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A research journey from national innovation systems to national entrepreneurship systems: Introducing the Sextuple Helix

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Abstract

National innovation systems (NIS) have attracted substantial interest from public administrations, the scientific community, and international organizations. Countries must innovate and generate competitive advantages based on local agents, processes, and dynamics to compete in today's globalized world economy. Entrepreneurship is a potential source of innovation that has recently become a recurring theme in NIS research. This focus on entrepreneurship in the context of NIS has led scholars to propose novel concepts such as entrepreneurial ecosystems and the national entrepreneurship system (NES). This paper uses bibliometric techniques and the Web of Science Core Collection database to explore how entrepreneurship fits into NIS research and to study the increasing importance of entrepreneurship in NIS research. The most common keywords in this area are used to develop the NIS conceptual framework, and the most influential NIS studies are identified using the total number of citations and the number of citations per year. Two sets of studies are analyzed: (1) older documents on traditional topics such as the origins and evolution of NISs, the capacity of countries to innovate, and the relationships of institutions, different organizational forms, networking, production, and competence building with innovation and (2) newer entrepreneurship research documents. Based on analysis of the most common keywords and the most influential studies, we propose a Sextuple Helix model as an analytical framework that brings together innovation and entrepreneurship.

Keywords: National systems of innovation, national systems of entrepreneurship, Sextuple Helix, bibliometrics, Web of Science

JEL Classification: O30 O31 O38

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1. Introduction

Recent decades have seen an increase in innovation research output. This increase reflects a growing interest from public administrations, the scientific community, and international organizations in the factors that encourage innovation, economic development, and technical progress (OECD, 2015; Cancino, Merigó & Coronado, 2017; European Commission, 2018). These factors include research and development (R&D) activities, R&D expenditure, public policies, patents, knowledge management, product and process innovation, internal organization, external innovation relationships, external innovation collaboration, and entrepreneurship. Product and process innovation and R&D activities are likely to improve the productivity of manufacturing firms. Meanwhile, internal organization and external collaboration for innovation increase productivity levels (Sánchez-Sellero et al., 2015). According to López-Rubio *et al*. (2021), public policies focused on technology transfer, innovation and entrepreneurship, as well as knowledge management, university licensing, patenting, and entrepreneurial universities and ecosystems are paramount for successful technology transfer processes.

A national innovation system (NIS) consists of a network of economic agents, together with the institutions and policies whose interactions affect the innovation performance of firms in a given country (Freeman, 1987; Lundvall, 1992; Nelson 1993). National and regional perspectives are essential to build the relationship networks that firms need to innovate. Accordingly, nations have become even more important within today's globalized economy (Freeman, 1995). Hence, public administrations are increasingly investing in stimulating innovation processes and developing innovation policies to improve the business environment (OECD, 2015; Edler & Fagerberg, 2017; European Commission, 2018). Public administrations in Western countries and international organizations such as the European Union (EU), the World Bank, and the Organisation for Economic Cooperation and Development (OECD) have widely adopted the NIS approach to develop innovation policies (Fagerberg, 2017).

Since the concept of the NIS was developed at the end of the 1980s, it has been a key topic in innovation research, along with innovation policies. However, entrepreneurship has recently emerged as a crucial economic and social catalyst for innovation, becoming a popular topic in this field (Leyden, 2016). Entrepreneurship has in fact become so prevalent that the term "national systems of entrepreneurship" (NESs) was coined in 2014 by Acs, Autio, and Szerb (2014). Defining entrepreneurship is difficult because it can be conceptualized from different perspectives, such as self-employment or new firm creation (Reynolds, Bosma & Autio, 2005), the firm-level behavioral disposition of entrepreneurial orientation (Lumpkin & Dess, 1996), and individual-level cognitive attributes related to opportunity perception (Shane & Venkataraman, 2000). The challenge of measuring entrepreneurship at the country level is exacerbated by the fact that entrepreneurship has never been thoroughly studied as a country-level phenomenon. The core NIS literature rarely mentions the term entrepreneurship. Therefore, entrepreneurship indicators are simple aggregates of individual-level activities. Nowadays, two main entrepreneurship indicators are used to measure country-level entrepreneurship: Global Entrepreneurship Monitor (GEM) indicators and the Global Entrepreneurship and Development Index (GEDI; Szerb, Aidis & Acs, 2013).

Regardless of the definition, context, or measurement indicator, the broad consensus is that entrepreneurship matters, although not all entrepreneurs innovate. In fact, the GEM does not consider innovation an intrinsic characteristic of entrepreneurship. Instead, the GEM defines entrepreneurs as "adults

in the process of setting up a business they will (partly) own or currently owning and managing an operating young business," with no mention of innovation. The GEM distinguishes between two types of entrepreneurs: opportunity entrepreneurs and necessity entrepreneurs. Although the GEM's general definition of entrepreneurship does not mention innovation, innovation is cited as an intrinsic characteristic in the definition of opportunity entrepreneurship (Headd, 2003; Kelley, Bosma & Amorós, 2010; Mas-Tur & Moya, 2015).

Linking entrepreneurship to innovation, many countries, regions, and universities have adopted policies to stimulate innovation by entrepreneurial firms in an attempt to foster economic growth. Consequently, entrepreneurship has gained importance in the context of the NIS (Autio et al., 2014). Innovation is present not only in business activity but also in the ability to discover, evaluate, and exploit the opportunities that the market puts within the reach of entrepreneurs (Shane & Venkataraman, 2000). Innovation in the entrepreneurial process exists from the outset. In other words, innovation is born the moment an entrepreneur looks for unfilled gaps in the market to create new products, services, or production processes. Entrepreneurship fits into NIS research in a specific way because NESs center on entrepreneurs, whereas NIS frameworks have an institutional focus (Acs, Autio & Szerb, 2014). However, the idea of institutional entrepreneurship can break the circularity of the NIS, leading to an understanding of institutional entrepreneurship as "the activities of actors who have an interest in particular institutional arrangements and who leverage resources to create new institutions or to transform the existing ones" (Maguire, Hardy & Lawrence, 2004, p. 657). From this perspective, entrepreneurs can transcend the institutional constraints of the NIS to create new organizational forms (Hung & Whittington, 2011).

The primary goal of this study is to analyze the academic literature on NISs and to assess the involvement and influence of NESs and entrepreneurship on NISs. Bibliometric methods are used to do so. All relevant data from the Web of Science Core Collection (WoS CC) database were analyzed to identify the most cited and influential NIS studies and to develop a NIS conceptual framework. Finally, the study explores the effect of the most influential NIS and NES studies on subsequent research. The rest of the article is structured as follows. Section 2 describes the method. Section 3 presents the results of the bibliometric analysis. Finally, Section 4 offers the main conclusions.

2. Method

The research method used in this paper is based on bibliometrics (Pritchard, 1969), which is defined as the study of all quantitative aspects of bibliographic material (Broadus, 1987). This paper uses bibliometric techniques and the Web of Science Core Collection (WoS CC) database to present an overview of the shift from NIS to NES, explore how entrepreneurship fits into NIS research, and study the increasing importance of entrepreneurs and entrepreneurial activity in recent years. The WoS is one of the most important sources of bibliometric information for scholars, providing consistent, standardized information (Mas-Tur et al., 2019).

The search executed in WoS CC to gather the data for this study 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

considered all years up to and including 2017. The search returned 1,107 documents, classified as 707 articles, 392 proceedings papers, 70 book chapters, 26 book reviews, 24 reviews, 8 editorial materials, 4 books, 2 news items, 1 letter, and 1 meeting abstract.

The analyses presented in this paper are based on bibliometrics indicators and maps. The most commonly used bibliometric indicators are the total number of studies, the total number of citations, the h-index, and word frequency analysis (Mas-Tur et al., 2019). The total number of studies is an indicator of absolute productivity. It does not account for the number of citations of a study. The total number of citations is also an absolute measure. It does not consider a study's lifetime (i.e., publication year). The h-index combines the total number of studies and total number of citations into a single measure. If, for a given set of studies, N studies have received at least N citations, then the h-index for that set of studies will be N (Hirsch, 2005). We analyze the evolution of publications and citations in NIS research and identify the most cited and influential NIS documents indexed in WoS CC using these bibliometric indicators. We also use the number of citations per year and citations per study, which offer proxy variables for efficiency.

Bibliometric maps, or science mapping, are used to visually represent a scientific field and thereby determine its cognitive structure, evolution, and main actors (Noyons, Moed & Van Raan, 1999). VOSviewer software (Van Eck & Waltman, 2010) was used to perform science mapping, although there are other science mapping tools, each with its own advantages and disadvantages (Cobo et al., 2011). Among the most commonly used bibliometric maps are co-citation maps (Small, 1973) and keyword co-occurrence maps (Callon et al., 1983). Co-citation analysis measures the similarities between studies by counting the number of times that two documents are cited together by a third document. Co-citation analysis considers the references cited by the documents under study, thereby broadening the focus of the analysis. This technique is used for units of analysis such as authors, references, and journals. Likewise, keyword co-occurrence identifies links between research topics in a particular field based on the frequency of co-occurrence of keywords in documents. It also tracks developments in that field (Callon et al., 1983).

In this paper, we study the most cited references by NIS documents, regardless of whether they are indexed in the WoS CC database. By doing so, we partially overcome the limitation of ignoring NIS studies that, by virtue of not being indexed in the WoS CC database, do not appear among the most cited and influential papers. Keyword co-occurrence mapping of NIS papers is also used to identify the most common keywords in the set of documents under study and to determine the conceptual framework of the NIS research field. Lastly, the documents are divided into two sets of studies for separate analyses. The first set consists of older documents on traditional topics such as the origins and evolution of NISs, the capacity of countries to innovate, and the relationships of institutions, different organizational forms, networking, production, and competence building with innovation. The second set consists of newer entrepreneurship research documents.

3. Results

3.1. Evolution and structure of NIS publications and citations

The search was conducted in December 2018 and identified 1,107 records on NIS research indexed in WoS CC between 1960 and 2017. By December 2018, these 1,107 documents had received 17,031 citations, with 15.4 citations per study and an h-index of 65. The oldest NIS study indexed in the WoS CC

was published in 1990 ("Management of national technology programs in a newly industrialized country – Taiwan"; Chiang, 1990). Thus, the real period of analysis was 1990 to 2017.

Figure 1 shows the publications and citations per year. The number of NIS publications and the number of citations received by these publications reveal the considerable attention and increasing interest that this research field has received from public administrations, the scientific community, and international organizations, especially since 2007, when 65 studies were published, and 598 citations were registered.

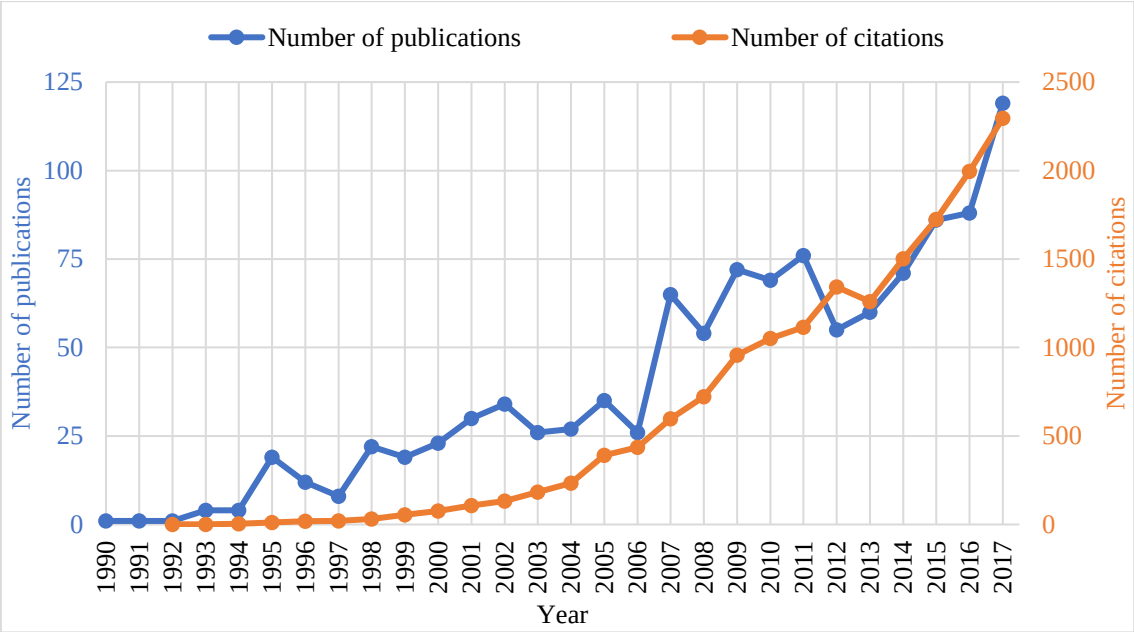

Figure 1. Annual number of publications and citations of NIS research.

Another way of measuring the influence and importance of these publications is through their citation structure. Table 1 shows the distribution of publications over five periods: 1990 to 1999, 2000 to 2004, 2005 to 2009, 2010 to 2014, and 2015 to 2017. Table 1 also shows the number of citations received by these publications, the h-index, and the citations per study. According to Table 1, the highest h-index (41) was for the period 2000 to 2004. The lowest h-index (12) was for the most recent period (2015 to 2017). The highest efficiency in terms of citations per study (45.1) was for the period 1990 to 1999, closely followed by the period 2000 to 2004 (citations per study = 44.3). The lowest number of citations per study (2.0) was for the most recent period (2015 to 2017). These results make sense because the lifetime of newer papers is shorter. Consequently, they have less time to accumulate citations.

Period	TS	TC	h	C/S
1990–1999	92	4,152	25	45.1
2000–2004	140	6,201	41	44.3
2005–2009	252	3,231	29	12.8
2010–2014	331	2,871	26	8.7
2015–2017	292	576	12	2.0
Total	1,107	17,031	65	15.4

Table 1. General publication and citation structure according to WoS CC data.

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

3.2. The most cited NIS studies according to WoS CC

The analysis of the most cited NIS studies reflects these papers' influence and popularity and the attention received from the scientific community (López-Rubio, Roig-Tierno & Mas-Tur, 2020). In this section, we analyze the most cited NIS research papers. The total number of citations measure is biased toward older papers because they have been published for longer. Therefore, we also use the number of citations per year.

Table 2 presents an all-time list of the 25 NIS studies with more than 150 citations based on WoS CC data. The five most cited NIS papers have more than 475 citations. The first study, by Freeman (1995), explains that national and regional innovation systems are still essential, even in a globalized world, because competitive advantage is created and sustained through local agents, processes, and dynamics. The second, by Cooke, Uranga and Etxeberria (1997), shows that NIS-related problems inherent to its complexity can be attenuated by considering smaller areas such as regional or even local innovation systems. The third, by Furman, Porter and Stern (2002), focuses on a country's ability to produce and commercialize a long-term flow of innovative technology (i.e., national innovative capacity) to evaluate the determinants of country-level differences in innovation intensity. According to the authors, the innovation orientation of a national industry cluster is composed of four elements: (1) the local context, which may encourage innovation-related investment, (2) the demand conditions, which may be sophisticated, (3) the related and supporting industries, especially when they form clusters rather than isolated industries, and (4) the input conditions such as human resources, research infrastructures, and access to risk capital. The fourth, by Pittaway *et al*. (2004), explores the principal benefits of business networking for innovativeness, highlighting the idea that network relationships with suppliers, customers, and intermediaries such as professional and trade associations are important factors affecting innovation performance and productivity. The fifth, by Lundvall *et al*. (2002), addresses the origins of the NIS and how NISs have evolved due to a combination of ideas that have moved from production structure toward all the elements and relationships that contribute to innovation and competence building.

RTC	TC	Author	Document title	PY	C/Y	RCY
1	864	Freeman, C	The National System of Innovation in historical perspective	1995	37.6	6
2	825	Cooke, P; Uranga, MG; Etxebarria, G	Regional innovation systems: Institutional and organisational dimensions	1997	39.3	4
3	713	Furman, JL; Porter, ME; Stern, S	The determinants of national innovative capacity	2002	44.6	1
4	542	Pittaway, L; Robertson, M; Munir, K; Denyer, D; Neely, A	Networking and innovation: a systematic review of the evidence	2004	38.7	5
5	486	Lundvall, BA; Johnson, B; Andersen, ES; Dalum, B	National systems of production, innovation and competence building	2002	30.4	7
6	389	Meyer-Krahmer, F; Schmoch, U	Science-based technologies: university-industry interactions in four fields	1998	19.5	11
7	374	Muller, E; Zenker, A	Business services as actors of knowledge transformation: the role of KIBS in regional and national innovation systems	2001	22.0	8

8	289	Liu, XL; White, S	Comparing innovation systems: a framework and application to China's transitional context	2001	17.0	15
9	253	Phene, A; Fladmoe-Lindquist, K; Marsh, L	Breakthrough innovations in the US biotechnology industry: The effects of technological space and geographic origin	2006	21.1	9
10	245	Colombo, MG; Delmastro, M	How effective are technology incubators? Evidence from Italy	2002	15.3	17
11	235	Owen-Smith, J; Riccaboni, M; Pammolli, F; Powell, WW	A comparison of US and European university-industry relations in the life sciences	2002	14.7	20
12	231	Carlsson, B	Internationalization of innovation systems: A survey of the literature	2006	19.3	13
13	221	Mowery, DC; Oxley, JE	Inward technology transfer and competitiveness - the role of National Innovation Systems	1995	9.6	38
14	217	Freeman, C	Continental, national and sub-national innovation systems - Complementarity and economic growth	2002	13.6	22
15	212	Cooke, P; Uranga, MG; Etxebarria, G	Regional systems of innovation: an evolutionary perspective	1998	10.6	34
16	206	Hassink, R	How to unlock regional economies from path dependency? From learning region to learning cluster	2005	15.8	16
17	194	Fagerberg, J; Srholec, M	National innovation systems, capabilities and economic development	2008	19.4	12
18	178	Spencer, JW	Firms' knowledge-sharing strategies in the global innovation system: Empirical evidence from the flat panel display industry	2003	11.9	29
19	171	Le Bas, C; Sierra, C	'Location versus home country advantages' in R&D activities: some further results on multinationals' locational strategies	2002	10.7	33
20	166	Acs, ZJ; Autio, E; Szerb, L	National Systems of Entrepreneurship: Measurement issues and policy implications	2014	41.5	2
21	165	Sharif, N	Emergence and development of the National Innovation Systems concept	2006	13.8	21
22	161	Archibugi, D; Michie, J	The globalization of technology - a new taxonomy	1995	7.0	57
23	160	Autio, E; Kenney, M; Mustar, P; Siegel, D; Wright, M	Entrepreneurial innovation: The importance of context	2014	40.0	3
24	160	Metcalfe, JS	Technology systems and technology policy in an evolutionary framework	1995	7.0	60
25	157	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	19.6	10

Table 2. The 25 most cited NIS studies indexed in WoS CC.

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

Finally, Table 3 presents the results of the co-citation analysis based on the cited references. VOSviewer software was used to do so. The total link strength refers to the total number of co-citations of each cited reference. These cited references need not be indexed in the WoS CC database, so these data

complement the results in Table 2. Three publications have more than 200 citations and a total link strength of more than 750: *National Innovation Systems. A Comparative Analysis*, by Nelson (1993), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, by Lundvall (1992), and *Technology policy and economic performance. Lessons from Japan*, by Freeman (1987). These seminal works are not indexed in WoS CC.

R	Cited reference	Citations	TLS	Type
1	Nelson, RR (1993). National Innovation Systems. A comparative Analysis	333	1006	B
2	Lundvall, BA (1992). National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning	311	964	B
3	Freeman, C (1987). Technology Policy and Economic Performance. Lessons from Japan	227	753	B
4	Freeman, C (1995). The "National System of Innovation" in historical perspective	106	361	A
5	Edquist, C (1997). Systems of Innovation: Technologies, Institutions and Organizations	100	406	B
6	Porter, ME (1990). The competitive Advantage of Nations	100	354	A
7	Nelson, RR and Winter SG (1982). An Evolutionary Theory of Economic Change	93	332	B
8	Cohen, WM and Levinthal DA (1990). Absorptive Capacity: A New Perspective on Learning and Innovation	68	175	A
9	Lundvall, BA, Johnson B, Andersen, ES and Dalum, B (2002). National systems of production, innovation and competence building	67	241	A
10	Etzkowitz, H and Leydesdorff L (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations	66	184	A

Table 3. The 10 most cited documents by NIS papers.

Notes: R = ranking; TLS = total link strength; A = article; B = book.

3.3. The most influential NIS studies indexed in WoS CC

Interestingly, the five most cited papers are also among the seven studies with the highest number of citations per year. This finding implies that these studies are highly influential in both absolute and relative terms. Surprisingly, the two most recent papers of the 25 most cited studies, which were published in 2014, are ranked highly in this ranking. They occupy the 2nd and 3rd positions, with 41.5 and 40.0 citations per year, respectively. Both studies focus on entrepreneurship research. Table 4 presents the seven most influential papers in NIS research sorted by citations per year. Figure 2 shows the annual citations of these articles by year of publication until 2017.

The 2nd most influential NIS article, by Acs, Autio and Szerb (2014), defines the novel concept of the national system of entrepreneurship as "the dynamic, institutionally embedded interaction between entrepreneurial attitudes, ability, and aspirations, by individuals, which drives the allocation of resources through the creation and operation of new ventures" (Acs, Autio, & Szerb, 2014, p. 479). According to the authors, entrepreneurship research has failed to address country-level aspects of the entrepreneurial process. Therefore, the main goal of the aforementioned paper was to fill this gap by introducing the notion of the national entrepreneurship system and proposing an index methodology (the Global Entrepreneurship and Development Index, GEDI) to highlight interactions between the components of the NES and identify the

bottleneck factors hampering system performance. This index methodology accounts for three considerations: (1) the systemic view of interactions between all NES components, (2) the penalty for bottleneck to identify bottleneck factors holding back system performance, and (3) contextualization, because national entrepreneurial processes are always embedded in a country's institutional framework.

The 3rd most influential NIS article, by Autio *et al*. (2014), focuses on the theoretical, managerial, and policy implications of entrepreneurial innovation by examining the role of context in stimulating such activity, as well as the impact of these implications on entrepreneurial innovation outcomes.

RCY	C/Y	Author	Document title	PY	TC	RTC
1	44.6	Furman, JL; Porter, ME; Stern, S	The determinants of national innovative capacity	2002	713	3
2	41.5	Acs, ZJ; Autio, E; Szerb, L	National Systems of Entrepreneurship: Measurement issues and policy implications	2014	166	20
3	40.0	Autio, E; Kenney, M; Mustar, P; Siegel, D; Wright, M	Entrepreneurial innovation: The importance of context	2014	160	23
4	39.3	Cooke, P; Uranga, MG; Etxebarria, G	Regional innovation systems: Institutional and organisational dimensions	1997	825	2
5	38.7	Pittaway, L; Robertson, M; Munir, K; Denyer, D; Neely, A	Networking and innovation: a systematic review of the evidence	2004	542	4
6	37.6	Freeman, C	The National System of Innovation in historical perspective	1995	864	1
7	30.4	Lundvall, BA; Johnson, B; Andersen, ES; Dalum, B	National systems of production, innovation and competence building	2002	486	5

Table 4. The most influential NIS studies indexed in WoS CC by citations per year.

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

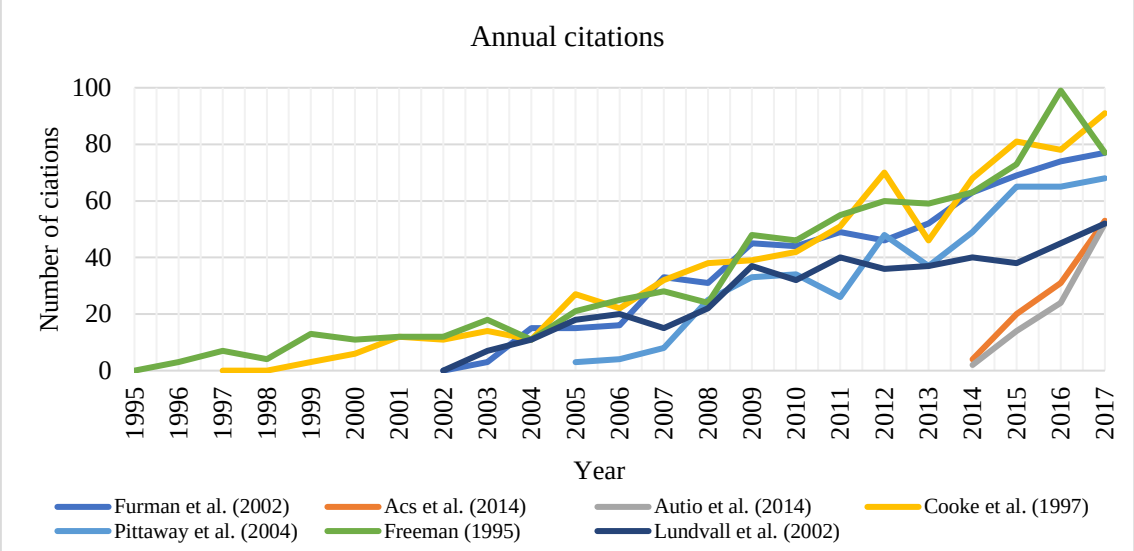

Figure 2. Annual citations of the seven most influential NIS articles.

Another interesting method for studying the influence of these seven articles is to compare the number of citations with the citations received by the rest of the documents published in the same year (Prévot et al., 2010). The 1,107 documents under analysis had received 17,031 citations by December 2018,

when the search for this paper was conducted. Figure 3 shows the percentage of the total number of citations each year and the percentage of citations of the seven most influential articles with respect to the total citations each year.

According to Figure 3, the three most disruptive papers are "Regional innovation systems: Institutional and organizational dimensions" (Cooke, Uranga & Etxeberria, 1997), "The 'National System of Innovation' in historical perspective" (Freeman, 1995), and "Networking and innovation: a systematic review of the evidence" (Pittaway et al., 2004). Interestingly, the two most recent papers, "National Systems of Entrepreneurship: Measurement issues and policy implication" (Acs, Autio & Szerb, 2014) and "Entrepreneurial innovation: The importance of context" (Autio et al., 2014), account for almost two thirds of the total number of citations received by all the studies published in 2014.

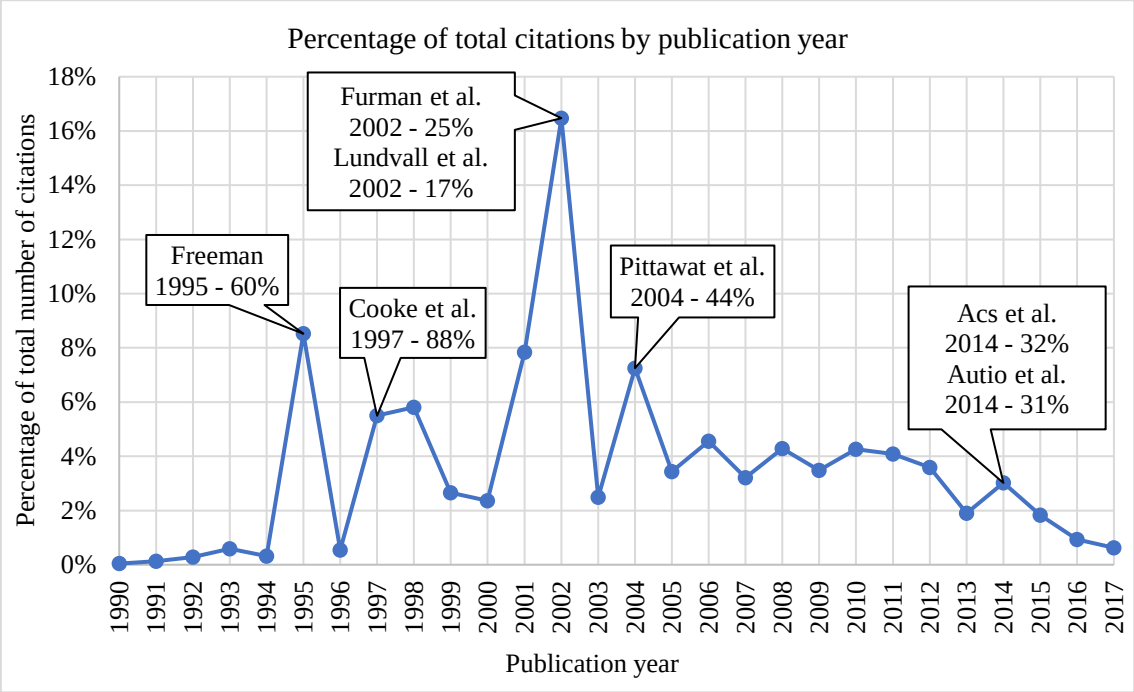

Figure 3. Historical distribution of citations per year (total citations = 17,031).

Figure 3 shows three main breaks according to publication year. Table 5 complements Figure 3 by presenting the following information for these breaks:

- Period 1998 to 2001: The eight studies with more than 100 citations.
- Period 2005 to 2013: The nine studies with more than 100 citations.
- Period 2015 to 2017: The three most cited studies published in 2015, in 2016, and in 2017.

In general, these studies cover traditional innovation system topics such as NISs in different international, national, and regional contexts, knowledge management, and university-industry relationships. However, some of the documents from the last period (2015–2017) focus on sustainability (Huang et al., 2016; Leyden, 2016; Fagerberg & Srholec, 2017) and entrepreneurship (Leyden, 2016; Wu, Zhuo & Wu, 2017).

Period	Author	Document title	PY	TC	C/Y
1998-2001	Meyer-Krahmer, F; Schmoch, U	Science-based technologies: university-industry interactions in four fields	1998	389	19.5

	Muller, E; Zenker, A	Business services as actors of knowledge transformation: the role of KIBS in regional and national innovation systems	2001	374	22.0
	Liu, XL; White, S	Comparing innovation systems: a framework and application to China's transitional context	2001	289	17.0
	Cooke, P; Uranga, MG; Etxebarria, G	Regional systems of innovation: an evolutionary perspective	1998	212	10.6
	Lundvall, BA	Why study national systems and national styles of innovation?	1998	137	6.9
	Sternberg, R; Arndt, O	The firm or the region: What determines the innovation behavior of European firms?	2001	127	7.5
	Martin, BR; Johnston, R	Technology foresight for wiring up the national innovation system - Experiences in Britain, Australia, and New Zealand	1999	106	5.6
	Hall, A; Bockett, G; Taylor, S; Sivamohan, MVK; Clark, N	Why research partnerships really matter: Innovation theory, institutional arrangements and implications for developing new technology for the poor	2001	103	6.1
2005-2013	Phene, A; Fladmoe-Lindquist, K; Marsh, L	Breakthrough innovations in the US biotechnology industry: The effects of technological space and geographic origin	2006	253	21.1
	Carlsson, B	Internationalization of innovation systems: A survey of the literature	2006	231	19.3
	Hassink, R	How to unlock regional economies from path dependency? From learning region to learning cluster	2005	206	15.8
	Fagerberg, J; Srholec, M	National innovation systems, capabilities and economic development	2008	194	19.4
	Sharif, N	Emergence and development of the National Innovation Systems concept	2006	165	13.8
	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	157	19.6
	Block, F	Swimming against the current: The rise of a hidden developmental state in the United States	2008	147	14.7
	Filippetti, A; Archibugi, D	Innovation in times of crisis: National Systems of Innovation, structure, and demand	2011	123	17.6
	Motohashi, K	University-industry collaborations in Japan: The role of new technology-based firms in transforming the National Innovation System	2005	115	8.8
2015-2017	Watkins, A; Papaioannou, T; Mugwagwa, J; Kale, D	National innovation systems and the intermediary role of industry associations in building institutional capacities for innovation in developing countries: A critical review of the literature	2015	37	12.3
	Kruss, G; McGrath, S; Petersen, IH; Gastrow, M	Higher education and economic development: The importance of building technological capabilities	2015	37	12.3
	Cunningham, JA; Link, AN	Fostering university-industry R&D collaborations in European Union countries	2015	35	11.7
	Huang, P; Negro, SO; Hekkert, MP; Bi, KX	How China became a leader in solar PV: An innovation system analysis	2016	21	10.5
	Leyden, DP	Public-sector entrepreneurship and the creation of a sustainable innovative economy	2016	16	8.0
	Kou, MT; Chen, KH; Wang, SY; Shao, YM	Measuring efficiencies of multi-period and multi-division systems associated with DEA: An application to OECD countries' national innovation systems	2016	16	8.0
	Acs, ZJ; Audretsch, DB; Lehmann, EE; Licht, G	National systems of innovation	2017	11	11.0

Wu, J; Zhuo, SH; Wu, ZF	National innovation system, social entrepreneurship, and rural economic growth in China	2017	9	9.0
Fagerberg, J; Srholec, M	Capabilities, economic development, sustainability	2017	8	8.0

Table 5. The most cited NIS studies published in the periods 1998–2001, 2005–2013, and 2015–2017.
Notes: PY = year of publication; TC = total citations; C/Y = citations per year.

3.4. Conceptual framework and influence on subsequent research

The primary goal of science mapping is to show the structure and dynamics of a discipline (Noyons, Moed & Van Raan, 1999). In this study, keyword co-occurrence analysis is used to study the conceptual structure of the research field under investigation (Callon et al., 1983). Figure 4 presents the map of keyword co-occurrence for the entire study period (1990–2017), with a threshold of 14 occurrences and the 100 most representative links. Many of the keywords in Figure 4 refer to innovation system agents and factors affecting innovation. Examples include *R&D*, *technology*, *industry*, *policies*, *science*, *firms*, *knowledge*, *networks*, *universities*, *patents*, *entrepreneurship*, *technology transfer*, *institutions*, *globalization*, *foreign direct investment*, *absorptive capacity*, and *clusters*. The keywords also refer to models of innovation, such as *innovation system*, *Triple Helix* (Etzkowitz & Leydesdorff, 2000), *regional innovation system* (*RIS*; Cooke, 1992), and *open innovation* (Chesbrough, 2003), as well as indicators to measure the impact of innovation on the economy, such as *growth*, *performance*, and *competitiveness*.

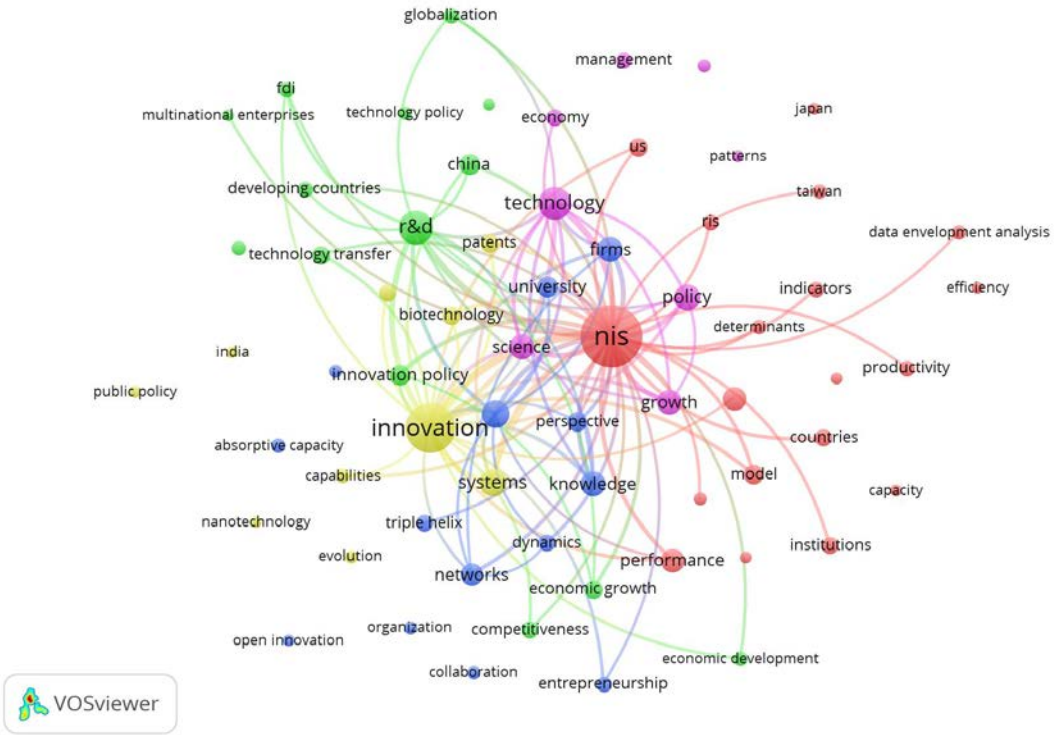

Figure 4. Map of keyword co-occurrence in NIS research (1990–2017).

Another interesting question is how the most influential NIS and NES papers have influenced subsequent research. We considered the seven most influential papers, which appear in Table 4. These

seven papers can be sorted into two sets: (1) the five main NIS papers on traditional topics such as the origins and evolution of NISs, the capacity of countries to innovate, and the relationships of institutions, different organizational forms, networking, production, and competence building with innovation (Freeman, 1995; Cooke, Uranga & Etxebarria, 1997; Furman, Porter & Stern, 2002; Lundvall et al., 2002; Pittaway et al., 2004); (2) two papers dealing with NESs, measurement issues, policy implications (Acs, Autio & Szerb, 2014), and the importance of context in entrepreneurial innovation (Autio et al., 2014).

By analyzing who has cited these two sets of papers, we can identify the influence that these papers have had on later research. The first set of papers received 3,430 citations in 2,796 citing documents, whereas the second set received 326 citations in 302 citing documents. Figures 4 and 5 show the keyword co-occurrence maps of the citing documents for the first and the second sets of papers, respectively. The thresholds are 65 occurrences for Figure 5 and nine occurrences for Figure 6. Both Figures 4 and 5 display the 100 most representative links. Table 6 presents the 20 most common keywords in all NIS documents indexed in WoS CC (1,107 documents), in the 2,796 documents to have cited the first set of papers, and in the 302 documents to have cited the second set of papers.

Citing documents usually discuss the same research topics as the papers they cite. Accordingly, most keywords included in the NIS framework are also among the keywords of documents citing NIS research. However, *absorptive capacity*, *clusters*, and *RIS* are more prevalent among the keywords of documents citing NIS research, as shown in Table 6. *Small and medium-sized enterprises* (*SMEs*) is a new research topic among the documents citing NIS research. These results reveal the increasing influence of absorptive capacity, clusters, RISs, and SMEs on subsequent research because of their impact on generating innovation and enhancing competitiveness (Huber, 2011; Fu, Woo & Hou, 2016).

Comparing the NIS framework with the most common keywords of the documents citing NES research shows that, perhaps understandably, *entrepreneurship* is more prevalent among the documents citing NES research. New research topics emerge in documents citing NES research. Examples include *entrepreneurial ecosystems*, *knowledge spillovers*, and *startups*. These results reveal the increasing importance of a region's social, political, economic, and cultural elements (i.e., the entrepreneurial ecosystem) in encouraging entrepreneurs and promoting innovative startups.

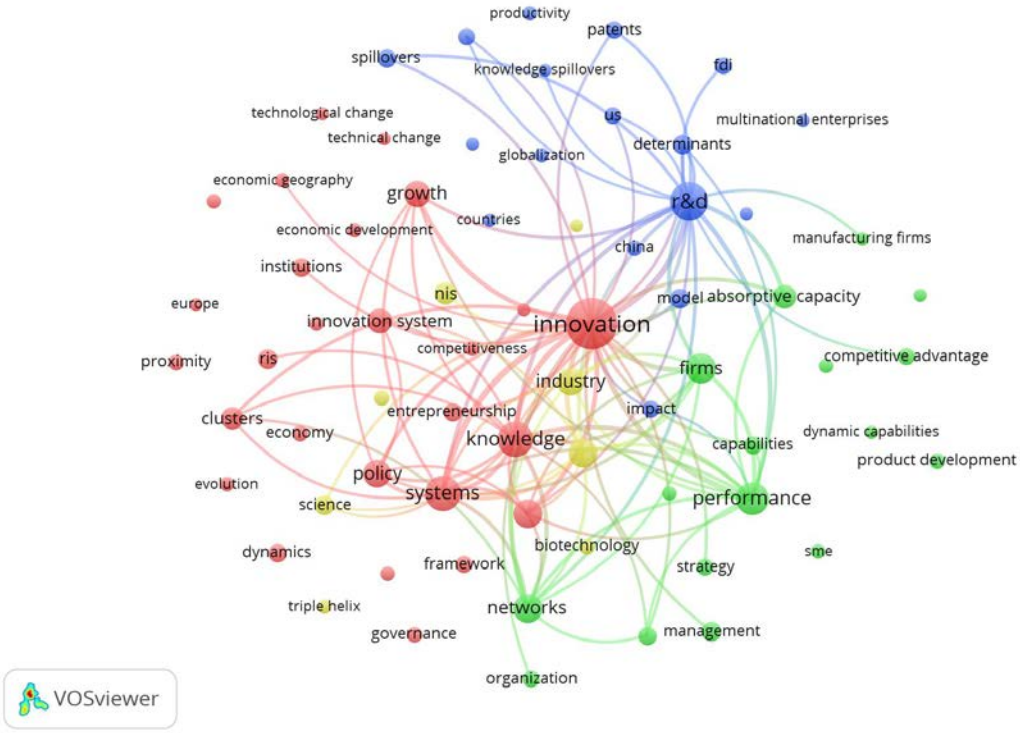

Figure 5. Keyword co-occurrence of the documents that have cited the five most influential NIS studies on traditional topics.

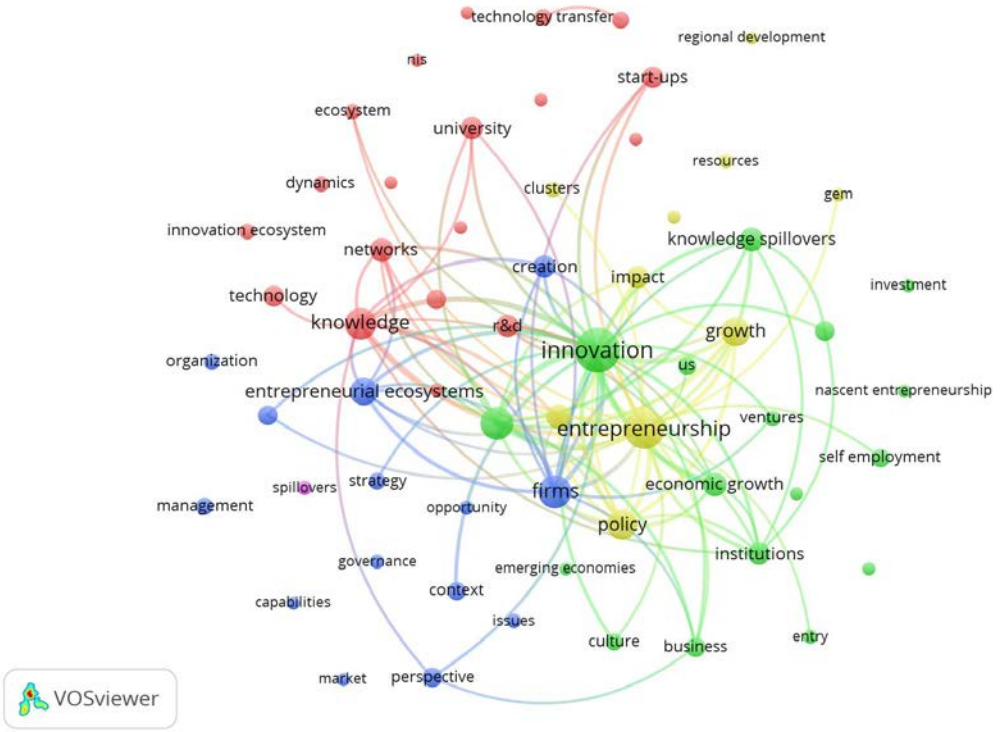

Figure 6. Keyword co-occurrence of the documents that have cited the two most influential NIS studies on entrepreneurship.

	All NIS documents (1,107 documents)			Citers of main NIS studies (2,796 citing documents)			Citers of main NES studies (302 citing documents)		
R	Kw	Oc	Co	Kw	Oc	Co	Kw	Oc	Co
1	NIS	371	1026	Innovation	963	3614	Innovation	104	465
2	Innovation	253	711	R&D	547	2497	Entrepreneurship	87	400
3	R&D	116	466	Systems	483	1983	Performance	57	296
4	Technology	105	425	Knowledge	466	2195	Firms	55	276
5	Systems	80	304	Performance	404	1829	Knowledge	52	270
6	Industry	76	335	Firms	331	1574	Policy	49	252
7	Policy	69	273	Technology	327	1532	Growth	45	215
8	Science	65	253	Perspective	316	1322	Entrepreneurial ecosystems	41	191
9	Firms	63	278	Networks	314	1519	Systems	33	186
10	Knowledge	61	288	Policy	283	1244	Networks	30	167
11	Growth	61	258	Industry	282	1366	Economic growth	30	150
12	Performance	57	227	Growth	271	1214	Knowledge spillovers	28	131
13	Innovation system	55	140	Innovation system	240	913	Institutions	27	136
14	Networks	54	213	Absorptive capacity	223	1046	University	26	139
15	China	48	186	Clusters	196	924	R&D	26	127
16	Innovation policy	48	146	NIS	183	724	Creation	25	131
17	University	45	139	RIS	157	689	Impact	25	129
18	Perspective	42	178	Management	155	612	Start-ups	24	124
19	Model	42	172	Determinants	150	709	Technology	24	117
20	Biotechnology	36	163	Science	143	641	Perspective	21	108

Table 6. Most common keywords.

Notes: R = ranking; Kw = keyword; Oc = occurrences; Co = co-occurrences.

4. Conclusions

This paper analyzes all NIS studies indexed in WoS CC. Bibliometrics are used to study publications and citations over time, identify the most influential NIS research papers, observe how entrepreneurship and NIS interact, and depict the NIS research framework. Lastly, the documents citing the most influential NIS and NES papers are analyzed separately to illustrate how both research fields have influenced later studies.

We first discuss the most influential studies in NIS research. The five most cited NIS papers were published more than one decade ago, between 1995 and 2004. These studies address traditional NIS topics, including the origins of the concept, the role of institutions and various organizations, the innovative capacity of countries, the relationship networks needed to innovate, and the way that production and competence building fit into NIS research. These five papers are also five of the seven articles with the most citations per year. Two recent papers on NES published in 2014 occupy the 2nd and 3rd places of the ranking by citations per year. These seven studies are considered the most influential studies because of their high ranking according to both number of citations and article lifetime. These results highlight the increasing influence and impact of NES and entrepreneurial activities on NIS.

Overall, the NIS framework comprises traditional research concepts such as innovation system actors, factors affecting innovation, and indicators to measure the impact of innovation on economic development and technical progress. Entrepreneurship is also included in the NIS framework. Certain research topics have influenced subsequent research. Absorptive capacity, clusters, RISs, and SMEs have become more prominent in NIS research, whereas entrepreneurial ecosystems, knowledge spillovers, and startups have become key research topics in NES research.

The NIS framework also comprises different innovation models such as the innovation system, the Triple Helix, RISs, and open innovation. These results highlight the fact that the systemic approach to innovation is often supported by two other models. The first is the open innovation model, which involves strategic, carefully managed exchanges of information with actors outside the boundaries of an organization such as firms, universities, and not-for-profit organizations. These actions are aimed at integrating their resources and knowledge into the organization's own innovative process (Bogers, Chesbrough & Moedas, 2018). The second model is the Triple Helix, which is based on innovation experience in developed countries. In such contexts, it has been observed that relationships between government (public administrations), universities (science), and business (industry and firms) are essential to foster innovation, economic development, and technical progress in a knowledge-based economy (Ranga & Etzkowitz, 2013).

The Triple Helix model has now evolved into the Quadruple Helix model and even the Quintuple Helix model (government, university, industry, knowledge society, and sustainability). The Triple Helix centers on the knowledge economy, the Quadruple Helix on the knowledge society and the knowledge democracy, and the Quintuple Helix on socioecological transitions and the natural environment (Carayannis et al., 2018; López-Rubio, Roig-Tierno & Mas-Verdú, 2021). In the particular case of China, the Triple Helix has been hugely important because it has allowed smooth interactions between the Chinese government, multinational enterprises, and universities. Moreover, well-funded programs to build innovation infrastructure to increase the absorptive capacity of Chinese firms have resulted in the successful transfer of foreign technology to Chinese firms (Fu, Woo & Hou, 2016). The EU innovation policy for the period 2021 to 2027 (*Horizon Europe*) is another example of the innovation system approach. It is based on three pillars: (1) open science, (2) global challenges such as industrial leadership, societal challenges, and sustainable development, and (3) open innovation to make Europe a front runner in market-creating innovation (European Commission, 2018).

The innovation literature has historically focused on business, institutions, structures, and policies, whereas the entrepreneurship literature has centered on the individual or the firm (Zahra and Wright, 2011). However, entrepreneurs have become key innovation actors in recent years and have been analyzed from multiple approaches such as that of the NES and the importance of context in entrepreneurial innovation (Acs, Autio & Szerb, 2014; Autio et al., 2014; Acs et al., 2016; Lafuente, Szerb & Acs, 2016; Schillo, Persaud & Jin, 2016; López-Rubio, Roig-Tierno & Mas-Verdú, *in press*), entrepreneurial ecosystems (Audretsch & Belitski, 2017; Spigel, 2017; Audretsch et al., 2019; López-Rubio, Roig-Tierno & Mas-Tur, 2020), entrepreneurship support policies (Cowling, 2016; Leyden, 2016; McCann & Ortega-Argilés, 2016; Colombo et al., 2019; Guerrero & Urbano, 2019), entrepreneurial universities (D'Este & Perkmann, 2011; Guerrero & Urbano, 2012), the entrepreneurial society (Audretsch, 2014), and social entrepreneurship (Fagerberg et al., 2011; Wu, Zhuo & Wu, 2017).

Based on the analysis of the most common keywords and the most influential studies in this area, we propose a Sextuple Helix model as an analytical framework that brings together innovation and entrepreneurship. This model builds on the Quintuple Helix of government, university, industry, the knowledge society, and sustainability, augmenting this model by adding a sixth dimension: entrepreneurship. This analytical framework may have massive potential for investigating the specific fit of entrepreneurship and entrepreneurial innovation into a NIS (Acs, Autio & Szerb, 2014; Autio et al., 2014) and the role of institutional entrepreneurship as a possible solution for the structural problem of insufficient agency in the NIS perspective (Hung & Whittington, 2011).

Finally, it is important to note some of this study's limitations. NIS publications not indexed in WoS CC were not included among the analyzed studies. Thus, the seminal works by Lundvall, Nelson, and Freeman were not included in the analysis. However, by also examining the most cited references, we were able to enrich the results and partially overcome this limitation. Although researchers should keep these limitations in mind, this paper nonetheless provides key results regarding the most important documents and the conceptual framework of the NIS research field, the fit of entrepreneurship into NIS research, and future lines of investigation.

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