 1994	340
Singapore	32	0	Energy Policy	62	1	North D, 1990	320
Valencia	31	0	Entrep. Reg. Dev.	62	1	Etzkowitz H, 2000	310

Note. This table reports some basic information on the articles in the WoS corpus, such as the most often appearing institutions, journals, and the most (corpus internally) cited references. Overall, the corpus contains 6,368 articles, published between 1980 and 2018 (August).

In table 2, we report some basic characteristics of our final corpus of 6,370 publications. As for the publication outlet, the biggest share of articles in our final corpus was published in *Research Policy* (10%), *European Planning Studies* (4%), *Regional Studies* (4%), and *Technological Forecasting and Social Change* (3%). Overall, the basic reference pattern of the publications in our corpus overlaps with the results of previous studies in terms of high impact works in the field of science policy and innovation studies (Fagerberg et al., 2012; Martin, 2012a), confirming the validity of our corpus selection, and the reproducibility of stylized facts across different corpora.

4.2 Results of the Topic Modeling and Identification of Themes within the IS literature

Table 3 reports the identified topics and associated terms based on the latent Dirichlet allocation (LDA). They can be interpreted as broad themes within the corpus, as expressed by the authors' description of the publications' theory, applied frameworks, context, and method. The topics have to be interpreted broadly, since some of them indicate an association with a certain theoretical framework (e.g., topic *IS*, which appears to be strongly associated with the IS framework), the study of a

Table 3: Topics and Associated Terms

Topic	Top-10 Associated Terms
Firms, Capabilities & Strategic Alliances	Firms, Capability, Strategic Alliances, Competitive Advantage, Resources, Dynamic Capabilities, Strategy, Partner, Organization, Resource-based-View
Learning Processes, Organizations & Interaction	Learning, Model, Process, Design, Organization, Interaction, Integration, Complexity, Mechanism, Transfer
Globalization, Processes & Global Economy	Production, Global, Business, ICT, Communication, Relation, Service, Globalization, World Economy, Trade
R&D, Patents & Productivity	R&D, Patents, Data, Productivity, Analysis, Growth, Indicator, Trade, Efficiency, Invention
Localization, Clusters & Spillovers	Local, Clusters, Spatial Proximity, Industry, City, Agglomeration, Geography, Location, Knowledge Spillovers, District
University-Industry Relations & Technology Transfer	University, Science, Collaboration, Academic, Technology, Interaction, Researchers, Intellectual Property, Collaborative, Technology Transfer
Firm-Level Innovation Determinants	Firms, Industry, Manufacturing, SME, Sector, Size, Survey, Characteristics, Market, Determinant
Innovation Policy	Policy, Government, Support, Innovation Policy, Sector, Evaluation, Barriers, Challenges, Incentives, Implication
HR Mamagement, Practices & Outcomes	Institution, Organization, Management, Work Practices, Outcomes, Adoption, Formal, Informal, Quality, Employees
Open Innovation, External Sources & Users	Process Innovation, Product Innovation, Open Innovation, Strategy, External Sources, Radical, Innovation Activity, Innovation Process,
Technological Change & Industrial Dynamics	Technological Change, Industry, Evolution, Diffusion, Dynamics, Development, Patterns, Competition, Trajectory, Emergence
Innovation Systems	Innovation System, National, Function, Actor, Sectoral, Framework, Systemic, Approach, Regional, Foresight
Networks, Embeddedness & Social Capital	Networks, Social Capital, Relationships, Structure, Embeddedness, Community, Position, Exchange, Innovation Networks, Information
Literature, Framework, Theoretical & Conceptual	Literature, Theory, Framework, Concept, Approach, Understanding, Implication, Contribution, Issues, Review
International Business, Entrepreneurship & Cultural Distance	Entrepreneurship, Cultural Distance, Opportunity, Entry Mode, Culture, International, Uncertainty, Joint Venture, Acquisition, Differences
Transitions, Sustainability & Environment	Transition, Energy, Governance, Sustainability, Niche Management, MLP, Socio-Technical, Transformation, Climate, Regime, Political
Internationalization, MNE's & Entry Modes	Foreign, International, Emerging, Strategy, Subsidiary, Institution, MNE, Host, FDI, Internationalization
Knowledge Transfer, Creation & Absorptive Capacity	Knowledge Creation, Capacity, Knowledge Transfer, Knowledge Flows, Absorptive Capacity, Tacit Knowledge, Knowledge Base, R&D, Knowledge Production, External Sources
Regional Performance, RIS & Higher Education	Region, Economic Growth, Economic Development, Regional Innovation, Related Variety, RIS, Europe, Competitiveness, Economic Ceography, Higher Education
Empirical Evaluation, Econometrics, Performance	Performance, Effect, Impact, Relationship, Results, Firm Performance, Data, Findings, Influence, Factor

Note. This table lists the topics identified with the LDA analysis of the abstracts of our main corpus, and their 10 most associated terms. The topic name reflects the authors' own description.

certain phenomenon (e.g., topic *University-Industry Relations & Technology Transfer*), or the application of particular methods (e.g., topic *Empirical evaluation, Econometrics, Performances*, broadly on empirical research). Overall, the identified topics appear to appropriately capture different academic and policy themes discussed within the IS literature. They will subsequently be used to capture the context of research effort in the research areas, and to derive specialization measures of those areas.

4.3 Results of the community detection analysis

4.3.1 Knowledge bases: Co-citation network

Table 4 provides a condensed summary of the identified knowledge bases, which are the result of a clustering exercise on the co-citation network of cited references.[9] In the following, we provide a brief qualitative summary of these knowledge bases' content and context.

Territorial innovation models: This biggest among the identified knowledge bases includes seminal contributions on NIS (Lundvall, 1992), the competitive advantage of nations (Porter, 1990), and regional clusters (Saxenian, 1994), as well as prominent theories on externalities and the economics of agglomeration (Glaeser et al., 1992; Jacobs, 1969; Marshall, 1920), which are also identified as core literature in the innovation studies field by former studies (eg., Fagerberg et al., 2012). The remainder of consists of earlier works by economic geographers interested in spatial dimensions of innovation activity such as R&D spillovers (Jaffe et al., 1993) and the geography of innovation and production (Audretsch and Feldman, 1996). More recent references discuss the competitiveness of clusters (Bathelt et al., 2004), and the impact of proximity on interactive learning and innovation (Boschma, 2005). The most central journals are *Regional Studies*, *Research Policy* and *Journal of Economic Geography*.

Organizational learning: Mostly originating from strategic management and organizational studies, the most central references include seminal contributions on defining central concepts of intra-organizational learning, such as a resource-based-view and the firm's sustained competitive advantage (Barney, 1991), "absorptive capacity" (Cohen and Levinthal, 1990), combinative capabilities (Kogut and Zander, 1992), and exploration and exploitation(March, 1991). Furthermore, initial formulations of central concepts in inter-organizational learning such as "structural holes" Burt (1992), and network "embeddedness" (Uzzi, 1997), and broadly the role of collaboration networks for innovation (Ahuja, 2000; Powell et al., 1996) are to be found

[9] In addition, an exhaustive summary on the most central references and authors is provided in table A.2 in the Appendix.

Table 4: Summary of Knowledge Bases

Knowledge Base	N	Central References	Central Journals	Central Concepts
Territorial Innovation Models	8396 (25%)	Lundvall B, 1992 (0.32) Bathelt H, 2004 (0.3) Boschma R, 2005 (0.29) Jaffe A, 1993 (0.28) Audretsch D, 1996 (0.27)	Reg. Stud. (0.8) Res. Policy (0.53) J. Econ. Geogr. (0.27) Am. Econ. Rev. (0.18) Eur. Plan. Stud. (0.15)	–Competitive advantage of nations, regions and clusters –Geography of innovation and production –Localization of knowledge spillovers –Proximity and interactive learning –MAR and Jacob's externalities
Organizational Learning	6259 (19%)	Cohen W, 1990 (0.37) Powell W, 1996 (0.29) Nelson R, 1982 (0.27) Burt R, 1992 (0.22) Ahuja G, 2000 (0.2)	Strateg. Manage. J. (1) Admin. Sci. Quart. (0.31) Organ. Sci. (0.26) Acad. Manage. J. (0.17) Res. Policy (0.17)	–Absorptive capacity –Organizational learning –Collaboration networks and innovation –Firm's resources and cooperative strategy as a source of competitive advantage
Internationalization, Institutions & MNEs	5137 (15%)	Kogut B, 1988 (0.63) Johanson J, 1977 (0.56) Hofstede G, 1980 (0.51) Kostova T, 1999 (0.46) Shenkar O, 2001 (0.37)	Int. Bus. Stud. (1) Strateg. Manage. J. (0.16) Acad. Manage. J. (0.06) Acad. Manage. Rev. (0.03) Int. Bus. Rev. (0.03)	–Cultural distance and foreign entry mode choice –Cultural distance and foreign investment expansion –MNE/TNE activities and performances
Transitions & Sustainability	4309 (13%)	Kemp R, 1998 (0.31) Geels F, 2002 (0.31) Geels F, 2007 (0.31) Rip A, 1998 (0.21) Hekkert M, 2007 (0.21)	Res. Policy (0.65) Energ. Policy (0.33) Technol. Forecast. Soc. (0.2) Technol. Anal. Strateg. (0.12) J. Evol. Econ. (0.04)	–Multi-level perspective –Strategic niche management –Transition management –Technological innovation systems
Knowledge Production	3514 (10%)	Etzkowitz H, 2000 (0.44) Cohen W, 2002 (0.39) Gibbons M, 1994 (0.25) D'Este P, 2007 (0.25) Meyer-Krahmer F, 1998 (0.24)	Res Policy (1) J. Technol. Transf. (0.12) Scientometrics (0.11) Technovation (0.02) Sci. Publ. Policy (0.01)	–Modes of knowledge production –University-industry interaction –University-industry collaboration –Economics of science
Entrepreneurship	3218 (10%)	Shane S, 2000 (0.56) Baumol W, 1990 (0.38) Davidsson P, 2003 (0.36) Reynolds P, 2005 (0.36) Shane S, 2000 (0.31)	J. Bus. Venturing (0.99) Small Bus. Econ. (0.98) Entrep. Theory Pract. (0.65) Acad. Manage. Rev. (0.08) Strateg. Entrep. J. (0.04)	–Discovery and exploitation of entrepreneurial opportunities –Entrepreneurship and competition –Entrepreneurship effect on the economy –Individual characteristics of entrepreneur
HR Management & Performance	1821 (5%)	Huselid M, 1995 (0.75) Ichniowski C, 1997 (0.61) MacDuffie J, 1995 (0.58) Appelbaum E, 2000 (0.58) Osterman P, 1994 (0.55)	Int. J. Hum. Res. Man. (0.55) Acad. Manage. J. (0.51) Ind. Labor. Relat. Rev. (0.33) Ind. Relat. (0.21) Int. Bus. Stud. (0.16)	–HRM practices and firm performance –Strategic HRM –High performance work practices
Institutional Entrepreneurship	1088 (3%)	Seo M, 2002 (0.3) DiMaggio P, 1988 (0.3) Greenwood R, 2006 (0.3) Maguire S, 2004 (0.27) Battilana J, 2009 (0.26)	Acad. Manage. J. (0.76) Organ. Stud. (0.66) Acad. Manage. Rev. (0.43) Admin. Sci. Quart. (0.28) Organ. Sci. (0.18)	–Institutional entrepreneurship –Institutional change and innovation –Organizations and their relations to the institutional environments

Note: This table summarizes the identified knowledge bases by their number of references (% in parentheses), the most central references and journals (in parentheses: Jaccard-weighted within cluster centrality), and the central concepts (author's summary).

here. Finally, it includes the field's defining book by Nelson and Winter (1982), *An Evolutionary Theory of Economic Change*, are also central references. The most central journals are associated with management or organizational fields of study, such as *Strategic Management Journal, Administrative Science Quarterly*, and *Organizational Science Journal* as well as *Research Policy*.

Internationalization, Institutions and MNEs: This knowledge base includes mainly contributions in international business and management studies, concerned with the role of multinational enterprises (MNEs) (Buckley and Casson, 1976) and transnational organisations (Bartlett and Ghoshal, 1989) and their internationalization process (Johanson and Vahlne, 1977) more generally,and the role of cultural for their organization (Hofstede and Bond, 1984) and foreign entry mode choice (Kogut and Singh, 1988), on which is also critically reflected (Shenkar, 2001). SOme contributions are also more founded in institutional theory include work on "new institutionalism"

(North, 1990) and the concept of "institutional isomorphism" (DiMaggio and Powell, 1983), while others apply an evolutionary perspective on the growth of the firm (Kogut and Zander, 1993; Kostova and Zaheer, 1999). The most central journals are *Journal of International Business Studies*, *Strategic Management Journal*, and *Academy of Management Journal*.

Transitions and Sustainability: References are in this relatively young field including central concepts in sustainability transition research, such as technological systems, technological regimes, niches, and the multi-level perspective (MLP) (Geels, 2004, 2002; Geels and Schot, 2007a; Rip and Kemp, 1998). Representative examples of topics are the development of a strategic niche management perspective on how to transition into a new regime (Kemp et al., 1998), the governance of socio-technical transitions (Smith et al., 2005), and transition management in public policy (Rotmans et al., 2001). Another body of work in this group focuses on a functional approach to studying technological innovation systems (Bergek et al., 2008; Hekkert et al., 2007). The most central journals are *Research Policy, Energy Policy*, and *Technological Forecasting and Social Change*. The results are highly in line with the results obtained in the study by Markard et al. (2012) on identifying the intellectual contours of the emerging field of sustainability transition research.

Knowledge Production: Research in this knowledge base is centered around the role of universities in innovation in "knowledge-based" economies. It includes seminal work by Etzkowitz (1998); Etzkowitz and Leydesdorff (2000) on the "Triple Helix" concept of university, industry, and government relations, and "the third mission" of the emerging entrepreneurial universities, as well as work on new modes of knowledge production in contemporary societies (Gibbons et al., 1994). Other central references deal with different aspects of university-industry interactions, such as on the influence of public research on industrial R&D (Cohen et al., 2002), the different channels of researcher-industry interaction (D'Este and Patel, 2007), and the industrial firms and universities co-operation pattern in specific technological fields (Meyer-Krahmer and Schmoch, 1998). Other contributions propose a "new economics of science" framework (Partha and David, 1994), discuss the role of patents as knowledge transfer indicator (Agrawal and Henderson, 2002) and the impact of regulation on university patenting (Henderson et al., 1998; Mowery et al., 2001). The most central publication outlets are concerned with different aspects of science (*Scientometrics*), technological innovation (*Technovation*), and the practice of technology transfer (*Journal of Technological Transfers*). More multidisciplinary outlet for this knowledge base is *Research Policy*.

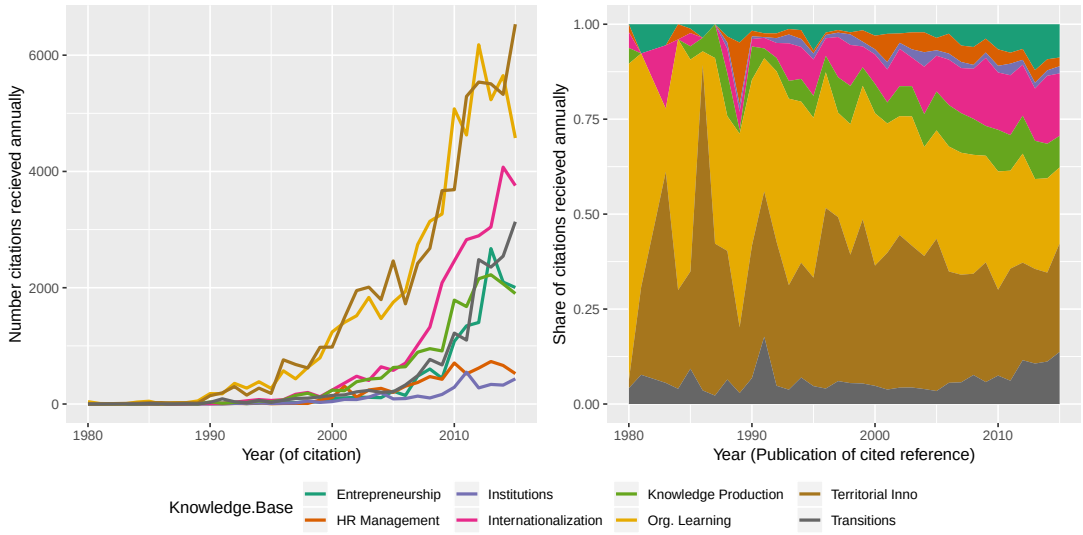
Entrepreneurship: This knowledge base includes mainly contributions concerned with different aspects of entrepreneurship, most notably classical works on entrepreneurship and competition (Israel, 1973; Kirzner, 1997). Other central references analyze productive, unproductive, or destructive contributions of the society's entrepreneurial activities (Baumol, 1990). More recent references address the promise of entrepreneurship as a field of research (Shane and Venkataraman, 2000), a general theory of entrepreneurship (Shane, 2003), and the limitations of the existing theories in entrepreneurship (McMullen and Shepherd, 2006). Further central references deal with the role of the entrepreneurs' knowledge, social and human capital in the discovery and utulization of opportunities (Davidsson and Honig, 2003; Shane, 2000). The most central journals are *Journal of Business Venturing*, *Small Business Economics* and *Entrepreneurship Theory and Practice*.

HR Management and Performance: This is the smallest of all identified knowledge bases, where the most central references include contributions dealing with human resource management (HRM) practices more generally, and with "high-performance" work practices or systems for organizing work and managing employees mainly in the manufacturing sector, more particularly. Most of the studies in this knowledge base are empirical studies dealing with different aspects of the relationship between the HRM practices or systems and the performances of firms (Appelbaum et al., 2000; Arthur, 1994; Becker and Gerhart, 1996; Cappelli and Neumark, 2001; Huselid, 1995; Ichniowski et al., 1997; MacDuffie, 1995; Osterman, 1994, 2000). However, it also includes a contribution on modes of theorizing in strategic HRM (Delery and Doty, 1996). The most central journals are *International Journal of Human Resource Management*, *Academic Management Journal*, *Industrial and Labor Relations Review*, and *Industrial Relations*. In addition to management oriented journals, outlets also include journals from the field of psychology.

Institutional Entrepreneurship: The knowledge base consists mainly of central references sharing an institutional approach to organization theory and the role of agency in institutional change. It includes work on a sensemaking perspective on organisations (Weick, 1995); and the conception of human agency (Emirbayer and Mische, 1998). Different aspects of "institutional entrepreneurship" (Battilana et al., 2009; DiMaggio, 1988; Garud et al., 2007; Greenwood and Suddaby, 2006; Maguire et al., 2004; Seo and Creed, 2002); and the concept of "cultural entrepreneurship" (Lounsbury and Glynn, 2001) are also addressed. Another contributions is on the relationship between innovations and established institutional fields (Hargadon and Douglas, 2001). The majority of the central publication outlets are journals in the

field of strategy, management, and organization theory, but journals covering the field of sociology more broadly are also used.

Figure 4: Development of citations to the corresponding knowledge bases



Note. These figures illustrate the knowledge bases' absolute (left) and relative (right) amount of annual citations received. Only citations originating from our corpus are taken into account. Absolute citations are associated with the year of the citing publication, relative citations by the year of the corresponding reference.

In figure 4, we depict the development of citations received by the corresponding knowledge bases, which serves as an indicator of popularity in a certain period. While in most cases the number of citations received by references in the corresponding knowledge bases constantly grows (left figure), we see particularly *Organizational Learning* and *Territorial Innovation* over time to become the by far dominant knowledge bases drawn from. However, we also see some of the knowledge bases that entered later to receive increased attention and citation growth, such as *Internationalization* in the late 2000*s* and *Transitions* in the 2010*s*. In relative terms (left figure), we see that in its emergence in the 1980*s* the dominant knowledge base was *Organizational learning*, a time when many of its core contributions were written (eg., Granovetter, 1985; Nelson and Winter, 1982; Teece, 1986). Simultaneously, *Territorial Innovation* started to increase in influence, and partially punctuated the dominance of *Organizational Learning* in years of its seminal contributions (eg., Freeman, 1987; Freeman and Soete, 1982; Pavitt, 1984). While many core contributions constituting initial knowledge bases, *Organizational Learning* (eg., Cohen and Levinthal, 1990) and *Territorial Innovation* (eg., Lundvall, 1992; Nelson, 1993; Porter, 1990), remained relevant, also new knowledge bases started to emerge, particularly *Internationalization* (mainly its foundation in institutional as well as evolutionary economics, such as Kogut and Zander (1993); North (1990); Scott (2013) and to some extent *Knowledge*

Production (eg., Gibbons et al., 1994; Zucker et al., 1994)). This trend continued in the 2000s, where *Internationalization* but also *Knowledge Production* (eg., Etzkowitz and Leydesdorff, 2000) grew in importance. Finally, in the late 2000^s and afterwards, we observe a rather diverse set of knowledge bases in the field of IS, including growing prominance of *Entrepreneurship* (eg., Acs et al., 2013, 2014; Bruton et al., 2010) and *Tranistions* (eg., Bergek et al., 2008; Geels and Schot, 2007b; Markard et al., 2012).

4.3.2 Research areas: Bibliographic-coupling network

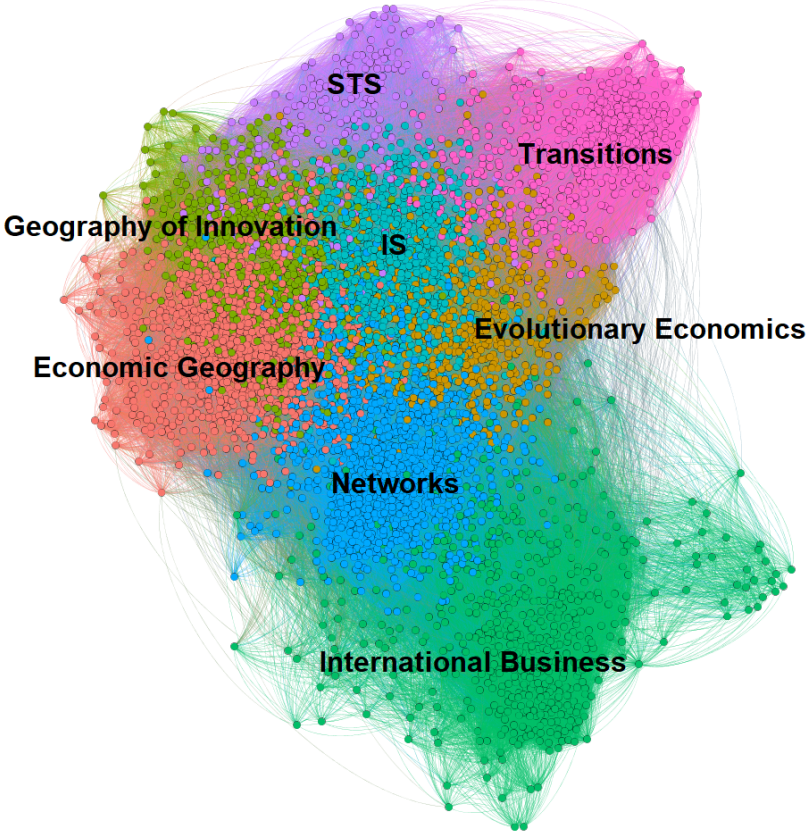
We now shift our focus to the results of a community detection analysis on a bibliographic-coupling network of articles, which we interpret as RESEARCH AREAS. Again, bibliographic coupling analysis tends to favor current over older publications, therefore deemed as suitable to depict the state of research at the time of analysis. Since bibliographic coupling strength is not influenced by a publications number of received citations or other measures of popularity, the most central publications within do not necessarily represent the most important seminal ones, but rather "typical" examples of research in terms of content, methods and theories applied.[10] A graphical illustration of this network of publications is provided in figure 5, and a condensed summary of the identified research areas is provided in table 5, followed again by a qualitative description.

Economic Geography: This research areas focuses on the role of geography for knowledge spillovers (Audretsch, 2003), and why it matters for innovation activity (Audretsch, 2002), mostly in form of empirical and policy-geared contributions. Commonly, the concept of the "knowledge production function" is applied. Further topics discussed are inter-regional (Greunz, 2003), inter-state (Smith, 1999) and university-industry (Acs et al., 2002b) knowledge spillovers, the economic effect of the spatial decentralization (Andersson et al., 2004), specialization and diversification (Feldman and Audretsch, 1999), urban economics (Andersson et al., 2005) and the innovation advantages of cities (Audretsch, 2002), as well as the international comparative advantage (Audretsch, 1998).

Most cited references include defining works on externalities in general (Jacobs, 1969; Marshall, 1920; Romer, 1990), spatially bounded knowledge spillovers (Griliches, 1979, 1990; Jaffe, 1989; Jaffe et al., 1993), and urban economics Glaeser et al. (1992). Two most prominent journals are *Regional Studies* and *Research Policy*. Publication outlets generally reflect the main focus of the research area being on economic ge-

[10] Therefore we, for the sake of brevity, do not report them here and limit ourselves to a general overview, while providing a list of the most central publications and cited references per research area in table A.3 in the Appendix.

Figure 5: Bibliographic coupling network of the IS literature



Note. Nodes represent the identified publications within the IS field of research, edges the bibliographic-coupling strength between them. Nodes are colored according to their association with identified research areas.

ography of innovation and regional science, the exception being *Small Business Economics* and *Journal of Technology Transfer*.

Networks and inter-organizational learning: This research area includes publications thematically oriented on firms' capabilities, strategic technology alliances, and inter and intra-organizational networks as a means to knowledge creation, diffusion, absorption and use, consisting of mostly empirical contributions. It includes work on different aspects of the firms' alliance networks and their influence on firms' learning and innovation (Gilsing et al., 2008; Karamanos, 2012; Paruchuri, 2010; Phelps, 2010; Schoenmakers and Duysters, 2006; Soh, 2003; Vanhaverbeke et al., 2015). Other contributions propose a model of partner selection in which firms ally for the purpose of learning and innovating (Baum et al., 2010); and a theoretical approach to bridging the gap between the resource-based-view of firms and the competitive advantage of firms participating in alliances (Lavie, 2006).

Table 5: Summary of Research Areas

Research Area	N	Central Journals	Relevant Topics	Related Knowledge Bases
Economic Geography: Externalities, Growth, Urban Economics	1.146 (18%)	Reg. Stud. (1.00) Res. Policy (0.90) Ann. Reg. Sci. (0.76) J. Econ. Geogr. (0.59) Small Bus. Econ. (0.56)	R&D, Productivity (0.09) Localization, Spillovers (0.09) Reg. Performance, RIS (0.07) Empirical (0.06) University-Industry (0.06)	Territorial Innov. Models (0.22) Knowledge Production (0.07) Entrepreneurship (0.04) Organizational Learning (0.04) Internationalization (0.02)
Networks: Strategic Alliances, Interfirm Relations, Open Innovation	1.103 (17%)	Strateg. Manage. J. (1.00) Res. Policy (0.67) Organ. Sci. (0.58) Acad. Manage. J. (0.42) Technovation (0.34)	Capab., Strateg. Allian. (0.11) Networks (0.08) Empirical (0.06) Knowledge Transfer (0.06) Open Innovation (0.06)	Organizational Learning (0.32) Internationalization (0.06) Territorial Innov. Models (0.05) Knowledge Production (0.04) Entrepreneurship (0.03)
International Business: Distance Studies, Institutions	1.041 (16%)	J. Int. Bus. Stud. (1.00) Int. Bus. Rev. (0.64) Manage. Int. Rev. (0.47) J. World Bus. (0.42) J. Int. Manage. (0.38)	Int., Entrep., Distance (0.12) Internationalization (0.11) HR Management (0.08) Empirical (0.07) Literature (0.06)	Internationalization (0.29) Entrepreneurship (0.15) HR Management (0.1) Organizational Learning (0.05) Institutional Entrep. (0.03)
Innovation Systems: National, Regional & Sectoral Approaches	783 (12%)	Res. Policy (1.00) Tech. Forecast. Soc. Ch. (0.61) Eur. Plan. Stud. (0.56) Scientometrics (0.45) Technovation (0.42)	Innovation Systems (0.09) Innovation Policy (0.06) Tech. Change, Industry (0.06) Reg. Performance, RIS (0.06) Open Innovation (0.06)	Territorial Innov. Models (0.14) Knowledge Production (0.07) Transitions (0.05) Organizational Learning (0.04) Internationalization (0.02)
Geography of Innovation: Knowledge Sourcing, Flows, & Bases	669 (11%)	Eur. Plan. Stud. (1.00) Reg. Stud. (0.76) J. Econ. Geogr. (0.41) Eur. Urban Reg. Stud. (0.34) Environ. Plan. A (0.33)	Localization, Spillovers (0.09) Reg. Performance, RIS (0.09) Knowledge Transfer (0.06) Globalization (0.06) Networks (0.05)	Territorial Innov. Models (0.18) Organizational Learning (0.02) Knowledge Production (0.02) Transitions (0.01) Entrepreneurship (0.01)
Technological Change & Evolutionary Economics	635 (10%)	Res. Policy (1.00) J. Evol. Econ. (0.84) Ind. Corp. Change (0.7) Tech. Anal. Strg. Mng. (0.48) Small Bus. Econ. (0.47)	Technol. Change, Industry (0.1) Open Innovation (0.06) Learning Processes (0.06) Firm Innov. Determinants (0.06) Literature (0.06)	Organizational Learning (0.08) Territorial Innov. Models (0.06) Transitions (0.05) Knowledge Production (0.04) Entrepreneurship (0.03)
Transitions: TIS, MLP, Regimes, Niches, Sustainability	605 (10%)	J. Clean Prod. (1.00) Environ. Innov. Soc. Tr. (0.92) Tech. Forecast. Soc. Ch. (0.91) Energy Policy (0.78) Tech. Anal. Strg. Mng. (0.67)	Transitions, Sustainability (0.19) Innovation Systems (0.08) Innovation Policy (0.07) Literature (0.06) Tech. Change, Industry (0.06)	Transitions (0.36) Territorial Innov. Models (0.02) Institutional Entrep. (0.02) Knowledge Production (0.01) Organizational Learning (0.01)
Science Technology Studies: Modes of Knowledge Production	386 (6%)	High. Educ. (1) Scientometrics (0.95) Minerva (0.86) J. Technol. Transf. (0.8) Sci. Public Policy (0.72)	University-Industry (0.14) Globalization (0.06) Literature (0.06) Innovation Policy (0.06) Learning Processes (0.06)	Knowledge Production (0.24) Institutional Entrep. (0.03) Transitions (0.03) Organizational Learning (0.01) Territorial Innov. Models (0.01)

Note. Summary includes most central journals; the most relevant topics; and the most related knowledge bases. All calculated centralities are Jaccard-weighted.

The most cited references include Cohen and Levinthal (1990) on the concept of "absorptive capacity", Barney (1991) on the link between firm resources and sustained competitive advantage, Kogut and Zander (1992) on the knowledge-based-view of the firm, Powell et al. (1996) on the inter-organizational networks of learning in biotechnology; Burt (1992) on the concept of "structural holes", Nelson and Winter (1982) on evolutionary theory of economic change, and Ahuja (2000) on collaboration networks, structural holes and innovation. Other highly influential references include work by Granovetter (1985) on the concept of "embeddedness" of economic behaviour in social relations, and March (1991) on exploitation and exploration in organizational learning. The most central publication outlets are *Strategic Management Journal* and *Research Policy*.

International business: This is a relatively homogeneous research area in terms of its thematic orientation being on various dimensions of cross-national cultural and institutional differences, and the internationalization process of firms in the context

of international business, management, and strategy studies. Central publications address the role of the host country's local demand on the relationship between cross-national distance and foreign direct investment (FDI) (Bailey and Li, 2015), cross-cultural distance on the establishment mode choice of the MNEs (Slangen and Hennart, 2008); the role of host country's "governance quality" on the relationship between cross-cultural distance and MNEs' entry mode (Chang et al., 2012), the impact of added cultural distance and diversity on MNEs' expansion patterns (Hutzschenreuter et al., 2011), the level of local isomorphism adopted by firms from different home countries (Salomon and Wu, 2012), the institutional determinants of the foreign subsidiary staffing policies (Ando, 2011), and the interaction effect of institutional differences on foreign market entry mode (Ang et al., 2015). Other central publications discuss the operationalization and measurement of the concepts of distance and international experience (Dow and Larimo, 2009), the impact of entry mode choice on foreign affiliate performance (Kim and Gray, 2008), and the relationship between cultural distance, international entry mode choice and performances (Wang and Schaan, 2008).

The highly cited references in this research area address dimensions of cultural differences among nations (Hofstede and Bond, 1984), the effect of national culture on the choice of firms' entry mode (Kogut and Singh, 1988), the institutional isomorphism and collective rationality (DiMaggio and Powell, 1983), an analytic framework for explaining how institutions and institutional changes affect economic performances of countries (North, 1990), a model of the internationalization of the firm with the main focus being on the knowledge of foreign markets and operations in explaining the extension of the firm's operations in individual countries (Johanson and Vahlne, 1977), the relationship between the institutional theory and the study of organisations (Scott, 2013), and the organizational legitimacy in the context of the MNEs (Kostova and Zaheer, 1999). The most central publication outlets are *Journal of International Business Studies* and *International Business Review*.

Innovation Systems (IS): The thematic orientation of this area includes the systemic, evolutionary and spatial approaches for innovation analysis as well as theoretical and innovation policy contributions and focus on external sources of knowledge. The most central publications are concerned with the characteristics of RIS from the view of the Triple Helix model (Danell and Persson, 2003); the characteristics of collaboration in product innovation among manufacturing establishments in the RIS (Edquist et al., 2002); a policy framework for IS-based strategies (Woolthuis et al., 2005); the regional strengths and weaknesses in the specific research domains (Islam and Miyazaki, 2010); the styles of innovation diffusion dynamics across countries (Weber and Hoogma, 1998); the role of firm's social capital formed in the context

of NIS in leading to success in innovation (Baba and Walsh, 2010); and the characteristics of RISs in the context of NIS (Chung, 2002). Other contributions discuss usefulness of the NIS approach and the concept of "style of innovation" (Lundvall, 1998); the relevance of the national system frameworks from policy and managerial perspectives (de la Mothe and Paquet, 1998); and usefulness of the systems of innovation approach for spatial innovation analysis (Fischer, 2001). The most cited references are four books explicitly dealing with the NIS: Lundvall (1992), Nelson (1993), Freeman (1987), and Edquist (1997). Other highly influential references include Nelson and Winter (1982) on evolutionary theory of economic change; and Porter (1990) on the patterns of competitive success of nations. They further include contributions on the relevance of national and regional systems of innovation as a domain of economic analysis (Freeman, 1995); a chapter on innovation as an interactive process in the seminal book on *Technical Change and Economic Theory* (Dosi et al., 1988); the concept of RIS (Cooke et al., 1997) and the concept of the "absorptive capacity" (Cohen and Levinthal, 1990). *Research Policy* is by far the most prominent journal in this research area.

Geography of Innovation: Here, the thematic orientation includes regional development contributions, the focus on the role of localization, clusters, knowledge spillovers and patterns/networks of knowledge sourcing/innovation activity, as well as focus on globalization and non-localized patterns/networks of interactions. Most of the central publications are concerned with the nature and geography of innovation, knowledge sourcing, and collaboration in the emerging biotechnology industry in the Prague metropolitan region (Blažek and Žížalová, 2010); the relationship between innovation and wider spatial structure (Doloreux and Shearmur, 2011); the sources of firms' product and process innovation in Norway (Fitjar and Rodríguez-Pose, 2013); the variety in knowledge sourcing and the relevance of geography in this respect for innovativeness of ICT firms in Austria (Grillitsch et al., 2015); the design and progress of regional innovation strategies in three regions of the Czech Republic (Blažek et al., 2013); the geography of linkages of the software industry between two regions (Chaminade, 2011); and the role of proximity for knowledge collaboration between biotechnology firms and other actors (Moodysson and Jonsson, 2007). The remainder of the most central contributions deal with the knowledge bases of a region (Martin, 2012b); the dangers associated with the use of regional systems of innovation as a normative concept (Uyarra and Flanagan, 2010); and the impact of various dimensions of proximity and entrepreneurial dimension on the functioning of an RIS (Sternberg, 2007). The research area's most cited references include studies on local buzz, global pipelines, and the process of knowledge creation (Bathelt et al., 2004); the impact of proximity on innovation (Boschma, 2005); the regional in-

novation system (Asheim and Coenen, 2005; Asheim and Gertler, 2005; Asheim and Isaksen, 2002; Cooke et al., 1998); and tacit knowledge and the economic geography of context (Gertler, 2003). Other most cited references include the seminal works on the concept of "absorptive capacity" (Cohen and Levinthal, 1990); knowledge formation and management (Amin and Cohendet, 2004) and the process of regional development (Cooke et al., 1998). *European Planning Studies*, *Regional Studies*, and *Journal of Economic Geography* appear as the most central publication outlets.

Technological change and evolutionary economics: This research areas focuses on various aspects of the process of technological change and the application of an evolutionary perspective in economics, management and organisation studies. Central publications include work on the sources and obstacles to entrepreneurial behavior across technological regimes (Marsili, 2002); the relationship between the technological regimes and Shumpeterian patterns of innovation (Breschi et al., 2000); the economics of the technological systems and the environmentally sustainable economic development (Kemp and Soete, 1992); the concept of "architectural innovation" and its competitive consequences for the established firms (Henderson and Clark, 1990); the competitive consequences of the incumbent business' patterns of introducing incremental innovations (Banbury and Mitchell, 1995); the effects of the introduction of the new technology on the innovative firms' survival (Levitas et al., 2006); and the effect of the demand heterogeneity on the development and evolution of technology (Adner and Levinthal, 2001). Other most central publications discuss the nature of the selection environment for innovations and the concept "techno-economic paradigms" (Freeman, 1991a), and the opportunities, incentives and collective patterns of technological change (Dosi, 1997). The work by Schumpeter (1942), Nelson and Winter (1982), Dosi (1982); Dosi et al. (1988); Dosi and Orsenigo (1988), and Freeman and Soete (1982) are the most cited references. Other highly influential references include work by Abernathy and Utterback (1978) on patterns of industrial change, and Pavitt (1984) on sectoral patterns of technological change, as well as Rosenberg (1994) collection of essays on technological change. *Research Policy* and *Journal of Evolutionary Economics* are the most central publication outlets.

Sustainability Transitions: This research area is thematically focused on transitions towards sustainability from a systems as well as evolutionary economic perspective; and includes conceptual, literature review and policy contributions. Central publications are studies concerned with a framework for analyzing sustainable innovation policy (Meelen and Farla, 2013); the multi-level perspective (MLP) framework for assessing policy to stimulate socio-technical transitions (Kern, 2012); an integrated framework of technological innovations system (TIS) and MLP approaches on tech-

nological change (Markard and Truffer, 2008); a system dynamic model that crosses over the TIS and MLP frameworks (Walrave and Raven, 2016); a review of the current transition research and on the limitations of the MLP approach (Genus and Coles, 2008); the socio-technical regimes (Fuenfschilling and Truffer, 2014); and a comparison of empirical approaches and results of two "path creation" frameworks (Lovio and Kivimaa, 2012). Empirical contributions include studies on the interactions between niche and regime (Ingram, 2015); the actor strategies and resources in transition processes (Farla et al., 2012); and the translation mechanisms in socio-technical niches (Raven et al., 2011). The most cited references in this line of research include a multi-level perspective on technological transitions (Geels, 2004, 2002; Geels and Schot, 2007a); a strategic niche management perspective on transitions (Kemp et al., 1998; Rip and Kemp, 1998; Schot and Geels, 2008; Smith et al., 2005); and a functional approach to studying technological innovation systems (Bergek et al., 2008; Hekkert et al., 2007). *Journal of Cleaner Production* and *Environmental Innovation and Societal Transitions* are the most central publication outlets.

Science and Technology Studies (STS): Here, we find a strong thematic focus on different aspects of modes of knowledge production, such as university-industry interactions, and the role of university in the context of global knowledge economy, as well as literature review and policy contributions. The most central articles address the paths of commercial knowledge occurring in scientist sponsored firms (Shinn and Lamy, 2006); different approaches to measuring the relationships among university, industry, and other sectors in the NIS (Sun and Negishi, 2010); the management of the multiple criteria for knowledge production within the context of collaborative research projects (Wehrens et al., 2014); the role of novel organizational forms on framing the science-industry activities (Merz and Biniok, 2010); the limits of entrepreneurialism within the traditional public university (Tuunainen, 2005); the multiple forms of university-industry linkages (Ramos-Vielba and Fernández-Esquinas, 2012); the role of higher education with regard to various knowledge society discourses (Välimaa and Hoffman, 2008); and the place of university in the system of knowledge production (Godin and Gingras, 2000). It also includes a systematic reflection on the Gibbons–Nowotny notion of "Mode 2" knowledge production (Hessels and Van Lente, 2008); and a critical assessment of the main approaches in the sociology of science and technology (Shinn, 2002). The most cited references consist of several contributions on the role of university in the knowledge economy and contemporary society (Clark, 1998; Etzkowitz, 1998, 2003; Etzkowitz and Leydesdorff, 2000; Gibbons et al., 1994; Nowotny et al., 2001). Others discuss the influence of public research on industrial R&D (Cohen et al., 2002); a "new economics of science" (Partha and David, 1994); patenting as a measure of the impact of the uni-

versity research (Agrawal and Henderson, 2002); and the different channels through which academic researchers interact with industry (D'Este and Patel, 2007). *Higher Education* and *Scientometrics* appear as the most central journals.

4.4 Development of coherence in IS as a field of research

Delineating the field of IS research and the identification of distinct areas of research within is by nature–while informative–a descriptive exercise. Yet, after setting the boundaries, further insights on the development of IS can be gained by analyzing its internal dynamics.

Figure 6: Developments in annual publications within research areas

Note. Absolute (left) and relative (right) number of publications per year in the research areas.

Figure 6 depicts the developments in terms of annual publications within the research areas. While we observe a somewhat steady increase in the annual number of publications across all research areas (left side), post-2010 we witness a stagnation or even decline for all except International Business and Transitions. In relative terms (right side), the composition reveals the evolving research agenda originating from Evolutionary Economics, the only research area present in the early 1980*s*. Around the mid-1980*s*, the emergence of Economic Geography suggest an interest in the territorial aspects of technological change and economic growth. The field splits further in the early 1990*s*, into IS with a focus on the link between the technological dynamics and social, institutional and political factors, and Geography of Innovation with an interest in combining territorial and institutional aspects to-

gether with systemic aspects of innovation and regional development. Late 1900*s*, the field specialized further into Networks, International Business, and the specialties STS and Transitions. While around 2000 representing the most popular research area, IS most recently became the one with the lowest share of annual contributions, while Transitions and International Business now occupy the top positions, reflecting that topics of transition towards sustainability and globalization lately have enjoyed increased attention from academics, policy makers and practitioners.

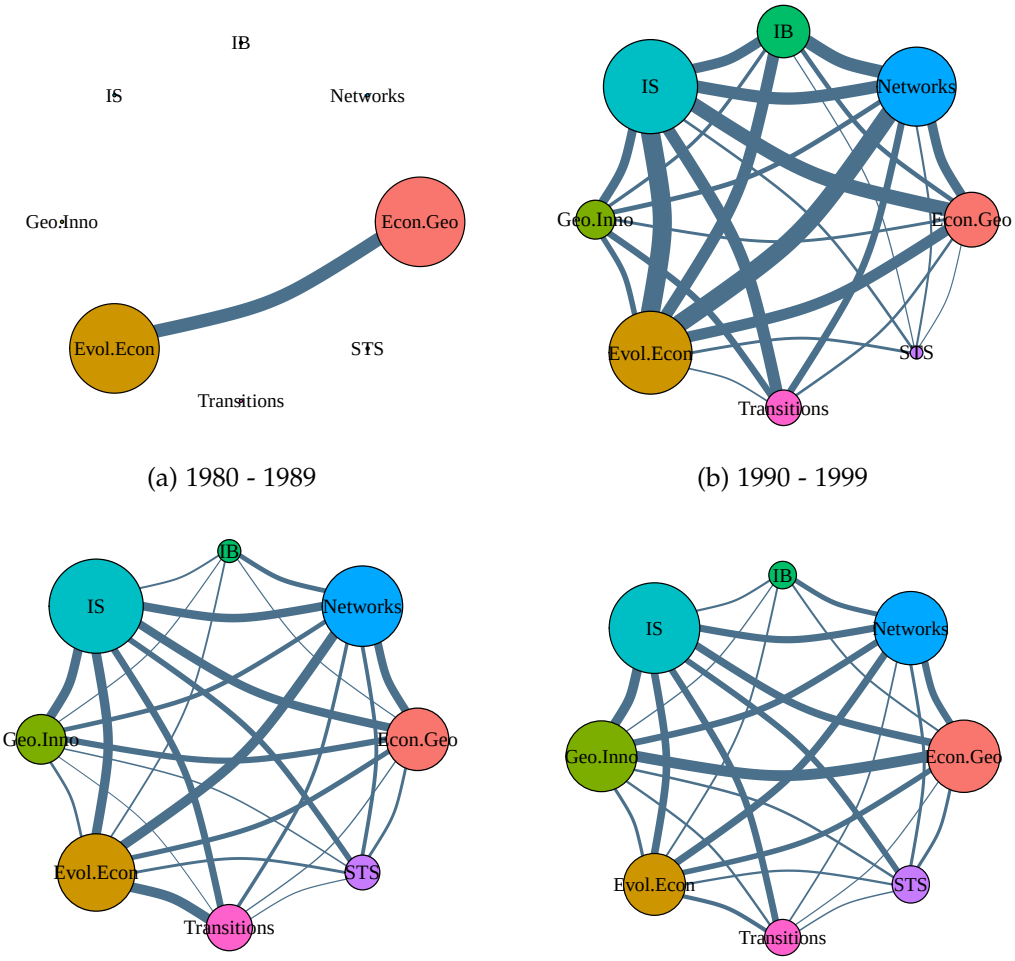
The growing number of distinct research areas of the IS field might either have developed from within, or entered IS as a result of broadening of disparate research agendas from outside the field. Yet, how has this growing diversity influenced its coherence? While research areas can be to some extent expected to specialize in terms of methods, topics, and theories, is there enough common ground left to collectively pursue a larger research agenda, or has fragmentation and isolation taken place? In a first attempt to provide answers to these questions, it is helpful to apply a network perspective and inspect the development of bibliographic coupling-strength between research areas in figure 7, measuring the extent to which they draw from a common pool of references and knowledge.

Figure 7a depicts the IS field's research areas in the 1980*s*, up to now only populated by Evolutionary Economics and Economic Geography. Both areas are connected during this period. Possible reasons are the increasing popularity of research on the relationship between the R&D, innovation and productivity growth among economic geography scholars, and related their shared body of references to the early contributions in the economics of technical change associated with the existence, and effect of knowledge spillover and the extent to which they are geographically localized (Breschi and Lissoni, 2001).

In the 1990*s* (figure 7b), all by now emerged research areas display an overall high level of coupling-strength, indicating a high consensus on core literature and dominant theories. This does not come as a surprise, keeping in mind that a major share of the field's seminal contributions which now form its core literature (e.g. Cohen and Levinthal, 1990; Edquist, 1997; Lundvall, 1992; Nelson, 1993) were published at this time. This demonstrates the influence of core contributions (in this case, mostly in the form of books) to inspire diverse streams of work and form a coherent higher-level field of research on its own right. Evolutionary Economics and IS stand in the center of this development.

In the 2000*s* we observe overall similar pattern yet of decreased strength. Interestingly, the coupling of Evolutionary Economics decreases with all research areas except Transitions, hinting at the challenges to develop further the field's overall theoretical evolutionary foundations. Likewise, International Business moves

Figure 7: Development of coherence between research areas



(a) 1980 - 1989

(b) 1990 - 1999

(c) 2000 - 2009

(d) from 2010

Note. Bibliographic coupling network between research areas by time periods. Node-size reflects the research area's degree. Edge-width reflects the (Jaccard-weighted) coupling strength.

further towards the most peripheral position, hinting at an up to now unsuccessful integration. This configuration remains somewhat stable in the post-2010 period.

Overall, we see the field after a formative stage of "groundwork" in the 1980*s* and 1990*s* to evolve in a diverse manner, yet settling below its initial level of coherence (cf. table A.4 for numerical values). This development might be explained by the diminishing interest in–and reference to–the field's original core contributions (Fagerberg and Sapprasert, 2011).

4.5 Development of coherence and diversity within research areas

While considering the 1-mode bibliographic-coupling network between research areas gives us a good general overview on the field's development in terms of overall coherence, yet many questions remain unanswered in this type of analysis. What are the field's unifying theoretical building blocks? And how did these foundations develop over time? Were they strengthened and developed further, neglected, or even substituted, and are these pattern homogeneous across research areas?

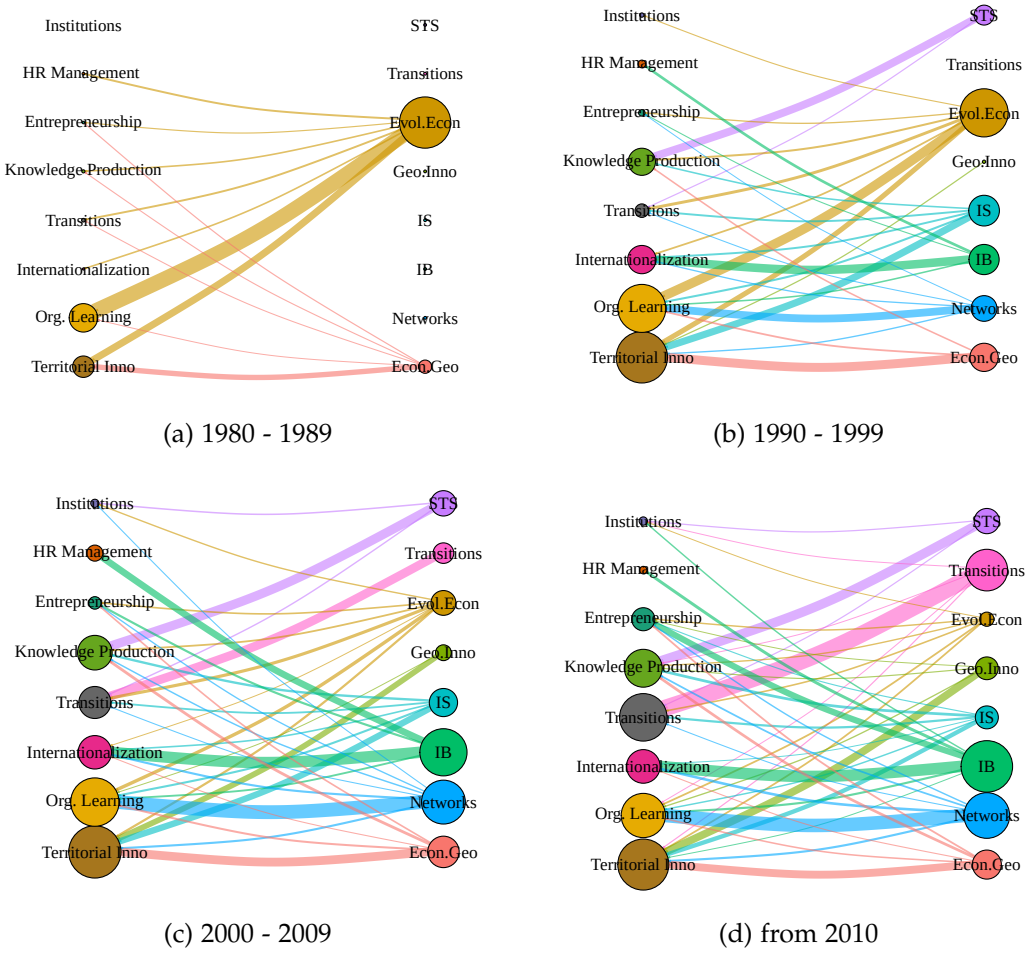
In an attempt to provide first answers, considering the full information contained in the bibliographic structure appears to be a promising way forward. We therefore in figure 8 presents the 2-mode network (research area → knowledge base), which provides insights in the pattern how the field's research areas integrate and draw from (as measured by citations) the knowledge bases over time.

Figure 8a depicts field's state in the 1980*s*, where we see that Evolutionary Economics first mainly drew from literature associated with the knowledge bases *Organizational Learning* and *Territorial Innovation Models*, and to a lesser extent from almost all knowledge bases. This pattern is in line with the early attempts of the creators of an evolutionary program in economics and management research to develop and integrate a coherent theory of firm into analysis of the large systems (Winter, 2017). Initially, Economic Geography mainly drew from *Territorial Innovation Models* and to a lesser extent from several other knowledge bases. This connection of Economic Geography corresponds with the beginnings of the regional endogenous development approach (Moulaert and Sekia, 2003).

Evolutionary Economics in the 1990*s* (figure 8b) maintains the strong connection to its original knowledge bases, while additionally integrating *Institutions* to further increase the richness of its theoretical foundation. IS developed in a similar fashion of broadening its knowledge bases overtime, while decreasing the focus on its original foundation. In contrast, Economic Geography over time maintained and even strengthened its association with *Territorial Innovation Models*, while overall integrating with a relatively large number of knowledge bases. Similarly, Networks shows an overall tendency of increasing diversity of knowledge bases, while also growing a strong connection with its main knowledge base *Organizational Learning*. Both Geography of Innovation and Transitions mainly drew from literature associated with *Territorial Innovation Systems* and *Transitions*, respectively. While continuously strengthening these connections over time, both just in the post-2010 became increasingly connected to diverse knowledge bases such as *Organizational Learning* and *Knowledge Production*.

Somewhat different tendency is observed for International Business, which in the 1990*s* mainly drew from literature associated with *Internationalization* and only to

Figure 8: Network of knowledge bases and research areas over time



(a) 1980 - 1989

(b) 1990 - 1999

(c) 2000 - 2009

(d) from 2010

Note. Node-size reflects the degree of the research area/knowledge base. Edge-weight corresponds to the (Jaccard weighted) number of citations a knowledge base receives from a research area. The corresponding numerical values can be found in table A.5 in the Appendix.

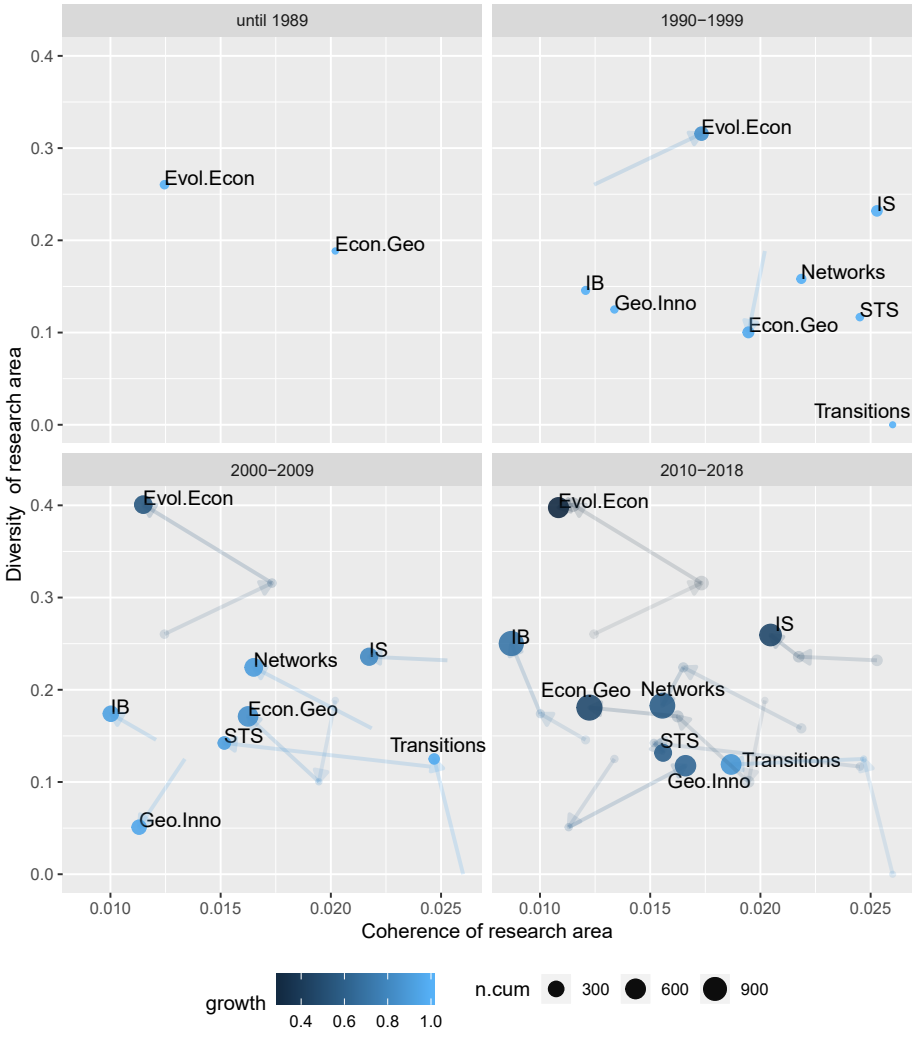
some extent from *HR Management*, *Entrepreneurship*, and *Organizational Learning*. In the later periods (figure 8c and 8d), one finds a growing connection to several knowledge bases while increasingly encompassing different streams of literature such as *Institutions* and *Territorial Innovation Models*. Interestingly, we also observe a shift from the focus on *HR Management* in the 2000*s* to afterwards *Entrepreneurship*, reflecting a re-focusing away from global MNE activity to global entrepreneurship.

In summary, we over time observe heterogeneous processes of knowledge inclusion across research. Most started relatively focused, but expanded their sources of knowledge over time while maintaining their initial speciality (namely Economic Geography, Geography of Innovation, STS and Networks). In contrast, IS and Evolutionary Economics started already rather diverse and even increased to do

so, yet at the cost of loosing their initial focus. IB is the only research area that shows changes in the importance given to distinct knowledge bases over time, indicating their ability to pivot towards timely strands of research.

As discussed in section 2, in order to assess the process of knowledge integration within the research field, it is useful to trace the research areas' diversity and coherence trajectories (figure 1) over time, which illustrate heterogeneous processes of knowledge integration. Therefore, figure 9 depicts the joint developments of coherence-diversity dynamics on research area level (the numeric values can be found in table A.5 in the Appendix).

Figure 9: Developments in the research areas' coherence and diversity



Note: (Internal) *Diversity* represents the (Leydesdorff, ming) diversity measure of the corresponding research area with respect to cited knowledge bases ($Div = V * B * D$). *Coherence* is measured by the (internal) density of the (Jaccard weighted) bibliographic-coupling network among publications within the research area. *Growth* represents the research area's growth rate in terms of number of publications. Node size reflects the area's cumulative number of publications.

In the 1980*s*, Evolutionary Economics emerged around the seminal contribution of Nelson and Winter (1982) in a comparably less coherent way, while Economic Geography started advancing a less diverse and more coherent line of inquiry related to the issues around "localized knowledge spillovers".

While Economic Geography firstly continued to maintain its level of coherence while decreasing in diversity in the 1990*s*, which hints at a time of successful focus, it afterwards continued to decrease in coherence and increase in diversity, which might be a sign of theoretical expansion (mid left in figure 9), Evolutionary Economics first joint increases in diversity and coherence in the 1990*s*, but over time further decreases in coherence while maintaining the high level of diversity (upper left in figure 9). As suggested by Hodgson and Lamberg (2018), our results for Evolutionary Economics point to the combination of growth, diversification, and deepening theoretical fragmentation, supporting the idea that work in this research area, while drawing from diverse knowledge bases, makes relatively few common references to core theoretical works. In contrast, the results for Economic Geography display tendencies towards specialization but also towards diversification and reintegration, in line with the attitudes expressed by Bathelt and Glückler (2018). In particular, the trend towards diversification and reintegration may be due to the launch of the *Journal of Economic Geography* in 2000 with the specific purpose of stimulating debate across research traditions converging around the common research interest (Bathelt and Glückler, 2018).

IB changed its position in the process of knowledge integration from fragmented specialization in the 1990*s* and through the 2000*s* to the position of fragmented diversification in the post-2010. A possible explanation for this finding may be a lack of substantial integration of the diverse theoretical perspectives applied in the context of international business as suggested by Buckley et al. (2017). Starting in the 1990*s* the research area Networks drawing from somewhat distinct knowledge bases shows in the 2000*s* further increase in diversity while slightly decreasing in coherence, indicating an incipient integration of new knowledge bases. The change in position in the post-2010 points to some integration around the core literature. It seems likely that these results reflect the continuing tradition of this research area to engage with the concepts across a spectrum of knowledge bases.

IS and STS emerged in the 1990*s* as theoretically cohesive research areas while exhibiting different levels of diversification. IS's starting position confirms earlier studies that claim this strand of literature to have emerged at the intercept of disciplines and schools of thoughts. Even tough IS over time remains connected to diverse knowledge bases, its decrease in coherence suggests a lack of advancements in its theoretical core. In contrast, STS is an example of a trajectory moving from the position of more to less coherent diversification. One possible interpretation for the

trend observed in relation to STS is the progression over time from drawing from the influential "Mode 2" concept of 1990*s* to successive interest in the alternative theoretical approaches for studying changes in the science system, such as "Triple Helix" and "strategic science" that became popular through the 2000*s*, and to post-2010s refocus on university-industry linkages and academic entrepreneurship. Yet, no successful integrative development can be observed. Geography of Innovation displays rather different trajectory. The starting point in the 1990*s* signalizes a rather specialized research area but loosely connected in terms of theoretical basis. Interestingly, in the 2000*s* its shows further specialization and fragmentation , while the post-2010 witnesses increasing in both diversity and the coherence, that is, moving to the position of coherent diversification.

While starting from the position of a highly coherent and specialized research area in the 1990*s*, Transitions in the 2000*s* shows an increase in diversity and slight decrease in coherence, which may be attributed to reliance on insights from new knowledge bases while focusing on a narrow research interest. This trend changes in the post-2010, where research becomes more fragmented, probably as a result of an increasing interest in sustainability issues from researchers in other research areas, as indicated by (Markard et al., 2012).

4.6 Some reflections: How did the field develop, and why?

Our analysis so far illustrated the current state as well as the past development of the IS field, confirming the results of previous studies on the whole field (eg., Fagerberg et al., 2013; Martin, 2012a) as well as its distinct research areas (e.g. Bathelt and Glückler, 2018; Buckley et al., 2017; Hodgson and Lamberg, 2018; Markard et al., 2012), thereby validating our methodology as well as corpus selection techniques. However, while attempting to exploit the full richness of bibliographic data, ultimately we face limits in terms of what the data at hand can explain in relation to reasons why the field of research developed in this manner. For this–arguable more interesting question–we in the following try to provide some tentative answers going beyond the inference possible base on our analysis.

To start with, what provided the initial spark for IS as a field of research on its own right? While systemic approaches to the economy in general and innovation in particular can be traced back throughout the history of economic thoughts (eg., List, 1909), there exists a general consensus that the specific research on IS has been launched in reference to the seminal book by Nelson and Winter (1982), "*An Evolutionary Theory of Economic Change*", aiming at establishing a more realistic evolutionary foundation in economics which is useful for policy and management alike.

Along these lines, IS can be seen as one of the specializations of the broadly defined evolutionary agenda, yet more focused on informing science and technology policy. Since such policy at that point in time was to a large extent formulated on the national level, it is not surprising that the development of the "National Innovation System" concept around the seminal contributions by Freeman (1987); Lundvall (1992); Nelson (1993) was the initial focus. It has to be noted that the seminal contributions so far have in common that they attempted to theoretically bridge across several disciplines while being practically relevant. Consequently, it does not surprise that all so far listed contributions come in the form of books, a format that enables the formulation of complex and interdisciplinary concepts in sufficient detail while also being shielded from the selection environment of established journals. We also observe that the publication of these books was also associated with a sharp increase of coherence of the overall IS field, and the formation of a stable pattern that persisted over time.

Since the corpus we used to define the field's research areas is limited to articles in academic journals, it seems appropriate to carry out further analyses on such non-journal publications, which can in our case only be found in the articles reference list. The non-journal publications here are in the form of books, but also technical reports and white-papers. This gives us, while imperfect, still a good indicator of the relevance of non-journal publications. It turns out that they constitute 33% of all cited references, and account for 29% of all corpus-internal citations. The research areas with the highest share of citations to non-journal publications are Innovation Systems (45%) and Evolutionary Economics (45%). That indicates the strong role that books, book chapters and similar publications had on the central research areas within IS. Furthermore, within both research areas, the contributions to be found in books have a particularly high within- but also between-area centrality, again demonstrating the crucial importance of these seminal contributions to unify this field of research and stratify its future development.[11]

Notably, many of these seminal and formative contributions to the field of IS research–and research on innovation, R&D and technological change generally–was enabled and driven by the public policy needs of that time. A well known examples are Christopher Freeman and Dick Nelson's early involvements with public policy institutions such as the OECD and RAND. Therefore, it is also reasonable to assume that forces external to the academic community shape its development as much as interactions within the academia. Indeed, many historical accounts on IS as a field

[11] However, the share of non-journal publications over time dropped from almost 59% in the late 1980*s* to around 25% in the post-2010 period. Likewise, while non-journal publications from the 1980*s* received about the same average amount of annual citations, this continuously shifted in favor of journal publications since 2000, where nowadays they receive about 1.5 times higher annual citations than non-journal publications

of research pronounce that this external engagement with the governmental and intergovernmental organizations were instrumental for the formation of the field of innovation studies and which continue to shape its development (Fagerberg et al., 2013). A notable example is the concept of NIS. As explained by Sharif (2006), the NIS concept itself emerged at the same time in academic and policy arena, while its development has been facilitated by the intercept of academics working at the OECD.

When taking a closer look if traces of such interactions and engagements between policy and academia can also be found within our bibliometric data, we do not see this to be manifested in academic publications by actors from the policy space.[12] We, however, indeed see intergovernmental organizations appearing among the cited references, suggesting them less to be involved in academic knowledge production, yet nevertheless present as a source of knowledge. The by far most cited organization here is the OECD (597 citations, making it combined the 43*th* most cited author right behind Michael Storper), followed by the European Commission (149 citations, rank 266). Particularly, the number of citations towards OECD references steadily increased over time, with a sharp increase after 2008 (18 citations) to 2016 (58 citations). Most of the cited references of OECD documents (50%) are located in the knowledge base *Territorial Innovation Models*, followed by *Knowledge Production* (19%), and receive the highest amount of citations from the research areas IS (31%) and Geography of Innovation (22%). Both research areas aspire–at least by internal claims–to inform policy.

While a wide range of OECD reports receive little citations within our corpus, two stand out, namely the "Oslo Manual" (OECD, 1997b, 65 citations) and the "OECD Main Science and Technology Indicators" (OECD, 1988, 63 citations across different volumes). When considering the topic distribution (result of the LDA analysis) within the publications citing OECD documents, we see that particularly the topic `R&D, Patents & Productivity` is strongly over-represented, followed by `Regional Performance & RIS` and `Empirical Evaluations`, suggesting the OECD to mainly serve as a provider of data–and guidance on how to gather and compose such data–for empirical work.

However, the third most cited OECD publication in our corpus is the project white paper on "National Innovation Systems" (OECD, 1997a, 46 combined citations), a compilation of work on *NIS* geared towards explaining and promoting the concept to policy-makers. Generally, it appears plausible that the importance given to the concept of innovation systems by the OECD, as evident by the volume of policy related documents, had and continue to have an effect on boosting research on in-

[12] We only find two publications with a first author directly affiliated with the OECD, and one with the European Commission.

novation systems by providing it with greater legitimacy. Others (Godin, 2009) even claim that most of the main building blocks of the NIS framework can be traced back to–and are built upon–previous efforts at the OECD. While the jury is still out on this claim, it appears evident that the systemic approach to innovation fell on fertile ground at the OECD, which undertook substantial efforts to promote and diffuse it among policy makers across the globe. Likewise, many innovation scholars collaborated in various OECD studies, using concepts and indicators in their academic research suggests a mutual legitimization between academics and the OECD (Albert and Laberge, 2007). Moreover, the close cooperation between the OECD and the European Commission on the design of innovation survey instruments and the commitment of resources for collection of firm level innovation survey data in Europe and elsewhere, made this type of data more widely available and used by researchers. It is the new evidence stemming from these surveys that significantly influenced the evolution of the research agenda, including the emergence of new research frameworks and the importance given to specific issues such as *dynamic capabilities* (Fagerberg et al., 2013, 2006). At the same time, the conceptual foundations of science, technology and innovation indicators reflect the ideas, more or less informed by the innovation research, that have been taken up by data gatherers and indicator developers. Consequently, one would expect the field to continue to be shaped by the demands but also to some extent driven by the work of policy makers and intergovernmental organizations. This type of analysis, while limited with our approach, would certainly provide a valuable insights on the societal role of different research areas.

In summary, it can be speculated that the OECD and other intergovernmental organizations influenced the field as "producer of knowledge" from the supply (of data) as well as "user of knowledge" from the demand (of policy) side.

5 Conclusion

In this article, we delineate the field of IS research. We are able to identify consistent and distinct research areas, thereby enhancing our understanding of the diversity of research efforts that contribute to it. However, we go further and establish a conceptual as well as analytic link between those research areas and the bodies of knowledge they utilize in their pursuit. We thereby provide a comprehensive and consistent overview of the IS field's state in terms of its current areas of research, which are consistent and informative in terms of their central publications, journals, and related knowledge bases. This is also evident from the topic modeling exercise, in which each research area is associated with the specific thematic orientations.

Likewise, our co-citation network-based community detection analysis provides an overview of the variety of knowledge bases that the field's research areas draw from.

We develop and demonstrate a sound methodology to delineate an interdisciplinary academic field with blurry boundaries within a bibliometric corpus. We provide an inductive "bottom up" approach to identify meaningful clusters of publications within the current research frontier as well as their corresponding knowledge bases without relying on predefined classifications. In an integrated network analysis of the resulting co-citation as well as bibliographic coupling network, we illustrate how the multidimensional structure of bibliometric data can be exploited to identify and disentangle the structure of knowledge production as well as the underlying knowledge bases utilized. By deploying methods from natural-language-processing, we add a further qualitative layer of information and thereby exploit the full richness of bibliometric data to create insightful summaries of distinct research areas and their content. This is useful to verify such a data-driven analysis, but also for giving the identified research areas meaning and context. Besides the ability to provide an accurate and informative snapshot of a given research field, our method enables us to unveil a persistent heterogeneity of knowledge integration across research areas and over time, which cannot be captured by commonly used methods for literature summary solely based on aggregated citation numbers. It also proves useful to derive temporal metrics and visualizations that provide insights in the process of knowledge integration as well as some guidance and implications for its future development. We believe, the presented methodology will prove useful to map and understand other academic fields with similar characteristics.[13]

As a result, we provide, to the best of our knowledge, the most comprehensive bibliographic overview over the state of IS research, its intellectual contours, and its heterogeneous internal dynamics of coherence and diversity. We thereby contribute to the discussion on what constitutes the IS field now and how it evolved over time. We find after the cataclysm of the field centered around seminal work in Evolutionary Economics, IS served as the main unifying area of research that forged the field together. After its initial dominance (1990*s* and 2000*s*) we witness a growing importance of other streams of research, especially International Business and Sustainability Transitions. The composition and changes within the field's research areas reveal the evolving research agenda originating from the influential works in the 1980*s* and 1990*s* that inspired subsequent development of research specialties. We illustrate how literature on IS has expanded its audience and contributors, and

[13]The present analysis also spurred the development of a bibliometrics package for the statistical programming environment R, which aims at easing its reconstruction and application in different settings. The current beta version of this package can be found under `https://github.com/ANONYMOUS` (anonymized for review). We hope other researchers will find that useful, and apply it to further enhance our knowledge on the development of research fields.

with it the questions addressed by the growing number of research areas. Despite the initial success of diverse streams of literature to form a coherent higher level specialty of research on its own, the field has over time become less coherent, where diverse but fragmented research areas pursue more narrow lines of inquiry.

Likewise, the field's knowledge bases have changed over time, as well as the way the research areas make use of them. Across research areas, we identify distinct development patterns that include starting from a relatively narrow knowledge bases, and over time including new ones while maintaining the strong connection to a single source (e.g., Economic Geography, Geography of Innovation and Transitions); as well as starting from a relatively diverse knowledge bases and subsequent movement to even higher levels of diversity (e.g., IS and Evolutionary Economics), while decreasing connections to its theoretical core. From the joint perspective of developments in coherence and diversity, we again illustrate how identified research areas follow different trajectories in the knowledge process integration. Evolutionary Economics appear to follow a trajectory of growing diversification and deepening fragmentation, while Economic Geography resemble a disposition towards both specialization, diversification and reintegration. In turn, Geography of Innovation and Transitions research areas move from the position of more or less coherent but specialized lines of inquiry and only in the last period seem to show broadening of its knowledge bases.

Our analysis of coherence-diversity dynamics provides insights beyond the context of IS, particularly about how research fields develop, and what might be promising development paths. We show that research areas commonly associated with IS follow rather different trajectories in terms of internal consistency and diversity of the knowledge integration process. Thus, as the field grows larger in size as well as more diverse in thematic orientation, there is a danger of fragmented specialization to take place, where different specialties of IS pursue a narrow line of research interest without further enhancement of the common research agenda. There exists a general consensus that a diversity of knowledge bases is integral to generally tackle complex phenomena successful, but also being able to respond to changing "grand challenges" posed by policy and society. We yet illustrate that the process of knowledge integration leading to increasing diversity can also harm the collective alignment of research efforts, if not accompanied by a maintenance of internal coherence. How can such a coherence be maintained? While not being able to make a strong empirical case, anecdotal evidence hints to the key role of institutions. This can be in form of intergovernmental organizations, such as in our case the OECD, which support the research and data-gathering infrastructure, compile a diverse set of results and simplify them for–and promote them to–the relevant audience such as policy makers. Our results also hint at the role joint interdisciplinary journal out-

lets play in shaping a joint research agenda, in our case foremost *Research Policy* as the only journal significant in almost all research areas (and which scores highest on our measure of diversity on journal level). However, we also illustrate that such integration attempts are not always successful, as it is in the case for International Business which remains peripheral, despite the evolutionary overlap in intellectual origins and the growing importance of analyzing innovation systems on a global scale.

While we believe to have done some substantial groundwork for a more nuanced discussion on where IS research came from, what it is now and how it became so, and how it might and should develop, we are yet far from providing conclusive answers. To eventually do so, we suggest the following avenues for future research we deem promising and fruitful. First, we hint at the importance of books as an outlet to establish the basis of a interdisciplinary and diverse theoretical foundation and research agenda, yet fall short in thoroughly analyzing this process. Reasons therefore are the limitations in available data, since up to now there exists no comprehensive collection of bibliographic meta-data for books reaching back in time far enough. However, such shortcomings might be overcome by utilizing modern document-processing-tools to efficiently create such data for books (particularly on the way they cite a field's bodies of knowledge), where we consider the ones central in our identified knowledge bases naturally a good point to start. Likewise, a similar exercise could be done for policy-reports, to shed light on the pattern intergovernmental organizations collect, compile, and promote a field's bodies of research, and the impact thereof. Likewise, we speculate the mobility of researchers between policy and academia to be an important driver of these dynamics, consequently digging deeper in the affiliation-dynamics on the level of individual researchers appears promising. Finally, we demonstrate the usefulness of techniques from natural-language-processing to "make sense" of text corpora too large for human comprehension, yet strongly underutilized the potentials of such methods. More thorough applications could, for instance, shed light into the unanswered question of directionality, meaning if new directions of research are originating from the academic community (and if, where), policy makers, or intergovernmental "transfer institutions". Here the application of semantic lead-lag models (eg., Ramage et al., 2010) appears particularly promising.

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References

Abernathy, W. J. and Utterback, J. M. (1978). Patterns of industrial innovation. *Technology Review*, 80(7):40–47.

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

Acs, Z. J., Audretsch, D. B., and Lehmann, E. E. (2013). The knowledge spillover theory of entrepreneurship. *Small Business Economics*, 41(4):757–774.

Acs, Z. J., Autio, E., and Szerb, L. (2014). National systems of entrepreneurship: measurement issues and policy implications. *Research Policy*, 43(3):476–494.

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

Adner, R. and Levinthal, D. (2001). Demand heterogeneity and technology evolution: implications for product and process innovation. *Management Science*, 47(5):611–628.

Agrawal, A. and Henderson, R. (2002). Putting patents in context: exploring knowledge transfer from MIT. *Management Science*, 48(1):44–60.

Ahuja, G. (2000). Collaboration networks, structural holes, and innovation: a longitudinal study. *Administrative Science Quarterly*, 45(3):425–455.

Albert, M. and Laberge, S. (2007). The legitimation and dissemination processes of the innovation system approach: the case of the Canadian and Québec science and technology policy. *Science, Technology, & Human Values*, 32(2):221–249.

Amable, B. (2000). Institutional complementarity and diversity of social systems of innovation and production. *Review of International Political Economy*, 7(4):645–687.

Amin, A. and Cohendet, P. (2004). *Architectures of knowledge: Firms, capabilities, and communities*. Oxford University Press, Oxford.

Andersson, R., Quigley, J. M., and Wilhelmson, M. (2004). University decentralization as regional policy: the Swedish experiment. *Journal of Economic Geography*, 4(4):371–388.

Andersson, R., Quigley, J. M., and Wilhelmsson, M. (2005). Agglomeration and the spatial distribution of creativity. *Papers in Regional Science*, 84(3):445–464.

Ando, N. (2011). Isomorphism and foreign subsidiary staffing policies. *Cross Cultural Management: An International Journal*, 18(2):131–143.

Ang, S. H., Benischke, M. H., and Doh, J. P. (2015). The interactions of institutions on foreign market entry mode. *Strategic Management Journal*, 36(10):1536–1553.

Appelbaum, E., Bailey, T., Berg, P., and Kalleberg, A. L. (2000). *Manufacturing advantage: Why high-performance work systems pay off*. Cornell University Press, Ithaca.

Arthur, J. B. (1994). Effects of human resource systems on manufacturing performance and turnover. *Academy of Management Journal*, 37(3):670–687.

Asheim, B. T., Boschma, R., and Cooke, P. (2011). Constructing regional advantage: platform policies based on related variety and differentiated knowledge bases. *Regional Studies*, 45(7):893–904.

Asheim, B. T. and Coenen, L. (2005). Knowledge bases and regional innovation systems: comparing Nordic clusters. *Research Policy*, 34(8):1173–1190.

Asheim, B. T. and Gertler, M. S. (2005). The geography of innovation: regional innovation systems. In Fagerberg, J., Mowery, D. C., and Nelson, R. R., editors, *The Oxford Handbook of Innovation*. Oxford University Press, Oxford.

Asheim, B. T. and Isaksen, A. (2002). Regional innovation systems: the integration of local sticky and global ubiquitous knowledge. *The Journal of Technology Transfer*, 27(1):77–86.

Audretsch, B. (1998). Agglomeration and the location of innovative activity. *Oxford Review of Economic Policy*, 14(2):18–29.

Audretsch, D. B. (2002). The innovative advantage of US cities. *European Planning Studies*, 10(2):165–176.

Audretsch, D. B. (2003). Innovation and spatial externalities. *International Regional Science Review*, 26(2):167–174.

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

Baba, Y. and Walsh, J. P. (2010). Embeddedness, social epistemology and breakthrough innovation: the case of the development of statins. *Research Policy*, 39(4):511–522.

Bailey, N. and Li, S. (2015). Cross-national distance and FDI: the moderating role of host country local demand. *Journal of International Management*, 21(4):267–276.

Balzat, M. and Hanusch, H. (2004). Recent trends in the research on national innovation systems. *Journal of Evolutionary Economics*, 14(2):197–210.

Banbury, C. M. and Mitchell, W. (1995). The effect of introducing important incremental innovations on market share and business survival. *Strategic Management Journal*, 16(S1):161–182.

Barney, J. B. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1):99.

Bartlett, C. A. and Ghoshal, S. (1989). *Managing across borders: The transnational solution*. Harvard Business School Press, Boston, MASS.

Bathelt, H. and Glückler, J. (2018). Relational Research Design in Economic Geography. In Clark, G. L., Gertler, M. S., and Feldman, M. P., editors, *The New Oxford Handbook of Economic Geography*. Oxford University Press, Oxford.

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

Battilana, J., Leca, B., and Boxenbaum, E. (2009). How actors change institutions: towards a theory of institutional entrepreneurship. *Academy of Management Annals*, 3(1):65–107.

Baum, J. A., Cowan, R., and Jonard, N. (2010). Network-independent partner selection and the evolution of innovation networks. *Management Science*, 56(11):2094–2110.

Baumol, W. J. (1990). Entrepreneurship: productive, unproductive, and destructive. *Journal of Political Economy*, 98(5, Part 1):893–921.

Becker, B. and Gerhart, B. (1996). The impact of human resource management on organizational performance: progress and prospects. *Academy of Management Journal*, 39(4):779–801.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., and Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: a scheme of analysis. *Research Policy*, 37(3):407–429.

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

Blažek, J., Žížalová, P., Rumpel, P., Skokan, K., and Chládek, P. (2013). Emerging regional innovation strategies in Central Europe: institutions and regional leadership in generating strategic outcomes. *European Urban and Regional Studies*, 20(2):275–294.

Blei, D. M. (2012). Probabilistic topic models. *Communications of the ACM*, 55(4):77–84.

Blondel, V. D., Guillaume, J.-L., Lambiotte, R., and Lefebvre, E. (2008). Fast unfolding of communities in large networks. *Journal of Statistical Mechanics: Theory and Experiment*, 2008(10):12.

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

Boyack, K. W. and Klavans, R. (2010). Co-citation analysis, bibliographic coupling, and direct citation: which citation approach represents the research front most accurately? *Journal of the American Society for Information Science and Technology*, 61(12):2389–2404.

Breschi, S. and Lissoni, F. (2001). Knowledge spillovers and local innovation systems: a critical survey. *Industrial and Corporate Change*, 10(4):975–1005.

Breschi, S. and Malerba, F. (1997). Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries. In *Systems of innovation: Technologies, institutions and organizations*. Pinter, London.

Breschi, S., Malerba, F., and Orsenigo, L. (2000). Technological regimes and Schumpeterian patterns of innovation. *The Economic Journal*, 110(463):388–410.

Bruton, G. D., Ahlstrom, D., and Li, H.-L. (2010). Institutional theory and entrepreneurship: where are we now and where do we need to move in the future? *Entrepreneurship Theory and Practice*, 34(3):421–440.

Buckley, P. and Casson, M. (1976). *Future of the multinational enterprise*. Palgrave Macmillan, London.

Buckley, P. J., Doh, J. P., and Benischke, M. H. (2017). Towards a renaissance in international business research? Big questions, grand challenges, and the future of IB scholarship. *Journal of International Business Studies*, 48(9):1045–1064.

Burt, R. S. (1992). *Structural holes: the social structure of competition*. Harvard University Press, Cambridge, MA.

Burt, R. S. (2001). Structural holes versus network closure as social capital. *Social cCapital: Theory and Research*, pages 31–56.

Cappelli, P. and Neumark, D. (2001). Do âĂIJhigh-performanceâĂİ work practices improve establishment-level outcomes? *Ilr Review*, 54(4):737–775.

Carlsson, B., Jacobsson, S., Holmén, M., and Rickne, A. (2002). Innovation systems: analytical and methodological issues. *Research Policy*, 31(2):233–245.

Carlsson, B. and Stankiewicz, R. (1991a). In search of useful public policies: key lessons and issues for policy makers. *Journal of Evolutionary Economics*, 1(2):93–118.

Carlsson, B. and Stankiewicz, R. (1991b). On the nature, function and composition of technological systems. *Journal of Evolutionary Economics*, 1(2):93–118.

Chaminade, C. (2011). Are knowledge bases enough? A comparative study of the geography of knowledge sources in China (Great Beijing) and India (Pune). *European Planning Studies*, 19(7):1357–1373.

Chang, Y.-C., Kao, M.-S., Kuo, A., and Chiu, C.-F. (2012). How cultural distance influences entry mode choice: the contingent role of host country's governance quality. *Journal of Business Research*, 65(8):1160–1170.

Chung, S. (2002). Building a national innovation system through regional innovation systems. *Technovation*, 22(8):485–491.

Clark, B. R. (1998). *Creating entrepreneurial universities: organizational pathways of transformation*. Pergamon, Amsterdam.

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

Cohen, W. M., Nelson, R. R., and Walsh, J. P. (2002). Links and impacts: the influence of public research on industrial R&D. *Management Science*, 48(1):1–23.

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

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

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

Cooke, P., Uranga, M. G., and Etxebarria, G. (1998). Regional systems of innovation: an evolutionary perspective. *Environment and Planning A*, 30:1563–1584.

Danell, R. and Persson, O. (2003). Regional R&D activities and interactions in the Swedish Triple Helix. *Scientometrics*, 58(2):203–218.

Davidsson, P. and Honig, B. (2003). The role of social and human capital among nascent entrepreneurs. *Journal of Business Venturing*, 18(3):301–331.

de la Mothe, J. and Paquet, G. (1998). National innovation systems,âĂŸreal economiesâĂŹ and instituted processes. *Small Business Economics*, 11(2):101–111.

Delery, J. E. and Doty, D. H. (1996). Modes of theorizing in strategic human resource management: tests of universalistic, contingency, and configurational performance predictions. *Academy of Management Journal*, 39(4):802–835.

D'Este, P. and Patel, P. (2007). University–industry linkages in the UK: What are the factors underlying the variety of interactions with industry? *Research Policy*, 36(9):1295–1313.

DiMaggio, P. (1988). Interest and agency in institutional theory. In Zucker, L., editor, *Research on institutional patterns*. Ballinger Publishing Co., Cambridge.

DiMaggio, P. and Powell, W. (1983). The iron cage revisited: institutional isomorphism and collective rationality in organizational fields. *American Sociological Review*, 48(2):147–160.

Doloreux, D. and Shearmur, R. (2011). Collaboration, information and the geography of innovation in knowledge intensive business services. *Journal of Economic Geography*, 12(1):79–105.

Dosi, G. (1982). Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change. *Research Policy*, 11(3):147–162.

Dosi, G. (1997). Opportunities, incentives and the collective patterns of technological change. *The Economic Journal*, 107(444):1530–1547.

Dosi, G., Freeman, C., Nelson, R., Silverberg, G., and Soete, L. (1988). *Technical Change and Economic Theory*. Laboratory of Economics and Management (LEM), Sant'Anna School of Advanced Studies, Pisa, Italy.

Dosi, G. and Orsenigo, L. (1988). Coordination and transformation: an overview of structures, behaviours and change in evolutionary environments. In Dosi, G., Freeman, C., Nelson, R., and Soete, L., editors, *Technical change and economic theory*, pages 13–37. Pinter Publishers, London.

Dow, D. and Larimo, J. (2009). Challenging the conceptualization and measurement of distance and international experience in entry mode choice research. *Journal of International Marketing*, 17(2):74–98.

Edquist, C. (1997). *Systems of innovation: technologies, institutions, and organizations*. Pinter, London.

Edquist, C. (2005). Systems of Innovation: Perspectives and Challenges. In Fagerberg, J., Mowery, D. C., and Nelson, R. R., editors, *The Oxford Handbook of Innovation*, pages 181–208. Oxford University Press, Oxford.

Edquist, C., Eriksson, M.-L., and Sjögren, H. (2002). Characteristics of collaboration in product innovation in the regional system of innovation of East Gothia. *European Planning Studies*, 10(5):563–581.

Emirbayer, M. and Mische, A. (1998). What is agency? *American Journal of Sociology*, 103(4):962–1023.

Etzkowitz, H. (1998). The norms of entrepreneurial science: cognitive effects of the new university–industry linkages. *Research Policy*, 27(8):823–833.

Etzkowitz, H. (2003). Research groups as âĂŸquasi-firmsâĂŹ: the invention of the entrepreneurial university. *Research Policy*, 32(1):109–121.

Etzkowitz, H. and Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and Mode 2 to a Triple Helix of university-industry-government relations. *Research Policy*, 29(2):109–123.

Fagerberg, J., Fosaas, M., and Sapprasert, K. (2012). Innovation: Exploring the knowledge base. *Research Policy*, 41(7):1132–1153.

Fagerberg, J., Martin, B. R., and Andersen, E. S., editors (2013). *Innovation studies: evolution and future challenges*. OUP Oxford.

Fagerberg, J., Mowery, D. C., and Nelson, R. R., editors (2006). *The Oxford Handbook of Innovation*. Oxford University Press, Oxford.

Fagerberg, J. and Sapprasert, K. (2011). National innovation systems: the emergence of a new approach. *Science and Public Policy*, 38(9):669–679.

Farla, J., Markard, J., Raven, R., and Coenen, L. (2012). Sustainability transitions in the making: a closer look at actors, strategies and resources. *Technological Forecasting and Social Change*, 79(6):991–998.

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

Fischer, M. M. (2001). Innovation, knowledge creation and systems of innovation. *The Annals of Regional Science*, 35(2):199–216.

Fitjar, R. D. and Rodríguez-Pose, A. (2013). Firm collaboration and modes of innovation in Norway. *Research Policy*, 42(1):128–138.

Fleming, L., Mingo, S., and Chen, D. (2007). Collaborative brokerage, generative creativity, and creative success. *Administrative Science Quarterly*, 52(3):443–475.

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

Freeman, C. (1991a). Innovation, changes of techno-economic paradigm and biological analogies in economics. *Revue économique*, pages 211–231.

Freeman, C. (1991b). Networks of innovators: a synthesis of research issues. *Research Policy*, 20(5):499–514.

Freeman, C. (1995). The National System of Innovation in historical perspective. *Cambridge Journal of Economics*, 19(1):5–24.

Freeman, C. and Soete, L., editors (1982). *The economics of industrial innovation*. Routledge, London.

Fuenfschilling, L. and Truffer, B. (2014). The structuration of socio-technical regimesâĂŤconceptual foundations from institutional theory. *Research Policy*, 43(4):772–791.

Furman, J., Porter, M., and Stern, S. (2002). The determinants of national innovative capacity. *Research Policy*, 31(6):899–933.

Garud, R., Hardy, C., and Maguire, S. (2007). Institutional entrepreneurship as embedded agency: an introduction to the special issue. *Organization Studies*, 28(7):957–969.

Geels, F. (2004). From sectoral systems of innovation to socio-technical systems: insights about dynamics and change from sociology and institutional theory. *Research Policy*, 33(6):897–920.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy*, 31(8):1257–1274.

Geels, F. W. and Schot, J. (2007a). Comment on âĂŸTechno therapy or nurtured niches?âĂŹby Hommels et al.[Res. Policy 36 (7)(2007)]. *Research Policy*, 36(7):1100–1101.

Geels, F. W. and Schot, J. (2007b). Typology of sociotechnical transition pathways. *Research Policy*, 36(3):399–417.

Genus, A. and Coles, A.-M. (2008). Rethinking the multi-level perspective of technological transitions. *Research Policy*, 37(9):1436–1445.

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

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., and Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. Sage, Los Angeles, CA.

Gilsing, V., Nooteboom, B., Vanhaverbeke, W., Duysters, G., and van den Oord, A. (2008). Network embeddedness and the exploration of novel technologies: Technological distance, betweenness centrality and density. *Research Policy*, 37(10):1717–1731.

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

Godin, B. (2009). National innovation system: the system approach in historical perspective. *Science, Technology & Human Values*.

Godin, B. and Gingras, Y. (2000). The place of universities in the system of knowledge production. *Research Policy*, 29(2):273–278.

Granovetter, M. S. (1985). Economic action and social structure: the problem of embeddedness. *American Journal of Sociology*, 91(3):481–510.

Greenwood, R. and Suddaby, R. (2006). Institutional entrepreneurship in mature fields: the big five accounting firms. *Academy of Management Journal*, 49(1):27–48.

Greunz, L. (2003). Geographically and technologically mediated knowledge spillovers between European regions. *The Annals of Regional Science*, 37(4):657–680.

Griliches, Z. (1979). Issues in assessing the contribution of research and development to productivity growth. *The Bell Journal of Economics*, pages 92–116.

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

Grillitsch, M., Tödtling, F., and Höglinger, C. (2015). Variety in knowledge sourcing, geography and innovation: evidence from the ICT sector in Austria. *Papers in Regional Science*, 94(1):25–43.

Hamers, L., Hemeryck, Y., Herweyers, G., Janssen, M., Keters, H., Rousseau, R., and Vanhoutte, A. (1989). Similarity measures in scientometric research: the Jaccard index versus Salton's cosine formula. *Information Processing & Management*, 25(3):315–318.

Hargadon, A. B. and Douglas, Y. (2001). When innovations meet institutions: Edison and the design of the electric light. *Administrative Science Quarterly*, 46(3):476–501.

Hart, D. M. (2009). Accounting for change in national systems of innovation: a friendly critique based on the US case. *Research Policy*, 38(4):647–654.

Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S., and Smits, R. (2007). Functions of innovation systems: a new approach for analysing technological change. *Technological Forecasting and Social Change*, 74(4):413–432.

Henderson, R., Jaffe, A. B., and Trajtenberg, M. (1998). Universities as a source of commercial technology: a detailed analysis of university patenting, 1965–1988. *Review of Economics and Statistics*, 80(1):119–127.

Henderson, R. M. and Clark, K. B. (1990). Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly*, pages 9–30.

Hessels, L. K. and Van Lente, H. (2008). Re-thinking new knowledge production: a literature review and a research agenda. *Research Policy*, 37(4):740–760.

Hodgson, G. M. and Lamberg, J.-A. (2018). The past and future of evolutionary economics: some reflections based on new bibliometric evidence. *Evolutionary and Institutional Economics Review*, 15(1):167–187.

Hofstede, G. and Bond, M. H. (1984). Hofstede's culture dimensions. *Journal of Cross-cultural Psychology*, 15(4):417.

Huselid, M. A. (1995). The impact of human resource management practices on turnover, productivity, and corporate financial performance. *Academy of Management Journal*, 38(3):635–672.

Hutzschenreuter, T., Voll, J. C., and Verbeke, A. (2011). The impact of added cultural distance and cultural diversity on international expansion patterns: a Penrosean perspective. *Journal of Management Studies*, 48(2):305–329.

Ichniowski, C., Shaw, K., and Prennushi, G. (1997). The effects of human resource management practices on productivity: a study of steel finishing lines. *The American Economic Review*, pages 291–313.

Ingram, J. (2015). Framing niche-regime linkage as adaptation: an analysis of learning and innovation networks for sustainable agriculture across Europe. *Journal of Rural Studies*, 40:59–75.

Islam, N. and Miyazaki, K. (2010). An empirical analysis of nanotechnology research domains. *Technovation*, 30(4):229–237.

Israel, K. (1973). *Competition and entrepreneurship*. The University of Chicago Press, Chicago.

Jacobs, J. (1969). *The economy of cities*. Vintage international. Random House, New York.

Jacobsson, S. and Johnson, A. (2000). The diffusion of renewable energy technology: an analytical framework and key issues for research. *Energy Policy*, 28(9):625–640.

Jaffe, A. B. (1989). Real effects of academic research. *The American Economic Review*, pages 957–970.

Jaffe, A. B., Trajtenberg, M., and Henderson, R. (1993). Geographic localization of knowledge spillovers as evidenced by patent citations. *The Quarterly Journal of Economics*, 108(3):577–598.

Jensen, M. B., Johnson, B., Lorenz, E., and Lundvall, B. Å. (2007). Forms of knowledge and modes of innovation. *Research Policy*, 36(5):680–693.

Johanson, J. and Vahlne, J.-E. (1977). The internationalization process of the firm-a model of knowledge development and increasing foreign market commitments. *Journal of International Business Studies*, pages 23–32.

Jurowetzki, R., Lema, R., and Lundvall, B.-Å. (2018). Combining innovation systems and global value chains for development: towards a research agenda. *The European Journal of Development Research*.

Karamanos, A. G. (2012). Leveraging micro-and macro-structures of embeddedness in alliance networks for exploratory innovation in biotechnology. *R&D Management*, 42(1):71–89.

Kemp, R., Schot, J., and Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. *Technology Analysis & Strategic Management*, 10(2):175–198.

Kemp, R. and Soete, L. (1992). The greening of technological progress: an evolutionary perspective. *Futures*, 24(5):437–457.

Kern, F. (2012). Using the multi-level perspective on socio-technical transitions to assess innovation policy. *Technological Forecasting and Social Change*, 79(2):298–310.

Kessler, M. M. (1963). Bibliographic coupling between scientific papers. *Journal of the Association for Information Science and Technology*, 14(1):10–25.

Kim, Y. and Gray, S. J. (2008). The impact of entry mode choice on foreign affiliate performance: the case of foreign MNEs in South Korea. *Management International Review*, 48(2):165.

Kirzner, I. M. (1997). Entrepreneurial discovery and the competitive market process: an Austrian approach. *Journal of Economic Literature*, 35(1):60–85.

Kogut, B. and Singh, H. (1988). The effect of national culture on the choice of entry mode. *Journal of International Business Studies*, pages 411–432.

Kogut, B. and Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science*, pages 383–397.

Kogut, B. and Zander, U. (1993). Knowledge of the firm and the evolutionary theory of the multinational corporation. *Journal of International Business Studies*, pages 625–645.

Kostova, T. and Zaheer, S. (1999). Organizational legitimacy under conditions of complexity: the case of the multinational enterprise. *Academy of Management Review*, 24(1):64–81.

Kuhn, T. S. (1971). *The Structure of Scientific Revolutions*. University of Chicago Press, Chicago.

Landström, H., Harirchi, G., and Åström, F. (2012). Entrepreneurship: exploring the knowledge base. *Research Policy*, 41(7):1154–1181.

Lavie, D. (2006). The competitive advantage of interconnected firms: an extension of the resource-based view. *The Academy of Management Review*, 31(3):638–658.

Levitas, E. F., McFadyen, M. A., and Loree, D. (2006). Survival and the introduction of new technology: a patent analysis in the integrated circuit industry. *Journal of Engineering and Technology Management*, 23(3):182–201.

Leydesdorff, L. (2008). On the normalization and visualization of author co-citation data: Salton's Cosine versus the Jaccard index. *Journal of the Association for Information Science and Technology*, 59(1):77–85.

Leydesdorff, L. (forthcoming). Diversity and Interdisciplinarity: How Can One Distinguish and Recombine Disparity, Variety, and Balance? *Scientometrics*.

List, F. (1909). *The National System of Political Economy*. Longmans, Green and Co, London.

Liu, X. and White, S. (2001). Comparing innovation systems: a framework and application to ChinaâĂŹs transitional context. *Research Policy*, 30(7):1091–1114.

Liu, Z., Yin, Y., Liu, W., and Dunford, M. (2015). Visualizing the intellectual structure and evolution of innovation systems research: a bibliometric analysis. *Scientometrics*, 103(1):135–158.

Lounsbury, M. and Glynn, M. A. (2001). Cultural entrepreneurship: stories, legitimacy, and the acquisition of resources. *Strategic Management Journal*, 22(6-7):545–564.

Lovio, R. and Kivimaa, P. (2012). Comparing alternative path creation frameworks in the context of emerging biofuel fields in the Netherlands, Sweden and Finland. *European Planning Studies*, 20(5):773–790.

Lundvall, B.-Å. (1992). *National Systems of Innovation: Toward a theory of innovation and interactive learning*. Pinter Publishers, London.

Lundvall, B.-Å. (1998). Why study national systems and national styles of innovation? *Technology Analysis & Strategic Management*, 10(4):403–422.

Lundvall, B.-Å. (2007). Innovation System Research, Where it came from and where it might go. Globelics working paper series, No. 2007-01.

Lundvall, B.-Å., Johnson, B., Andersen, E. S., and Dalum, B. (2002). National systems of production, innovation and competence building. *Research Policy*, 31(2):213–231.

MacDuffie, J. P. (1995). Human resource bundles and manufacturing performance: organizational logic and flexible production systems in the world auto industry. *ILR Review*, 48(2):197–221.

Macroberts, M. and Macroberts, B. (1987). Testing the Ortega hypothesis: facts and artifacts. *Scientometrics*, 12(5-6):293–295.

Maguire, S., Hardy, C., and Lawrence, T. B. (2004). Institutional entrepreneurship in emerging fields: HIV/AIDS treatment advocacy in Canada. *Academy of Management Journal*, 47(5):657–679.

Malerba, F. (2002). Sectoral systems of innovation and production. *Research Policy*, 31(2):247–264.

Malerba, F. (2005). Sectoral systems of innovation: a framework for linking innovation to the knowledge base, structure and dynamics of sectors. *Economics of Innovation and New Technology*, 14(1-2):63–82.

Malmberg, A. and Maskell, P. (2002). The elusive concept of localization economies: towards a knowledge-based theory of spatial clustering. *Environment and Planning A*.

March, J. G. (1991). Exploration and exploitation in organizational learning. *Organization Science*, 2(1):71–87.

March, J. G. (2005). Parochialism in the evolution of a research community: the case of organization studies. *Management and Organization Review*, 1(1):5–22.

Markard, J., Raven, R., and Truffer, B. (2012). Sustainability transitions: an emerging field of research and its prospects. *Research Policy*, 41(6):955–967.

Markard, J. and Truffer, B. (2008). Technological innovation systems and the multi-level perspective: towards an integrated framework. *Research Policy*, 37(4):596–615.

Marshall, A. (1920). *Principles of economics (8.th ed., Palgrave classics in economics)*. Palgrave Macmillan, Houndmills.

Marsili, O. (2002). Technological regimes and sources of entrepreneurship. *Small Business Economics*, 19(3):217–231.

Martin, B. R. (2012a). The evolution of science policy and innovation studies. *Research Policy*, 41(7):1219–1239.

Martin, B. R., Nightingale, P., and Yegros-Yegros, A. (2012). Science and technology studies: exploring the knowledge base. *Research Policy*, 41(7):1182–1204.

Martin, R. (2012b). Measuring knowledge bases in Swedish regions. *European Planning Studies*, 20(9):1569–1582.

McMullen, J. S. and Shepherd, D. A. (2006). Entrepreneurial action and the role of uncertainty in the theory of the entrepreneur. *Academy of Management Review*, 31(1):132–152.

Meelen, T. and Farla, J. (2013). Towards an integrated framework for analysing sustainable innovation policy. *Technology Analysis & Strategic Management*, 25(8):957–970.

Merz, M. and Biniok, P. (2010). How technological platforms reconfigure science-industry relations: the case of micro-and nanotechnology. *Minerva*, 48(2):105–124.

Meyer, M., Pereira, T. S., Persson, O., and Granstrand, O. (2004). The scientometric world of Keith Pavitt: a tribute to his contributions to research policy and patent analysis. *Research Policy*, 33(9):1405–1417.

Meyer-Krahmer, F. and Schmoch, U. (1998). Science-based technologies: university–industry interactions in four fields. *Research Policy*, 27(8):835–851.

Moodysson, J. and Jonsson, O. (2007). Knowledge collaboration and proximity: the spatial organization of biotech innovation projects. *European Urban and Regional Studies*, 14(2):115–131.

Moore, J. F. (1993). Predators and Prey: A New Ecology of Competition. *Harvard Business Review*, 71(3):75–86.

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

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

Mowery, D. C., Nelson, R. R., Sampat, B. N., and Ziedonis, A. A. (2001). The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh–Dole act of 1980. *Research Policy*, 30(1):99–119.

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

Nelson, R. R. (1993). *National innovation systems: a comparative analysis*. Oxford University Press, New York, NY.

Nelson, R. R. and Winter, S. G. (1982). *An evolutionary theory of economic change*. The Belknap Press of Harvard Univ. Press., Cambridge, MA.

Newman, M. E. (2004). Fast algorithm for detecting community structure in networks. *Physical Review*, 69(6):066133.

North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge University Press, Cambridge.

Nowotny, H., Gibbons, M., and Scott, P. (2001). *Re-thinking science: Knowledge and the public in an age of uncertainty*. Polity Press, Oxford.

OECD (1988). Main Science and Technology Indicators.

OECD (1997a). National Innovation Systems.

OECD (1997b). Oslo Manual: Proposed Guidelines for Collecting and Interpreting Technological Innovation Data.

Osterman, P. (1994). How common is workplace transformation and who adopts it? *ILR Review*, 47(2):173–188.

Osterman, P. (2000). Work reorganization in an era of restructuring: trends in diffusion and effects on employee welfare. *ILR Review*, 53(2):179–196.

Partha, D. and David, P. A. (1994). Toward a new economics of science. *Research Policy*, 23(5):487–521.

Paruchuri, S. (2010). Intraorganizational networks, interorganizational networks, and the impact of central inventors: a longitudinal study of pharmaceutical firms. *Organization Science*, 21(1):63–80.

Pavitt, K. (1984). Sectoral patterns of technical change: towards a taxonomy and a theory. *Research Policy*, 13(6):343–373.

Phelps, C. C. (2010). A longitudinal study of the influence of alliance network structure and composition on firm exploratory innovation. *Academy of Management Journal*, 53(4):890–913.

Pons, P. and Latapy, M. (2005). Computing communities in large networks using random walks. In *ISCIS*, volume 3733, pages 284–293.

Porter, A. L., Roessner, J. D., Cohen, A. S., and Perreault, M. (2006). Interdisciplinary research: meaning, metrics and nurture. *Research Evaluation*, 15(3):187–195.

Porter, M. (1990). *The competitive advantage of nations*. Free Press, New York.

Powell, W. W., Koput, K. W., and Smith-Doerr, L. (1996). Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Administrative Science Quarterly*, 41(1):116–145.

Raffo, J. and Lhuillery, S. (2009). How to play the Names Game: patent retrieval comparing different heuristics. *Research Policy*, 38(10):1617–1627.

Rafols, I., Leydesdorff, L., O'Hare, A., Nightingale, P., and Stirling, A. (2012). How journal rankings can suppress interdisciplinary research: a comparison between innovation studies and business & management. *Research Policy*, 41(7):1262–1282.

Rafols, I. and Meyer, M. (2010). Diversity and network coherence as indicators of interdisciplinarity: case studies in bionanoscience. *Scientometrics*, 82(2):263–287.

Raghavan, U. N., Albert, R., and Kumara, S. (2007). Near linear time algorithm to detect community structures in large-scale networks. *Physical Review*, 76(3):036106.

Ramage, D., Manning, C. D., and McFarland, D. A. (2010). Which universities lead and lag? Toward university rankings based on scholarly output. In *Proceedings of NIPS Workshop on Computational Social Science and the Wisdom of the Crowds*.

Ramos-Vielba, I. and Fernández-Esquinas, M. (2012). Beneath the tip of the iceberg: exploring the multiple forms of university–industry linkages. *Higher Education*, 64(2):237–265.

Raven, R., Verbong, G., Schilpzand, W., and Witkamp, M. (2011). Translation mechanisms in socio-technical niches: a case study of Dutch river management. *Technology Analysis & Strategic Management*, 23(10):1063–1078.

Reagans, R. and McEvily, B. (2003). Network structure and knowledge transfer: the effects of cohesion and range. *Administrative Science Quarterly*, 48(2):240–267.

Rip, A. and Kemp, R. (1998). Technological change. In Rayner, S. and L, M., editors, *Human Choice and Climate Change*, volume 2 Resources and Technology, pages 327–399. Battelle Press, Washington D.C.

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, 98(5):S71–S102.

Rosenberg, N. (1994). *Exploring the black box: Technology, economics, and history*. Cambridge University Press, Cambridge.

Rosvall, M. and Bergstrom, C. T. (2007). An information-theoretic framework for resolving community structure in complex networks. *Proceedings of the National Academy of Sciences*, 104(18):7327–7331.

Rotmans, J., Kemp, R., and Van Asselt, M. (2001). More evolution than revolution: transition management in public policy. *Foresight*, 3(1):15–31.

Salomon, R. and Wu, Z. (2012). Institutional distance and local isomorphism strategy. *Journal of International Business Studies*, 43(4):343–367.

Saxenian, A. (1994). *Regional networks: Industrial adaptation in Silicon Valley and route 128*. Harvard University Press, Cambridge, MA.

Schoenmakers, W. and Duysters, G. (2006). Learning in strategic technology alliances. *Technology Analysis & Strategic Management*, 18(2):245–264.

Schot, J. and Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management*, 20(5):537–554.

Schumpeter, J. A. (1942). *Capitalism, socialism and democracy*. Harper & Brothers, New York.

Scott, W. R. (2013). *Institutions and organizations: ideas, interests, and identities*. Sage Publications.

Seo, M.-G. and Creed, W. D. (2002). Institutional contradictions, praxis, and institutional change: a dialectical perspective. *Academy of Management Review*, 27(2):222–247.

Shane, S. (2000). Prior knowledge and the discovery of entrepreneurial opportunities. *Organization Science*, 11(4):448–469.

Shane, S. and Venkataraman, S. (2000). The promise of entrepreneurship as a field of research. *Academy of Management Review*, 25(1):217–226.

Shane, S. A. (2003). *A general theory of entrepreneurship: The individual-opportunity nexus*. Edward Elgar, Cheltenham.

Sharif, N. (2006). Emergence and development of the National Innovation Systems concept. *Research Policy*, 35(5):745–766.

Shenkar, O. (2001). Cultural distance revisited: towards a more rigorous conceptualization and measurement of cultural differences. *Journal of International Business Studies*, 32(3):519–535.

Shinn, T. (2002). The triple helix and new production of knowledge: prepackaged thinking on science and technology. *Social Studies of Science*, 32(4):599–614.

Shinn, T. and Lamy, E. (2006). Paths of commercial knowledge: forms and consequences of university–enterprise synergy in scientist-sponsored firms. *Research Policy*, 35(10):1465–1476.

Slangen, A. H. and Hennart, J.-F. (2008). Do multinationals really prefer to enter culturally distant countries through greenfields rather than through acquisitions? The role of parent experience and subsidiary autonomy. *Journal of International Business Studies*, 39(3):472–490.

Smith, A., Stirling, A., and Berkhout, F. (2005). The governance of sustainable socio-technical transitions. *Research Policy*, 34(10):1491–1510.

Smith, P. J. (1999). Do knowledge spillovers contribute to US state output and growth? *Journal of Urban Economics*, 45(2):331–353.

Soete, L., Verspagen, B., and Ter Weel, B. (2010). Systems of innovation. In *Handbook of the Economics of Innovation*, volume 2, pages 1159–1180. Elsevier Science.

Soh, P.-H. (2003). The role of networking alliances in information acquisition and its implications for new product performance. *Journal of Business Venturing*, 18(6):727–744.

Sternberg, R. (2007). Entrepreneurship, proximity and regional innovation systems. *Tijdschrift Voor Economische En Sociale Geografie*, 98(5):652–666.

Stirling, A. (2007). A general framework for analysing diversity in science, technology and society. *Journal of the Royal Society Interface*, 4(15):707–719.

Sun, Y. and Negishi, M. (2010). Measuring the relationships among university, industry and other sectors in JapanâĂŹs national innovation system: a comparison of new approaches with mutual information indicators. *Scientometrics*, 82(3):677–685.

Teece, D. J. (1986). Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. *Research Policy*, 15(6):285–305.

Teixeira, A. A. (2013). Evolution, roots and influence of the literature on National Systems of Innovation: a bibliometric account. *Cambridge Journal of Economics*, 38(1):181–214.

TerWal, A., Alexy, O., Block, J., and Sandner, P. (2016). The best of both worlds: the benefits of open-specialized and closed-diverse syndication networks for new venturesâĂŹ success. *Administrative Science Quarterly*, 61(3):393–432.

Tuunainen, J. (2005). Contesting a hybrid firm at a traditional university. *Social Studies of Science*, 35(2):173–210.

Uriona-Maldonado, M., dos Santos, R. N. M., and Varvakis, G. (2012). State of the art on the Systems of Innovation research: a bibliometrics study up to 2009. *Scientometrics*, 91(3):977–996.

Üsdiken, B. and Pasadeos, Y. (1995). Organizational analysis in North America and Europe: a comparison of co-citation networks. *Organization Studies*, 16(3):503–526.

Uyarra, E. and Flanagan, K. (2010). From regional systems of innovation to regions as innovation policy spaces. *Environment and Planning C: Government and Policy*, 28(4):681–695.

Uzzi, B. (1996). The sources and consequences of embeddedness for the economic performance of organizations: the network effect. *American Sociological Review*, 61(4):674–698.

Uzzi, B. (1997). Social structure and competition in interfirm networks: the paradox of embeddedness. *Administrative Science Quarterly*, 42(1):35–67.

Välimaa, J. and Hoffman, D. (2008). Knowledge society discourse and higher education. *Higher Education*, 56(3):265–285.

Vanhaverbeke, W., Belderbos, R., Duysters, G., and Beerkens, B. (2015). Technological performance and alliances over the industry life cycle: evidence from the ASIC industry. *Journal of Product Innovation Management*, 32(4):556–573.

Walrave, B. and Raven, R. (2016). Modelling the dynamics of technological innovation systems. *Research Policy*, 45(9):1833–1844.

Wang, H. and Schaan, J.-L. (2008). How much distance do we need? Revisiting the âĂIJnational cultural distance paradoxâĂİ. *Management International Review*, 48(3):263–278.

Weber, W. and Hoogma, R. (1998). Beyond national and technological styles of innovation diffusion: a dynamic perspective on cases from the energy and transport sectors. *Technology Analysis & Strategic Management*, 10(4):545–566.

Wehrens, R., Bekker, M., and Bal, R. (2014). Hybrid management configurations in joint research. *Science, Technology, & Human Values*, 39(1):6–41.

Weick, K. E. (1995). *Sensemaking in organizations*, volume 3. Sage, Los Angeles, CA.

Whitley, R. (2000). The institutional structuring of innovation strategies: business systems, firm types and patterns of technical change in different market economies. *Organization Studies*, 21(5):855.

Winter, S. G. (2017). Pursuing the evolutionary agenda in economics and management research. *Cambridge Journal of Economics*, 41(3):721–747.

Woolthuis, R. K., Lankhuizen, M., and Gilsing, V. (2005). A system failure framework for innovation policy design. *Technovation*, 25(6):609–619.

Zucker, L. G., Darby, M. R., and Brewer, M. B. (1994). Intellectual capital and the birth of US biotechnology enterprises. Technical report, National Bureau of Economic Research, Cambridge, MA.

A Appendix

Table A.1: List of Seed Articles

Publications	TC	TC_{year}
Etzkowitz & Leydesdorff, 2000, "The Dynamics of Innovation: From National Systems and Mode 2 to...", *Res. Policy*	1.788	94
Geels, 2004, "From Sectoral Systems of Innovation to Socio-Technical Systems...", *Res. Policy*	828	55
Malerba, 2002, "Sectoral Systems of Innovation and Production", *Res. Policy*	764	45
Freeman, 1995, "The National System of Innovation in Historical-Perspective", *Cambr. J. Econ.*	763	32
Cooke et al., 1997, "Regional Innovation Systems: Institutional and Organisational Dimensions", *Res. Policy*	741	34
Furman et al., 2002, "The Determinants of National Innovative Capacity", *Res. Policy*	636	37
Hekkert et al., 2007, "Functions of Innovation Systems: A New Approach for Anal. Tech. Ch.", *Tech. Forecast. Soc. Ch.*	622	52
Carlsson & Stankiewicz, 1991, "On the Nature, Function and Composition of TS", *J. Evol. Econ.*	574	20
Freeman, 1991, "Networks of Innovators - A Synthesis of Research Issues", *Res. Policy*	556	20
Acs et al., 2002, "Patents and Innovation Counts as Measures of Regional Production of New Knowledge ...", *Res. Policy*	518	30
Bergek et al., 2008, "Analyzing the Functional Dynamics of Tech. Inn. Systems: A Scheme of Analysis", *Res. Policy*	514	47
Markard et al., 2012, "Sustainability Transitions: An Emerging Field of Research...", *Res. Policy*	508	73
Jensen et al., 2007, "Forms of Knowledge and Modes of Innovation", *Res. Policy*	505	42
Asheim & Coenen, 2005, "Knowledge Bases and Regional Innovation Systems: Comparing...", *Res. Policy*	494	35
Lundvall et al., 2002, "National Systems of Production, Innovation and Competence Building", *Res. Policy*	445	26
Carlsson et al., 2002, "Innovation Systems: Analytical and Methodological Issues", *Res. Policy*	374	22
Jacobsson & Johnson, 2000, "The Diffusion of Renewable Energy Technology: An Analytical Frwk...", *Energy Policy*	370	19
Meyer-Krahmer & Meyer-Krahmer, 1998, "Science-Based Technologies: University-Industry Interactions ...", *Res. Policy*	360	17
Markard & Truffer, 2008, "Technological Innovation Systems and the Multi-Level Perspective...", *Res. Policy*	357	32
Smith & Raven, 2012, "What Is Protective Space? Reconsidering Niches in Transitions to Sustainability", *Res. Policy*	337	48
Muller & Zenker, 2001, "Business Services as Actors of Knowledge Transformation: the Role of KIBS ...", *Res. Policy*	337	19
Morgan, 2004, "The Exaggerated Death of Geography: Learning, Proximity and Territorial IS", *J. Econ. Geogr.*	334	22
Cooke P, 1992, "Regional Innovation Systems - Competitive Regulation in the New Europe", *Geoforum*	301	11
Asheim et al., 2011, "Constructing Regional Advantage: Platform Policies Based on Related Variety and ...", *Reg. Stud.*	286	36
Liu & White, 2001, "Comparing Innovation Systems: A Framework and Application to China's Trans. Cntxt", *Res. Policy*	276	15
Berry et al., 2010, "An Institutional Approach to Cross-National Distance", *J. Int. Bus. Stud.*	274	30
Gilsing et al., 2008, "Network Embeddedness and the Exploration of Novel Technologies...", *Res. Policy*	264	24
Coenen et al., 2012, "Toward a Spatial Perspective on Sustainability Transitions", *Res. Policy*	258	37
Boschma & Iammarino, 2009, "Related Variety, Trade Linkages, and Regional Growth in Italy", *Econ. Geogr.*	248	25
Hessels & Van Lente, 2008, "Re-Thinking New Knowledge Production: A Lit. Review and a Res. Agenda", *Res. Policy*	245	22
Wolfe & Gertler, 2004, "Clusters From the Inside and Out: Local Dynamics and Global Linkages", *Urban Stud.*	241	16
Christensen et al., 2005, "The Industrial Dynamics of Open Innovation - Evidence From...", *Res. Policy*	239	17
Schartinger et al., 2002, "Knowledge Interactions Between Universities and Industry in Austria: Sectoral...", *Res. Policy*	233	14
Owen-Smith et al., 2002, "A Comparison of US and European University-Industry Relations in the Life Sci.", *Mng. Sci.*	228	13
Phene et al., 2006, "Breakthrough Innovations in the US Biotechnology Industry: The Effects of...", *Strg. Mng. J.*	227	17
Rodriguez-Pose & Crescenzi, 2008, "Research and Development, Spillovers, Innovation Systems, and...", *Reg. Stud.*	223	20
Cantwell et al., 2010, "An Evolutionary Approach to Understanding International Business Activity...", *J. Int. Bus. Stud.*	222	25
Acs et al., 2014, "National Systems of Entrepreneurship: Measurement Issues and Policy Implications", *Res. Policy*	126	25

Note. This table reports the 38 initial seed articles. They represent the top 1% publications in terms of total plus top 1% in terms of average annual citations received in the WoS corpus which contain the terms "Innovation System(-s)" or "System(-s) of Innovation" in title, abstract, or keywords (total 2.885).

Table A.2: Knowledge Bases Summary

Central References		*Central Authors*		*Central Journals*	
Reference	C_{int}	Author	C_{int}	Source	C_{int}
Knowledge Base 1: Territorial Inno., N: 8396 (25%)					
Lundvall B, 1992	0.32	Cooke P	1.00	Reg. Stud.	0.80
Bathelt H, 2004	0.30	Boschma R	0.55	Res. Policy	0.53
Boschma R, 2005	0.29	Asheim B	0.39	J Econ. Geogr.	0.27
Jaffe A, 1993	0.28	Amin A	0.36	Am. Econ. Rev.	0.18
Audretsch D, 1996	0.27	Storper M	0.24	Eur. Plan. Stud.	0.15
Saxenian A, 1994	0.25	Lundvall B	0.24	Econ. Geogr.	0.10
Marshall A, 1920	0.24	Krugman P	0.23	Environ. Plann. A	0.06
Porter M, 1990	0.23	Audretsch D	0.22	Ind. Corp. Change	0.06
Glaeser E, 1992	0.22	Bathelt H	0.22	Q. J. Econ.	0.04
Jacobs J, 1969	0.21	Porter M	0.19	J. Polit. Econ.	0.04
Knowledge Base 2: Org. Learning, N: 6259 (19%)					
Cohen W, 1990	0.37	Gulati R	0.61	Strateg. Manage. J.	1.00
Powell W, 1996	0.29	Burt R	0.38	Admin. Sci. Quart.	0.31
Nelson R, 1982	0.27	Cohen W	0.27	Organ. Sci.	0.26
Burt R, 1992	0.22	Hagedoorn J	0.23	Acad. Manage. J.	0.17
Ahuja G, 2000	0.20	Baum J	0.23	Res. Policy	0.17
Kogut B, 1992	0.19	Teece D	0.22	Acad. Manage. Rev.	0.10
March J, 1991	0.19	Kogut B	0.18	Manage. Sci.	0.08
Baum J, 2000	0.17	Ahuja G	0.14	Am J. Sociol.	0.04
Barney J, 1991	0.17	Chesbrough H	0.14	J. Manage.	0.02
Uzzi B, 1997	0.17	Granovetter M	0.14	Harvard Bus. Rev.	0.02
Knowledge Base 3: Internationalization, N: 5137 (15%)					
Kogut B, 1988	0.63	Dunning J	0.80	Int. Bus. S	1.00
Johanson J, 1977	0.56	Cantwell J	0.51	StrateG. Manage. J.	0.16
Hofstede G, 1980	0.51	Luo Y	0.49	Acad. Manage. J.	0.06
Kostova T, 1999	0.46	Rugman A	0.47	Acad. Manage. Rev.	0.03
Shenkar O, 2001,	0.37	Peng M	0.43	Int. BuS. Rev.	0.03
Bartlett C, 1989	0.36	Buckley P	0.42	Manage. Int. Rev.	0.02
North D, 1990	0.36	Kogut B	0.33	J. World Bus.	0.02
Kogut B, 1993	0.33	Henisz W	0.29	J. Manage. Stud.	0.02
DiMaggio P, 1983	0.32	Birkinshaw J	0.28	J. Int. Manage.	0.01
Buckley P, 1976	0.30	Meyer K	0.25	Org. Sci.	0.01
Knowledge Base 4: Transitions, N: 4309 (13%)					
Kemp R, 1998	0.31	Geels F	1.00	Res. Policy	0.65
Geels F, 2002	0.31	Kemp R	0.24	Energ. Policy	0.33
Geels F, 2007	0.31	Smith A	0.16	Tech. Forecast. Soc. Ch.	0.20
Rip A, 1998	0.21	Garud R	0.11	Tech. Anal. Strg. Mng.	0.12
Hekkert M, 2007	0.21	Bergek A	0.10	J. Evol. Econ.	0.04
Geels F, 2004	0.21	Raven R	0.08	Futures	0.04
Bergek A, 2008	0.19	Dosi G	0.07	Environ. Innov. Soc. Tr.	0.03
Smith A, 2005	0.19	Markard J	0.07	J. Clean Prod.	0.03
Markard J, 2012	0.17	Jacobsson S	0.06	Ecol. Econ.	0.02
Rotmans J, 2001	0.17	Loorbach D	0.06	Ind. Corp. Change	0.02
Knowledge Base 5: Knowledge Production, N: 3514 (10%)					
Etzkowitz H, 2000	0.44	Leydesdorff L	0.63	Res. Policy	1.00
Cohen W, 2002	0.39	Etzkowitz H	0.32	J. Technol. Transfer	0.12
Gibbons M, 1994	0.25	Mowery D	0.04	Scientometrics	0.11
D'Este P, 2007	0.25	Bozeman B	0.04	Technovation	0.02
Meyerkrahmer F, 1998	0.24	Nelson R	0.03	Sci. Publ. Policy	0.01
Etzkowitz H, 1998	0.24	Zucker L	0.03	Manage. Sci.	0.01
Agrawal A, 2002	0.24	Meyer M	0.02	Ind. Corp. Change	0.01
Dasgupta P, 1994	0.23	Rosenberg N	0.02	R\D Manage.	0.01
Mowery D, 2001	0.19	Mansfield E	0.02	Tech. Forecast. Soc. Ch.	0.01
Zucker L, 1998	0.17	Merton R	0.02	Soc. Stud. Sci.	0.00
Knowledge Base 6: Entrepreneurship, N: 3218 (10%)					
Shane S, 2000	0.56	Audretsch D	0.97	J. Bus. Venturing	0.99
Baumol W, 1990	0.38	Acs Z	0.86	Small Bus. Econ.	0.98
Davidsson P, 2003	0.36	Shane S	0.38	Entrep. Theory Pract.	0.65
Reynolds P, 2005	0.36	Davidsson P	0.26	Acad. Manage. Rev.	0.08
Shane S, 2000	0.31	Aldrich H	0.23	Strateg. Entrep. J.	0.04
Kirzner I, 1997	0.29	Baumol W	0.13	Acad. Manage. J.	0.04
Mcmullen J, 2006	0.27	Reynolds P	0.13	Entrep. Region. Dev.	0.04
Kirzner I, 1973	0.26	Baron R	0.13	Am. Econ. Rev.	0.03
Arenius P, 2005	0.24	Kirzner I	0.09	Ind. Corp. Change	0.03
Shane S, 2003	0.23	Alvarez S	0.08	Reg. Stud	0.03
Knowledge Base 7: HR Management , N: 1821 (5%)					
Huselid M, 1995	0.75	Osterman P	0.76	Int. J. Hum. Resour. Mng.	0.55
Ichniowski C, 1997	0.61	Hofstede G	0.74	Acad. Manage. J.	0.51
Macduffie J, 1995	0.58	Schwartz S	0.67	Ind. Labor Relat. Rev.	0.33
Appelbaum E, 2000	0.58	Guest D	0.63	Ind. Relat.	0.21
Osterman P, 1994	0.55	Godard J	0.51	Int. Bus. Stud.	0.16
Arthur J, 1994	0.50	Huselid M	0.39	J. Appl. Psychol.	0.11
Osterman P, 2000	0.42	Ichniowski C	0.36	Brit. J. Ind. Relat.	0.11
Delery J, 1996	0.41	Ferner A	0.32	J. Manage.	0.10
Cappelli P, 2001	0.36	Cappelli P	0.31	Admin. Sci. Quart.	0.07
Becker B, 1996	0.36	Batt R	0.29	J. Cross Cult. Psychol.	0.06
Knowledge Base 8: Institutions, N: 1088 (3%)					
Seo M, 2002	0.30	Lawrence T	0.80	Acad. Manage. J.	0.76
DiMaggio P, 1988	0.30	Greenwood R	0.51	Organ. Stud.	0.66
Greenwood R, 2006	0.30	Suddaby R	0.36	Acad. Manage. Rev.	0.43
Maguire S, 2004	0.27	Battilana J	0.30	Admin. Sci. Quart.	0.28
Battilana J, 2009	0.26	March J	0.29	Organ. Sci.	0.18
Dorado S, 2005	0.19	Weick K	0.24	J Manage. Stud.	0.15
Greenwood R, 2002,	0.19	DiMaggio P	0.23	Am. J. Sociol.	0.06
Alford R, 1991	0.19	Winter S	0.16	Brit. J. Manage.	0.05
Fligstein N, 1997	0.19	Fligstein N	0.16	Ind. Corp. Change	0.05
Berger P, 1967	0.19	Maguire S	0.15	Strateg. Manage. J.	0.03

Note. This table reports the most central references, authors, and journals within the identified knowledge bases in the co-citation network. All calculated centralities are Jaccard-weighted.

Table A.3: Clusters of Research Areas, Summary

Publications		*References*	
Publication	C_{int}	Reference	Cit
Research Area 1: Economic Geography: Externalities, Growth, Urban Economics, N: 1146 (18%)			
Audretsch D (2003) "Innovation and Spatial Externalities", *Int. Reg. Sci. Rev.*	1.000	Audretsch D, 1996	426
Andersson et al. (2004) "University Decentralization as Regional Policy: the Swedish Experiment", *J. Econ. Geogr.*	0.987	Jaffe A, 1993	279
Greunz (2003) "Geographically and Technologically Mediated Knowledge Spillovers Between European Regions", *Ann. Reg. Sci.*	0.949	Jaffe A, 1989	243
Andersson et al. (2005) "Agglomeration and the Spatial Distribution of Creativity", *Pap. Reg. Sci.*	0.925	Anselin L, 1997	239
Smith P (1999) "Do Knowledge Spillovers Contribute to US State Output and Growth", *J. Urban Econ.*	0.923	Glaeser E, 1992	175
Feldman & Audretsch (1999) "Innovation in Cities: Science-based Diversity, Specialization and Localized Competition", *Eur. Econ. Rev.*	0.888	Marshall A, 1920	161
Acs et al. (2002) "Hightechnology Employment and R&D in Cities: Heterogeneity vs Specialization", *Ann. Reg. Sci.*	0.836	Griliches Z, 1979	153
Del Rey (2001) "Teaching Versus Research: A Model of State University Competition", *J. Urban Econ.*	0.830	Griliches Z 1990	150
Audretsch D (2002) "The Innovative Advantage of US Cities", *Eur. Plan. Stud.*	0.828	Jacobs J, 1969	150
Audretsch D (1998) "Agglomeration and the Location of Innovative Activity", *Oxf. Rev. Econ. Policy*	0.818	Romer P, 1990	149
Research Area 2: Networks: Strategic Alliances, Inter-firm Relations, Open Innovation, N: 1103 (17%)			
Gilsing et al. (2008) "Network Embeddedness and the Exploration of Novel Technologies: Technological Distance, Betweenness Centrality and Density", *Res. Policy*	1.000	Cohen W, 1990	608
Karamanos A (2012) "Leveraging Micro and Macrostructures of Embeddedness in Alliance Networks for Exploratory Innovation in Biotechnology", *R&D Manage.*	0.934	Powell W, 1996	306
Tzabbar et al. (2013) "When Does Tapping External Sources of Knowledge Result in Knowledge Integration", *Res. Policy*	0.922	Burt R, 1992	286
Phelps C (2010) "A Longitudinal Study of the Influence of Alliance Network Structure and Composition on Firm Exploratory Innovation", *Acad. Manage. J.*	0.909	Ahuja G, 2000	262
Paruchuri (2010) "Intraorganizational Networks, Interorganizational Networks, and the Impact of Central Inventors: A Longitudinal Study...", *Organ. Sci.*	0.904	Nelson R, 1982	248
Vanhaverbeke et al. (2015) "Technological Performance and Alliances Over the Industry Life Cycle: Evidence From the ASIC Industry", *J. Prod. Innov. Manage.*	0.904	Barney J, 1991	225
Schoenmakers & Duysters (2006) "Learning in Strategic Technology Alliances", *Technol. Anal. Strateg. Manage.*	0.904	Kogut B, 1992	225
Baum et al. (2010) "Networkindependent Partner Selection and the Evolution of Innovation Networks", *Manage. Sci.*	0.897	March J, 1991	224
Lavie (2006) "The Competitive Advantage of Interconnected Firms: An Extension of the Resource-Based View", *Acad. Manage. Rev.*	0.896	Granovetter M, 1985	192
Soh P (2003) "The Role of Networking Alliances in Information Acquisition and Its Implications for New Product Performance", *J. Bus. Ventur.*	0.890	Baum J, 2000	190
Research Area 3: International Business: Distance Studies, Institutions, N: 1041 (16%)			
Bailey & Li (2015) "Crossnational Distance and FDI: the Moderating Role of Host Country Local Demand", *J. Int. Manag.*	1.000	Hofstede G, 1980	280
Dow & Larimo (2009) "Challenging the Conceptualization and Measurement of Distance and International Experience in Entry Mode...", *J. Int. Market.*	0.992	Kogut B, 1988	242
Slangen & Hennart (2008) "Do Multinationals Really Prefer to Enter Culturally Distant Countries Through Greenfields...", *J. Int. Bus. Stud.*	0.991	DiMaggio P, 1983	186
Salomon & Wu (2012) "Institutional Distance and Local Isomorphism Strategy", *J. Int. Bus. Stud.*	0.976	North D, 1990	184
Chang et al. (2012) "How Cultural Distance Influences Entry Mode Choice: The Contingent Role of Host Countrys Governance Quality", *J. Bus. Res.*	0.951	Johanson J, 1977	176
Ang et al. (2015) "The Interactions of Institutions on Foreign Market Entry Mode", *Strateg. Manage. J.*	0.919	Kostova T, 1999	157
Hutzschenreuter et al. (2011) "The Impact of Added Cultural Distance and Cultural Diversity on International Expansion Patterns...", *J. Manage. Stud.*	0.917	Shenkar O, 2001	129
Ando (2011) "Isomorphism and Foreign Subsidiary Staffing Policies", *Cross Cult. Manage.*	0.912	Barkema H, 1996	117
Kim & Gray (2008) "The Impact of Entry Mode Choice on Foreign Affiliate Performance: the Case of Foreign MNEs in South Korea", *Manag. Int. Rev.*	0.907	Scott W, 1995	113
Wang & Schaan(2008) "How Much Distance Do We Need Revisiting the National Cultural Distance Paradox", *Manage. Int. Rev.*	0.898	Barney J, 1991	107
Research Area 4: Innovation Systems: National, Regional & Sectoral Approaches, N: 783 (12%)			
Danell & Persson (2003) "Regional R&D Activities and Interactions in the Swedish Triple Helix", *Scientometrics*	1.000	Lundvall B, 1992	499
Edquist et al. (2002) "Characteristics of Collaboration in Product Innovation in the Regional System of Innovation of East Gothia", *Eur. Plan. Stud.*	0.998	Nelson R, 1993	365
Woolthuis et al. (2005) "A System Failure Framework for Innovation Policy Design", *Technovation*	0.945	Edquist C, 1997	320
Islam & Miyazaki (2010) "an Empirical Analysis of Nanotechnology Research Domains", *Technovation*	0.920	Freeman C, 1987	208
Weber & Hoogma (1998) "Beyond National and Technological Styles of Innovation Diffusion: A Dynamic Perspective...", *Technol. Anal. Strateg. Manage.*	0.871	Nelson R, 1982	144
Baba & Walsh (2010) "Embeddedness, Social Epistemology and Breakthrough Innovation: The Case of the Development of Statins", *Res. Policy*	0.868	Freeman C, 1995	104
Chung (2002) "Building a National Innovation System Through Regional Innovation Systems", *Technovation*	0.855	Lundvall B, 1988	95
De La Mothe & Paquet (1998) "National Innovation Systems, 'Real Economies' and Instituted Processes", *Small Bus. Econ. Group*	0.841	Porter M, 1990	94
Lundvall B (1998) "Why Study National Systems and National Styles of Innovation", *Technol. Anal. Strateg. Manage.*	0.827	Cooke P, 1997	93
Fischer M (2001) "Innovation, Knowledge Creation and Systems of Innovation", *Ann. Reg. Sci.*	0.818	Cohen W, 1990	90
Research Area 5: Geography of Innovation: Knowledge Sourcing, Flows, & Bases, N: 669 (11%)			
Blazek & Zizalova (2010) "The Biotechnology Industry in the... Region: A Cluster Within a Fragmented Innovation System", *Environ. Plan. C-Gov. Policy*	1.000	Bathelt H, 2004	283
Doloreux & Shearmur (2012) "Collaboration, Information and the Geography of Innovation in Knowledge Intensive Business Services", *J. Econ. Geogr.*	0.999	Boschma R, 2005	181
Uyarra & Flanagan (2010) "From Regional Systems of Innovation to Regions as Innovation Policy Spaces", *Environ. Plan. C-Gov. Policy*	0.975	Asheim B, 2005	140
Fitjar & Rodriguez-Pose (2013) "Firm Collaboration and Modes of Innovation in Norway", *Res. Policy*	0.963	Cooke P, 2004	102
Sternberg (2007) "Entrepreneurship, Proximity and Regional Innovation Systems", *Tijdschr. Econ. Soc. Geogr.*	0.962	Asheim B, 2002	87
Grillitsch et al. (2015) "Variety in Knowledge Sourcing, Geography and Innovation: Evidence From the Ict Sector in Austria", *Pap. Reg. Sci.*	0.957	Amin A, 2004	85
Blazek et al. (2013) "Emerging Regional Innovation Strategies in...: Institutions and Regional Leadership in Generating Strategic Outcomes", *Eur. Urban Reg. Stud.*	0.904	Asheim B 2005	85
Martin (2012) "Measuring Knowledge Bases in Swedish Regions", *Eur. Plan. Stud.*	0.898	Cohen W, 1990	82
Chaminade (2011) "Are Knowledge Bases Enough? A Comparative Study of the Geography of Knowledge Sources in China...", *Eur. Plan. Stud.*	0.869	Gertler M, 2003	82
Moodysson & Jonsson (2007) "Knowledge Collaboration and Proximity the Spatial Organization of Biotech Innovation Projects", *Eur. Urban Reg. Stud.*	0.844	Cooke P, 1998	75
Research Area 6: Technological Change & Evolutionary Economics, N: 635 (10%)			
Wonglimpiyarat (2005) "The Nano-revolution of Schumpeters Kondratieff Cycle", *Technovation*	1.000	Nelson R, 1982	275
Breschi et al. (2000) "Technological Regimes and Schumpeterian Patterns of Innovation", *Econ. J.*	0.961	Dosi G, 1982	140
Kemp & Soete (1992) "The Greening of Technological Progress: An Evolutionary Perspective", *Futures*	0.950	Freeman C, 1982	103
Marsili (2002) "Technological Regimes and Sources of Entrepreneurship", *Small Bus. Econ. Group*	0.944	Dosi G 1988	97
Henderson & Clark (1990) "Architectural Innovation the Reconfiguration of Existing Product Technologies and the Failure of Established Firms", *Adm. Sci. Q.*	0.919	Abernathy W, 1978	95
Levitas et al. (2006) "Survival and the Introduction of New Technology: A Patent Analysis in the Integrated Circuit Industry", *J. Eng. Technol. Manage.*	0.876	Schumpeter J, 1942	89
Freeman (1991) "Innovation, Changes of Techno-Economic Paradigm and Biological Analogies in Economics", *Rev. Econ.*	0.818	Pavitt K, 1984	88
Adner & Levinthal (2001) "Demand Heterogeneity and Technology Evolution: Implications for Product and Process Innovation", *Manage. Sci.*	0.811	Dosi G, 1988	85
Banbury & Mitchell (1995) "The Effect of Introducing Important Incremental Innovations on Market Share and Business Survival", *Strateg. Manage. J.*	0.809	Rosenberg N, 1982	78
Dosi (1997) "Opportunities, Incentives and the Collective Patterns of Technological Change", *Econ. J.*	0.798	Arthur W, 1989	72
Research Area 7: Sustainability Transitions: TIS, MLP, Regimes, Niches & Systainability, N: 605 (10%)			
Meelen & Farla (2013) "Towards an Integrated Framework for Analysing Sustainable Innovation Policy", *Tech. Anal. Strateg. Mng.*	1.000	Geels F, 2002	239
Markard & Truffer (2008) "Technological Innovation Systems and the Multilevel Perspective: Towards an Integrated Framework", *Res. Policy*	0.994	Geels F, 2007	191
Ingram (2015) "Framing Niche-Regime Linkage as Adaptation: An Analysis of Learning and Innovation Networks...", *J. Rural Stud.*	0.939	Kemp R 1998	185
Walrave & Raven (2016) "Modelling the Dynamics of Technological Innovation Systems", *Res. Policy*	0.929	Bergek A, 2008	131
Fuenfschilling & Truffer (2014) "The Structuration of Socio-Technical Regimes-Conceptual Foundations From Institutional Theory", *Res. Policy*	0.928	Geels F, 2004	129
Lovio & Kivimaa (2012) "Comparing Alternative Path Creation Frameworks in the Context of Emerging Biofuel Fields in the Netherlands...", *Eur. Plan. Stud.*	0.881	Hekkert M, 2007	125
Farla et al. (2012) "Sustainability Transitions in the Making: A Closer Look at Actors, Strategies and Resources", *Tech. Forecast. Soc. Ch.*	0.849	Rip A, 1998	122
Genus & Coles (2008) "Rethinking the Multilevel Perspective of Technological Transitions", *Res. Policy*	0.847	Smith A, 2005	110
Kern (2012) "Using the Multi-Level Perspective on Socio-Technical Transitions to Assess Innovation Policy", *Tech. Forecast. Soc. Ch.*	0.841	Schot J 2008	92
Raven et al. (2011) "Translation Mechanisms in Socio-Technical Niches: A Case Study of Dutch River Management", *Tech. Anal. Strg. Mng.*	0.834	Markard J, 2008	91
Research Area 8: Science Technology Studies: Modes of Knowledge Production, N: 386 (6%)			
Shinn & Lamy (2006) "Paths of Commercial Knowledge: Forms and Consequences of University-Enterprise Synergy in Scientist-Sponsored Firms", *Res. Policy*	1.000	Gibbons M, 1994	171
Sun & Negishi (2010) "Measuring the Relationships Among University, Industry and Other Sectors in Japans National Innovation System:...", *Scientometrics*	0.880	Etzkowitz H, 2000	142
Wehrens et al. (2014) "Hybrid Management Configurations in Joint Research", *Sci. Technol. Hum. Values*	0.837	Etzkowitz H, 1998	61
Shinn (2002) "The Triple Helix and New Production of Knowledge: Prepackaged Thinking on Science and Technology", *Soc. Stud. Sci.*	0.792	Nowotny H, 2001	59
Merz & Biniok (2010) "How Technological Platforms Reconfigure Science-Industry Relations: the Case of Micro- and Nanotechnology", *Minerva*	0.772	Agrawal A, 2002	46
Hessels & Van Lente (2008) "Rethinking New Knowledge Production: A Literature Review and a Research Agenda", *Res. Policy*	0.763	Cohen W, 2002	46
Tuunainen (2005) "Contesting a Hybrid Firm at a Traditional University", *Soc. Stud. Sci.*	0.708	Clark B, 1998	44
Ramosvielba & Fernandezesquinas (2012) "Beneath the Tip of the Iceberg: Exploring the Multiple Forms of University-Industry Linkages", *High. Educ.*	0.695	Dasgupta P, 1994	43
Valimaa & Hoffman (2008) "Knowledge Society Discourse and Higher Education", *High. Educ.*	0.687	Etzkowitz H, 2003	41
Godin & Gingras (2000) "The Place of Universities in the System of Knowledge Production", *Res. Policy*	0.683	Slaughter S, 1997	40

Note: This table reports the most central publications and the most cited references for the identified research areas in the bibliographic coupling network. All calculated centralities are Jaccard-weighted.

Table A.4: Research Area Network (1-Mode, external): Density and Diversity

	1980-1989		1990-1999		2000-2009		from 2010		All Periods	
Research Area	$Dens^{1m}_{ext}$	Div^{1m}_{ext}	$Dens^{1m}_{ext}$	Div^{1m}_{ext}	$Dens^{1m}_{ext}$	Div^{1m}_{ext}	$Dens^{1m}_{ext}$	Div^{1m}_{ext}	$Dens^{1m}_{ext}$	Div^{1m}_{ext}
Econ.Geo	0.365	0.000	0.043	0.218	0.031	0.223	0.036	0.229	0.065	0.172
Networks	–	–	0.063	0.179	0.040	0.146	0.037	0.139	0.073	0.121
IB	–	–	0.042	0.150	0.012	0.236	0.014	0.197	0.035	0.170
IS	–	–	0.075	0.141	0.047	0.125	0.046	0.115	0.087	0.093
Geo.Inno	–	–	0.031	0.161	0.025	0.267	0.036	0.251	0.048	0.144
Evol.Econ	0.365	0.000	0.066	0.221	0.039	0.213	0.031	0.175	0.078	0.150
Transitions	–	–	0.028	0.092	0.023	0.317	0.018	0.237	0.036	0.181
STS	–	–	0.010	0.095	0.017	0.216	0.019	0.183	0.023	0.117
all	0.729	0.000	0.357	0.404	0.235	0.395	0.237	0.360	0.446	0.372

Note. This table reports the development of the research area's external degree density ($Dens^{1m}_{ext}$, based on the bibliographic coupling network between research areas), and their diversity (Div^{1m}_{ext}, Leydesdorff diversity of edge-weights to other research areas).

Table A.5: Research Area - Knowledge Base (2-mode) Network: Coherence and Diversity

	1980-1989		1990-1999		2000-2009		from 2010		All Periods	
Research Area	Coh^{2m}_{int}	Div^{2m}_{int}	Coh^{2m}_{int}	Div^{2m}_{int}	Coh^{2m}_{int}	Div^{2m}_{int}	Coh^{2m}_{int}	Div^{2m}_{int}	Coh^{2-m}_{int}	Div^{2m}_{int}
Econ.Geo	0.020	0.188	0.019	0.100	0.016	0.171	0.012	0.181	0.013	0.190
Networks	–	–	0.022	0.158	0.017	0.224	0.016	0.183	0.015	0.211
IB	–	–	0.012	0.146	0.010	0.174	0.009	0.250	0.008	0.238
IS	–	–	0.025	0.232	0.022	0.236	0.020	0.259	0.020	0.242
Geo.Inno	–	–	0.013	0.125	0.011	0.051	0.017	0.118	0.013	0.101
Evol.Econ	0.012	0.260	0.017	0.316	0.011	0.401	0.011	0.398	0.011	0.300
Transitions	–	–	0.111	0.000	0.025	0.125	0.019	0.119	0.018	0.108
STS	–	–	0.025	0.117	0.015	0.142	0.016	0.132	0.014	0.134
all	0.010	0.181	0.005	0.197	0.002	0.225	0.002	0.215	0.002	0.211

Note. This table reports the development of the research area's internal coherence (Coh^{2m}_{int}, based on internal bibliographic coupling network) measured by internal degree density, and their diversity (Div^{2m}_{int}, measured by their Leydesdorff diversity of cited knowledge bases).

Table A.6: Community Detection Algorithm Benchmark

	Bibliographic			Co-citation		
Algorithm	M	N_{com}	G_{size}	M	N_{com}	G_{size}
Louvain (Blondel et al., 2008)	0.36	8.00	0.24	0.42	8.00	0.22
Infomap (Rosvall and Bergstrom, 2007)	0.21	23.00	0.85	0.40	114.00	0.83
Fast Greedy (Newman, 2004)	0.27	6.00	0.62	0.35	4.00	0.28
Label Propagation (Raghavan et al., 2007)	0.00	2.00	0.50	0.00	1.00	0.00
Walktrap (Pons and Latapy, 2005)	0.27	21.00	0.79	0.37	35.00	0.77

Note. This table compares the achieved modularity (M), number of detected communities (N_{com}), and GINI coefficient (G_{size}) of community size between popular algorithms to detect communities in weighted networks.