Assessing the origins, evolution and prospects of national innovation systems

Authors: Pedro López-Rubio, Norat Roig-Tierno, Francisco Mas-Verdú

Abstract

This paper assesses the origins, evolution and prospects of national innovation systems (NISs) using bibliometric techniques. All available data in the Web of Science Core Collection database up to and including the year 2017 are considered in the analysis. Both the number of NIS studies and the number of citations of these studies reflect the influence of this topic and the attention and growing interest of the scientific community, public administrations and international organisations in NIS research. The co-citation analysis of cited references provides a historical view of the origins of the NIS, and the bibliographic coupling between the documents gives a current overview of the status of NIS research. Our approach highlights the fact that many studies belong to previous, well-developed research streams. We also examine the topics covered by recent studies in each stream and the evolution of the most common keywords over time. In conclusion, we propose a research agenda based on three pillars: (1) the adaptation of innovation systems to the current global economic crisis and the application of the Quintuple Helix model to deal with this new scenario; (2) the adaptation of innovation systems to developing countries; and (3) the specific fit of entrepreneurship and entrepreneurial innovations into NIS research.

Keywords: National innovation systems, Quintuple Helix, adaptation, entrepreneurship, bibliometrics
JEL Classification: O30 O31 O38

1. Introduction

The concept of the national innovation system (NIS; Freeman, 1987; Lundvall, 1992; Nelson 1993) originated between the end of the 1980s and the middle of the 1990s, when it became a popular topic in debates on European industrial policy. Bengt-Åke Lundvall was the first scholar to use this term, noting that the idea was actually proposed by Friedrich List in his book *The National System of Political Economy* (List, 1841). 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 (1987), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, edited by Lundvall (1992), and *National Innovation System: A Comparative Analysis*, edited by Nelson (1993).

According to these pioneers, the NIS can be defined as 'the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies' (Freeman, 1987, p.1), 'the organizations and institutions involved in search and exploring such as R&D departments, technological institutes and universities, but also all parts and aspects of the economic structure and the institutional setup affecting learning as well as searching and exploring' (Lundvall, 1992, p. 12) or 'the set of institutions whose interactions determine the innovative performance of national firms' (Nelson, 1993, p. 4). These definitions imply that the NIS has two main objectives: 1) to show international differences or similarities in the ability of countries to innovate and be at the technological frontier and 2) to offer policy suggestions to support firms' innovative activities (Vertova, 2014).

Since the concept was coined, an international body of literature has documented the growing influence of the NIS approach. Several supranational organisations, most notably the Organisation for Economic Cooperation and Development (OECD), but also the European Union (EU) through the European Commission, as well as the World Bank, have embraced the concept of the NIS as an integral part of their analytical perspective. The innovation systems approach is also widespread in Scandinavia and Western Europe in academic and policymaking contexts (Lundvall et al., 2002).

Academic studies of NISs initially aimed at understanding differences in technological development and the profiles of technological specialisation between countries. However, since the beginning of the 2000s, academic studies have increasingly focused on the relationship between the output of the innovation system and the factors that influence this system (e.g., Edquist, 2004; Lundvall, 2007; Bergek et al., 2008). Innovation, diffusion and use of technology, also known as technological dynamics, are the outputs of innovation systems, resulting from influences from abroad, activities within the business sector and interaction with other actors within society. A wide range of processes influence a country's technological dynamics. These processes include knowledge, skills, demand, finance and institutions, and they are affected by numerous policies and actors (Fagerberg, 2017). Consequently, NISs may differ greatly from one country to another, and a policy mix that works in one context may not suit another (Flanagan, Uyarra & Laranja, 2011; Borras & Edquist, 2013).

In view of the extent of the literature, the main goal of this study is to structure a conceptual framework for this research field, identifying how the concept has been established in the literature and how it has evolved. This paper describes the foundations and evolution of the NIS literature, giving scholars a stronger and more holistic view of the systemic approach to innovation.

We focus on a single research question:

RQ1. Based on the origins of the NIS, how has this research field evolved and what are its prospects?

To answer this question, we use a literature review approach. This approach is based on robust empirical bibliometric analysis followed by qualitative analysis of core documents. Using the key bibliometric methods of performance indicators, science mapping of bibliographic coupling, co-citations and keyword co-occurrence, we identify the most productive and influential authors, institutions and countries, as well as the historical development of the literature and the main streams within it. Bibliometric analysis is also used as a basis for qualitative analysis of the core literature, which in turn is used to build the narrative for this study.

This paper is structured as follows. Section 2 describes the method. Section 3 presents the results. Finally, Section 4 summarises the key conclusions.

2. Method

In this study, bibliometric techniques were used to develop a comprehensive overview of NIS research. The data source was the Web of Science Core Collection (WoS CC) database, which belongs to Clarivate Analytics. The WoS CC database is a digital scientific database that is internationally recognised by researchers for its high quality. It has become one of the main tools for searching for and evaluating different types of publications and journals. It contains more than 15,000 journals and 50,000,000 classified documents sorted into 251 categories and 150 thematic research areas (López-Rubio et al., 2018).

The search performed in the WoS CC was Topic = ‘national innovation system’ OR ‘national innovation systems’ OR ‘national innovations system’ OR ‘national innovations systems’ OR ‘national system of innovation’ OR ‘national systems of innovation’ OR ‘national system of innovations’ OR ‘national systems of innovations’. This search was conducted in December 2018 and covered all years up to and including 2017. The search returned 1,107 documents. This set of documents comprised 580 ‘articles’, 334 ‘proceedings papers’, 69 ‘articles; book chapters’, 58 ‘articles; proceedings papers’, 26 ‘book reviews’, 24 ‘reviews’, seven ‘editorial materials’, four ‘books’, two ‘news items’, one ‘book chapter’, one ‘letter’ and one ‘meeting abstract’. The WoS allows one document to be classified as several types.

These 1,107 documents span 57 research areas. Only 18 of these areas are associated with more than 10 studies. As with document types, one study can cover multiple research areas. Figure 1 shows these 18 major research areas. Business Economics is the primary research area, with substantially more documents than any other. This area is followed by Public Administration (254). These results show that NIS studies generally have a dual perspective that spans business administration and management as well as public governance.

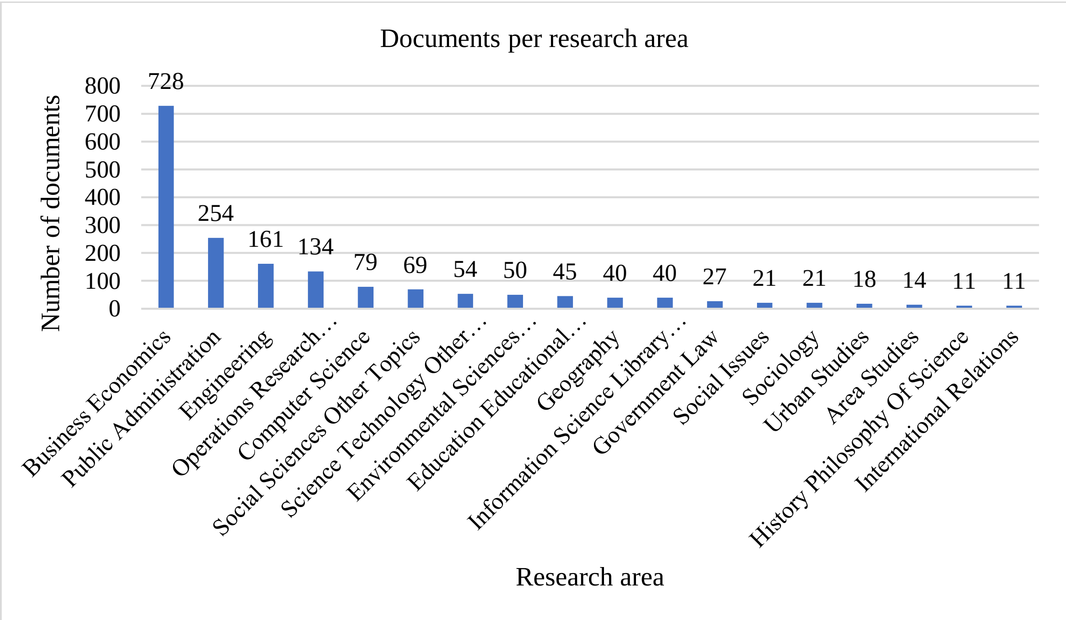

Figure 1. Research areas with more than 10 NIS studies indexed in the WoS CC.

The documents corresponding to these results were analysed using two key bibliometric procedures: performance analysis and science mapping (Cobo et al., 2011). Bibliometric performance analysis uses a wide range of indicators and techniques. These indicators include the number of published studies and the number of citations (where publications are counted by country, university or author), the h-index, and word frequency analysis. The h-index is a popular indicator amongst researchers. The calculation of the h-index involves the number of publications and citations. A variable (author, journal, country, institution, etc.) has an h-index of N when N documents have been cited at least N times (Hirsch, 2005). However, the h-index has limitations. For example, this indicator does not benefit researchers who have extremely cited documents and moderate productivity since they would have a similar or equal h-index as researchers with moderate or highly cited papers. In this study, a range of bibliometric indicators were calculated because certain limitations can be overcome by evaluating the research field using more than one indicator (Martin, 1996; Egghe, 2006).

Science mapping is another key procedure in bibliometrics. Science mapping consists of graphical representations of how research fields, topics and individual papers are interrelated. A bibliometric map represents a scientific field by determining its cognitive structure, evolution and main actors (Small, 1999). The most commonly used bibliometric maps include bibliographic coupling (Kessler, 1963), co-citation analysis (Small, 1973) and keyword co-occurrence in documents (Callon et al., 1983).

Bibliographic coupling measures the shared intellectual background of documents based on the references shared among documents (Kessler, 1963). This approach suggests that the more shared references there are, the stronger the theoretical foundations shared by the two documents will be. According to Glänzel and Czerwon (1996), bibliographic coupling highlights hot topics. Over a long analysis period, it underscores topical citing papers. Bibliographic coupling links documents with a similar research focus (Jarvening, 2007), revealing the knowledge structure of a field. By calculating the bibliographic coupling strength for all the documents in our data set, we were able to cluster and visualise networks of shared knowledge. These calculations were performed using the document as the unit of analysis and a full counting method.

Co-citation analysis identifies the shared background of the publications in a data set. Two documents are co-cited if one or more documents cite both articles (Small, 1973). The weight of co-citation is based on the count of articles that co-cite the two documents. Co-citation analysis was performed using the full counting method and the references as the unit of analysis. Thus, co-citation analysis creates a network of cited documents rather than linking the documents in the data set (Garfield, 2001).

Using bibliographic coupling and co-citation analysis in parallel allowed us to observe the structure of both the theoretical background and the current challenges of research in this area. In this study, co-citation analysis offers a historical view of the origins of this field, whilst bibliographic coupling gives a current overview of knowledge in this area (Youtie et al., 2013; Suominen et al., 2019).

Finally, keyword co-occurrence was used to study the conceptual structure of this research field based on the keywords of documents and their evolution over time (Callon et al., 1983).

VOSviewer software (Van Eck & Waltman, 2010) was used to perform the science mapping analysis and to analyse each network cluster. Other science mapping software tools are also capable of performing this analysis (Cobo et al., 2011). Core documents were identified not only by calculating the number of connections but also by evaluating how valuable the connections are. For each main stream in the NIS literature, five documents were selected for evaluation. These documents were selected based on their citation scores, selecting the highest in each cluster.

The clusters under analysis were then labelled. Each of the authors individually read the five most cited documents in each cluster. The authors then independently determined the main research streams. Finally, they worked towards a consensus until agreement was reached on the label for each cluster. In the labelling process, the researchers considered all the documents in a cluster and used the network measures to evaluate the weighting of each individual document.

3. Results

3.1. Publications and citations in NIS research

The search was conducted in December 2018. It returned 1,107 documents indexed in the WoS CC between 1990 and 2017. Up to 2017, these 1,107 documents had received 16,268 citations, equating to 16.2 citations per study. The h-index was 64.

Figure 2 shows the publications and citations per year. The first NIS research study indexed in the WoS CC was published in 1990. One study was also published each year in 1991 and 1992. The first study, 'Management of national technology programs in a newly industrialised country – Taiwan' (Chiang, 1990), addresses the eight national technology programmes launched in Taiwan in the early 1980s and the differences between Taiwan's experience in these programmes and those of the most industrialised countries. The second document, the book *How do National Systems of Innovation differ? A critical analysis of Porter, Freeman, Lundvall and Nelson* (McKelvey, 1991), analyses the approaches of the pioneers of NIS. The third document, the article 'The U.S. National Innovation System: Origins and prospect for change' (Mowery, 1992), analyses the early U.S. NIS and explores how it should evolve given the international economic and technological environment emerging at the time.

From 1993 to 2006, the annual number of publications ranged from 4 to 35. This number oscillated, exceeding the 50-study threshold in 2007. Since 2012, there has been a continuous upward trend of annual publications, starting with 55 studies in 2012. The 100-study threshold was surpassed in 2017, when the maximum (119 studies) was achieved. A substantial increase in NIS studies took place in 2007, although the annual upward trend did not begin until 2012. According to Figure 2, the evolution of citations reflects a consistent year-on-year increase, except from 2012 to 2013, when the number of citations decreased from 1,342 to 1,259. The 500- and 1,000-citation thresholds were surpassed in 2007 and 2010, respectively. The maximum number of citations (2,296) occurred in 2017.

Overall, both the number of NIS studies and the number of citations of these studies reflect their influence and the attention and growing interest of the scientific community in NIS research. This interest has been especially pronounced since 2007, when the 50-study and 500-citation thresholds were broken.

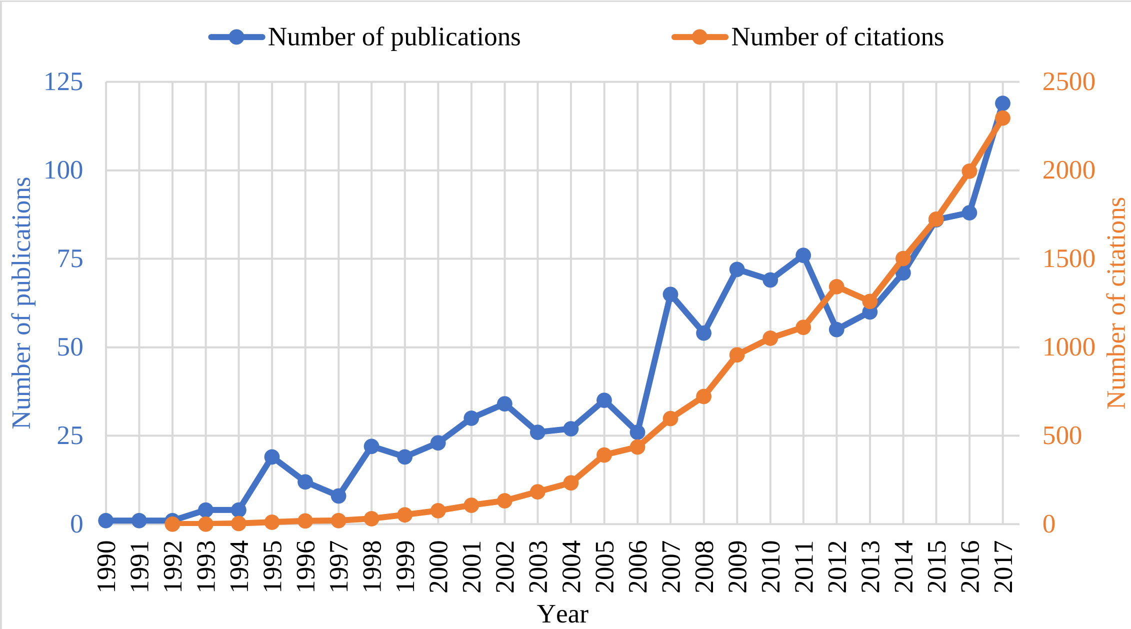

Figure 2. Number of publications and citations of NIS research by year.

3.2. *The most productive and influential authors in NIS research*

Since its emergence, NIS research has been characterised by increasing participation by researchers. One critical issue in developing an overview of NIS research is to determine the most productive and influential authors in this field. Some well-known authors may not appear because of the nature of this classification. Their absence may be a consequence of the year in which certain journals were indexed in the WoS CC or the fact that certain popular books are not indexed in the WoS. The classification in Table 1 shows the 17 authors with at least three studies and 100 citations. The classification is sorted by total citations. Where more than one author has the same number of citations, the order is based on the number of studies. The h-index is a composite indicator that combines productivity and influence. In contrast, citations per study is simply the ratio of the total number of studies to the total number of citations.

Lundvall has the most NIS studies indexed in the WoS CC. Lundvall also has the best combination of productivity and influence, with an h-index of 5. This h-index is shared by Mowery, Archibugi and Autio. The lists of scholars with the most citations and citations per study are both headed by Freeman. Although Freeman has only three NIS studies indexed in the WoS CC, this scholar has many more citations than the other authors in the list. The author with the second highest number of citations is Lundvall, with 705 citations, followed by Mowery, Archibugi and Autio.

R	Author	Affiliation	Country	TS	TC	h	C/S
1	Freeman C	Univ Sussex	UK	3	1,086	3	362.0
2	Lundvall BA	Aalborg Univ	Denmark	8	705	5	88.1
3	Mowery DC	UC Berkeley	USA	6	426	5	71.0
4	Archibugi D	CNR	Italy	7	404	5	57.7
5	Autio E	Imperial College London	UK	6	354	5	59.0
6	Liu XL	Chinese Acad Sci	China	4	294	3	73.5
7	Kenney M	UC Berkeley	USA	4	277	4	69.3
8	Niosi J	Univ Quebec Montreal	Canada	7	245	4	35.0

9	Michie J	Univ Oxford	UK	4	233	3	58.3
10	Fagerberg J	Univ Oslo	Norway	4	222	4	55.5
11	Motohashi K	Univ Tokyo	Japan	4	186	3	46.5
12	Dodgson M	Univ Queensland	Australia	3	175	3	58.3
13	Kaiser R	Univ Siegen	Germany	3	122	2	40.7
14	Vanhaverbeke W	Hasselt Univ	Belgium	3	121	3	40.3
15	Intarakumnerd P	Grad Inst Policy Studies GRIPS	Japan	3	116	2	38.7
16	Chen KH	Chinese Acad Sci	China	3	101	2	33.7
17	Guan JC	Chinese Acad Sci	China	3	101	2	33.7

Table 1. The most productive and influential authors in NIS research.

Notes: R = ranking; TS = total studies; TC = total citations; h = h-index; C/S = citations per study.

To strengthen the analysis, science mapping of the author co-citations was conducted. Author co-citation analysis reveals authorship structures and connections between the authors who are cited together (co-cited) most frequently (White & Griffith, 1981). Figure 3 presents the results of this analysis. A threshold of 55 citations was used, and the 100 most representative links were considered. Figure 3 confirms the importance of Lundvall (849 citations with a total link strength of 10,131) and Freeman (727 citations with a total link strength of 9,414) in NIS research. The size of the circles associated with these authors and their centrality in Figure 3 are notable. However, this map also shows other eminent authors such as Nelson (affiliated with Columbia University in the United States; 760 citations with a total link strength of 9,814), the OECD (728 citations with a total link strength of 7,161) and, to a lesser extent, Edquist (affiliated with Lund University in Sweden; 326 citations with a total link strength of 4,484). In addition to the OECD, two further international organisations (the European Commission and the World Bank) appear in the co-citation map of authors.

The results from Table 1 and Figure 3 show that the most influential authors work in institutions in Europe or the United States. Moreover, international organisations, especially the OECD, are prominent exponents of NIS research. These findings reveal that the NIS research field has gained considerable attention and exerts a growing influence amongst international organisations, the scientific community and public administrations in developed countries with a strong focus on innovation policies and activities.

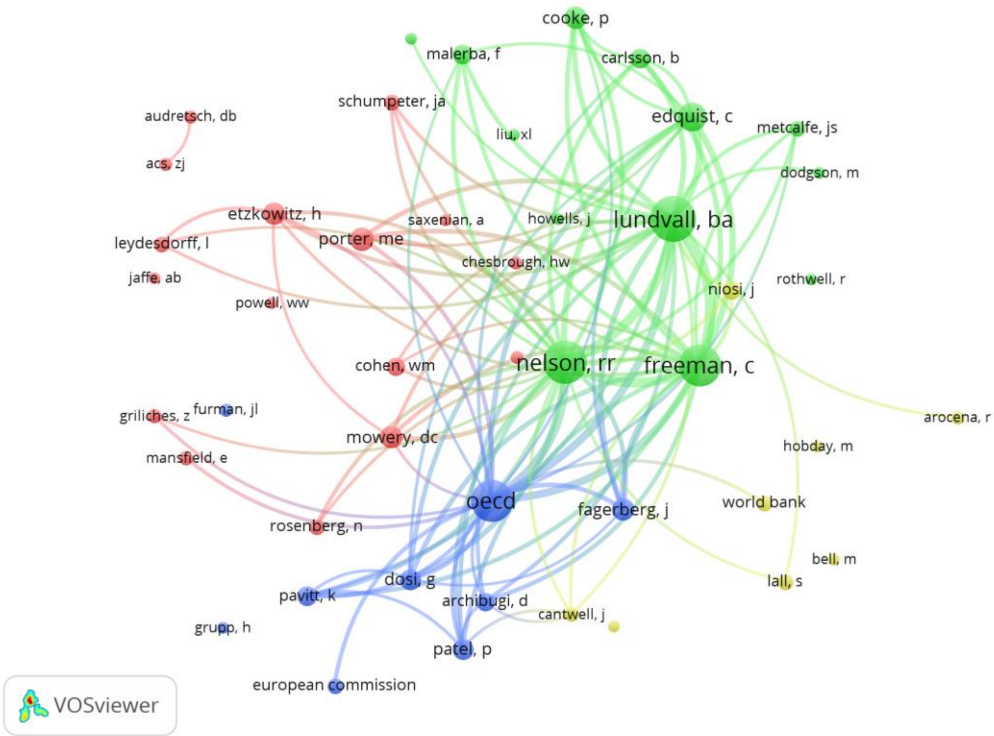

Figure 3. Co-citation map of authors.

3.3. *The most productive and influential institutions and countries in NIS research*

Table 2 lists the most productive and influential institutions according to the total number of studies by affiliated authors. The list shows the 18 institutions with at least seven NIS studies and 100 citations. Most are in Europe (13) and Asia (4).

According to Table 2, the University of Sussex (where Freeman is affiliated) has the most studies (18), the most citations (1,420) and the best balance between productivity and influence (h-index = 11). Aalborg University (where Lundvall is affiliated) has the second most studies (16) and citations (916) and the third highest h-index (7). The University of California Berkeley, Erasmus University of Rotterdam, Seoul National University and Utrecht University also have an h-index of 7. The University of Manchester has the second-best combination of productivity and influence (h-index = 9) and is the third most productive university with 14 studies.

As mentioned earlier, the University of Sussex has the most citations (1,420), followed by Aalborg University (916), Fraunhofer Gesellschaft (916), the University of Cambridge (884) and the University of California Berkeley (638). Interestingly, some of these institutions are also highly ranked in terms of citations per study. The University of Cambridge has an average of 126.3 citations, followed by Fraunhofer Gesellschaft (91.6), the University of California Berkeley (79.8) and the University of Sussex (78.5).

R	Institution	Country	TS	TC	h	C/S	ARWU	QS
1	Univ Sussex	UK	18	1,420	11	78.9	201–300	301–500
2	Aalborg Univ	Denmark	16	916	7	57.3	201–300	301–500
3	Univ Manchester	UK	14	520	9	37.1	34	35

4	Chinese Acad Sci	China	12	117	4	9.8	-	-
5	Lund Univ	Sweden	12	102	5	8.5	101–150	141–150
6	Fraunhofer Gesellschaft	Germany	10	916	5	91.6	-	-
7	Univ Oslo	Norway	10	283	6	28.3	62	201–250
8	Seoul Natl Univ	South Korea	10	219	7	21.9	101–150	23
9	Aalto Univ	Finland	9	240	5	26.7	301–400	201–250
10	CNRS	France	9	174	5	19.3	-	-
11	UC Berkeley	USA	8	638	7	79.8	5	8
12	CNR	Italy	8	467	6	58.4	-	-
13	Erasmus Univ Rotterdam	Netherlands	8	248	7	31.0	79	141–150
14	Univ Tokyo	Japan	8	210	4	26.3	22	19
15	Utrecht Univ	Netherlands	8	198	7	24.8	51	201–250
16	Univ Cambridge	UK	7	884	5	126.3	3	7
17	PSL Res Univ Paris Comue	France	7	160	4	22.9	-	-
18	Univ Chinese Acad Sci CAS	China	7	101	3	14.4	-	-

Table 2. The most productive and influential institutions in NIS research.

Notes: R = ranking; TS = total studies; TC = total citations; h = h-index; C/S = citations per study; ARWU = Academic Ranking of World Universities 2018; QS = Quacquarelli Symonds University Ranking 2019.

Regarding the country analysis and based on the premise that research and innovation foster economic development and growth, public administrations increasingly focus on innovation policy and the NIS (OECD, 2011, 2015; European Commission, 2014). To develop a complete picture of NIS research, this section analyses the geographical origin of NIS publications. Some researchers change their affiliations over their working life and may have several affiliations at the same time. Therefore, a single author may have publications corresponding to two or more countries. In this analysis, country affiliation refers to the country where the author was working at the time the relevant document was published.

Table 3 presents the 23 countries with at least 15 NIS studies. This table includes the total number of NIS studies, total number of citations received by these studies, h-index, citations per study, 2018 Global Innovation Index (GII), 2018 Global Competitiveness Index (GCI), population in millions, gross domestic product (GDP) in billions of U.S. dollars and GDP per capita in U.S. dollars. The GII is an innovation performance index co-published by Cornell University, INSEAD Business School and the World Intellectual Property Organization (WIPO). It is calculated for 126 countries and is composed of 80 indicators. More detailed information can be found at https://www.globalinnovationindex.org. The GCI is a competitiveness index published by the World Economic Forum. It covers 140 countries and 98 indicators. This index can be consulted at https://www.weforum.org. Data on population, GDP and GDP per capita were collected for the year 2017. These data were gathered from the International Monetary Fund website (https://www.imf.org). This information was included in the study to show the bibliometric indicators in relation to innovation performance, competitiveness, population and national wealth.

According to the data from the WoS CC, China, the United States and the UK have the most publications, with more than 100 each. Germany, the fourth-placed country, lags some way behind. Regarding indicators of influence, the UK has the most citations (5,007), the highest h-index (31) and the most citations per study (45.1). The United States has the second most citations (3,815), the second highest h-index (27) and the fourth most citations per study (31.8). Germany has the third most citations (1,908), the third highest h-index (18) and the third most citations per study (35.3). Other countries that perform well in any or several indicators of influence are Spain and Italy (more than 1,000 citations each, an h-index of 11 and more than 30 citations per study), the Netherlands (an h-index of 17 and 847 citations) and Denmark (43.7 citations per study and 962 citations).

Based on the previous bibliometric indicators, the UK may be considered the leading country in NIS research, followed by the United States and, lagging some distance behind, Germany, Spain, Italy, Denmark, the Netherlands and China. Most countries in this ranking are European (12 countries; 52% of the list). These results are consistent with the origins of the NIS in the European industrial economies of the end of the 1980s, which transformed into knowledge-based economies. The term *knowledge-based economy* was coined to describe the shift of advanced economies towards greater dependence on knowledge, information and advanced skills, coupled with an increasing need for the business and public sectors to have ready access to these resources (OECD, 1996).

Surprisingly, all BRICS countries (Brazil, Russia, India, China and South Africa) are also included in this ranking. The inclusion of these countries is linked to the challenge of adapting the innovation systems approach to developing countries (Lundvall et al., 2011; Lundvall, 2016).

Certain Nordic and Central European countries such as Finland, Denmark, Norway, the Netherlands, Austria and Sweden are the most productive countries per million people. Denmark is noteworthy because it has a high number of citations per million people (177.33). This number is much higher than the second best, which is the UK with 75.82. Regarding productivity by GDP, the top five countries are Finland, South Africa, Denmark, the Netherlands and Taiwan. The total number of citations by GDP is led by Denmark, the UK, Finland, Austria and the Netherlands. China is by far the most productive country by GDP per capita, followed by India and, lagging some distance behind, South Africa, Brazil and Russia. This ranking reflects the fact that these countries are highly populated yet have a low GDP per capita. Lastly, the most cited countries by GDP per capita are the UK, China, India, the United States and Spain. These results show that developed countries with a strong focus on innovation policies and processes are leaders in NIS research. However, developing countries are also responsible for research in this field to diversify their economies and foster growth.

RS	RC	Country	TS	TC	h	C/S	GII	ScI	GCI	ScC	Pop	TS/Pop	TC/Pop	GDP	TS/GDP	TC/GDP	GDPC	TS/GDPC	TC/GDPC
1	8	China	178	844	10	4.7	17	53.06	28	72.6	1,390,080	0.13	0.61	12,014.61	14.82	70.25	8,643.107	20.59	97.65
2	2	USA	120	3,815	27	31.8	6	59.81	1	85.6	325,886	0.37	11.71	19,485.4	6.16	195.79	59,792.013	2.01	63.80
3	1	UK	111	5,007	31	45.1	4	60.13	8	82.0	66,040	1.68	75.82	2,628.41	42.23	1,904.95	39,800.274	2.79	125.80
4	3	Germany	54	1,908	18	35.3	9	58.03	3	82.8	82,660	0.65	23.08	3,700.613	14.59	515.59	44,769.224	1.21	42.62
5	7	Netherlands	45	847	17	18.8	2	63.32	6	82.4	17,140	2.63	49.42	832.239	54.07	1,017.74	48,555.353	0.93	17.44
6	19	Russia	45	135	5	3.0	46	37.90	43	65.6	143,990	0.31	0.94	1,577.525	28.53	85.58	10,955.792	4.11	12.32
7	4	Spain	44	1,325	11	30.1	28	48.68	26	74.2	46,333	0.95	28.60	1,313.951	33.49	1,008.41	28,358.808	1.55	46.72
8	18	Brazil	44	283	7	6.4	64	33.44	72	59.5	207,679	0.21	1.36	2,055.143	21.41	137.70	9,895.765	4.45	28.60
9	5	Italy	40	1,251	11	31.3	31	46.32	31	70.8	60,589	0.66	20.65	1,938.679	20.63	645.28	31,996.984	1.25	39.10
10	9	France	38	787	12	20.7	16	54.36	17	78.0	64,801	0.59	12.14	2,587.682	14.68	304.13	39,932.686	0.95	19.71
11	13	S. Korea	35	428	10	12.2	12	56.63	15	78.8	51,454	0.68	8.32	1,540.458	22.72	277.84	29,938.450	1.17	14.30
12	10	Canada	34	577	10	17.0	18	52.98	12	79.9	36,657	0.93	15.74	1,653.043	20.57	349.05	45,094.605	0.75	12.80
13	17	Taiwan	30	354	11	11.8	-	-	13	79.3	23571	1.27	15.02	572.594	52.39	618.24	24,292.091	1.23	14.57
14	20	S. Africa	30	135	6	4.5	58	35.13	67	60.8	56,522	0.53	2.39	349.299	85.89	386.49	6,179.870	4.85	21.85
15	11	Australia	29	501	10	17.3	20	51.98	14	78.9	24,771	1.17	20.23	1,379.548	21.02	363.16	55,692.730	0.52	9.00
16	16	Japan	27	371	9	13.7	13	54.95	5	82.5	126746	0.21	2.93	4,873.202	5.54	76.13	38448.569	0.70	9.65
17	14	Finland	23	387	9	16.8	7	59.63	11	80.3	5,503	4.18	70.33	252.753	91.00	1531.14	45,927.492	0.50	8.43
18	6	Denmark	22	962	10	43.7	8	58.39	10	80.6	5,749	3.83	167.33	325.556	67.58	2,954.94	56,630.596	0.39	16.99
19	12	Austria	18	430	9	23.9	21	51.32	22	76.3	8,815	2.04	48.78	417.351	43.13	1,030.31	47,347.437	0.38	9.08
20	22	Sweden	18	124	6	6.9	3	63.08	9	81.7	10,120	1.78	12.25	535.615	33.61	231.51	52,925.128	0.34	2.34
21	15	Norway	17	380	8	22.4	19	52.63	16	78.2	5,290	3.21	71.83	398.832	42.62	952.78	75,389.46	0.23	5.04
22	21	India	17	135	4	7.9	57	35.18	58	62.0	1,316,896	0.01	0.10	2,602.309	6.53	51.88	1,976.093	8.60	68.32
23	23	Iran	17	62	4	3.6	65	33.44	89	54.9	81,423	0.21	0.76	430.709	39.47	143.95	5,289.795	3.21	11.72

Table 3. The most productive and influential countries in NIS research.

Notes: RS = ranking by total studies; RC = ranking by total citations; TS = total studies; TC = total citations; h = h-index; C/S = citations per study; GII = 2018 Global Innovation Index; ScI = GII score over 100; GCI = 2018 Global Competitiveness Index; ScC = GCI score over 100; Pop = 2017 population in thousands; TS/Pop = studies per million inhabitants; TC/Pop = citations per millions inhabitants; GDP = 2017 gross domestic product in billions of U.S. dollars; TS/GDP = number of studies divided by GDP and multiplied by 1,000; TC/GDP = number of citations divided by GDP and multiplied by 1,000; GDPC = 2017 gross domestic product per capita in U.S. dollars; TS/GDPC = number of studies divided by GDP per capita and multiplied by 1,000; TC/GDPC = number of citations divided by GDP per capita and multiplied by 1,000.

3.4. The most cited and influential studies in NIS research

Many influential NIS papers have been published. One method to identify these influential studies is to classify publications by number of citations, which reflects their influence and popularity and the attention received from the scientific community (López-Rubio et al., 2020). Table 4 presents the 30 most cited NIS studies according to the WoS CC. The total number of citations favours older papers because they have had more time to receive more citations. Therefore, the number of citations per year is also shown in Table 4.

According to Table 4, the five most cited papers have more than 450 citations and are focused on traditional NIS topics such as NIS history (Freeman, 1995), institutional and organisational dimensions (Cooke et al., 1997), the national innovative capacity (Furman et al., 2002), the relationship between networking and innovation (Pittaway et al., 2004), and the national systems of production, innovation and competence building (Lundvall et al., 2002). These five studies are also amongst the top seven when ranked by citations per year. Surprisingly, however, the fifth- and sixth-ranked documents in this ranking are two papers published as recently as 2014. These papers deal with the novel concept of the National System of Entrepreneurship (Acs et al., 2014) and with entrepreneurial innovation (Autio et al., 2014). These results highlight one pathway regarding the evolution and prospects of NIS research, which is broadening its focus to cover emerging actors such as entrepreneurs, who offer potential sources of innovation and interact with innovation systems.

R	TC	Author	Document title	PY	C/Y
1	820	Freeman, C	The National System of Innovation in historical perspective	1995	35.7
2	787	Cooke, P; Uranga, MG; Etxebarria, G	Regional innovation systems: Institutional and organisational dimensions	1997	37.5
3	683	Furman, JL; Porter, ME; Stern, S	The determinants of national innovative capacity	2002	42.7
4	519	Pittaway, L; Robertson, M; Munir, K; Denyer, D; Neely, A	Networking and innovation: a systematic review of the evidence	2004	37.1
5	470	Lundvall, BA; Johnson, B; Andersen, ES; Dalum, B	National systems of production, innovation and competence building	2002	29.4
6	383	Meyer-Krahmer, F; Meyer-Krahmer, F	Science-based technologies: university-industry interactions in four fields	1998	19.2
7	354	Muller, E; Zenker, A	Business services as actors of knowledge transformation: the role of KIBS in regional and national innovation systems	2001	20.8
8	282	Liu, XL; White, S	Comparing innovation systems: a framework and application to China's transitional context	2001	16.6
9	240	Phene, A; Fladmoe-Lindquist, K; Marsh, L	Breakthrough innovations in the US biotechnology industry: The effects of technological space and geographic origin	2006	20.0
10	239	Colombo, MG; Delmastro, M	How effective are technology incubators? Evidence from Italy	2002	14.9
11	230	Owen-Smith, J; Riccaboni, M; Pammolli, F; Powell, WW	A comparison of US and European university-industry relations in the life sciences	2002	14.4
12	221	Carlsson, B	Internationalization of innovation systems: A survey of the literature	2006	18.4

13	215	Mowery, DC; Oxley, JE	Inward technology-transfer and competitiveness - the role of national innovation systems	1995	9.3
14	210	Freeman, C	Continental, national and sub-national innovation systems - Complementarity and economic growth	2002	13.1
15	206	Cooke, P; Uranga, MG; Etxebarria, G	Regional systems of innovation: an evolutionary perspective	1998	10.3
16	198	Hassink, R	How to unlock regional economies from path dependency? From learning region to learning cluster	2005	15.2
17	185	Fagerberg, J; Srholec, M	National innovation systems, capabilities and economic development	2008	18.5
18	173	Spencer, JW	Firms' knowledge-sharing strategies in the global innovation system: Empirical evidence from the flat panel display industry	2003	11.5
19	165	Le Bas, C; Sierra, C	'Location versus home country advantages' in R&D activities: some further results on multinationals' locational strategies	2002	10.3
20	159	Metcalfe, JS	Technology systems and technology policy in an evolutionary framework	1995	6.9
21	158	Archibugi, D; Michie, J	The globalization of technology - a new taxonomy	1995	6.9
22	151	Sharif, N	Emergence and development of the National Innovation Systems concept	2006	12.6
23	149	Schneider, MR; Schulze-Bentrop, C; Paunescu, M	Mapping the institutional capital of high-tech firms: A fuzzy-set analysis of capitalist variety and export performance	2010	18.6
24	138	Acs, ZJ; Autio, E; Szerb, L	National Systems of Entrepreneurship: Measurement issues and policy implications	2014	34.5
25	135	Block, F	Swimming against the current: The rise of a hidden developmental state in the United States	2008	13.5
26	134	Viotti, EB	National Learning Systems - A new approach on technological change in late industrializing economies and evidences from the cases of Brazil and South Korea	2002	8.4
27	129	Autio, E; Kenney, M; Mustar, P; Siegel, D; Wright, M	Entrepreneurial innovation: The importance of context	2014	32.3
28	129	Lundvall, BA	Why study national systems and national styles of innovation?	1998	6.5
29	123	Sternberg, R; Arndt, O	The firm or the region: What determines the innovation behavior of European firms?	2001	7.2
30	117	Filippetti, A; Archibugi, D	Innovation in times of crisis: National Systems of Innovation, structure, and demand	2011	16.7

Table 4. The 30 most cited NIS studies indexed in the WoS CC.

Notes: R = ranking; TC = total citations; PY = year of publication; C/Y = citations per year.

3.5. A historical view of the origins of the NIS

The co-citation analysis of references provides a historical view of the origins of the NIS. A total of 31,283 cited references were identified. This number is too large to be practical for analysis. Therefore, Figure 4 presents the co-citation map of the 67 cited references with at least 20 citations and the 100 most representative links. Table 5 groups these results by the four clusters determined by VOSviewer. A review of the five most cited studies in each cluster and analysis of the rest of the studies in the cluster revealed four research streams in the NIS literature: the systemic approach to innovation, institutional and organisational dimensions, the economics of innovation, and the national capabilities regarding university-industry-government relations (the Triple Helix model; Etzkowitz & Leydesdorff, 2000), innovative capacity, patents, R&D productivity, technological learning, the openness of the economy, and other such areas.

The co-citation map of references shows that Cluster 1 (red) and Cluster 2 (blue) are the core streams. Cluster 3 (green) and Cluster 4 (yellow) are peripheral. Examination of these streams reveals that regardless of the focus (systemic approach to innovation and evolutionary economics, institutional and organisational dimensions, economics of innovation, or national capabilities), in all streams, the specific features of each country must be considered. These specific features depend on political, economic and sociocultural factors, as well as the legal, technological and environmental context. Accordingly, the Triple Helix model has evolved into the Quadruple Helix model, which 'encourages the perspective of the *knowledge society*, and of *knowledge democracy* for knowledge production and innovation', or the Quintuple Helix model, which 'stresses the necessary *socioecological transition* of society and economy' to address, for example, global warming (Carayannis et al., 2012, p. 1).

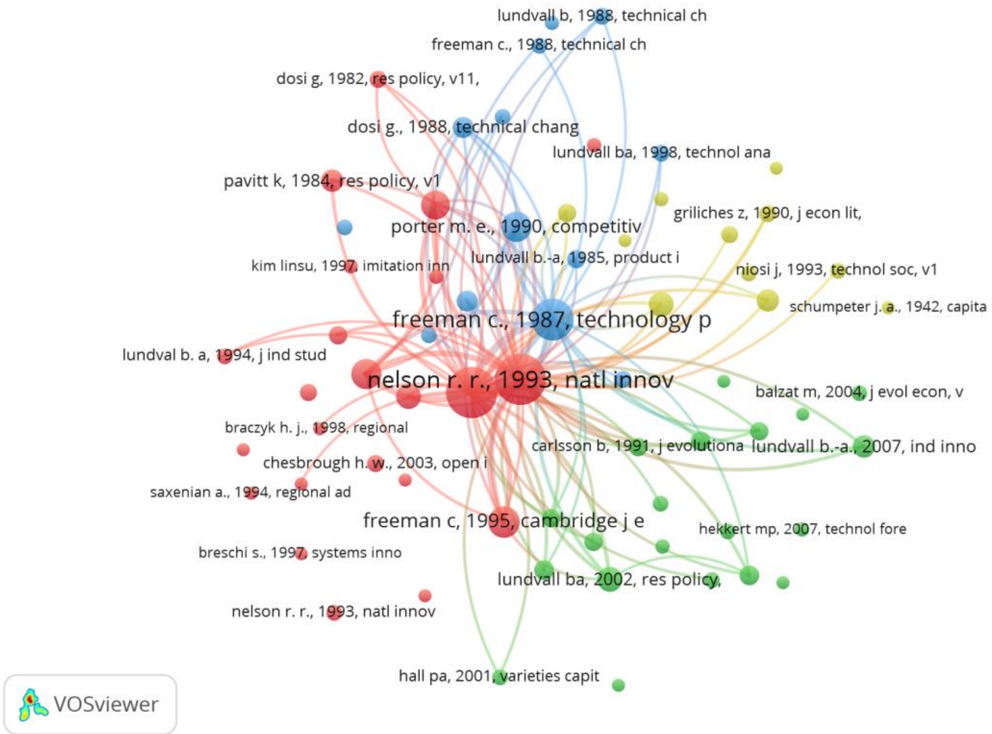

Figure 4. Co-citation map of references.

Cluster	TS	TC	TLS	Most cited studies	Label
1 (red)	24	1,390	7,475	Nelson (1993), Lundvall (1992), Freeman (1995), Edquist (1997), Nelson & Winter (1982)	Systemic approach to innovation
2 (blue)	20	665	4,614	Lundvall et al. (2002), Lundvall (2007), Freeman (2002), Cooke et al. (1997), Liu & White (2001)	Institutional and organisational dimensions
3 (green)	13	655	3,955	Freeman (1987), Porter (1990), Dosi et al. (1988), Lundvall (1985), OECD (1999)	The economics of innovation
4 (yellow)	11	368	2,123	Etzkowitz & Leydesdorff (2000), Furman et al. (2002), Patel & Pavitt (2004), Griliches (1990), Fagerberg & Srholec (2008)	National capabilities

Table 5. Descriptive values for co-citation-based clusters with researcher assigned labels.

Notes: TS = total studies; TC = total citations; TLS = total link strength.

3.6. A contemporary overview of NIS research

We performed bibliographic coupling analysis of the 66 documents with at least 60 citations (from the total pool of 1,107 documents). The aim was to develop a contemporary overview of NIS research. Figure 5 presents the bibliographic coupling map of these 66 studies and the 100 most representative links. Table 6 groups these results by the VOSviewer clusters.

This analysis reveals seven clusters in the literature. Cluster 6 (in light blue) and Cluster 7 (in orange) were discarded because they comprised only three studies between them. We reviewed the five most cited studies in the other five clusters. We also analysed the rest of the studies in the clusters. We labelled the clusters according to the main research stream that was common to all of them. The bibliographic coupling analysis gives an up-to-date view of NIS research in terms of four main research streams:

1. Cluster 1: Factors influencing innovation systems, such as networking (Pittaway et al., 2004), business services (Muller & Zenker, 2001), technological space and geographical origin (Colombo & Delmastro, 2002; Phene et al., 2006), and university-industry relations (Owen-Smith et al., 2002).
2. Cluster 2: National capabilities in terms of technology, patents and R&D productivity (Metcalfe, 1995; Furman et al., 2002), economic growth and development, institutional change and competence building (Lundvall et al., 2002; Faberberg & Shrolec, 2008), internationalisation (Carlsson, 2006) and other related areas.
3. Cluster 3: The dynamics of innovation, including diffusion and use of technology (Martin & Johnston, 1999; Schneider et al., 2010), innovation in times of crisis (Filippetti & Archibugi, 2011) and innovations generated by entrepreneurs (Acs et al. 2014; Autio et al., 2014).
4. Clusters 4 and 5: Innovation systems under different transnational, national and regional contexts.

VOSviewer ranks the clusters based on the number of documents. Cluster 3 has more documents and a greater total link strength than Cluster 4 and Cluster 5. However, it has fewer citations. This situation is probably because the five most cited documents in Cluster 3 were published recently (all since 2010, except for the study by Martin & Johnston, 1999). Therefore, they have had less time to accumulate citations.

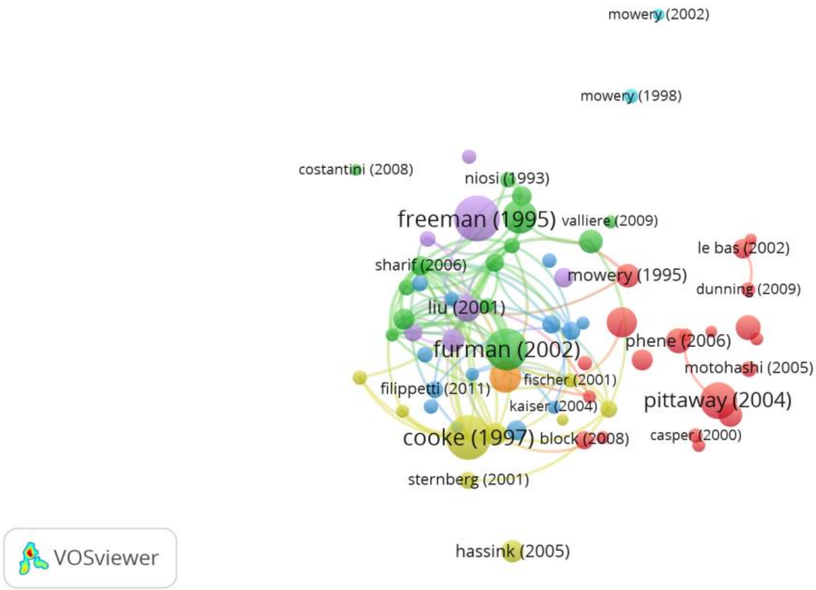

Figure 5. Bibliographic coupling map of documents.

Cluster	TS	TC	TLS	Most cited studies	Label
1 (red)	20	3,101	1,256	Pittaway et al. (2004), Muller & Zenker (2001), Phene et al. (2006), Colombo & Delmastro (2002), Owen-Smith et al. (2002)	Factors influencing innovation systems
2 (blue)	14	2,582	2,031	Furman et al. (2002), Lundvall et al. (2002), Carlsson (2006), Fagerberg & Shrolec (2008), Metcalfe (1995)	National capabilities
3 (green)	13	1,262	1,345	Schneider et al. (2010), Acs et al. (2014), Autio et al. (2014), Filippetti & Archibugi (2011), Martin & Johnston (1999)	The dynamics of innovation
4 (yellow)	9	1,744	1,172	Cooke et al. (1997), Cooke et al. (1998), Faber & Hesen (2004), Fischer (2001), Gregersen & Johnson (1997)	Innovation systems under different transnational, national and regional contexts
5 (purple)	7	1,786	818	Archibugi & Michie (1995), Freeman (1995), Freeman (2002), Hall et al. (2001), Liu & White (2001)	Innovation systems under different transnational, national and regional contexts

Table 6. Descriptive values for bibliographic coupling-based clusters with at least five studies with researcher assigned labels.

Notes: TS = total studies; TC = total citations; TLS = total link strength.

3.7. Analysis of the most common keywords in NIS research

It is also of interest to analyse the most common keywords and their co-occurrence. According to Callon et al. (1983), analysis of the co-occurrence of keywords can be used to establish the conceptual structure of a research field. Figure 6 presents the map of keyword co-occurrence over the entire period of NIS research (1990–2017) with a threshold of 25 occurrences and the 100 most representative links. The concepts are diverse. Besides ‘NIS’, ‘innovation’ and ‘systems’, which are a direct result of the search query for this study, ‘R&D’, ‘technology’, ‘industry’, ‘policy’, ‘science’, ‘firms’, ‘knowledge’ and ‘growth’ are the most common keywords in NIS research. The importance of these keywords is consistent with the fact that the innovation systems approach is widespread in knowledge-based economies and learning economies, in both academic and policymaking contexts (Cooke, 2001; Lundvall, 2016).

To observe how the use of these keywords has evolved, the VOSviewer overlay visualisation and the *average publication year* variable were used. The colour of the item indicates its average publication year. Table 6 presents these keywords with the number of occurrences and co-occurrences, the average publication year and the VOSviewer cluster sorted by number of occurrences. Interestingly, 'entrepreneurship', 'countries', 'Triple Helix', 'dynamics', 'innovation policy', 'developing countries' and 'management' are the newest keywords (from newest to oldest), with an average publication year of post-2012. The implication is that NIS research increasingly focuses on the relationship between the output of the innovation system and the factors that influence it (Etzkowitz & Leydesdorff, 2000; Campbell et al., 2015; Fagerberg, 2017) and entrepreneurs as emerging actors who interact with innovation systems (Acs, 2014; Autio et al., 2014). This finding corroborates some of the research streams identified in the current overview of the NIS field. The keyword 'developing countries' is linked to the increasing adoption of innovation systems by developing countries. This adoption is reflected by the fact that all the BRICS countries are amongst the biggest producers of NIS research. This keyword also reflects the need to adapt innovation systems to developing countries (Lundvall et al., 2011; Lundvall, 2016).

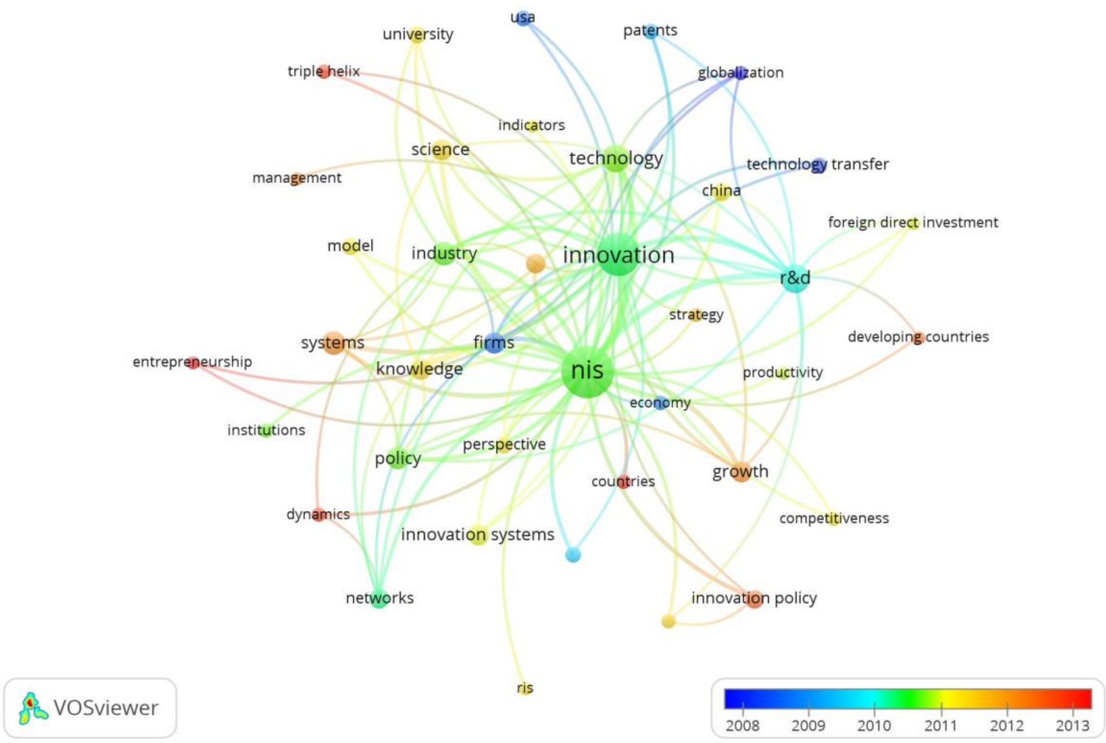

Figure 6. Map of keyword co-occurrence (1990–2017).

R	Kw	Oc	Co	Avg PY	Cluster
1	NIS	373	829	2010.58	3
2	Innovation	253	599	2010.37	2
3	R&D	116	380	2010.06	2
4	Technology	105	363	2010.74	4

5	Systems	80	258	2011.99	1
6	Industry	76	277	2010.66	1
7	Policy	69	230	2010.68	1
8	Science	65	219	2011.26	4
9	Firms	63	225	2008.70	1
10	Knowledge	61	241	2011.25	1
11	Growth	61	212	2011.97	3
12	Innovation systems	60	139	2010.97	1
13	Performance	57	183	2011.72	3
14	Networks	54	174	2010.28	1
15	China	48	151	2011.08	2
16	Innovation policy	48	118	2012.33	5
17	University	45	118	2011.20	4
18	Perspective	42	147	2011.10	1
19	Model	42	133	2011.10	3
20	Biotechnology	36	137	2009.61	1
21	Patents	36	127	2009.36	3
22	USA	35	121	2008.77	4
23	Technology transfer	34	91	2008.44	2
24	Economic growth	33	108	2011.33	5
25	Triple Helix	32	99	2012.69	4
26	Dynamics	31	125	2012.68	1
27	Globalisation	31	119	2007.90	2
28	Countries	31	118	2012.90	3
29	Economy	31	94	2008.94	2
30	Institutions	30	110	2010.70	1
31	Strategy	29	106	2011.48	2
32	Competitiveness	29	92	2011.10	2
33	Productivity	27	106	2010.89	3
34	Management	27	89	2012.07	4
35	RIS	26	55	2011.23	1
36	Foreign direct investment	25	89	2010.96	2
37	Indicators	25	89	2011.04	3
38	Entrepreneurship	25	85	2013.04	1
39	Developing countries	25	78	2012.28	2

Table 6. Most common keywords.

Notes: R = ranking; Kw = keyword; Oc = occurrences; Co = co-occurrences; Avg PY = average publication year.

4. Conclusions

The aim of this study was to analyse the origins, evolution and prospects of NIS research using bibliometric analysis based on data from the WoS CC database. The analyses included performance analysis and science mapping. The performance analysis used bibliometric indicators such as number of publications, number of citations, h-index and citations per study to evaluate the importance, impact and quality of NIS documents. Science mapping using co-citations, bibliographic coupling and keyword co-occurrence analysis complemented the performance analysis. Bibliometric maps were created using the VOSviewer software. Different units of analysis such as authors, institutions, countries, references, documents and keywords were used.

This study shows that NIS research has grown substantially since 2007. Overall, the UK may be considered the leader in NIS research, with 111 publications and 5,007 citations, followed by the United States (120 publications and 3,815 citations), and, lagging some distance behind, Germany (54 publications and 1,908 citations). Other prominent countries in NIS research are Spain and Italy (with more than 1,000 citations each), Denmark (962 citations), the Netherlands (847 citations) and China (844 citations). The BRICS countries minus China (i.e., Brazil, Russia, India and South Africa) are also amongst the countries with the most NIS publications. However, they have poor results in terms of indicators of influence (number of citations, citations per study and h-index).

The analysis of the most common keywords shows that the focus of NIS research has broadened to consider new emerging actors such as entrepreneurs. These actors interact with innovation systems and generate new outputs. The NIS research focus has also grown in scope to address the challenge of adapting the innovation systems approach to developing countries.

The results suggest that developed countries with knowledge-based economies and learning economies focus strongly on NIS research to foster economic growth, competitiveness and diversification. However, developing countries are also increasingly adopting the innovation systems approach.

The co-citation analysis provides a historical view of NIS research. The analysis highlighted four fundamental pillars: (1) the systemic approach to innovation, (2) institutional and organisational dimensions, (3) the economics of innovation, and (4) national capabilities regarding university-industry-government relations, innovative capacity, patents, R&D productivity, technological learning, the openness of the economy and other such factors.

The bibliographic coupling analysis provides a current overview of NIS research, revealing four main research streams: (1) factors influencing innovation systems, such as networking, business services, technological space, geographical origin and university-industry relations; (2) national capabilities in terms of technology, patents, R&D productivity, economic growth and development, institutional change and competence building; (3) the dynamics of innovation, including diffusion and use of technology, innovation in times of crisis or the innovations generated by entrepreneurs; and (4) innovation systems under different transnational, national and regional contexts.

Table 7 highlights the changes from the historical view to contemporary NIS research. This table illustrate the direction of current research, where scholars seek ways to contribute to the academic discussion about this topic. Table 7 shows that research has moved towards studies that investigate the factors influencing innovation, national capabilities, the dynamics or output of innovation systems, and the development of innovation systems in different transnational, national and regional environments. However, a review of the most cited contributions in these clusters reveals that the boundaries are blurred and that there is a certain degree of overlap between these areas.

No.	Historical view from CoC	Contemporary view from BbC

1	Systemic approach to innovation	Factors influencing innovation systems
2	Institutional and organisational dimensions	National capabilities
3	The economics of innovation	The dynamics of innovation
4	National capabilities	Innovation systems under different transnational, national and regional contexts

Table 7. Changes in NIS literature based on the labelled clusters.

Notes: CoC = co-citation; BbC = bibliographic coupling.

The topics addressed by recent studies in each contemporary cluster and the most common keywords with the most recent average year of publication can be used to propose a research agenda for the future development of the NIS literature:

(1) The first item on the agenda is the adaptation of innovation systems to the context of the current global economic crisis and the application of the Quintuple Helix model to cope with this new scenario (Carayannis et al., 2012; Campbell et al., 2015). As previously explained, the concept of the NIS originated during debates on European industrial policy as these developed countries searched to transform their economies into knowledge-based economies. Similarly, the Triple Helix model is based on innovation experience in developed countries. In these countries, relationships between universities (science), industry (business) and government (public administration) have been observed to be paramount for innovation and economic growth in a knowledge-based economy. We are facing a long-term global economic crisis due to the COVID-19 pandemic. This crisis will be aggravated by other global issues such as climate change and the current decline in the quality of democracy. Innovation systems must adapt to this new scenario in knowledge-based economies. The Quintuple Helix model has massive potential in this new global scenario.

(2) The second item on the agenda is the adaptation of innovation systems to developing countries (Lundvall et al., 2011; Lundvall, 2016). Developing countries are increasingly adopting the innovation systems approach as the basis for their innovation policies. Innovation systems must be adapted to the idiosyncrasies of each developing country.

(3) The third item on the agenda is the fit of entrepreneurship and entrepreneurial innovations in NIS research (Acs et al., 2014; Autio et al., 2014). Entrepreneurship fits into NIS research in specific ways, as explained by Acs et al. (2014, p. 476):

> National Systems of Entrepreneurship are fundamentally resource allocation systems that are driven by individual-level opportunity pursuit, through the creation of new ventures, with this activity and its outcomes regulated by country-specific institutional characteristics. In contrast with the institutional emphasis of the National Systems of Innovation frameworks, where institutions engender and regulate action, National Systems of Entrepreneurship are driven by individuals, with institutions regulating who acts and the outcomes of individual action. (Acs et al., 2014, p. 476)

Finally, the possible limitations of this study should be noted. First, NIS research documents that are not indexed in the WoS CC were not included in the analysis. Notable documents that were missing from the analysis include the pioneering books by Lundvall, Nelson and Freeman. However, this study partially overcame this limitation by using science mapping. This technique lent robustness to the results because the cited references were not required to be indexed in the WoS CC to be included in the analysis. Another limitation is that the complete counting system of the WoS CC means that documents attributed to multiple authors or affiliations tend to have a higher weighting in the analysis than papers with a single author because one unit is assigned to each researcher, regardless of the number of authors. Despite these limitations, this study nonetheless successfully identifies key results regarding the future evolution and prospects of NIS research.

References

Acs, Z. J., Autio, E., & Szerb, L. (2014). National Systems of Entrepreneurship: Measurement issues and policy implications. *Research Policy, 43*(3), 476–494. https://doi.org/10.1016/j.respol.2013.08.016.

Autio, E., Kenney, M., Mustar, P., Siegel, D., & Wright, M. (2014). Entrepreneurial innovation: The importance of context. *Research Policy, 43*(7), 1097–1108. https://doi.org/10.1016/j.respol.2014.01.015.

Archibugi, D., & Michie, J. (1995). The globalisation of technology: a new taxonomy. *Cambridge Journal of Economics, 19*(1), 121-140. https://doi.org/10.1093/oxfordjournals.cje.a035299.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy, 37*(3), 407-429. https://doi.org/10.1016/j.respol.2007.12.003.

Borras, S., & Edquist, C. (2013). The choice of innovation policy instruments. *Technological Forecasting and Social Change, 80*(8), 1513-1522. https://doi.org/10.1016/j.techfore.2013.03.002.

Callon, M., Courtial, J. P., Turner, W. A., & Bauin, S. (1983). From translations to problematic networks: An introduction to co-word analysis. *Social Science Information, 22*(2), 191–235. https://doi.org/10.1177/053901883022002003.

Campbell, D. F. J., Carayannis, E. G., & Rehman, S. S. (2015). Quadruple Helix structures of quality of democracy in innovation systems: the USA, OECD countries, and EU member countries in global comparison. *Journal of the Knowledge Economy, 6*, 467-493. https://doi.org/10.1007/s13132-015-0246-7.

Carayannis, E. G., Barth, T. D., & Campbell, D. F. J. (2012). The Quintuple Helix innovation model: global warming as a challenge and driver for innovation. *Journal of Innovation and Entrepreneurship, 1*, 1-12. https://doi.org/10.1186/2192-5372-1-2.

Carlsson, B. (2006). Internationalization of innovation systems: A survey of the literature. *Research Policy, 35*(1), 56-67. https://doi.org/10.1016/j.respol.2005.08.003.

Chiang, J. T. (1990). Management of national technology programs in a newly industrialized country – Taiwan. *Technovation, 10*(8), 531-554. https://doi.org/10.1016/0166-4972(90)90049-P.

Cobo, M. J., López-Herrera, A. G., Herrera-Viedma, E., & Herrera F. (2011). Science mapping software tools: Review, analysis, and cooperative study among tools. *Journal of the American Society for Information Science and Technology, 62*(7), 1382–1402. https://doi.org/10.1002/asi.21525.

Colombo, M. G., & Delmastro, M. (2002). How effective are technology incubators?: Evidence from Italy. *Research Policy, 31*(7), 1103-1122. https://doi.org/10.1016/S0048-7333(01)00178-0.

Cooke, P., Uranga, M.G., & Etxebarria, G. (1997). Regional innovation systems: Institutional and organisational dimensions. *Research Policy*, *26*(4-5), 475-491. https://doi.org/10.1016/S0048-7333(97)00025-5.

Cooke, P., Uranga, M. G., & Etxebarria, G. (1998). Regional systems of innovation: an evolutionary perspective. *Environment and Planning A, 30*, 1563–1584. https://doi.org/10.1068/a301563.

Cooke, P. (2001). Regional Innovation Systems, Clusters, and the Knowledge Economy. *Industrial and Corporate Change*, *10*(4), 945-974. https://doi.org/10.1093/icc/10.4.945.

Dosi, G., Freeman, C., Nelson, R., Silverberg, G., & Soete, L. (Eds.) (1988). *Technical change and economic theory*. Pinter, London.

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

Edquist, C. (2004). Systems of Innovation: Perspectives and challenges. In Fagerberg, J., Mowery, D., and Nelson, R. (eds.) *Oxford Handbook of Innovation*, Oxford: Oxford University Press, p. 181-208.

Egghe, L. (2006). Theory and practice of the g-index. *Scientometrics*, *69*(1), 131-152. https://doi.org/10.1007/s11192-006-0144-7.

Etzkowitz, H., & 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,* 109–123. https://doi.org/10.1016/S0048-7333(99)00055-4 .

European Commission (2014). *The European Union Explained: Research and Innovation*. Luxembourg, Publications Office of the European Union, 2014. doi:10.2775/74012.

Faber, J., & Hesen, A. B. (2004). Innovation capabilities of European nations: Cross-national analyses of patents and sales of product. *Research Policy, 33*(2), 193-207. https://doi.org/10.1016/S0048-7333(03)00122-7.

Fagerberg, J., & Srholec, M. (2008). National innovation systems, capabilities and economic development. *Research Policy, 37*(9), 1417-1435. https://doi.org/10.1016/j.respol.2008.06.003.

Fagerberg, J. (2017). Innovation policy: Rationales, lessons and challenges. *Journal of Economic Surveys*, *31*(2), 497-512. https://doi.org/10.1111/joes.12164.

Filippetti, A., & Archibugi, D. (2011). Innovation in times of crisis: National Systems of Innovation, structure, and demand. *Research Policy*, *40*(2), 179-192. https://doi.org/10.1016/j.respol.2010.09.001.

Fischer, M. (2001). Innovation, knowledge creation and systems of innovation. *The Annals of Regional Science, 35*, 199-216. https://doi.org/10.1007/s001680000034.

Flanagan, K., Uyarra, E., & Laranja, M. (2011). Reconceptualising the 'policymix' for innovation. *Research Policy, 40*(5), 702-713. https://doi.org/10.1016/j.respol.2011.02.005.

Freeman, C. (1987). *Technology policy and economic performance: lessons from Japan*. Pinter Publishers.

Freeman, C. (1995). The National System of Innovation in historical perspective. *Cambridge Journal of Economics*, *19*, 5-24. https://doi.org/10.1093/oxfordjournals.cje.a035309.

Freeman C. (2002). Continental, national and sub-national innovation systems – complementarity and economic growth. *Research Policy, 31*(2), 191-211. https://doi.org/10.1016/S0048-7333(01)00136-6.

Furman, J. L., Porter, M. E., & Stern, S. (2002). The determinants of national innovative capacity. *Research Policy, 31*(6), 899-933. https://doi.org/10.1016/S0048-7333(01)00152-4.

Garfield, E. (2001). *From Bibliographic Coupling to Co-citation Analysis via Algorithmic Historio-Bibliography: A Citationist's Tribute to Belver C. Griffith,* Drexel University, Philadelphia, PA.

Glänzel, W., & Czerwon, H. J. (1996). A new methodological approach to bibliographic coupling and its application to the national, regional and institutional level. *Scientometrics, 37*, 195-221. https://doi.org/10.1007/BF02093621.

Gregersen, B., & Johnson, B. (1997). Learning economics, innovation systems and European integration. *Regional Studies, 31*(5), 479-490. https://doi.org/10.1080/00343409750132270.

Griliches, Z. (1990). Patent statistics as economic indicators: a survey. *Journal of Economic Literature, 28*(4), 1661-1707. https://www.jstor.org/stable/2727442.

Hall, A., Bockett, G., Taylor, S., Sivamohan, M. V. K., & Clark, N. (2001). Why research partnerships really matter: Innovation theory, institutional arrangements and implications for developing new technology for the poor. *World Development, 29*(5), 783-797. https://doi.org/10.1016/S0305-750X(01)00004-3.

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. In: *Proceedings of the National Academy of Sciences of the United States of America, 102,* 16569–16572. https://doi.org/10.1073/pnas.0507655102.

Jarvening, B. (2007). Bibliographic coupling and its application to research-front and other core documents. *Journal of Informetrics, 1*(4), 287-307. https://doi.org/10.1016/j.joi.2007.07.004.

Kessler, M. M. (1963). Bibliographic coupling between scientific papers. *American Documentation, 14*, 10–25. https://doi.org/10.1002/asi.5090140103.

List, F. (1841). *The National System of Political Economy*. English Edition (1904). London, Longman.

Liu, X., & White, S. (2001). Comparing innovation systems: a framework and application to China's transitional context. *Research Policy, 30*(7), 1091-1114. https://doi.org/10.1016/S0048-7333(00)00132-3.

López-Rubio, P., Roig-Tierno, N., & Mas-Verdú, F. (2018). Technology transfer: A comparison between Web of Science Core Collection and Scopus. *Information and Innovations, 13*(2), 53–69. DOI: 10.31432/1994-2443-2018-13-2-53-69.

López-Rubio, P., Roig-Tierno, N., & Mas-Tur, A. (2020). Regional innovation system research trends: toward knowledge management and entrepreneurial ecosystems. *International Journal of Quality Innovation, 6*(1), 1-16. https://doi.org/10.1186/s40887-020-00038-x.

Lundvall, B. A. (1985). *Product Innovation and User-Producer Interaction*. Available at: https://www.researchgate.net/publication/251542478_Product_Innovation_and_User-Producer_Interaction.

Lundvall, B. A. (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.* London, Pinter.

Lundvall, B. A., Johnson B., Andersen, E. S., & Dalum, B. (2002). National Systems of production, innovation and competence-building. *Research Policy, 31*(2), 213-231. https://doi.org/10.1016/S0048-7333(01)00137-8.

Lundvall, B. A. (2007). National Innovation Systems – Analytical concept and development tool. *Industry & Innovation, 14*, 95-119. https://doi.org/10.1080/13662710601130863.

Lundvall, B. A., Joseph, K. J., Chaminade, C., & Vang, J. (2011). *Handbook of Innovation Systems and Developing Countries. Building Domestic Capabilities in a Global Setting*. Edited by B. A. Lundvall, K. J. Joseph, C. Chaminade and J. Vang. ISBN: 978 1 84720 609 1.

Lundvall, B. A. (2016). *The learning economy and the economics of hope*. NY: Anthem Press. ISBN: 9781783085965.

Martin, B. (1996). The use of multiple indicators in the assessment of basic research. *Scientometrics, 36*(3), 343-362. https://doi.org/10.1007/BF02129599.

Martin, C. R., & Johnston, R. (1999). Technology foresight for wiring up the National Innovation System: Experiences in Britain, Australia, and New Zealand. *Technological Forecasting and Social Change, 60*(1), 37-54. https://doi.org/10.1016/S0040-1625(98)00022-5.

McKelvey, M. (1991). How do National Systems of Innovation differ?: A critical analysis of Porter, Freeman, Lundvall and Nelson in G.M. Hodgson and E. Screpanti (eds), *Rethinking Economics. Markets, Technology and Economics Evolution.* Aldershot, Hants: Elgar, ISBN 1852784164, p. 117-137.

Metcalfe, J. S. (1995). Technology systems and technology policy in an evolutionary framework. *Cambridge Journal of Economics, 19*(1), 25-46. https://doi.org/10.1093/oxfordjournals.cje.a035307.

Mowery, D. C. (1992). The U.S. National Innovation System: Origins and prospects for change. *Research Policy, 21*(2), 125-144. https://doi.org/10.1016/0048-7333(92)90037-5.

Muller, E., & 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. https://doi.org/10.1016/S0048-7333(01)00164-0.

Nelson, R., & Winter, S. (1982). *An evolutionary theory of economic change*. Bellknap, Cambridge, Mass.

Nelson, R. R. (1993). National Innovation Systems. A Comparative Analysis. Edited by Richard R. Nelson. ISBN: 9780195076172.

OECD (1996). *The Knowledge-based Economy*. OECD Publishing, Paris.

OECD (1999). *Managing National Innovation Systems*. OECD Publishing, Paris.

OECD (2011). *Regions and Innovation Policy*. OECD Reviews of Regional Innovation. OECD Publishing, Paris.

OECD (2015). *The Innovation Imperative: Contributing to Productivity, Growth and Well-Being*. OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264239814-en.

Owen-Smith, J., Riccaboni, M., Pammolli, F. & Powell, W. W. (2002). A comparison of U.S. and European university-industry relation in the life sciences. *Management Science, 48*(1), 1-34. https://doi.org/10.1287/mnsc.48.1.24.14275.

Patel, P., & Pavitt, K. (1994). National innovation systems: why they are important, and how they might be measured and compared. *Economics of Innovation and New Technology, 3*(1), 77-95. https://doi.org/10.1080/10438599400000004.

Phene, A., Fladmoe-Lindquist, K., & Marsh L. (2006). Breakthrough innovations in the U.S. biotechnology industry: the effects of technological space and geographic origin. *Strategic Management Journal, 27*(4), 369-388. https://doi.org/10.1002/smj.522.

Pittaway, L., Robertson, M., Munir, K., & Neely, A. (2004). Networking and innovation: a systematic review of the evidence. *International Journal of Management Reviews, 5/6*(3&4), 137-168. https://doi.org/10.1111/j.1460-8545.2004.00101.x.

Porter, M. (1990). *The Competitive Advantages of Nations*. The Free Press Edition.

Schneider, M. R., Schulze-Bentrop, C., & Paunescu, M. (2010). Mapping the institutional capital of high-tech firms: A fuzzy-set analysis of capitalist variety and export performance. *Journal of International Business Studies, 41*, 246-266. https://doi.org/10.1057/jibs.2009.36.

Small, H. (1973). Co-citation in the scientific literature: a new measure of relationship between two documents. *Journal of the American Society for Information Science, 24*, 265–269.

Small, H. (1999). Visualizing Science by Citation Mapping. *Journal of the American Society for Information Science, 50*(9), 799–813. https://doi.org/10.1002/(SICI)1097-4571(1999)50:9<799::AID-ASI9>3.0.CO;2-G.

Suominen, A., Seppänen, M., & Dedehayir, O. (2019). A bibliometric review on innovation systems and ecosystems: a research agenda. *European Journal of Innovation Management, 22*(2), 335-360. https://doi.org/10.1108/EJIM-12-2017-0188.

Van Eck, N. J., & Waltman, L. (2010). Software survey: Vosviewer, a computer program for bibliometric mapping. *Scientometrics, 84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3.

Vertova, G. (2014). The State and National Systems of Innovation: A Sympathetic Critique. *The Levy Institute Working Paper Collection*. Working Paper No. 823.

White, H. D., & Griffith, B. C. (1981). Author co-citation: A literature measure of intellectual structure. *Journal of the American Society for Information Science, 21*, 163–172. https://doi.org/10.1002/asi.4630320302.

Youtie, J., Kay, L., & Melkers, J. (2013). Bibliographic coupling and network analysis to assess knowledge coalescence in a research center environment. *Research Evaluation, 22*(3), 145-156. https://doi.org/10.1093/reseval/rvt002.