Scientometrics (2012) 91:977–996
DOI 10.1007/s11192-012-0653-5

State of the art on the Systems of Innovation research: a bibliometrics study up to 2009

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Received: 19 September 2011 / Published online: 10 February 2012

Abstract Over the last decades there has been a growing interest on developing research and formulating public policy by using the Innovation Systems approach. However, as evidenced on the academic literature there is a lack of systematic, chronological and synthesizing studies indicating how this field has evolved over time. This paper has as main objective to consolidate the state of the art of academic research on IS, based on a bibliometrics study on literature published over the past 35 years. The results are discussed under the following perspectives: general results, chronological distribution, author relevance, articles and cited references of relevance, journals relevance and institutions and countries relevance. The paper ends with a discussion of the main implications and limitations of the study.

Keywords Innovation Systems · Systems of Innovation · Bibliometrics

JEL Classification B52 · C02 · O1 · O3

Introduction

Innovation Systems (IS) or Systems of Innovation (SI) are the terms used by scholars and policy makers to describe the emerging industrial, scientific and technological structures,

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institutions and processes that influence economic development (Freeman 1987; Lundvall 1992; Nelson 1992, 1993).

In the last decades there has been a major interest in the academic, public and supranational sectors in using the IS framework to inform science, technology and innovation policy making (Godin 2009), therefore, increasing the rate of publications in the subject.

Despite the growing rates of specialized literature, there is a lack of systematic, chronological and synthesizing studies indicating how this field has evolved over time and institutionalized as a field of science, moreover, evidence on its maturity—in terms of theoretical and empirical contributions—has rarely been explored. In spite of this matter, we propose the use of a bibliometrics approach, based on the quantitative analysis of peer-reviewed articles to consolidate the state of the art of academic research on Innovation Systems.

Bibliometric analysis uses statistical and mathematical tools to map out data and patterns of bibliographical records pertaining to a network of scientific documents (Santos and Kobashi 2009; Bellis 2009; Garfield et al. 1964; Small 1973).

More specifically, we systematically analyze data that emerged from 773 full length articles published between 1975 and 2009 in the Social Sciences Citation Index (SSCI) from Thomson Reuters ISI Web of Science. The SSCI is considered the most important source of data for bibliometric analysis in the social sciences (van Leeuwen 2006).

The results include the identification of the most relevant authors in terms of number of publications and citation analysis, the journals with most publications in the subject and also with most citations, the institutions and countries with more relevance and the co-citation networks among the most relevant authors.

In the following section a brief review of the Innovation Systems literature will be introduced, followed by the design of this research and a brief overview of bibliometrics theory. Next, the "Results" section presents the most relevant inferences taken out of the data, organized in terms of general results, author relevance, articles and cited references relevance, journal relevance and institutions/countries relevance. The paper ends with the conclusions and main implications of this research.

Innovation systems and economic development

As a result of the theoretical and conceptual evolution of research on the effects of innovation on economic development, the conceptual framework known as "Innovation Systems—IS" or "Systems of Innovation—SI" approach was proposed.

In the 1980's scholars such as Freeman (1987), Lundvall (1992) and Nelson (1993) were questioning the Neoclassical paradigm that was used to explain economic development. They believed that development was the result of a complex web of relationships between agents that were not only economic ones and also, that, institutions were also important to regulate *laissez-faire* markets when economic fluctuations appear. Thus, based on the work of Schumpeter and Keynes. List among others, they aligned the IS approach with the Evolutionary and Institutional Economics streams (Nelson 2007; Nelson and Winter 1982; Freeman 2004).

Freeman (1987), Lundvall (1992) and Nelson (1993) are known to be the creators of the approach. Although, there is no certainty on which one of them was actually the first proposer, all three shared important common foundations: (1) the need to embrace other agents rather than pure economic ones; (2) the complex interactions between institutional actors, processes and structures inside a geographical context, mainly national context and (3) the importance of scientific and technological knowledge to produce innovations.

In a nutshell, in 1987 Freeman wrote the book "*Technology Policy and Economic Performance: Lessons from Japan*" where he discussed how technology policy helped Japan in becoming an economic power, and highlighted the importance of the complex linkages among different institutional agents on the success of those policies (Freeman 1987). In 1988, Dosi et al. edited a book entitled "*Technical Change and Economic Theory*" (Dosi et al. 1988) which accounted with a specific section devoted to the discussion of National Innovation Systems including the work of Nelson (1988), Freeman (1988) and Lundvall (1988). Was Lundvall that in 1992 wrote another important book, entitled "*National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*" where he discussed about the IS approach in different settings (Lundvall 1992). And one year later, Nelson wrote "*National Innovation Systems: A Comparative Analysis*" where he compared and analysed the National Innovation Systems of fifteen different countries (Nelson 1993).

Soon after the publication of those books, many other scholars embraced the IS approach and contributed with their own views. Among them, in 1998, Bracyk and Cooke published a book entitled "*Regional Innovation Systems: The Role of Governances in a Globalized World*" where the authors discussed the role of other geographical contexts besides the national one (Braczyk et al. 1998). Cooke specially, had been working with the role of the regional context for Innovation Systems since the 1990s and has published many scholarly works since then (Cooke 1992; Cooke et al. 1997, 1998).

Another stream that emerged during the following years to the appearing of the National Innovation System approach, was the sectoral approach. In this approach, the proposing authors were interested in the notion that for some IS, the industrial sector is more important than geographical borders, given that some sectors outbound them. Scholars such as Malerba gave birth to this stream and thus, published many works on these subject (Malerba 2002).

Another important stream that outflowed from the original version was the technological Systems of Innovation approach, that proposed to look for technology-driven knowledge flows on the system rather than geographical or sectoral set-ups (Carlsson and Stankiewicz 1991; Carlsson et al. 2002). The technological approach outbounds geographical borders as well as sectoral borders, i.e. a specific technology might be used in different industrial sectors.

In addition to the blossoming of sub-types of Innovation Systems as discussed above, the IS approach has also been linked to similar frameworks and theories. It is the case of the Triple Helix framework, which particularly states the relationship between three actors: universities, firms and government (Etzkowitz and Leydesdorff 2000). For IS scholars, the Triple Helix represents one of its many sub-systems, because an IS entails additional relationships with other actors.

Since its first draft and especially during the last decade, the use of the IS approach has increased in both academic and policy-making fields. Organizations such as the Organization for Economic Cooperation and Development (OECD), the United Nations Conference on Trade and Development (UNCTAD), the World Bank and the International Monetary Fund (IMF) use the approach to inform policy-making and to conduct research on regional and national contexts (Sharif 2006; OECD 1997).

On the academic side, as a sample of the recent studies using the IS approach we can site Lee and Yoo (2007), whom have analyzed the National Innovation Systems of France and South Korea; Edgington (2008) who has studied the Japanese Innovation System and the OECD which has conducted studies on the National Innovation Systems of China and South Korea (OECD 2009a, b).

Although, the growing body of literature in the Innovation Systems research has promoted its diffusion across sectors, countries and continents, it has also produced a corpus of publications that needs to be systematized in order to understand the evolution of the field over time.

In this sense, the notion of how the field has been institutionalized, in terms of most relevant literature, authors, journals, institutions and countries, help in bringing key elements on the theoretical and practical contributions so far as well as on the future challenges the field must face.

Thus, in the next section, the approach we use in this paper to tackle this matter will be explained and described.

Research design

The issue of choosing a comprehensive method to approach the systematization and consolidation of a complex research field such as the Innovation Systems field requires careful considerations related to what qualitative/quantitative mix should be the most adequate.

In a broader sense, qualitative approaches are based on a certain degree of subjectivity in their assessments due to the nature of data collection which is basically done by interviewing experts or even by blind review processes. However, discursive approaches often lack a solid quantitative basis for sustaining their proposals and so expert-based judgments may be influenced by subjective elements, narrowness in mental models and limited cognitive horizons (van Leeuwen et al. 2003; van Raan 2003).

Quantitative approaches on the other hand, use bibliometric indicators as a measure of performance assessment, which are based on statistical and mathematical tools to map out data and patterns of bibliographical records pertaining to a network of scientific documents (Santos and Kobashi 2009; Bellis 2009; Garfield et al. 1964; Small 1973; Santos 2003).

What is bibliometrics?

When there is a lack of systematic, chronological and synthesizing studies indicating how a given science field has been institutionalized over time, bibliometrics might be used to shed light on this matter by analyzing the production of its scientific literature, based on the notion that the essence of any scientific field is to produce "knowledge" and that scientific literature is the product or tangible manifestation of that process (Okubo 1997).

In practice, bibliometric analyses use bibliographical data stored on electronic databases and the inferences are made under the premise that different databases do contain different metadata, therefore, the importance of choosing an adequate database to carry out the study.

In the following section, we describe the logic we used to choose a database to conduct our study.

Data and sample

The ISI Web of Science, owned by Thomson Reuters, is considered to be the most important source of data for bibliometric analysis in sciences (van Leeuwen 2006). Moreover, the Web of Science is comprised of three sub-field databases: the Science Citation Index (SCI), the Social Sciences Citation Index (SSCI) and the Arts and

Humanities Citation Index (AHCI) and accounts for approximately 10,000 journals of a total of around a million that circulates worldwide, reason by which it was dubbed as the database that contains the "mainstream" journals of all sciences (Okubo 1997).

In order to retrieve a relevant sample of articles, we used the SSCI from Thomson Reuters ISI Web of Science, as it is one of the most comprehensive databases of peer-reviewed journals in the social sciences. Moreover, the SSCI indexes more than 2,400 journals over 50 social science disciplines, adding around 60,000 new cited references per week.[1]

The SSCI also accounts with a unique feature of citation counts, which allows qualifying the relative importance of articles out of a large pool by using an objective measure of influence.

We initially searched for all articles with the words "Innovation Systems", "Innovation System", "System of Innovation" and "Systems of Innovation" in the *Title, Keywords* and *Abstract* fields.

We have used all years available in the SSCI database at the time of the study: from 1975 to 2009 (35 years) and the resulting sample was 773 articles. This set was then fixed as the basis for all future analysis.

The sample of 773 articles was then exported in.txt format to the specialized software Histcite® in order to run further analysis.

Results

This section presents the main results of the bibliometric analysis: the general results, showing a summary of the quantitative results; the chronological distribution of the articles studied, which helps in showing the exponential growth the field has had since 1990; the most relevant authors, the most relevant articles and cited references, the most relevant scientific journals, the most relevant institutions and countries on the Innovation Systems research field.[2]

Despite the search criteria had been narrowed down to peer-reviewed articles, it is known by the scientific community that the most important sources of new knowledge are precisely peer-reviewed articles published on scientific journals.

Thus, an adequate proxy to quantify how a research field has been institutionalized over time is the analysis of scientific production in terms of articles published in peer-reviewed journals indexed in electronic databases.

General results

Initially, Table 1 shows a summary of the general data extracted out of the sample collection of 773 articles.

As shown on Table 1, the search strategy used retrieved a total amount of 773 articles authored by a total of 1,115 authors, affiliated at 621 institutions in 50 countries and published in 189 peer-reviewed journals, citing a total of 25,117 references.

[1] http://thomsonreuters.com/products_services/science/science_products/a-z/web_of_science.

[2] It is worth to mention that since the study was carried out on an electronic database containing solely peer-reviewed articles, other bibliographical material like books, government and supranational reports were not taken into account unless otherwise noted.

Table 1 Summary of the general results

Criteria	Quantity
Articles	773
Authors	1,115
Journals	189
Countries	50
Institutions	621
Cited references	25,117

Source ISI Web of Knowledge

In many cases, articles were written by two or more authors whom could be affiliated to different institutions in different countries. In those cases, all authors, affiliations and countries were taken into account.

The values on Table 1 indicate an important number of scientific publications in the last two decades, however, do not indicate the growth pattern over time, the next section will fill this gap.

Chronological distribution

Equally important as the number of publications on the Innovation Systems research field in the last two decades is the chronological distribution over time of those publications, which is shown on Fig. 1.

Figure 1 shows the sustained growing pattern Innovation Systems research has had in the last twenty years (1990–2009), reaching over 100 articles published in 2009.

The collection contains five articles before 1990: Brooks (1975), discussing the technological progress in weapon systems and its effects on the negotiations to limit the deployment of offensive attacks between the United States and the former Soviet Union; Shapiro (1979), discussing how judicial and regulatory systems can boost or hinder a country's ability in using it science and technological capabilities to develop innovations,

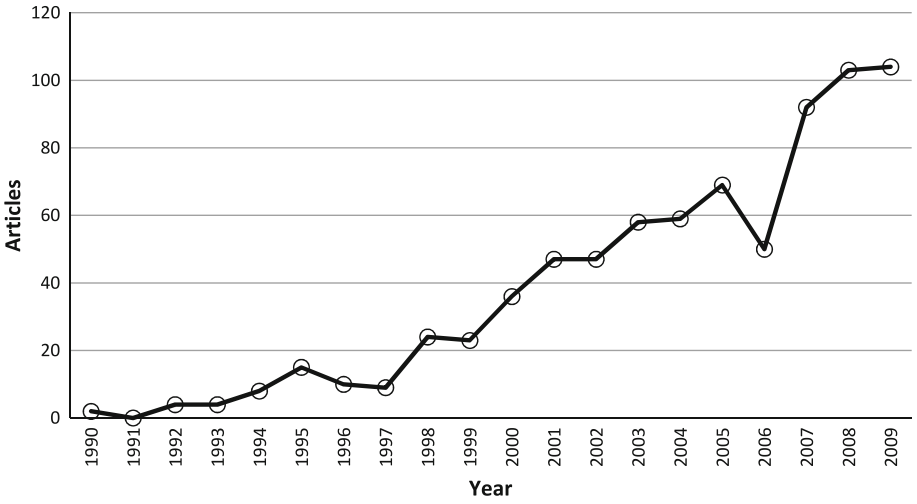

Fig. 1 Chronological distribution of Innovation Systems research. *Source* ISI Web of Knowledge

taken the US as case study; Thornton (1979); Krupp (1983), discussing the function of non-university research institutions for the national R&D system; and Macdowall (1984) is the first in the collection that uses the "Innovation System" approach closer to its current meaning, since it discusses the so-called web of relationships between industry, government and universities in Japan and its positive impact on the country's innovation capability.

Furthermore, the chronological analysis also reveals that 1992 was the first year when the IS framework—as it is known today—was cited. Those authors were:

- Bowonder and Miyake (1992), whom cited Freeman's book "*Technology Policy and Economic Performance: Lessons From Japan*." and Freeman's book chapter in "*Technical Change and Economic Theory*" (Freeman 1987, 1988);
- Granstrand et al. (1992) whom cited Lundvall's book chapter in "*Technical Change and Economic Theory*" (Lundvall 1988); and
- Mowery (1992) whom cited Dosi's book "*Technical Change and Economic Theory*", Freeman's book chapter and Nelson's book chapter on the same title (Dosi et al. 1988; Freeman 1988; Nelson 1988).

Author relevance

Author relevance is measured both as the number of articles published by each one of the authors in the collection and as the number of citations each author possess. Initially, Table 2 shows the inverse distribution between authors and articles produced.

As shown on Table 2, four authors account for 8 or more articles each. This results are in coherence with Lotka's law which predicts that in any discipline, there is only a small number of authors that produce a large quantity of articles meanwhile the majority of authors produces a small amount (Vanti 2002).

Accordingly, Cooke was the most productive author with a total of 10 articles (with co-authorships in some) and a Total Global Citation Score (TGCS) of 373 citations, all of Cooke's publications were related to Regional Innovation Systems. Leydesdorff produced 10 articles as well, most of them in collaboration with other authors and TGCS = 327, most of his studies relate to the Triple Helix model.

With 9 articles and a TGCS = 70, Hekkert's work is related to the functions of Innovation Systems, e.g. (Hekkert and Negro 2009). With 8 articles and a TGCS = 68, Niosi's research focuses on National and Regional Innovation Systems and, in some extent, on high-tech industries such as biotechnology and software e.g. (Niosi et al. 1993; Niosi and Tschang 2009).

The amount of papers per author is not the only productivity indicator, since it is only based on the quantity of papers. Citation analysis might evidence the relative weight of an

Table 2 Author/article distribution rate

Quantity of authors	% of total authors	Quantity of articles
566	73.2	1
166	21.5	2–3
33	4.3	4–5
4	0.5	6–7
4	0.5	8>

Source ISI Web of Knowledge

author by counting the times it has been cited by other works on the same database. Table 3 lists the most cited authors in the collection of 773 articles.

According to Table 3, Cooke is also the author with most citations (373). With 327 citations, the second most cited author is Leydesdorff, who is also the second most productive.

The latter produced in collaboration with Etzkowitz, the paper "*The Dynamics of Innovation: From National Systems and 'Mode 2' to a Triple Helix of University–Industry–Government Relations*" (Etzkowitz and Leydesdorff 2000), which accounted as the most cited article in the collection and gave Etzkowitz the third position in the most cited author ranking.

The fourth and fifth most cited authors, Uranga (217 citations) and Etxebarria (216 citations) respectively, co-authored Cooke in two highly cited articles: "*Regional Innovation Systems: Institutional and Organisational Dimensions*" and "*Regional Systems of Innovation: An Evolutionary Perspective*" (Cooke et al. 1997, 1998). Those two articles are the main explanations for the fourth and fifth places.

In the sixth place, Freeman with 210 citations in four articles: "*The National System of Innovation in Historical-Perspective*", "*Continental, National and Sub-National Innovation Systems—Complementarity and Economic Growth*", "*Technological Infrastructure and International Competitiveness*" and "*Developing Science, Technology and Innovation Indicators: What We Can Learn From the Past*" (Freeman 1995, 2002, 2004; Freeman and Soete 2009).

With 183 citations, Jacobsson is positioned on the seventh place and in the eighth place with 152 citations, Johnson.

In the ninth place, Malerba received 151 citations on his two articles: "*Technological Entry, Exit and Survival: An Empirical Analysis of Patent Data*" and "*Sectoral Systems of Innovation and Production*" (Malerba 2002; Malerba and Orsenigo 1999).

And last but not least, Lundvall in the tenth position with 149 citations of the five articles he authored: "*Why Study National Systems and National Styles of Innovation?*", "*National Systems of Production, Innovation and Competence Building*", "*Introduction to 'Technological Infrastructure and International Competitiveness' by Christopher Freeman*", "*Forms of Knowledge and Modes of Innovation*" and "*How Europe's Economies Learn: A Comparison of Work Organization and Innovation Mode for the EU-15*" (Arundel et al. 2007; Lundvall 1998, 2004; Lundvall et al. 2002).

Table 3 Most cited authors in the collection

Rank	Authors	Citation count	Article count
1	Cooke	373	10
2	Leydesdorff	327	10
3	Etzkowitz	275	3
4	Uranga	217	3
5	Etxebarria	216	2
6	Freeman	210	4
7	Jacobsson	183	5
8	Johnson	152	6
9	Malerba	151	2
10	Lundvall	149	5

Source ISI Web of Knowledge

Articles and cited references of relevance

Article relevance has been estimated by using the number of citations each article has received, measured by the GTCS, which includes all the citations on the ISI Web of Science database. In this sense, all 773 articles in the collection have been assessed to re-arrange them by using the citation criteria.

However, the relevance of bibliographical works in any scientific field goes beyond peer-reviewed articles to include as well books, book chapters, reports and others. In this sense, one of the major shortcomings electronic database searches have is that they do not account for these other types of work.

In interdisciplinary fields such as the Innovation Systems field, it is especially important to account for those complementary bibliographical works. Bibliometrics deals with this issue by collecting metadata from the so-called *Cited References* of each article in the collection.

In this way, collected metadata from the bibliographical references that each article has used might proxy the relevance of other bibliographical work—besides peer-reviewed articles—for the field, specifically for the IS field.

Accordingly, the relevance of other bibliographical works has been measured by the number of times each of them has been cited inside the 773 collection. In this sense, the maximum number of citations of a specific work would be 773 (meaning a specific work has been cited by all 773 articles in the collection) and the minimum number 1 (meaning that a specific work has been cited by 1 article in the collection).

Article relevance

Table 4 shows the ten most cited articles in the collection.

As noted before on Table 3 and currently on Table 4, there is strong correlation between cited authors and cited articles.

As mentioned before, the article "*The Dynamics of Innovation: From National Systems and 'Mode 2' to a Triple Helix of University–Industry–Government Relations*" is the most cited one in the collection with a total of 268 citations, authored by the third and second most cited authors in the collection. This study introduces the Triple Helix model which is composed by three main components: universities, industries and government (Etzkowitz and Leydesdorff 2000).

The sixth most-cited author Freeman is the author of the second most-cited article in the collection "*The National System of Innovation in Historical-Perspective*", accounting for 167 citations. This article points-out the importance of national and regional boundaries for economic development, policy formulation and even for trade and internationalization (Freeman 1995).

The first, fourth and fifth most cited authors collaborated and produced the third most-cited article "*Regional Innovation Systems: Institutional and Organisational Dimensions*", which relates to the importance of sub-national perspectives complementing National Innovation Systems and suggesting that a good unit of analysis is in fact the region (Cooke et al. 1997).

In the same line, Malerba relates in his work entitled "*Sectoral Systems of Innovation and Production*" (124 citations) the importance of alternate complementary perspectives to the national focus, and suggests the sector as an adequate unit of analysis (Malerba 2002).

In the fifth position, with 115 citations, the work entitled "*The Determinants of National Innovative Capacity*" which introduces the concept of "national innovative capacity"

Table 4 Most cited articles in the collection

Rank	Authors	Title	Year	Citation count
1	Etzkowitz and Leydesdorff	The Dynamics of Innovation: From National Systems and "Mode 2" to a Triple Helix of University–Industry–Government Relations	2000	268
2	Freeman	The National System of Innovation in Historical-Perspective	1995	167
3	Cooke et al.	Regional Innovation Systems: Institutional and Organisational Dimensions	1997	156
4	Malerba	Sectoral Systems of Innovation and Production	2002	124
5	Furman et al.	The Determinants of National Innovative Capacity	2002	115
6	Meyer-Krahmer and Schmoch	Science-Based Technologies: University–Industry Interactions in Four Fields	1998	104
7	Carlsson et al.	Innovation Systems: Analytical and Methodological Issues	2002	90
8	Lundvall et al.	National Systems of Production, Innovation and Competence Building	2002	89
9	Morgan	The Exaggerated Death of Geography: Learning, Proximity and Territorial Innovation Systems	2004	87
10	Archibugi and Michie	The Globalization of Technology—A New Taxonomy	1995	76

Source ISI Web of Knowledge

which depends on the common innovation infrastructure, the specific clusters within the national borders and the linkages among both (Furman et al. 2002).

The sixth position is occupied by the work "*Science-Based Technologies: University–Industry Interactions in Four Fields*" in which the authors discuss the co-operation and interactions between universities and industry with a focus on Germany (Meyer-Krahmer and Schmoch 1998).

The work "*Innovation Systems: Analytical and Methodological Issues*" accounted for a total of 90 citations and discusses analytical and methodological issues regarding the level and unit of analysis of Innovation Systems, the means to identify the key relationships that capture the important interactions and behavior, and also the proper ways to measure the performance of Innovation Systems (Carlsson et al. 2002). It is worth mentioning that Jacobsson is the seventh most-cited author in the collection.

The eight position is for Lundvall et al. (2002) and his work "*National Systems of Production, Innovation and Competence Building*". In this work, the authors discuss the overall diffusion of the "national system of innovation" approach as well as its theoretical and practical evolution and use in both high income and low income countries. Two authors in this paper also appear in the most-cited author list, specifically, Lundvall appears as the tenth most-cited author and Johnson as the eight most-cited one.

The article "*The Exaggerated Death of Geography: Learning, Proximity and Territorial Innovation Systems*" appears in the ninth position (87 citations) and is related to the discussion of territorial importance even for globalization and digitalization processes, by arguing that the embeddedness of knowledge in human agents makes difficult its free-flowing among non-geographical environments (Morgan 2004).

Finally, with 76 citations the work entitled "*The Globalization of Technology—A New Taxonomy*" discusses the role of nation states in face of technological globalization (Archibugi and Michie 1995).

Cited references of relevance

As mentioned before, direct counts of citations only measure the relative relevance of an article that is already included in the database. Other bibliographical works, different than articles, that are not included in the databases are not taken into account.

Therefore, 'cited references counting' retrieves the number of times bibliographical references have been cited by the articles in the collection.

As shown on Table 5, many of the most relevant cited references are articles that are part of the 773 collection. Also, 11 out of the 20 cited references are books.

In line with the former, the first six most-cited references in the collection are books published from 1982 to 1997. A portion of those books deal with the importance of the national framework and the set of institutions inside of it for producing innovations (Edquist 1997; Lundvall 1992; Nelson 1993; Freeman 1987), the elements that might provide a nation a competitive advantage over others (Porter 1990) and the discuss the nature of economic change from an evolutionary perspective (Nelson and Winter 1982).

In the seventh position, Cohen and Levinthal (1990) discusses the importance of the so-called absorptive capacity for firms to successfully recognize external information and knowledge, assimilate and apply it to commercial ends.

Then, in the eighth and ninth positions, Cooke at al. discusses the Regional Innovation System as a unit of analysis for innovation-driven policy (Cooke et al. 1997; Braczyk et al. 1998). In this same line follows the 11th reference on the list (Morgan 1997) and the 20th (Storper 1997).

Keith Pavitt's paper of 1984 "*Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory*" describes different and similar patterns among sectors, in terms of their providers, nature of the sector and impact on innovations and classifies them in a general taxonomy (Pavitt 1984). As described before, Malerba (2002)'s work follows on this same line, by discussing sectoral Innovation Systems (19th position).

Freeman (1995) and Carlsson et al. (2002) also appear on this list, those papers were described in the last section. A second paper by Carlsson is also on the list, entitled "*On the Nature, Function and Composition of Technological Systems*" where, in collaboration with Stankiewicz, the concept of 'technological systems' is discussed, as an alternative to National Innovation Systems (Carlsson and Stankiewicz 1991).

The 13th most cited reference is the book written by Gibbons et al. whom discuss the so-called 'Mode 2' form of knowledge production, which is problem-focused and inter-disciplinary produced (Gibbons et al. 1994).

Moreover, two references are made to Dosi's book "*Technical Change and Economic Theory*", one to the book itself (18th) and one to Lundvall's chapter on that book (14th) (Lundvall 1988; Dosi et al. 1988). Dosi appears again on the list, in the 17th position with his paper about technological paradigms and trajectories (Dosi 1982).

Journal relevance

The analysis of the most relevant journals for the IS field is also composed by two different indicators: the amount of papers published on each journal and the amount of citations received by each journal.

Table 5 Most cited references in the collection

Rank	Authors	Title	Type	Year	Citation count
1	Lundvall	National Systems of Innovation	Book	1992	239
2	Nelson	National Innovation Systems	Book	1993	196
3	Freeman	Technology Policy and Economic Performance	Book	1987	111
4	Edquist	Systems of Innovation. Technologies, Institutions and Organizations	Book	1997	110
5	Porter	The Competitive Advantage of Nations	Book	1990	96
6	Nelson	An Evolutionary Theory of Economic Change	Book	1982	95
7	Cohen and Levinthal	Absorptive Capacity: A New Perspective on Learning and Innovation	Administrative Science Quarterly	1990	71
8	Cooke et al.	Regional Innovation Systems: Institutional and Organisational Dimensions	Research Policy	1997	63
9	Braczyk	Regional Innovation	Book	1998	62
10	Pavitt	Sectoral Patterns of Technical Change—Towards a Taxonomy and a Theory	Research Policy	1984	59
11	Morgan	The Learning Region: Institutions, Innovation and Regional Renewal	Regional Studies	1997	51
12	Freeman	The National System of Innovation in Historical-Perspective	Cambridge Journal of Economics	1995	47
13	Gibbons et al.	The New Production of Knowledge	Book	1994	47
14	Lundvall	Technical Change and Economic Theory	Book chapter	1988	47
15	Carlsson et al.	Innovation Systems: Analytical and Methodological Issues	Research Policy	2002	46
16	Carlsson and Stankiewicz	On the Nature, Function, and Composition of Technological Systems	Journal of Evolutionary Economics	1991	45
17	Dosi	Technological Paradigms and Technological Trajectories—A Suggested Interpretation of the Determinants and Directions of Technical Change	Research Policy	1982	44
18	Dosi	Technical Change and Economic Theory	Book	1988	44
19	Malerba	Sectoral Systems of Innovation and Production	Research Policy	2002	43
20	Storper	The Regional World: Territorial Development in a Global Economy	Book	1997	43

Source ISI Web of Knowledge

In terms of the amount of papers published on each journal, Table 6 shows the twenty journals with most publications in the collection (Fig. 2).

The twenty most cited journals in the collection account for 483 articles, a 62% of the total of 773. The journal with most publications is 'Research Policy', with 120 papers. It can be inferred from this result, that a significant part of the authors in the collection recognize this journal as the most adequate channel to communicate research findings in the IS field.

On the other hand, Table 6 shows the journals with more citations in the collection.

As shown on Table 6, 14 out of the top twenty most-cited journals are also part of the collection (70%), meaning that most of the scientific publications are produced in a rather common source of past publications.

The journal produced by SPRU at Sussex University—Research Policy—is also the first in the most cited journals list, with a total of 547 citations in the 773 articles of the collection.

Institution and country relevance

In terms of the most relevant Institutions researching on the IS field, Table 7 presents the Institutions with most publications in the collection.

According to Table 7, the University of Utrecht (Netherlands) was the most productive Institution in the collection, with a total of 26 articles, followed by the University of Manchester and the University of Sussex with 19 articles both (United Kingdom). It is worth mentioning that in total four Institutions from the Netherlands and four from the United Kingdom appear in the list.

In terms of citations received by Institutions in the collection, Table 8 shows the top twenty most-cited institutions.

Table 8 indicates that the University of Wales in the UK is the most cited institution, with a total of 461 citations, followed by the University of Sussex of the same country, with 382 citations. In this Table, the seven institutions from the United States appear on the list, standing as the country with most institutions on the list.

Table 6 Most cited journals in the collection

Ranking	Journal	Citation count
1	Research Policy	547
2	European Planning Studies	81
3	Cambridge Journal of Economics	63
4	Regional Studies	58
5	Energy Policy	46
6	Technological Forecasting and Social Change	45
7	Technology in Society	39
8	Geoforum	35
9	Technology Analysis & Strategic Management	25
10	Scientometrics	21
11	International Regional Science Review	20
12	Technovation	18
13	World Development	17
14	Environment and Planning A	16
15	Journal of Economic Geography	15
16	Organization Studies	14
17	Environment and Planning C-Government and Policy	14
18	Urban Studies	13
19	International Journal of Technology Management	10
20	Journal of International Business Studies	10

Source ISI Web of Knowledge

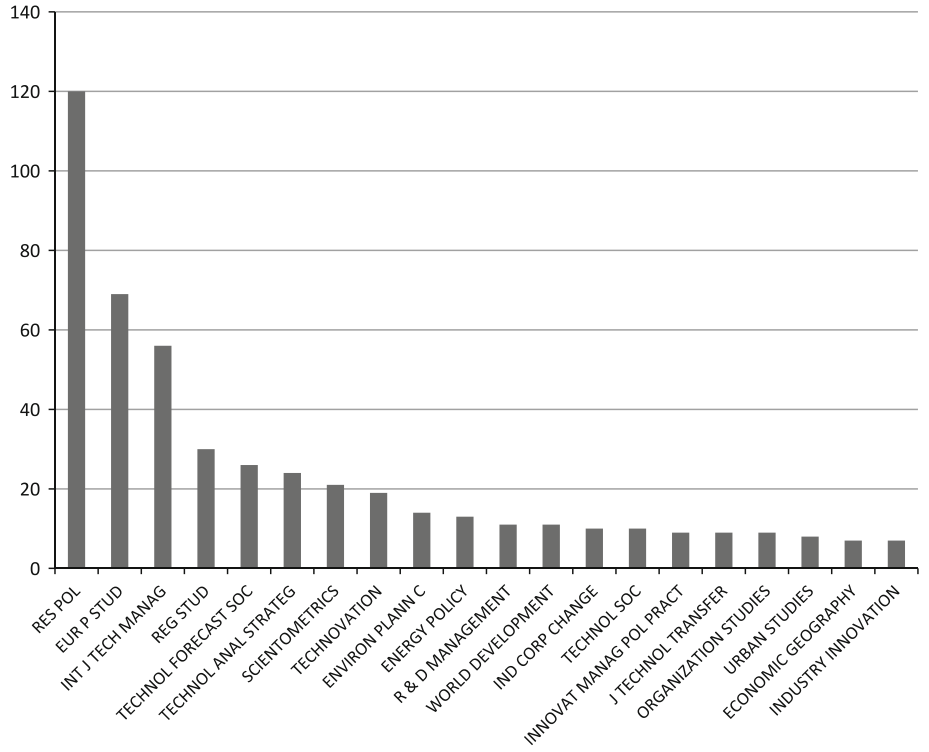

Fig. 2 Amount of articles in the top 20 journals in the collection. *Source* ISI Web of Knowledge

On the other hand, Table 9 presents the summary of the number of articles published by country (article count) and also the position on the ranking of citation count.

According to Table 9, the most productive country was the United Kingdom with a total of 130 articles on the collection, followed by the United States with 110. In terms of citation count, as shown on Table 9, there is a strong correlation among the countries with most publications and the countries with most citations.

Moreover, all countries in the most productive column except two catching up economies, Taiwan (21st position on citation count) and India (23rd position on citation count), are also represented in the twenty most cited countries.

It also can be drawn from the results in the last two tables, Tables 8 and 9, that there is also a strong correlation between the most relevant institutions and the most productive and cited countries.

Conclusions

The Innovation Systems approach has proven to be an adequate focusing device to understand the complex interrelationships emerging between different actors from the public, private and academic sector in order to achieve economic development.

Proof of this is the growing amount of literature that has been evidenced by this and previous studies, related to the use of the approach at different levels of scope (national, regional, local, sectoral, technological, etc.).

Table 7 Most productive institutions in the IS field with more than 7 articles

Ranking	Institutions	Country	Article
1	University of Utrecht	Netherlands	26
2	University of Manchester	United Kingdom	19
3	University of Sussex	United Kingdom	19
4	University of Quebec	Canada	14
5	Lund University	Sweden	13
6	University of Aalborg	Denmark	12
7	University of Amsterdam	Netherlands	11
8	Viena University	Austria	10
9	CNRS	France	9
10	University of Toronto	Canada	9
11	University of Wales	United Kingdom	8
12	University of California at Berkeley	United States	8
13	Delft University of Technology	Netherlands	7
14	Fraunhofer Institute for Systems and Innovation Research	Germany	7
15	Georgia Institute of Technology	United States	7
16	Helsinki University of Technology	Finland	7
17	Linkoping University	Sweden	7
18	Seoul National University	South Korea	7
19	University of Cambridge	United Kingdom	7
20	University of Ottawa	Canada	7
21	Eindhoven University of Technology	Netherlands	7

Source ISI Web of Knowledge

However, there is no evidence of previous systematic, chronological and synthesizing studies in this field and this paper tries to shed some light on this matter, configuring our main contribution as the consolidation of a large body of literature by a systematically reproducible procedure—bibliometrics—in order to present the state of the art of academic research on Innovation Systems.

In this sense, the bibliometrics approach allowed us to analyze a collection of 773 articles on the IS subject and to sub-divide the analysis of 1.115 authors, 621 institutions, 50 countries, 189 peer-reviewed journals, and a total of 25.117 cited references.

This paper addressed a considerable amount of data and organized it according to: general results, showing a summary of the quantitative results; a chronological distribution of the articles studied, which helps in showing the exponential growth the field has had since 1990; the most relevant authors, the most relevant articles and cited references, the most relevant scientific journals, the most relevant institutions and the most relevant countries on the Innovation Systems research field.

The main results suggested that there have been a growing number of published papers on the subject, reaching over 100 studies in 2009. This pattern appears to persist, as more articles are being submitted each year.

The paper also shows the relative relevance of scholars in the field, by analyzing the productivity and citation count of 1.115 authors. The results suggest that an important part of these authors are, at the same time, the more productive and the more cited ones. Of

Table 8 Most cited institutions in the collection

Ranking	Institutions	Country	Citation
1	University of Wales	United Kingdom	461
2	University of Sussex	United Kingdom	382
3	University of Amsterdam	Netherlands	331
4	State University of New York	United States	272
5	Chalmers University of Technology	Sweden	254
6	University of the Basque Country	Spain	228
7	Fraunhofer Institute for Systems and Innovation Research	Germany	216
8	University of Aalborg	Denmark	214
9	University of Cambridge	United Kingdom	206
10	Case Western Reserve University	United States	204
11	University of Utrecht	Netherlands	188
12	University of Manchester	United Kingdom	179
13	Bocconi University	Italy	153
14	Boston University	United States	148
15	University of Toronto	Canada	146
16	University of California at Berkeley	United States	131
17	Lund University	Sweden	115
18	Harvard University	United States	115
19	Northwestern University	United States	115
20	Stanford University	United States	113

Source ISI Web of Knowledge

particular attention, is the appearance of some highly cited—low productive authors which might suggest the highly relative importance of a few articles written by them (by means of citation counts).

Our approach to identify the most relevant authors used two indicators: the number of papers published in the subject and the number of citations per author. From these double analyses we identified Cooke and Leydesdorff as the two most productive authors. The first one working on Regional Innovation Systems and the second one working on the Triple Helix framework. Other important authors that have appeared on our analysis were Niosi, Freeman, Malerba and Lundvall. Since the 1990s, Niosi have contributed enormously with the study of regional systems and national systems after Cooke, Lundvall, Freeman and others. Freeman has been focused on studying the different macro and sub levels of national innovation systems, taking a leap over his 1987 book and advancing on the theory construction of IS. On the other hand, Lundvall, after his 1992 book has focused on studying the process of competence building as the single most important element of national innovation systems. And Malerba's theory of sectoral innovation systems is basically what has put him in the most relevant authors list, since then, he continues to work on developing his theory.

An interesting result of this article is that there is a strong correlation among the most cited and productive authors with the most cited articles, in some cases even including the cited references articles. It is the case of Etzkowitz and Leydesdorff, whom as described in the "Innovation systems and economic development" section, have been known by their article "*The Dynamics of Innovation: From National Systems and 'Mode 2' to a Triple*

Table 9 Article count by country

Ranking	Country	Article count	Position (citation count)
1	United Kingdom	130	1 (1,591)
2	United States	110	2 (1,425)
3	Netherlands	80	4 (744)
4	Germany	76	3 (802)
5	France	48	7 (355)
6	Canada	43	8 (329)
7	Sweden	40	5 (512)
8	Italy	34	6 (470)
9	Spain	26	9 (268)
10	Japan	24	13 (98)
11	Australia	23	14 (98)
12	South Korea	23	18 (80)
13	Austria	20	11 (204)
14	Finland	20	17 (90)
15	Denmark	19	10 (238)
16	Taiwan	19	21 (74)
17	Norway	17	16 (94)
18	China	16	19 (79)
19	India	12	23 (42)
20	Belgium	12	12 (116)

Source ISI Web of Knowledge

Helix of University–Industry–Government Relations", which is the most relevant article, by citation count. The misunderstanding of this paper by some scholars and practitioners has led to a common confusion in many publications since then, which is to believe that both, the Innovation Systems framework and the Triple Helix framework are the same, where in fact, the Triple Helix is a subset or subsystem of the Innovation System, which is compounded by a larger amount of agents.

The second most relevant publication was the paper "*The National System of Innovation in Historical Perspective*" written by Freeman in which the author relates the theory of Innovation Systems to older proposals, among them, the contributions of List in the 1800s. This paper was one of the first publications that brought up a historical perspective on the theory of IS.

The third place is for Cooke et al. (1997) discussing Regional Innovation Systems and the fourth is Malerba (2002) discussing Sectoral Systems of Innovation, both major theoretical streams from the IS literature.

In terms of cited references, our analysis quantitatively confirmed many of the most relevant publications that have been used by scholars in the IS field, among them: Lundvall's "*National Systems of Innovation*"; Nelson's "*National Innovation Systems*" and Freeman's "*Technology Policy and Economic Performance*", the three most relevant cited references.

Another strong correlation was evidenced between the most relevant authors, journals in the field, the institutions behind them and the countries they represent, suggesting that there is in fact a growing and institutionalized scientific community behind the IS approach.

Journals like "*Research Policy*, *Technological Forecasting and Social Change*, *Scientometrics*, *Technovation and World Development*" appear in the forefront of research

in the field and in some cases they even represent an attached scientific community, like Research Policy, which was created by SPRU, Freeman's research lab.

In addition, the most relevant institutions are European and North-American, which are basically where the main authors described above are affiliated in. An interesting observation to point out is the predominance of European institutions in terms of article count and a predominance of North-American institutions in terms of citation count (see Tables 7, 8). It might be inferred from this difference that articles written by scholars affiliated to North-American institutions are less in terms of quantity but more cited in terms of scientific impact, than European institutions.

In this sense, these results suggest that the approach used in our paper was successful in obtaining an accurate approximation to the IS field as a science field pertaining to a scientific community.

As main shortcomings, we should characterize the use of only one database as a source to retrieve the metadata—although being the most recognized—as this database might have omitted other relevant research.

Another shortcoming is the use of bibliometrics *per sé*, since scientific publications is only one way scientists have to convey information and knowledge, other means of communication can be oral communication between scientists, internal reports between research institutions or even other informal-like channels (Okubo 1997). Although, this, in part, has been taken into account in the paper by including the cited references field in our analyses (including other publication materials than articles, namely books, reports, etc.) there is still room for other complementary mechanisms to include a greater number of other communication channels.

The next step for this research would be to run a qualitative analysis using expert-based opinions to include a more descriptive and analytical flavor to this quantitative study and to bring a more in depth discussion into the results that have been introduced in the former sections.

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