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Regional innovation system research trends: toward knowledge management and entrepreneurial ecosystems

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Abstract

The regional innovation system (RIS) is a popular way of explaining a region's development and competitiveness based on innovation activities and processes. In this paper, bibliometric techniques are used to analyze all RIS studies indexed in the Web of Science Core Collection (WoS CC) database as of December 2017. The goal of the analysis is to identify the main trends in RIS research. The evolution of the total number of publications and citations per year indicates that this research field has garnered considerable attention from the scientific community, public administrations, and international organizations. Analysis of the most common keywords and their co-occurrence sheds light on the conceptual framework of RIS research, where *knowledge*, *innovation*, *clusters*, *policy*, *networks*, *systems*, *R&D*, *firms*, and *industry* are key concepts. The 17 most influential RIS articles indexed in WoS CC are identified according to the total number of citations and the ratio of number of citations per year. Reviewing these 17 articles reveals 3 groups of underlying research trends: (1) research on innovation systems, which was mainly conducted in the 1990s, (2) research on knowledge management since the beginning of the 2000s, and (3) research on entrepreneurial ecosystems in recent years. Finally, analysis of citations to these 17 most influential RIS articles reveals strong interconnections according to the number of times they are cited together.

Keywords: Regional innovation system, Innovation systems, Knowledge management, Entrepreneurial ecosystems, Bibliometrics, Web of Science

JEL classification: O29 O30 O38

Introduction

Innovation systems [1–3] and regional science [4] are two research fields that relate to spatial economics and economic geography from different approaches. Regional science focuses on the locational dimension of human activities in the context of their institutional structure and coordination. It is only implicitly aimed at the study of innovation processes. In contrast, innovation systems research studies the economic actors and institutions that contribute to generating innovation by focusing on innovation processes [5].

According to Forrest [6], firms are open systems that receive feedback from their external context. Generally, the origin of innovations in a firm or an organization, in a country or a region, will depend not only on its human capital and internal factors but also on external factors such as the institutions and agents of each country or region. These interdependencies between the firm and its context give rise to the innovation systems, which comprise a great variety of institutions, networks, and interrelationships.

The application of the innovation systems to a subnational area (regional or even local) was carried out to mitigate the most severe problems related to the national scale [7]. This regional approach was dubbed *regional innovation systems* (RISs) by Philip Cooke in 1992 [8]. Research on regional innovation has grown significantly since the term “RIS” was coined. This growth owes to the greater intensity of international competition in the globalized economy, the shortcomings of traditional regional development models and policies, and the emergence of successful clusters of firms and industries in many regions around the world [9, 10]. The literature on RIS provides extensive descriptions and analysis of relationships between innovation, learning, and economic performance of particular regions [11–14].

In view of this background, the main objective of this paper is to identify the research trends that have characterized RIS research from its beginnings to the present day. Bibliometric techniques are applied to data on all RIS-related publications indexed in the Web of Science Core Collection (WoS CC) database to outline the RIS conceptual framework and select the most influential RIS articles. The aims, scope, and conclusions of the most influential articles are then studied to identify the main research trends.

The rest of the article is structured as follows. The next section describes the theoretical framework; then there is a section that explains the methodology and another section that presents the results of the bibliometric analysis and of the review of the most influential articles. Finally, the last section provides the main conclusions.

Theoretical framework

The systemic approach to innovation emerged in the context of debates over industry policy in Europe at the end of the 1980s, giving place to the national innovation systems (NIS). The collaboration between Chris Freeman, Richard Nelson, and Bengt-Åke Lundvall in the International Federation of Institutes for Advanced Study (IFIAS) was crucial for the subsequent development of the concept. Three books pioneered the idea of the NIS: *Technology policy and economic performance: lessons from Japan*, by Freeman [1], *National systems of innovation: towards a theory of innovation and interactive learning*, edited by Lundvall [2], and *National innovation system: a comparative analysis*, edited by Nelson [3].

According to these pioneers, a NIS consists of a network of economic agents together with the institutions and policies that influence these agents' innovation behavior and performance. Within the NIS-based conceptual framework, innovation is an interactive process in which firms that interact with and receive support from institutions and organizations (e.g., industry associations; R&D, innovation, and productivity centers; standard-setting bodies and institutes; and universities and training centers) play a key role in bringing new products, new processes, and new forms of organization into economic use [15].

Contrary to what might seem in a globalized world, the national and regional approaches are key factors to build the relational networks that firms need to innovate, so the role played by nations regarding innovation has become even more important [16]. For this reason, public administrations are investing heavily in stimulating innovation processes, as well as in improving the business environment through the design, implementation, and evaluation of innovation policies [17–19]. The innovation systems approach is widespread in Scandinavia and Western Europe in both academic and policymaking contexts. Not only national public administrations but also supranational organizations such as the Organisation for Economic Cooperation and Development (OECD), the European Union (EU), and the World Bank have adopted the NIS approach to develop innovation policies [20, 21].

The systemic approach to innovation may be complemented with other two models: (1) on the one hand, the Triple Helix [22] establishes that the conditions for the innovation process are mainly determined from the relationship between three kinds of agents: academia (science or universities), industry (or firms), and state (government or public sector); (2) on the other hand, the open innovation [23] reinforces the previous models because it considers the firms' boundaries permeable to the exterior, so they can be affected by the external context.

The RIS may be taken into account as a special case of the NIS, arising from the application of a subnational focus to this concept and seeking to reduce the complexity by considering a smaller area. Moreover, while national, international, and sector factors are essential, the regional dimension is also crucial. Therefore, different innovation policies should be applied to different types of regions to deal with particular innovation barriers affecting a given region [24].

The theoretical foundations of the RIS lie in the regional scaling of economic processes and in systemic and evolutionary approaches to innovation and learning. The innovation systems approach considers innovation a systemic and dynamic process that emerges from interactive learning among firms and other organizations such as universities and research centers [25]. Accordingly, subsequent development of the RIS concept has linked research on regional science to evolutionary economics and the evolutionary dynamics of change and adaptation of regions [26, 27], the economics of innovation [28, 29], theories of interactive learning [2], and institutional economics [30].

Regardless of whether the focus is on the institutional and organizational dimensions [7, 30], the systemic approach of innovation [16, 31], or the evolutionary perspective [5, 32, 33], the broad consensus is that innovation policies must consider each region's specificities, which depend on political, economic, and sociocultural factors, as well as the legal, technological, and environmental context [14, 17, 34, 35].

Based on this theoretical framework and focusing on the RIS evolution and possible prospects, the central research question of this study was: what have the main underlying RIS research trends been over time?

Method

Bibliometric analysis

Bibliometrics [36] refers to the quantitative analytical methods used to analyze citations by articles in academic journals. The goal of bibliometrics is to evaluate the impact of

publications based on the extent of their dissemination [37]. The most commonly used bibliometric indicators are the total number of publications, the total number of citations, and h-index [38]. The h-index is a popular indicator among researchers because it combines the number of publications and citations into a single indicator. For example, if an author has an h-index of N , this means that that author has written N documents that have been cited at least N times [39]. The ratio of number of citations received by an article per year (as opposed to total citations of that article) might be the preferred measure to identify the most influential studies, because by only considering the total number of citations, we create a bias toward older documents.

Bibliometric maps are graphical representations of how research fields and topics and individual papers are interrelated [40]. These tools map a research field, helping researchers identify its cognitive structure, evolution, and main actors and providing a clear visualization of results [41]. Analysis of keyword co-occurrence is based on the study of the most common keywords in documents. Thus, a bibliometric map of keyword co-occurrence helps identify the conceptual framework of a research field [42]. Other common bibliometric maps include bibliographic coupling, co-citation, and co-authorship. Bibliographic coupling and co-citation map the relationship between key ideas in a specific scientific domain. Bibliographic coupling [43] occurs when two documents cite the same third document (the number of references shared by citing documents), while co-citation [44] refers to situations where two documents are cited in one or more published articles (the number of times they are cited together). Finally, co-authorship analyzes the number of co-authored documents to study the social structure and research collaboration networks [45]. VOSviewer is used to produce the bibliometric maps presented in this paper [46], although other bibliometric software tools also exist. Each tool has certain advantages and disadvantages [47]. VOSviewer is freely available. Further information can be found at <http://www.vosviewer.com/>.

First, the bibliometric technique of keyword co-occurrence in the selected RIS research documents is used to perform descriptive analysis of the theoretical and conceptual framework of RIS. Then, the total number of citations and the ratio of number of citations per year are calculated for each document to identify the most influential RIS studies. Finally, the most influential studies are reviewed to determine the main trends in RIS research from its beginnings to the present day.

Data

All data were taken from the Web of Science Core Collection (WoS CC) database. This database belongs to Clarivate Analytics. WoS CC is internationally recognized by researchers as a high-quality source of information for searching and evaluating different types of publications and journals [48].

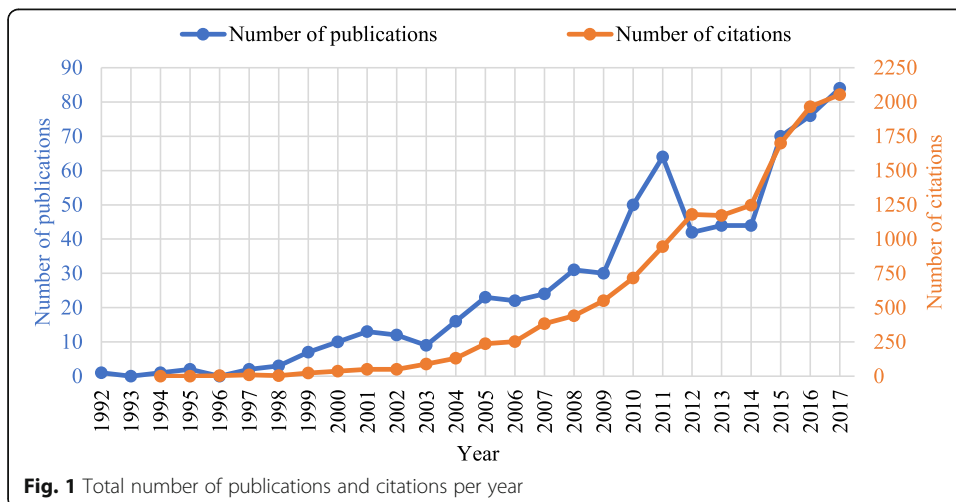
The search implemented in WoS CC to extract the data for this paper was Topic = “regional innovation system” OR “regional innovation systems” OR “regional innovations system” OR “regional innovations systems” OR “regional system of innovation” OR “regional systems of innovation” OR “regional system of innovations” OR “regional systems of innovations”. This search was conducted in April 2019. All years up to and

including 2017 were considered. The search returned 972 studies. Studies exclusively classified as proceedings papers were excluded because most had received 0 citations and were therefore irrelevant to the analysis. Thus, the final set of studies comprised 680 studies. This set of studies consisted of 533 articles, 63 book chapters, 29 proceedings papers, 18 reviews, 18 book reviews, 11 editorials, four books, and four editorial book chapters. Note that WoS allows the same study to be classified as several document types.

This set of 680 studies had received 16,166 citations by the end of 2018, with a ratio of 23.8 citations per study and an h-index of 60. This h-index indicates that 60 of these publications had received at least 60 citations. These 680 studies cover 39 research areas, although there are just five research areas including more than 100 studies: Business & Economics (364), Public Administration (242), Environmental Sciences & Ecology (220), Geography (218), and Urban Studies (131). Note that the same study can cover multiple research areas.

Figure 1 shows the yearly evolution of the total number of publications and the total number of citations. The first RIS research study indexed in WoS CC was published in 1992. “Regional Innovation Systems: Competitive Regulation in the New Europe” [8] is widely accepted as the paper that coined the term “RIS.” Since then, documents have been published every year, except 1993 and 1996. The number of studies each year has oscillated, reaching 23, 50, and 70 studies in 2005, 2010, and 2015, respectively. Although the number of RIS studies increased significantly in 2010 and 2011, with 50 and 64 publications, respectively, a consistent upward trend of annual publications cannot be observed until 2015. The maximum number of studies in a given year was 84 (in 2017).

The annual evolution of the total number of citations increased steadily from 1999 onward, with the exception of 2013. The number of citations decreased from 1179 in 2012 to 1172 in 2013. The 100-, 500-, 1000-, 1500- and 2000-citation thresholds were reached in 2004, 2009, 2012, 2015, and 2017. The maximum number of citations (2054) occurred in 2017. The evolution of the total number of publications and citations per year reflects the scientific community’s growing attention and interest in RIS research.



Results

Conceptual framework: common keywords and co-occurrences

According to Callon et al. [42], analysis of the co-occurrence of keywords is used to study the conceptual structure of a research field. Figure 2 maps the keyword co-occurrence for the most common keywords in RIS research from 1992 to 2017. The map is based on a threshold of 20 occurrences and the 100 most representative links. Table 1 presents the 45 keywords with at least 20 occurrences.

The concepts captured by the keywords are diverse. *Knowledge, innovation, clusters, policy, networks, systems, R&D, industry, and firms* appear to be the most frequently used keywords in RIS research, with more than 80 occurrences each.

The VOSviewer keyword co-occurrence map shows four clusters. Clusters generated by VOSviewer are for guidance and help identify the most connected keywords according to the co-occurrence between them [46]. The principal keywords in these clusters (1–4) are the following: (1) *knowledge, innovation, policy, and systems*; (2) *clusters, networks, and industry*; (3) *R&D, firms, and performance*; and (4) *technology and innovation system*.

Research trends: the most influential RIS articles indexed in WoS CC

Many influential papers on RIS have been published. One method to identify these influential papers is to classify publications based on the number of citations. The number of citations reflects the influence and popularity of the article and the attention it has received from the scientific community [48]. The ratio of number of citations per year was also calculated for all publications because the total number of citations has a certain bias toward older papers that have had longer to accumulate citations.

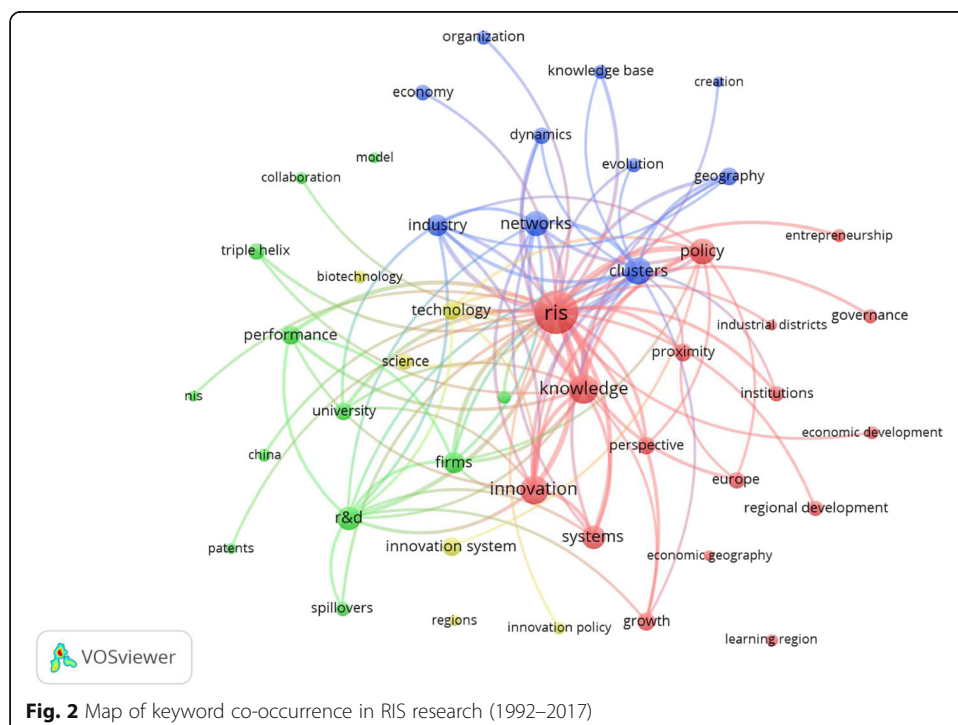


Fig. 2 Map of keyword co-occurrence in RIS research (1992–2017)

Table 1 Most common keywords

R	Kw	Oc	Co	R	Kw	Oc	Co	R	Kw	Oc	Co
1	RIS	311	1284	16	University	54	301	31	Entrepreneurship	32	171
2	Knowledge	144	702	17	Growth	52	228	32	Absorptive capacity	31	154
3	Innovation	138	618	18	Proximity	51	286	33	Economic development	31	152
4	Clusters	124	674	19	Europe	48	259	34	China	31	145
5	Policy	114	519	20	Dynamics	46	260	35	Biotechnology	28	150
6	Networks	106	525	21	Triple helix	44	218	36	collaboration	25	141
7	Systems	98	426	22	Science	42	220	37	Innovation policy	25	117
8	R&D	90	447	23	Institutions	41	242	38	Learning region	24	99
9	Industry	80	435	24	Regional development	41	173	39	Economic geography	21	123
10	Firms	80	419	25	Economy	39	181	40	Patents	21	115
11	Technology	63	351	26	Spillovers	37	235	41	Creation	21	112
12	Performance	61	333	27	Knowledge base	34	183	42	Industrial districts	20	107
13	Innovation system	58	222	28	Organization	33	187	43	NIS	20	96
14	Perspective	57	289	29	Evolution	33	175	44	Regions	20	95
15	Geography	55	318	30	Governance	33	168	45	Model	20	88

R ranking, Kw keyword, Oc occurrences, Co co-occurrences, NIS national innovation system

Table 2 presents the most influential RIS articles indexed in WoS CC based on the total number of citations. To determine the most influential articles, we used two criteria: (1) articles that have received at least 150 citations and (2) articles with a minimum ratio of 13 citations per year.

Table 2 displays 12 articles with at least 150 citations and 14 articles with a minimum ratio of 13 citations per year, resulting in a total of 17 articles. This table includes the ranking by total citations (RTC), the total number of citations (TC), the ratio citations per year (C/Y), and the ranking by citations per year (RCY). Nine of the articles in Table 2 meet both criteria (at least 150 received citations and at least a ratio of 13 citations per year). Surprisingly, the article with the highest ratio of citations per year, focused on entrepreneurial ecosystems, was published recently (in 2017) and has received 106 citations in just 2 years (2017 and 2018).

Finally, RIS research trends are identified by reviewing the most influential articles in this field. This review was based on the aims and scope, and conclusions of the articles (see Table 2). On the basis of the review of the articles' aims, scope, and conclusions, Table 3 presents the main RIS-related topics dealt with by each article. The articles are ordered chronologically within each group. The article review reveals three groups of trends in RIS research.

First, the innovation systems research trend comprises six articles. All were published in the 1990s, except the articles by Todtling and Trippel [24], which focuses on regional-based innovation policies, and Oh et al. [58], which is a critical examination of the fledgling concept of the innovation ecosystem. These articles are especially aimed at exploring the systemic approach of innovation from different perspectives such as institutions, organizations, networks, policies, regulations, or the evolutionary approach.

Table 2 Most influential studies in RIS research

RTC	TC	C/Y	RCY	Article	Aims and scope	Conclusions
1	874	36.4	5	Freeman [21]	To explore the importance of national and regional education systems, industrial relations, technical and scientific institutions, government policies, and cultural traditions for firms to innovate, even in a globalized economy where external international relationships are increasingly important.	Nations, national economies, and national innovation systems are still essential for economic and political development, despite the globalization of the economy. Nevertheless, the interaction of national innovation systems with regional innovation systems and with transnational corporations will become increasingly important.
2	840	38.2	4	Cooke et al. [7]	To verify that most of the scale and complexity problems of national innovation systems regarding the institutional and organizational dimensions may be mitigated by a subnational focus, advocating that regional level capabilities are useful for promoting both systemic learning and interactive innovation.	Learning, which is a key strategic element in any innovative process, has important specific and local characteristics. It can therefore be improved through certain regional institutional changes and properly oriented regional policies.
3	696	49.7	2	Todtling and Trippel [24]	To demonstrate that there is no ideal model for innovation policy but rather that innovation policy depends on each region's characteristics. Three kinds of regions are analyzed: central regions, peripheral regions, and old industrial regions.	Different kinds of regions require different innovation policies and strategies because the conditions for innovation and networking and the innovation barriers differ greatly from one type of region to another.
4	581	34.2	6	Acs et al. [49]	To address the problem of measuring innovation because the innovation process is a crucial aspect of economic growth. Regional analysis of the innovations introduced in the US in 1982 and US patent data from 1982 is performed to demonstrate how patents and innovation counts can be used to measure economically useful new knowledge creation.	The measure of patented inventions provides a fairly reliable measure of innovative activity. This finding supports the use of patent and innovation counts in studies examining technological change.
5	559	39.9	3	Asheim and Coenen [11]	To demonstrate that regional innovation systems must consider the knowledge base of the industries in the area because the innovation processes of firms are determined by their specific knowledge base. Five empirical illustrations from a Nordic comparative project on small and medium-sized enterprises (SMEs) and regional innovation systems are used.	The regionalization of innovation policy enables more accurate consideration of the region's specific context and characteristics in terms of industrial structure, institutional setup, and knowledge base. However, regionalization should not be understood as regionalism by neglecting the embeddedness of regions in a national and transnational framework.
6	376	20.9	8	Muller and Zenker [50]	To study the role and function of knowledge-intensive business services (KIBS) in innovation systems because KIBS produce and diffuse knowledge that is crucial for innovation processes. The results of a postal innovation survey in different French and German regions are used to empirically analyze the role of innovation interactions between KIBS and SMEs for the benefit of their respective knowledge bases and innovation activities.	Interactions between KIBS and SMEs affect innovation processes and activities. The interregional comparison shows that regional differences concerning interactions between SMEs and KIBS lead to differences in innovation capabilities and performance. Besides interregional differences, the French and German innovation systems have a perceptible influence on the interactions between SMEs and

Table 2 Most influential studies in RIS research (*Continued*)

RTC	TC	C/Y	RCY	Article	Aims and scope	Conclusions
						KIBS, their knowledge-related activities, and their innovation capabilities.
7	346	12.8	15	Cooke [8]	To examine the role of regulation as a form of proactive support for industry by focusing on three approaches to regional innovation: (1) Japan, Germany, and France, (2) regional innovation in the UK, particularly in reference to Wales, and (3) changes in the regulatory structure in Wales to improve its regional innovation system.	The key elements of a successfully regulated, networked region include a major network of public and private industrial support institutions, high-grade labor market intelligence and training, rapid diffusion of technology transfer, a high degree of inter-firm networking, and, above all, firms that are receptive to innovation.
8	243	22.1	7	Rodriguez-Pose and Crescenzi [51]	To measure the impact of innovation on regional economic performance in 25 European Union countries by considering the relationships between investment in R&D, patents, and economic growth, the efficiency of regional innovation systems, and the geographical diffusion of regional knowledge spillovers.	Proximity is important for the transmission of economically productive knowledge because spillovers are affected by strong distance decay effects. A region can rely on both internal and external sources of innovation, but the socioeconomic conditions to maximize the innovation potential of each region are necessarily internal.
9	212	10.1	24	Cooke et al. [5]	To analyze the processes and conditions that characterize the institutional and organizational dimensions, the infrastructures, and the cultural superstructure for the specification of strong regional innovation systems.	Regional innovation systems where firms and other organizations are systematically engaged in interactive learning through an institutional context provide the strongest potential for regions to innovate.
10	206	20.6	9	Ter Wal and Boschma [52]	To demonstrate that social network analysis has a huge potential to enrich the literature on clusters, regional innovation systems, and knowledge spillovers. Network analysis techniques using primary (survey) and secondary (patent) data are described.	Social network analysis is a valuable tool in economic geography to empirically investigate the structure and evolution of interorganizational interactions and knowledge flows within and across regions.
11	193	13.8	12	Cooke [53]	To assess social scientific debate about the origins and nature of innovation at a regional level. The following models are reviewed: (1) the triple helix model, which focuses on the role of entrepreneurial universities in innovation in relation to industry and government, (2) new regionalism, which stresses the importance of institutions, industry, and science in regional economic development, and (3) globalization 2, which is a newer theory of economic geography in the knowledge economy based on regional knowledge capabilities.	In the knowledge economy based on regional knowledge capabilities, globalization has evolved from the globalization 1 model, which was directed by multinational corporations and multilateral trade institutions, to the globalization 2 model, which is driven by multinationals' quest for exploitable knowledge in knowledgeable regions, often depending on public research funding. Therefore, the globalization 2 model is a ground-up knowledge-driven evolution of the earlier top-down globalization 1 model.
12	166	11.1	18	Fritsch and Franke [54]	To investigate the impact of knowledge spillovers and R&D cooperation on innovation activities in three German regions.	The article concludes that R&D cooperation plays a minor role as a medium for knowledge spillovers, but it cannot explain how innovation-relevant knowledge spillover occurs within a region.

Table 2 Most influential studies in RIS research (*Continued*)

RTC	TC	C/Y	RCY	Article	Aims and scope	Conclusions
14	132	13.2	13	Hansen and Niedomysl [55]	To analyze the migration of the creative class because talented people are a potential source of knowledge creation and exploitation. The paper is focused on the migration of the creative class in Sweden.	The creative class tends to migrate more than non-creatives, but the difference is marginal. Therefore, there is no empirical support for the influential creative class theory, which posits that talent is highly mobile.
16	127	15.9	11	Yam et al. [56]	To explore the relationship between the RIS and the firm's innovation system because firms that better utilize sources of information available in their RIS achieve superior performance. The available sources of information within a given RIS include external sources and external expert organizations, also known as knowledge-intensive business services (KIBS). Data on a region of Hong Kong were obtained through a mailed survey using a self-administered questionnaire.	External sources supported by KIBS have a positive relationship with all firms' technological innovation capabilities. This finding provides empirical evidence of the bridging function of KIBS in facilitating the use of sources of information for the enhancement of technological innovation capabilities. Also, KIBS have a positive relationship with external sources because better use of KIBS helps firms use external sources of information. This finding highlights the source of innovation role of KIBS.
21	106	53.0	1	Spigel [57]	To theoretically develop the concept of entrepreneurial ecosystems to understand the processes through which ecosystems emerge, change, and influence the activities of entrepreneurial actors. The illustrative cases of the Canadian cities of Waterloo (Ontario) and Calgary (Alberta) are used to explore different possible configurations of entrepreneurial ecosystems.	Entrepreneurial ecosystems can be defined as a composition of cultural (supportive culture, and histories of entrepreneurship), social (worker talent, investment capital, networks, and mentors and role models), and material (policy and governance, universities, support services, physical infrastructure, and open markets) attributes that provide benefits and resources to entrepreneurs, where the relationships between these attributes reproduce the ecosystem.
75	48	16.0	10	Oh et al. [58]	To review the recently emerged concept of innovation ecosystems, which has quickly spread among policymakers.	The concept of the innovation ecosystem adds little to the traditional concept of the innovation system. Moreover, the innovation ecosystem is not yet a clearly defined concept and much less a theory.
140	26	13.0	14	Audretsch and Belitski [59]	To investigate variation in entrepreneurial activity in 70 European cities using exploratory factor analysis and structural equation modeling for regional systems of entrepreneurship. The survey data capture individual perceptions based on the Eurostat statistical database and the Regional Entrepreneurship and Development Index (REDI). A complex model is developed based on the number of start-ups in a city as the dependent variable; culture and norms, physical infrastructure and amenities, formal institutions, information technologies and Internet access, the Melting Pot index, and the demand and workforce	The regional context, proxied by the REDI, and local context, proxied by the framework conditions (the local socioeconomic, informational, and institutional aspects) of the entrepreneurship ecosystem, are complementary and influence the startup rate in cities. Adding information technologies and Internet access to existing models of regional entrepreneurship systems reveals the strong association between information and communications technologies and entrepreneurship. New

Table 2 Most influential studies in RIS research (*Continued*)

RTC	TC	C/Y	RCY	Article	Aims and scope	Conclusions
					as six explanatory variables; and the REDI as the main control variable.	policies for developing urban entrepreneurial ecosystem models can exploit both the REDI at a regional level and the framework conditions of entrepreneurial ecosystems at a local level.

Second, the knowledge management research trend—knowledge management can be defined as the process of creating, sharing, using, and managing an organization’s knowledge and information [60]—comprises nine articles, all published in the 2000s, except the article by Yam et al. [56]. This research trend focuses on the importance of economically useful knowledge in the regional innovation process, including the study of knowledge creation, knowledge spillovers, knowledge diffusion, knowledge flows, knowledge bases, knowledge-intensive business services (KIBS), R&D, patents, and clusters [61–63].

The third trend is that of entrepreneurial ecosystems, which are “combinations of social, political, economic, and cultural elements within a region that support the development and growth of innovative start-ups and encourage nascent entrepreneurs and other actors to take the risks of starting, funding, and otherwise assisting high-risk ventures” (Spigel, p. 50) [57]. This research trend comprises two articles published recently (in 2017). The fact that only two articles have followed this research trend is probably because it is a recent research trend. Consequently, it requires more research and development. Entrepreneurship is a potential source of innovation that has become a popular topic in recent years because countries and regions must innovate and

Table 3 Main trends in RIS research

Article	Main RIS-related topic	Main research trend
Cooke [8]	Competitive regulation in RIS	Innovation systems
Freeman [21]	Relations, institutions, policies, traditions, and networks in NISs and RISs	
Cooke et al. [7]	Institutional and organizational dimensions in RIS	
Cooke et al. [5]	An evolutionary approach to RISs	
Todtling and Trippl [24]	Regional-based innovation policies	
Oh et al. [58]	Innovation ecosystems	
Muller and Zenker [50]	Knowledge-intensive business services (KIBS)	Knowledge management
Acs et al. [49]	Knowledge creation and patents	
Fritsch and Franke [54]	Knowledge spillovers	
Asheim and Coenen [11]	Knowledge base	
Cooke [53]	Exploitable knowledge	
Rodriguez-Pose and Crescenzi [51]	Knowledge spillovers	
Ter Wal and Boschma [52]	Knowledge flows	
Hansen and Niedomysl [55]	Knowledge creation and creative class	
Yam et al. [56]	Knowledge-intensive business services (KIBS)	
Spigel [57]	Entrepreneurial ecosystems	Entrepreneurial ecosystems
Audretsch and Belitski [59]	Urban entrepreneurial ecosystems	

generate competitive advantages based on local agents, processes, and dynamics to compete in the globalized world economy [64, 65].

Co-citations between the most influential RIS articles

This section presents the results of analysis of citations to the 17 most influential RIS articles. The aim of this analysis is to identify the relationships between these articles based on the number of times they are cited together. A total of 4199 studies indexed in WoS CC have cited these 17 most influential articles.

Figure 3 shows the VOSviewer co-citation map for the most influential articles based on the citations appearing in the 4199 citing studies. This figure shows the name of only the first author of each document, in addition to the publication year and the journal where the article was published. The visibility of labels in VOSviewer is not optimized, so some labels may not be visible because of a lack of space [46]. However, Table 4 shows the publication year of each article, its authors, and the full title of the article. Table 4 presents the 17 most influential articles grouped by the clusters in VOSviewer to identify all nodes of Fig. 3, including the two nodes that have no associated text in the figure.

Table 4 is ordered chronologically within each cluster and displays data for the following variables: total number of citations (TC) received by each article; total number of co-citations (TCo), which counts the times that each article has been cited with any other article; number of co-citations between the 17 most influential articles (Co), which counts the times that each article has been cited with any of the other 16 most influential RIS articles; number of co-citation links of each article with the other 16 most influential RIS articles.

The number of co-citations and links between the 17 most influential RIS articles can be used to identify how these articles are interconnected. Interestingly, the articles by Cooke et al. [7] and Asheim and Coenen [11] are the only articles that have co-citations with all the other most influential RIS articles. The articles by Hansen and Niedomysl [55] and Yam et al. [56] are the articles with the fewest links (six links). Articles with more citations are more likely to have more co-citations and links.

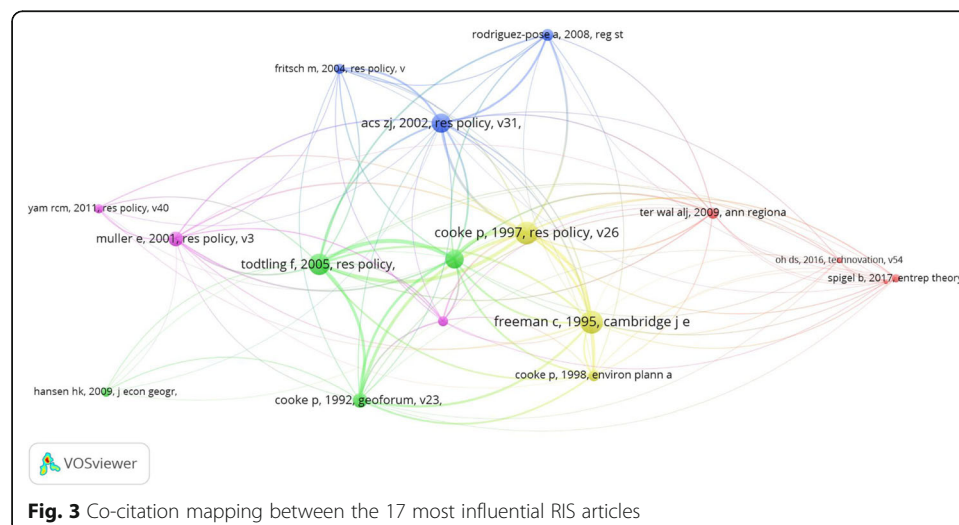


Fig. 3 Co-citation mapping between the 17 most influential RIS articles

Table 4 Co-citation analysis between the 17 most influential RIS articles

PY	Author	Article title	TC	TCo	Co	Links
1992	Cooke P	Regional innovation systems: competitive regulation in the new Europe	346	6619	271	15
2005	Todtling F, Trippel M	One size fits all? Towards a differentiated regional innovation policy approach	696	12555	401	15
2005	Asheim BT, Coenen L	Knowledge bases and regional innovation systems: comparing Nordic clusters	559	10869	403	16
2009	Hansen HK, Niedomysl T	Migration of the creative class: evidence from Sweden	132	1449	11	6
1995	Freeman C	The national system of innovation in historical perspective	874	10938	226	15
1997	Cooke P, Uranga MG, Etxebarria G	Regional innovation systems: institutional and organisational dimensions	840	15535	524	16
1998	Cooke P, Uranga MG, Etxebarria G	Regional systems of innovation: an evolutionary perspective	212	4277	156	13
2001	Muller E, Zenker A	Business services as actors of knowledge transformation: the role of KIBS in regional and national innovation systems	376	4985	87	12
2005	Cooke P	Regionally asymmetric knowledge capabilities and open innovation exploring 'Globalisation 2' - a new model of industry organisation	193	3229	93	11
2011	Yam RCM, Lo W, Tang EPY, Lau AKW	Analysis of sources of innovation, technological innovation capabilities, and performance: an empirical study of Hong Kong manufacturing industries	127	1403	26	6
2002	Acs ZJ, Anselin L, Varga A	Patents and innovation counts as measures of regional production of new knowledge	581	10572	209	15
2004	Fritsch M, Franke G	Innovation, regional knowledge spillovers and R&D cooperation	166	3248	82	10
2008	Rodriguez-Pose A, Crescenzi R	Research and development, spillovers, innovation systems, and the genesis of regional growth in Europe	243	5236	122	10
2009	Ter Wal ALJ, Boschma RA	Applying social network analysis in economic geography: framing some key analytic issues	206	4373	63	13
2016	Oh DS, Phillips F, Park S, Lee E	Innovation ecosystems: a critical examination	48	647	22	9
2017	Spigel B	The relational organization of entrepreneurial ecosystems	106	1230	36	10
2017	Audretsch DB, Belitski M	Entrepreneurial ecosystems in cities: establishing the framework conditions	26	401	28	10

PY year of publication, TC total number of citations, TCo total number of co-citations, Co number of co-citations between the 17 most influential RIS articles

Surprisingly, however, the most recent articles [57, 59] have a significant number of links (10 links).

Conclusions

This paper identifies the main research trends in the RIS literature using bibliometric analysis of RIS studies indexed in WoS CC. The search was conducted in April 2019 and considered all years up to and including 2017. The search returned 972 studies. Proceedings papers were discarded because most had received 0 citations. After these proceedings papers had been removed, 680 studies were left. This set of studies had received 16,166 citations by the end of 2018, with an h-index of 60. These values reflect the high influence, popularity, and impact of RIS research among academics. Business & Economics, Public Administration, Environmental Sciences & Ecology, Geography, and Urban Studies are the research areas with most published RIS studies. The

literature review indicates that this field covers a diverse range of concepts. Based on this review and the bibliometric analysis, three underlying research trends can be identified.

First, the general conceptual framework of RIS was built by analyzing the most common keywords and their co-occurrences in the set of 680 studies. *Knowledge, innovation, clusters, policy, networks, systems, R&D, firms, and industry* were the key concepts.

Second, the most influential RIS articles were identified by calculating the total number of citations and the ratio of number of citations per year of each article. The criteria of having at least 150 citations or a minimum ratio of 13 citations per year were then applied to identify the 17 most influential articles published between the years 1992 and 2017.

Third, the review of these articles reveals three main research trends that have dominated RIS research since its beginnings to the present day. The first is innovation systems research, which was mainly conducted in the 1990s. Innovation systems research focuses on the systemic approach of innovation in different contexts in terms of institutions, organizations, networks, policies, or regulations. The second is knowledge management research, which has been prominent since the beginning of the 2000s. This area includes knowledge creation, knowledge spillovers, knowledge flows, knowledge-intensive business services (KIBS), and different knowledge bases. It also considers other knowledge-related activities, processes, and agents such as R&D, patents, and clusters. The third is entrepreneurial ecosystem research, which has emerged in the last few years because of the key role of the social and economic context in local and regional entrepreneurship. The analysis of co-citations between the most influential RIS articles and the reviews of these articles shows that these research trends are strongly interconnected and are linked to other concepts such as R&D, firms, industry, innovation policy, clusters, patents, and technology. In addition, the high number of co-citations of the 17 most influential RIS articles and the significant numbers of co-citation links among them corroborate this finding.

Finally, this study has some limitations. First, RIS documents that are not indexed in WoS CC were not included in the set of studies. Use of a different database and the inclusion of proceedings might have affected the results. Second, although the co-citation analysis reveals a relationship between the co-cited articles, this relationship may not necessarily imply similarities between the studies. For instance, co-cited articles may be cited in two unrelated parts of the citing document. Although researchers should consider these limitations, this paper nonetheless sheds light on the field of RIS research.

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Authors' contributions

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Availability of data and materials

The datasets generated and/or analyzed during the current study are available in the Web of Science database.

Competing interests

The authors declare that they have no competing interests.

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