PAPER

Title: Assessing the origins, evolution and prospects of National Innovation Systems

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Abstract: National Innovation System (NIS) is a research field that has gained large attention and a growing influence among the scientific community, public administrations and international organizations. This article presents a bibliometric overview of NIS research by considering all the data indexed in WoS CC database up to year 2017 and using various bibliometric methods, such as performance analysis and science mapping. The performance analysis uses different bibliometric indicators, like the h-index, productivity and citations among others. Science mapping uses co-citations and keywords co-occurrences and was implemented with the VOSviewer software. The most relevant issues in NIS research were identified and classified according to articles, authors, institutions, countries and journals. The results show that NIS research has increased significantly since 2007 and that the UK is the most influential country followed by the USA. Other countries highly focused on NIS research are Germany, China, Spain, Italy, the Netherlands and Denmark.

Keywords: National Innovation Systems, bibliometrics, Web of Science, VOSviewer

JEL codes: O30, O31, O38

1. Introduction

The National Innovation System (NIS) concept (Freeman, 1987; Lundvall, 1992; Nelson 1993), also known as National System of Innovation, had its origins by the end of the 1980s and the middle of the 1990s in the context of debates over industrial policy in Europe. According to Freeman (1995), Bengt-Åke Lundvall was the first person to use this term pointing out that the idea actually comes from Friedrichs List and 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. In its origins there were 3 pioneering books: "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 the pioneers of this concept, the National Innovation System is 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 interacts determine the innovative performance of national firms" (Nelson, 1993, p. 4). From this perspective, NIS has two main objectives: to show international differences or similarities in countries' ability to innovate and to be on the technological edge, and to give policy suggestions for the support of firms' innovative activities (Vertova, 2014).

Since the concept was coined, an international body of literature documents the growing influence of the NIS approach. Several supra-national organizations, most notably the Organisation for Economic Cooperation and Development (OECD) but also the European Union (EU) and the World Bank among others, have taken in the NIS concept as an integral part of their analytical perspective (Lundvall, Johnson, Andersen & Dalum, 2002). Moreover, the innovation systems approach is widespread in

Scandinavia and Western Europe, in both academic and policymaking contexts (Sharif, 2006).

Academic studies on NIS initially aimed at understanding the differences in technological development and profiles of technological specialization among countries. However, since the beginning of the 2000s such academic studies were increasingly focused on the relationship between the output of the innovation system and the factors influencing it (e.g., Liu & White, 2001; Edquist, 2004; Lundvall, 2007; Bergek et al., 2008). Innovation, diffusion and use of technology, also known as technological dynamics, are the output of the innovation systems as a result of influences from abroad, activities within the business sector and interaction with other actors of society. There is a wide range of processes influencing the technological dynamics of a nation such as knowledge, skills, demand, finance and institutions, and these processes are affected by numerous policies and actors (Fagerberg, 2015). As a consequence of that, NIS may differ greatly from one country to another and a policy mix that works in one context may not be adequate in another (Flanagan, Uyarra & Laranja, 2011; Borras & Edquist, 2013).

In view of the presented background, the main aim of this study is to complement previous work and provide a comprehensive quantitative and qualitative overview of NIS research by using the main bibliometric procedures, namely, performance analysis and science mapping (Cobo et al., 2011). To achieve this aim, Web of Science (WoS) Core Collection database is used to collect all the NIS related data and bibliometrics techniques are applied to different units of analysis such as authors, journals, institutions, countries and keywords.

This work is structured as follows. Section 2 describes the methodology. Section 3 presents the results, which are divided in 2 subsections: Section 3.1 examines the bibliometric performances analyses of NIS studies, authors, institutions, countries and journals, whereas Section 3.2 presents the science mapping analysis of NIS research. Finally, Section 4 presents the main conclusions.

2. Methodology

This paper uses bibliometric techniques to conduct a general and comprehensive overview in NIS research and the Web of Science Core Collection (WoS CC) database, which belongs to Clarivate Analytics, to collect all related data. The WoS is a digital scientific database internationally recognized among researchers for its high-quality standards and has become one of the main tools for searching and evaluating different types of publications and journals, containing more than 15,000 journals and 50,000,000 classified documents in 251 categories and 150 thematic research areas (Thelwall, 2008; Gaviria-Marin, Merigó & Baier Fuentes, 2018).

The search executed in 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 considers all the years up to 2017, resulting in a total of 1,107 studies. This set of studies includes 580 documents classified as article, 334 as proceedings paper, 69 as article and book chapter, 58 as article and proceedings paper, 26 as book review, 24 as review, 7 as editorial material, 4 as book, 2 as news item, 1 as book chapter, 1 as letter, and 1 as meeting abstract. These studies comprise 57 research areas, from those only 18 with more than 10 studies. As with document types, one study can cover multiple research areas. Figure 1 shows those 18 research areas. Business Economics is the first research area with a substantial difference over the others. Only 4 research areas account for more than 100 studies: Business Economics (728 studies), Public Administration (254), Engineering (161) and Operations Research Management Science (134).

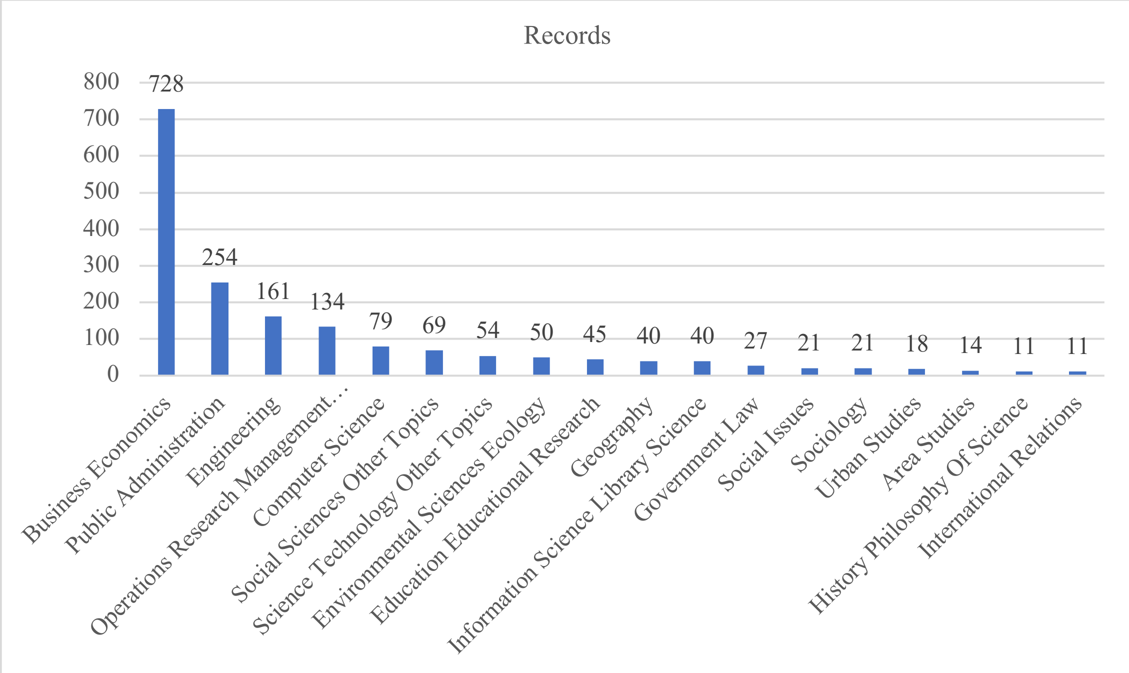

Figure 1. Research areas with more than 10 NIS studies indexed in WoS CC.

The records corresponding to these results were analyzed using bibliometrics, which combine two main procedures: performance analysis and science mapping (Cobo et al., 2011). Bibliometric performance analysis uses a wide range of indicators and techniques, including the number of published studies and the number of received citations, citation analysis, counting publications by countries, universities or authors, calculation of the h-index and word frequency analysis (Thelwall, 2008). The h-index is a very popular indicator among researchers that takes into account the number of publications and citations for its calculation, so a variable (authors, journals, countries, institutions, etc.) has an h-index of N, when N documents were cited at least N times (Hirsch, 2005). However, the h-index has some 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 productivity or highly cited papers (Egghe, 2006). This paper calculates diverse bibliometric indicators because h-index limitations can be overcome by evaluating the research field using more than one indicator (Martin, 1996).

Science mapping is another main procedure of bibliometrics consisting of graphical representations of how research fields and topics, and individual papers of authors are interrelated. A bibliometric mapping monitors a scientific field to determine its cognitive structure, evolution and main actors and provides a clearer visualization of the results (Noyons, Moed & Van Raan, 1999). Among the most used bibliometric mappings are co-citation analysis (Small, 1973) and keywords co-occurrence in documents (Callon et al., 1983). Note that co-citation analysis examines the structure of a field using pairs of documents that are commonly cited together, so such an analysis considers the references cited by the set of documents under study broadening the focus of the analysis. This technique is used in units of analysis such as authors, references and journals. Likewise, the keywords co-occurrence (Callon et al., 1983) studies the conceptual structure of a research field based on the keywords of the documents. This paper analyses the keywords co-occurrence in several periods of time to observe the evolution over time. Finally, we used the VOSviewer software (Van Eck & Waltman, 2010) to perform the science mapping analysis, although there are other science mapping software tools (Cobo et al., 2011).

3. Results

3.1. Performance bibliometric analysis

In this section we present a performance analysis based on the bibliometric indicators described above, such as the number of studies published, number of citations received, h-index of the different actors analyzed, and various ratios obtained from these indicators.

3.1. 1. Publications and citations in NIS research

The search for this paper was conducted in December 2018 and comprises a total of 1,107 studies indexed in WoS Core Collection between 1960 and 2017. Up to 2017, these 1,107 studies received a total of 16,268 citations with a ratio of citation per study of 16.2 and an h-index of 64.

Figure 2 shows the publications and the citations evolution per year. The first NIS research study indexed in WoS CC was published in 1990, while the years 1991 and 1992 also accounts for one study each. From 1993 to 2006 the annual number of publications was between 4 and 35 and its evolution includes several ups and downs, exceeding the 50-study threshold in 2007. From 2012 a continuous upward trend of annual publications is observed, starting with 55 studies in 2012 and overcoming the

100-study threshold in 2017, when the maximum is achieved with 119 studies. Therefore, a significant increase of NIS studies took place in 2007 although an annual upward trend did not begin until 2012. According to figure 2, the citations evolution shows a continuous and consistent year-wise increase with the exception of year 2013, when the number of citations decreased from 1,342 in 2012 to 1,259 in 2013. The 500 and 1,000-citation thresholds were passed respectively in 2007 and 2010, obtaining the maximum number of 2,296 citations in 2017.

Overall, both number of NIS studies and number of citations to these studies reflect the influence, attention and growing interest of the scientific community in NIS research, especially from year 2007 where the 50-study and the 500-citation thresholds were exceeded.

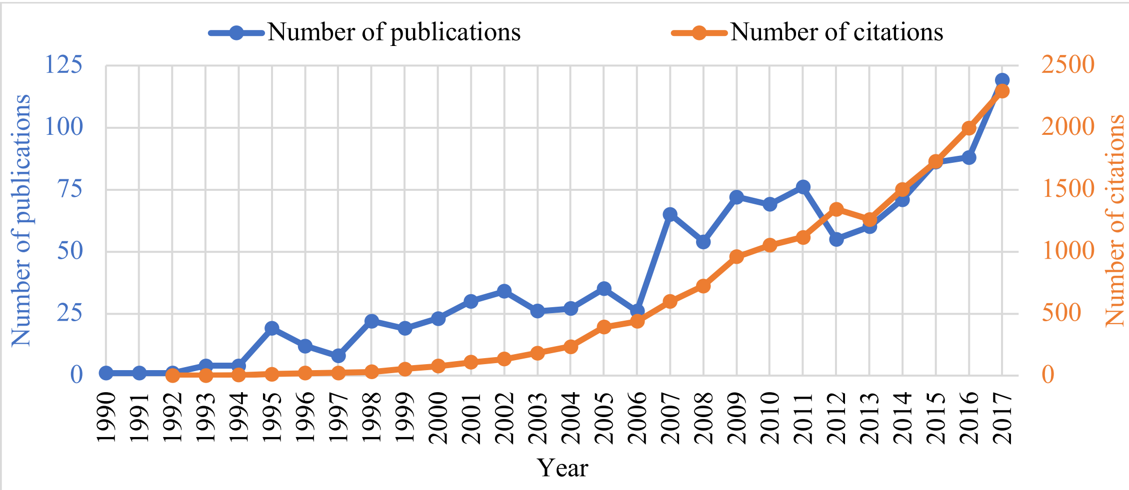

Figure 2. Number of publications and citations in NIS research per year.

3.1.2. *An overview of the most productive and influential authors in NIS research*

Since its conception and over the time, the NIS research has been characterized by a growing participation of a large number of researchers. One important issue to obtain an overview of NIS research is to determine the most productive and influential authors in this field. It is necessary to consider that some known authors may not appear because of the nature of this classification, which can occur as a result of the year indexing the journals in the WoS CC or because certain popular books are not indexed in WoS. The classification presented in table 1 shows the 29 authors with at least 3 studies and 70 citations and it is ordered according to the total number of citations. Remark that the h-index is a composite indicator that combines productivity and influence, while the citations per study is the ratio between the total number of studies and the total number of citations.

Lundvall is the author with most studies in NIS literature indexed in WoS CC and is also the author with the best combination of productivity and influence with an h-index of 5 together with Mowery, Archibugi and Autio. The total number of citations and the ratio of citations per study are headed by Freeman. Note that although Freeman only has 3 NIS studies indexed in Wos CC, he has obtained many more citations than the other authors in the list. The second author in total 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	1086	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	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
18	Link AN	Univ N Carolina	USA	3	80	3	26.7
19	Vertova G	Univ Bergamo	Italy	4	77	3	19.3
20	Sutz J	Univ Republica	Uruguay	5	75	3	15.0
21	Chung S	Sejong Univ	S Korea	3	72	1	24.0

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

Notes: R = Rank; TS = Total studies; TC = Total citations; h = h-index; C/S = Citations per study.

3.1.3. The most productive and influential institutions in NIS research

Table 2 presents the most productive and influential institutions ordered by the total number of studies, by considering the 26 institutions with at least 7 NIS studies, most of them are located in Europe (15), followed by Asia (6) and America (4).

According to table 2, the University of Sussex, where Freeman is affiliated, leads the total number of studies with 18, the total number of citations with 1,420, and has the best combination of productivity an influence with an h-index of 11. Aalborg University, where Lundvall is affiliated, is in second place based on the total number of studies with 16 and the total number of citations with 916, while holds the third place in h-index category with 7 together with University of California Berkeley, Erasmus University of Rotterdam, Seoul National University and Utrecht University. The University of Manchester obtains the second best combination of productivity and influence with an h-index of 9 and is in the third productivity place with 14 studies.

As for the total number of citations, the University of Sussex stands out with 1,420 citations, 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 top in ranking for the ratio of citations per study where the University of Cambridge stands out with 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	1420	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	Univ Estadual Campinas	Brazil	13	75	4	5.8	301-400	251-300
5	Chinese Acad Sci	China	12	117	4	9.8	-	-
6	Lund Univ	Sweden	12	102	5	8.5	101-150	141-150
7	Natl Res Univ	Russia	11	48	4	4.4	901-1000	251-300
8	Fraunhofer Gesellschaft	Germany	10	916	5	91.6	-	-
9	Univ Oslo	Norway	10	283	6	28.3	62	201-250
10	Seoul Natl Univ	S Korea	10	219	7	21.9	101-150	23
11	Univ Fed Minas Gerais	Brazil	10	61	4	6.1	401-500	301-500
12	Aalto Univ	Finland	9	240	5	26.7	301-400	201-250
13	CNRS	France	9	174	5	19.3	-	-
14	Univ Pretoria	S Africa	9	54	4	6.0	401-500	301-500
15	UC Berkeley	USA	8	638	7	79.8	5	8

16	CNR	Italy	8	467	6	58.4	-	-
17	Erasmus Univ Rotterdam	Netherlands	8	248	7	31.0	79	141-150
18	Univ Tokyo	Japan	8	210	4	26.3	22	19
19	Utrecht Univ	Netherlands	8	198	7	24.8	51	201-250
20	Univ Complutense Madrid	Spain	8	76	2	9.5	201-300	101-110
21	Thammasat Univ	Thailand	8	33	3	4.1	-	201-250
22	Univ Cambridge	UK	7	884	5	126.3	3	7
23	PSL Res U Paris Comue	France	7	160	4	22.9	-	-
24	Univ CAS	China	7	101	3	14.4	-	-
25	Georgia Inst Technol	USA	7	74	4	10.6	79	44
26	Tsinghua Univ	China	7	57	1	8.1	45	17

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

Notes: R = Rank; 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.

3.1.4. *Country analysis*

Based on the premise that research and innovation foster economic development and growth, Public Administrations are increasingly focusing on innovation policy and NIS (OECD, 2011, 2015; European Commission, 2014). To achieve a complete picture of NIS research, this section analyzes the geographical origin of NIS publications. It is important to note that particularities can be observed in a country because some researchers can change their affiliation over their working life and also some may have several affiliations at the same time (Merigó, Gil-Lafuente & Yager, 2015). Therefore, an author may have publications in two or more countries. In this analysis the country's affiliation refers to the country in which the author was working at the time of publication.

Table 3 presents the 23 countries with 15 or more studies ordered by the total number of studies. This table includes the total number of NIS studies, total number of received citations by these studies, h-index, ratio of citations per study, the Global Innovation Index of year 2018 (GII), the Global Competitiveness Index of year 2018 (GCI), the population in millions of people, the Gross Domestic Product (GDP) in billions of US dollars and the GDP per capita in US dollars . The GII is an innovation performance index co-published by Cornell University, INSEAD Business School and the World Intellectual Property Organization (WIPO), calculated for 126 countries and 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 which includes 140 countries and 98 indicators; this index can be consulted at https://www.weforum.org . Data of population, GDP and GDP per capita belongs to year 2017 and has been extracted from the International Monetary Fund web page https://www.imf.org . All this information has been included to show the bibliometric indicators in relation to the innovation performance, the competitiveness, the population or the wealth of countries.

The three most productive countries are China with 178 publications, the USA with 120 and the UK with 111, followed in the distance by Germany with 54 publications, the Netherlands and Russia with 45 each, and Spain and Brazil with 44 each.

Regarding influence indicators, the UK heads the total number of citations with 5007, the h-index category with 31 and the ratio of citations per study with an average of 45.1; the USA holds the second place in total number of citations (3815) and h-index (27), and the fourth place in citations per study (31.8); and Germany holds the third position in total number of citations (1908), h-index (18) and citations per study (35.3). Other countries that obtain good results in any or several influence indicators are Spain and Italy with more than 1000 received citations each, an h-index of 11 and more than 30 citations per study, the Netherlands with an h-index of 17 and a total of 847 citations, and Denmark with 43.7 citations per study for a total of 962 citations.

All the previous bibliometric indicators considered, we can conclude that the UK is the leading country in NIS research, followed by the USA and at some distance by Germany. Remark that most of the countries in this ranking are European (14 countries, i.e. the 50% of the list). Likewise, we observe that the 28% of the list is Asian. However, the participation of both Latin American and African countries is quite scarce in this field. Note that all the BRICS countries (Brazil, Russia, India, China and South Africa) are included in this list, with some of them among the most productive countries: China in the first place, Russia in the sixth and Brazil in the eighth. China moves down to the seventh place as per total number of citations with 844 and the tenth place in the h-index category with a value of 10, dropping to the twenty-fifth place based on the ratio of citations per study with an average of 4.7. All the remaining BRICS countries obtain poor results in influence indicators.

It is interesting to note that some 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 also remarkable because it has a relatively large number of citations per million people (177.33), much higher than the second best which is the UK with 75.82. Regarding the productivity per GDP the top 5 comprises Finland, South Africa, Denmark, the Netherlands and Taiwan, while the total number of citations per GDP is leaded by Denmark, the UK, Finland, Austria and the Netherlands. The most productive country per GDP per capita is, by far, China followed by India and in the distance by South Africa, Brazil and Russia. This is due to the fact that these are highly-populated emergent countries with a low GDP per capita. Lastly, the most cited countries per GDP per capita are the UK, China, India, the USA and Spain.

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 = Global Innovation Index 2018; ScI = GII Score over 100; GCI = Global Competitiveness Index 2018; ScC = GCI Score over 100; Pop = Population in thousands in year 2017; TS/Pop = Studies per million inhabitants; TC/Pop = Citations per millions inhabitants; GDP = Gross Domestic Product in billions of US dollars in year 2017; TS/GDP = number of studies divided by GDP and multiplied by 1000; TC/GDP = number of citations divided by GDP and multiplied by 1000; GDPC = Gross Domestic Product per Capita in US dollars in year 2017; TS/GDPC = number of studies divided by GDP per capita and multiplied by 1000; TC/GDPC = number of citations divided by GDP per capita and multiplied by 1000.

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	1390080	0.13	0.61	12014.61	14.82	70.25	8643.107	20.59	97.65
2	2	USA	120	3815	27	31.8	6	59.81	1	85.6	325886	0.37	11.71	19485.4	6.16	195.79	59792.013	2.01	63.80
3	1	UK	111	5007	31	45.1	4	60.13	8	82.0	66040	1.68	75.82	2628.41	42.23	1904.95	39800.274	2.79	125.80
4	3	Germany	54	1908	18	35.3	9	58.03	3	82.8	82660	0.65	23.08	3700.613	14.59	515.59	44769.224	1.21	42.62
5	7	Netherlands	45	847	17	18.8	2	63.32	6	82.4	17140	2.63	49.42	832.239	54.07	1017.74	48555.353	0.93	17.44
6	19	Russia	45	135	5	3.0	46	37.90	43	65.6	143990	0.31	0.94	1577.525	28.53	85.58	10955.792	4.11	12.32
7	4	Spain	44	1325	11	30.1	28	48.68	26	74.2	46333	0.95	28.60	1313.951	33.49	1008.41	28358.808	1.55	46.72
8	18	Brazil	44	283	7	6.4	64	33.44	72	59.5	207679	0.21	1.36	2055.143	21.41	137.70	9895.765	4.45	28.60
9	5	Italy	40	1251	11	31.3	31	46.32	31	70.8	60589	0.66	20.65	1938.679	20.63	645.28	31996.984	1.25	39.10
10	9	France	38	787	12	20.7	16	54.36	17	78.0	64801	0.59	12.14	2587.682	14.68	304.13	39932.686	0.95	19.71
11	13	S Korea	35	428	10	12.2	12	56.63	15	78.8	51454	0.68	8.32	1540.458	22.72	277.84	29938.45	1.17	14.30
12	10	Canada	34	577	10	17.0	18	52.98	12	79.9	36657	0.93	15.74	1653.043	20.57	349.05	45094.605	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	24292.091	1.23	14.57
14	20	S Africa	30	135	6	4.5	58	35.13	67	60.8	56522	0.53	2.39	349.299	85.89	386.49	6179.87	4.85	21.85
15	11	Australia	29	501	10	17.3	20	51.98	14	78.9	24771	1.17	20.23	1379.548	21.02	363.16	55692.73	0.52	9.00
16	16	Japan	27	371	9	13.7	13	54.95	5	82.5	126746	0.21	2.93	4873.202	5.54	76.13	38448.569	0.70	9.65
17	14	Finland	23	387	9	16.8	7	59.63	11	80.3	5503	4.18	70.33	252.753	91.00	1531.14	45927.492	0.50	8.43
18	6	Denmark	22	962	10	43.7	8	58.39	10	80.6	5749	3.83	167.33	325.556	67.58	2954.94	56630.596	0.39	16.99
19	12	Austria	18	430	9	23.9	21	51.32	22	76.3	8815	2.04	48.78	417.351	43.13	1030.31	47347.437	0.38	9.08
20	22	Sweden	18	124	6	6.9	3	63.08	9	81.7	10120	1.78	12.25	535.615	33.61	231.51	52925.128	0.34	2.34
21	15	Norway	17	380	8	22.4	19	52.63	16	78.2	5290	3.21	71.83	398.832	42.62	952.78	75389.46	0.23	5.04
22	21	India	17	135	4	7.9	57	35.18	58	62.0	1316896	0.01	0.10	2602.309	6.53	51.88	1976.093	8.60	68.32
23	23	Iran	17	62	4	3.6	65	33.44	89	54.9	81423	0.21	0.76	430.709	39.47	143.95	5289.795	3.21	11.72

3.1.5. *The most productive and influential journals in NIS research*

Table 4 presents the 11 journals with more than 10 studies published in NIS research. Where several journals have the same number of studies, the ordering is based on the number of citations. Some of these results should be taken with caution because some journals may not have all their volumes and issues indexed in the WoS, e.g. *Journal of Technology Transfer* has only indexed from year 2007 onwards and six articles of 1994.

Despite these limitations, it is clear that *Research* Policy, which is published in the Netherlands, is the leading journal on NIS research by far with 87 publications, 7313 received citations and an h-index of 45. *Technological Forecasting and Social Change*, published also in the Netherlands, is the second according to the total number of studies with 37 and in the h-index category together with Technovation, published in the UK, with a value of 11, while is the third most cited with 566 citations received. In addition, *Technovation* is the third most productive journal together with *International Journal of Technology* Management, also published in the UK, with 27 publications each, and the fourth most cited with 546 citations received.

R	Journal	TS	TC	h	C/S
1	Research Policy	87	7313	45	84.1
2	Technological Forecasting and Social Change	37	566	11	15.3
3	Technovation	27	546	11	20.2
4	International Journal of Technology Management	27	273	8	10.1
5	Technology Analysis & Strategic Management	20	336	10	16.8
6	European Planning Studies	15	378	9	25.2
7	Science and Public Policy	15	118	6	7.9
8	Journal of Technology Transfer	13	160	8	12.3
9	Scientometrics	13	139	7	10.7
10	R&D Management	12	81	5	6.8
11	Innovation-Management Policy & Practice	11	62	5	5.6

Table 4. The most productive and influential journals in NIS research.

Notes: R = Rank; TS = Total studies; TC = Total citations; h = h-index; C/S = Citations per study.

3.2. *Science mapping of NIS research*

The previous section presents a comprehensive performance analysis of NIS research. To complement and strengthen it, science mapping is conducted aiming at showing the structural and dynamics aspects of a research field (Noyons, Moed & Van Raan, 1999). This analysis allows us to identify the main documents and analyze the most representative structures and connections between the actors that perform in this field (Blanco-Mesa, Merigó & Gil-Lafuente, 2017). This analysis is implemented by means of bibliometric techniques such as co-citation and co-occurrence of keywords. In the latter technique a temporal analysis is added to observe how the conceptual structure changes over time and the variation of the research interests and topics in different years.

First, a co-citation analysis of the NIS research is conducted. According to the taxonomy of the bibliometric techniques presented by Cobo et al. (2011), co-citations can be analyzed based on the authors or journals of the cited references, or on the cited references themselves. Co-citation analysis maps the structure of a research field using pairs of documents that are commonly cited together.

The co-citation of authors analysis seeks to show the structure and connections of authors who are cited together more frequently (White & Griffith, 1981). Figure 3 presents the results of this analysis and is implemented with a threshold of 55 citations and the 100 most representative links. Figure 3 corroborates the relevance 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, where the size of their circles and their centrality in the figure stand out. However, this mapping also shows other very relevant authors, such as Nelson (760 citations with a total link strength of 9,814), the OECD (728 citations with a total link strength of 7,161) and, in a lesser extent, Edquist (326 citations with a total link strength of 4,484).

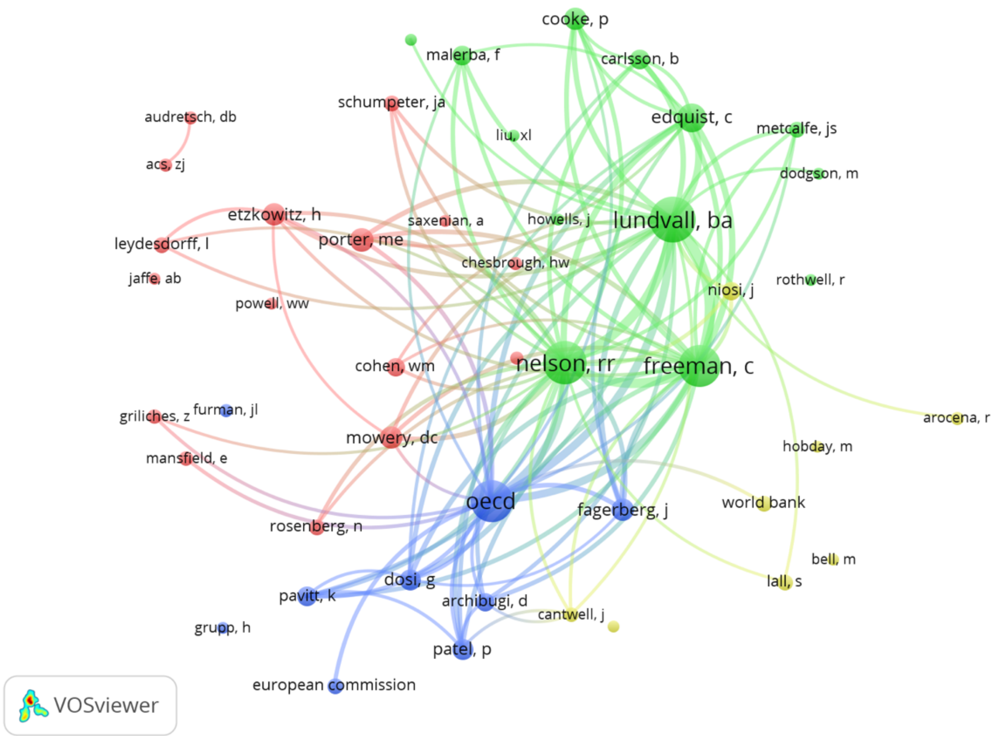

Figure 3. Co-citation mapping of authors.

Another unit that is analyzed using co-citation is journals. Co-citation of journals seeks to identify those that are frequently cited together (McCain, 1991). Figure 4 presents the co-citation mapping of journals, which is performed using a threshold of 60 citations and the 100 most representative links. The size and centrality of *Research Policy* circle indicates that this journal leads NIS research by far, and therefore it possesses a wide network of connections. These *Research Policy* connections are particularly strong with 7 journals with which have a minimum link strength of 2000: *Technovation* (with a link strength of 3,339), *Technological Forecasting and Social Change* (link strength of 3,281), *Journal of Technology Transfer* (link strength of 3,043), *Scientometrics* (link strength of 2,577), *Industrial and Corporate Change* (link strength of 2,199), *Strategic Management Journal* (link strength of 2,066) and *Science and Public Policy* (link strength of 2,000). Observe that this result is consistent with the data of table 4 and also complements those data.

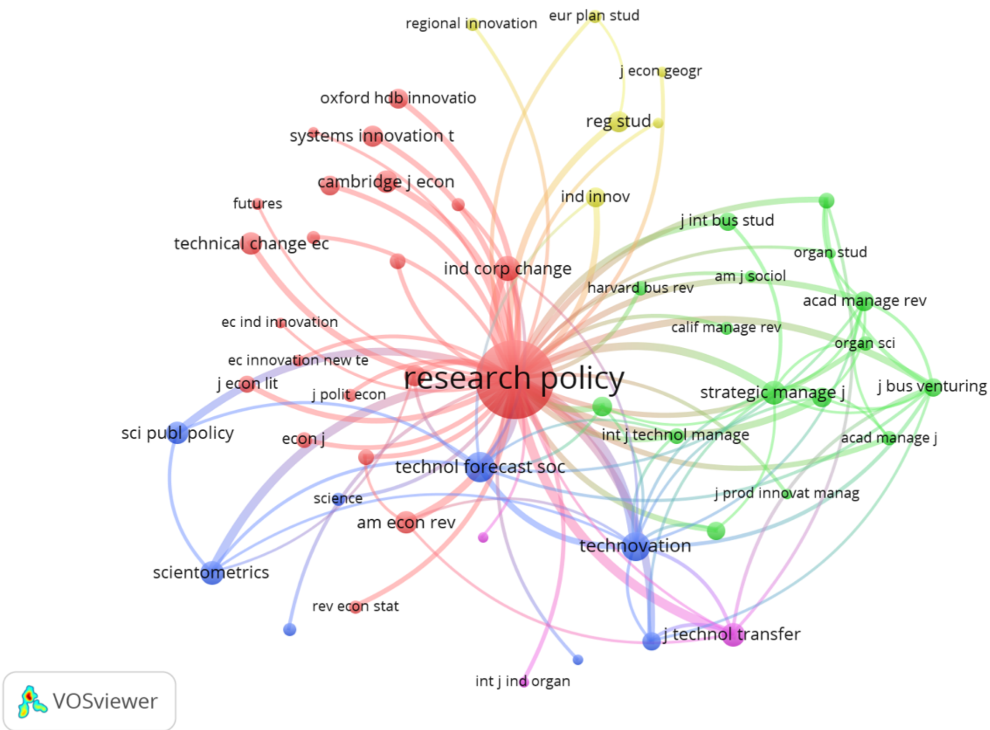

Figure 4. Co-citation mapping of journals.

Another interesting issue is the co-occurrence of keywords, which seeks to study the conceptual structure of a research field. Figure 5 presents the mapping of keyword co-occurrences for all the period of time with NIS studies (1990-2017) with a threshold of 14 occurrences and the 100 most representative links. There is a great diversity of concepts among which “NIS”, “innovation”, “R&D”, “technology”, “systems”, “industry”, “policy”, “science”, “firms”, “knowledge” and “growth” are the most frequently keywords used in NIS research.

To observe how the use of these keywords evolves over time, figures 6, 7 and 8 present the keyword co-occurrences between 1990-1999, 2000-2009 and 2010-2017. The thresholds for these figures are 2, 5 and 10 occurrences respectively. In the first decade, the keywords “NIS”, “innovation”, “firms”, “R&D” and “policy” stand out from the others. In the second decade the keywords “NIS”, “innovation”, “R&D”, “firms” and “policy” are certainly consolidated while the keyword “technology” gains importance. Lastly, in the period 2010-2017 the keywords “NIS”, “innovation”, “R&D”

and "technology" continue being the most frequent keywords, followed by the keywords "systems", "industry", "science", "growth", "knowledge", and "policy".

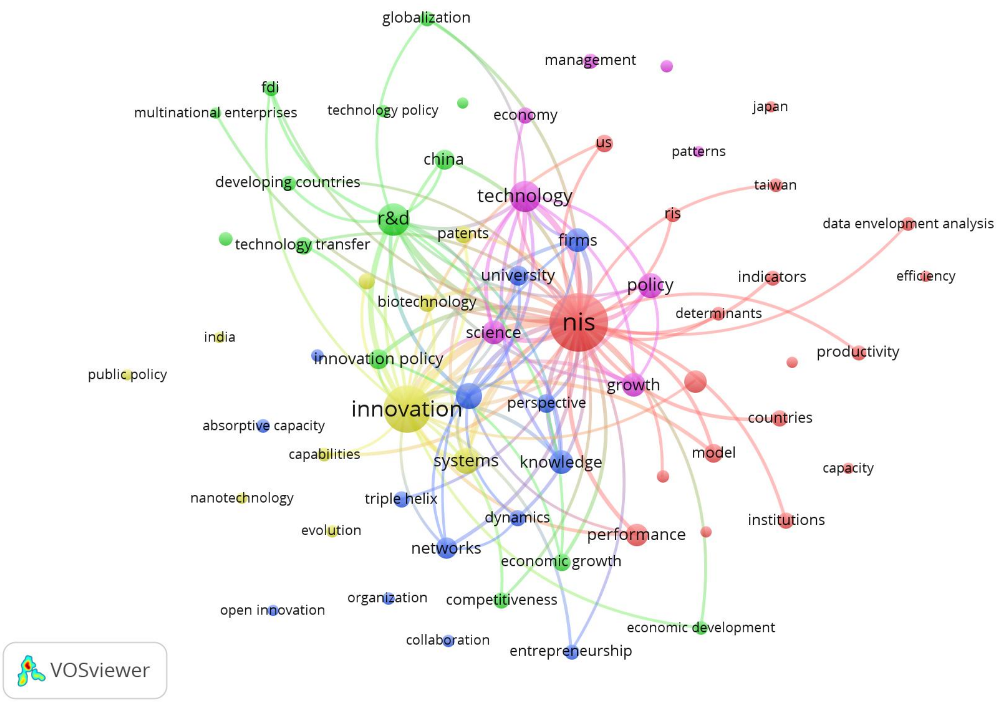

Figure 5. Mapping of keywords co-occurrences (1990-2017).

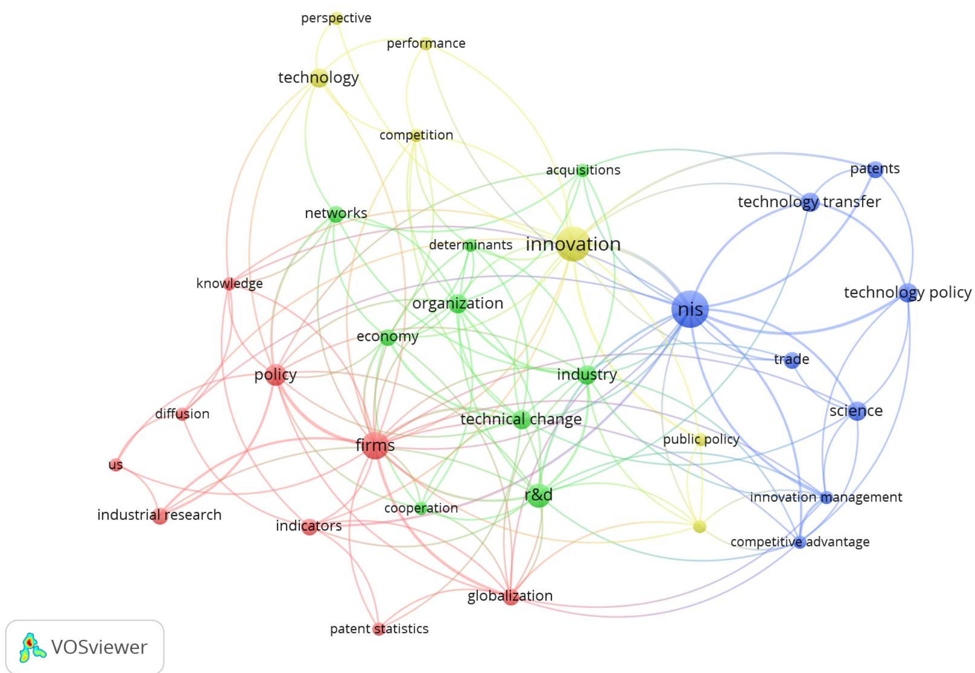

Figure 6. Mapping of keywords co-occurrences (1990-1999).

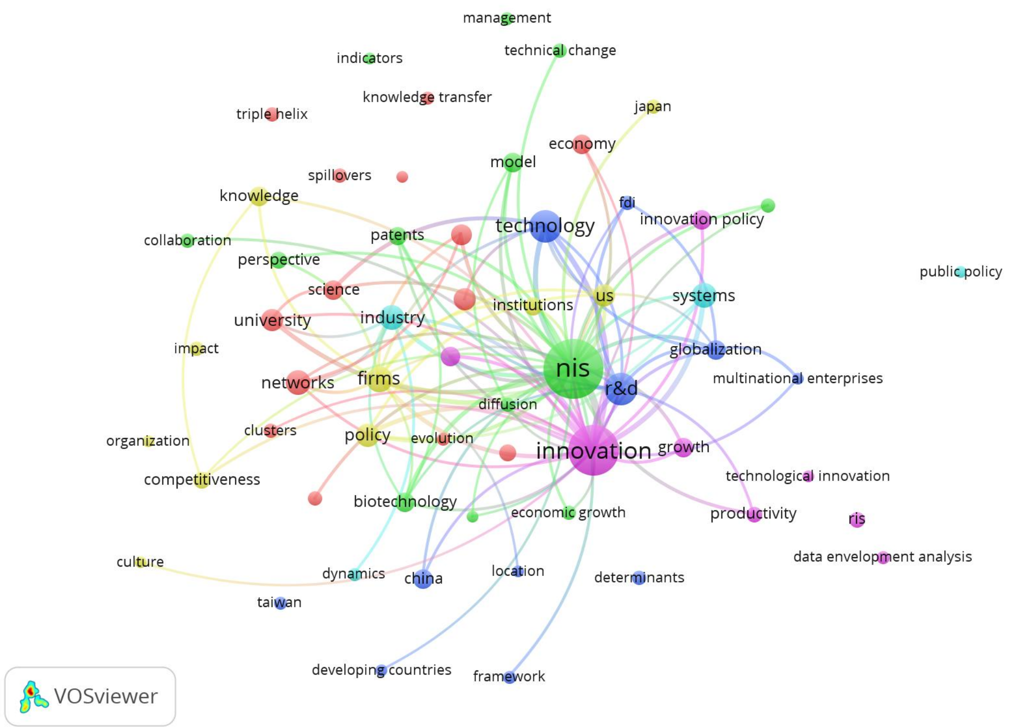

Figure 7. Mapping of keywords co-occurrences (2000-2009).

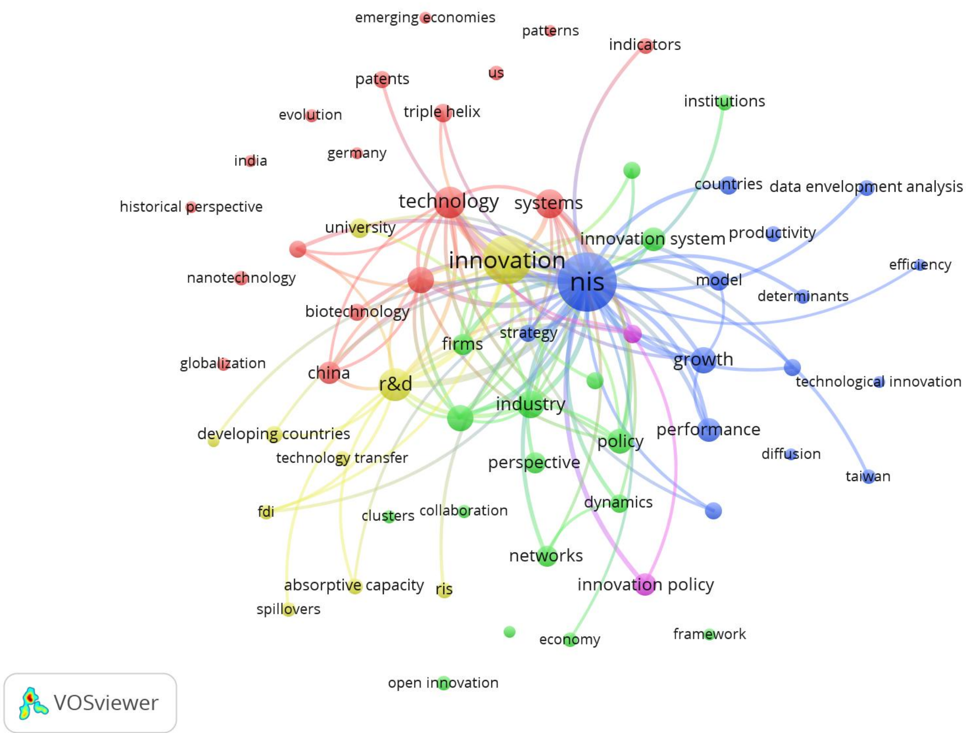

Figure 8. Mapping of keywords co-occurrences (2010-2017).

4. Conclusions

The objective of this work is to present a complete overview of NIS research through a bibliometric analysis of the results extracted from WoS CC database, including performance analysis and science mapping. The first method uses several bibliometric indicators such as the number of publications, the number of citations, the h-index and the ratio of citations per study to evaluate the importance, impact and quality of the publications. Science mapping aims at complementing performance analysis using co-citation and keywords co-occurrence. Bibliometric mappings were implemented using the VOSviewer software and considering different units of analysis such as authors, journals and keywords.

From an overall perspective, this study shows that NIS research has experienced a significant growth since 2007. All the bibliometric indicators considered, the UK attempts to be the leader in NIS research with 111 publications, 5,007 citations received and an h-index of 31, followed by the USA with 120 publications, 3,815 citations and h-index of 27, and at some distance by Germany with 54 publications, 1,908 citations and h-index of 18. China is the most productive country with 178 publications, receiving 844 citations and having an h-index of 10. Other countries that obtain good results in NIS research are Spain and Italy with more than 1000 received citations each, an h-index of 11 and more than 30 citations per study, the Netherlands with an h-index of 17 and a total of 847 citations, and Denmark with 43.7 citations per study for a total of 962 citations.

Regarding institutions, the UK has the largest number of institutions with 5 among the most productive and influential. The most prominent UK institutions in NIS research are the University of Sussex, the University of Manchester, the University of Cambridge, the University College of London, and the University of Oxford. The USA and China are in the second place with 4 institutions each. The US institutions comprise the University of California Berkeley, Georgia Institute of Technology, the University of North Carolina, and George Washington University, whereas the Chinese institutions are the Chinese Academy of Sciences, the University of Chinese Academy of Sciences, Tsinghua University, and Beihang University. However, most of these institutions are not among the top ones. The University of Sussex leads the total number of studies, the total number of citations and the h-index. Aalborg University in Denmark is the second based on the total number of studies and the total number of citations, and the third in h-index category together with the University of California Berkeley, Erasmus University of Rotterdam in the Netherlands, Seoul National University in South Korea and Utrecht University in the Netherlands. The University of Manchester obtains the second h-index and is the third most productive institution. Fraunhofer Gesellschaft in Germany is the second most cited together with Aalborg University, and followed by the University of Cambridge and the University of California Berkeley.

Regarding individual researchers and considering all the bibliometric indicators together, Freeman and Lundvall are, by far, the most influential researchers in this field, followed by Mowery, Archibugi and Autio. Science mapping of authors co-citation allow to overcome WoS CC limitations since there may be relevant documents on NIS research that are not indexed in WoS CC. Such science mapping shows Lundvall, Nelson and Freeman as the most influential authors, followed closely by the OECD and in the distance by Edquist. In fact, Lundvall, Nelson and Freeman are considered the fathers of NIS.

In relation to the journals, *Research Policy* is clearly the leader in NIS research, followed by *Technological Forecasting and Social Change*, and *Technovation.* Science mapping of journals co-citation corroborates and complements this analysis showing that the most connected journals with *Research Policy* in NIS research are *Technovation*, *Technological Forecasting and Social Change*, *Journal of Technology Transfer*, *Scientometrics*, *Industrial and Corporate Change*, *Strategic Management Journal*, and *Science and Public Policy*.

Finally, it is important to remark some limitations that this work may have. First, documents on NIS research that are not indexed in WoS will not be included in the set of studies under analysis in the performance analysis. This is the case of the pioneer books of Lundvall, Nelson and Freeman. However, our work also includes science mapping that seeks to complement and give robustness to the results as well as to help partially overcome such a limitation, since the cited references do not need to be indexed in WoS CC. Another limitation is that WoS implements the complete counting system in which papers attributed to multiple authors or affiliations tend to be more important in the analysis compared to those papers that appear with a single author,

since it assigns one unit to each researcher regardless the number of authors. Although researchers must take these limitations into account, this paper identifies the most significant results of the NIS research field. Their importance lies in the information presented in a complete manner and in considering different perspectives so that each reader understands the data according to their own interests and priorities.

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