Interaction Activity Patterns in the Scientific Literature on Innovation Systems approach: A Bibliometric Analysis and Network Mapping Study

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***Abstract*—In recent decades, the Innovation System (IS) approach has generated attention and has been adopted as an analytical framework for studying innovation processes; this has been reflected in the large increase and constant growth of its scientific literature. However, few studies have been oriented to analyze it, which is of interest to understand the development and current state of research on the subject; and even fewer are those oriented to study the interaction activity that occurs in the flow and diffusion of knowledge. In response, this work performs a bibliometric analysis and mapping to explore the interaction activities between the countries involved in the production of literature, considering 7,605 documents retrieved from the Scopus database. The results of this work may be useful for several reasons, among them, to establish the organizational structure of countries in IS literature and its evolution, as well as to identify some effects regarding interaction activity on research.**

***Index Terms*—Bibliometrics, collaboration, innovation system, social network**

I. Introduction

A. Innovation System Approach

During the last decades, the role of innovation and related activities (as scientific and technological) has become crucial for economics and social development: it is considered fundamental to build and strengthen capabilities in these to achieve and sustain societal progress [1]. In a general sense, innovation implies transferring from an idea to a practical implementation in a new or improved product, service or process, generating value, therefore, having the capacity to be exploited [2, 3]. According to most scholars, the economist Joseph Alois Schumpeter [4] introduced this term in the economic-business sphere, referring to: a good or product, a method or procedure of production and organization [5]. In the late 1980s, a systematic approach for understanding the processes and dynamics concerning innovation began to sprout up among academics, researchers and policy makers (Cooke [6], dating the starting point to 1987 by Freeman [7]), commonly referred to as Innovation System (IS), rapidly gaining attention and relevance as a new field of study [8]. IS approach emerged from the studies on the innovative process, evolving from being considered as a linear-unidirectional process to an interactive-multidirectional one. In line with Cooke *et al*. [9], IS can be defined as a set of interactive and networked agents/elements implicated in innovation-related activities;

IS comprises the interrelationships between users and producers of new knowledge, exploited for practical/commercial application. In addition, these authors named some main agents, such as firms, universities, research centers, technological institutes, training agencies, technology transfer offices, government departments, funding and non-profit organizations. Lundvall [10] described some fundamental premises of IS: innovation is a social process, therefore, it can be understood as a result of the interaction between agents; there is no single IS model or configuration, these differ from each other, both in terms of productive and commercial specialization, and also, with respect to the knowledge base; a IS is a systemic, arranged network, in which distinct and varied agents are interdependent, but at the same time, these are interconnected, being the relationships between them determinative for the IS performance. In this regard, Toivanen & Ponomariov [1] further stated, recognizing the interaction activities that take place in IS (such as collaboration and linkages), as key aspects, principally for the creation and application of knowledge; this being acknowledged by authors involved in the study of sociology of science, obtaining popularity and attention as a thematic area ([11] as cited in [1]).

Over time, different types and conceptual branches of IS were developed in order to meet a broader and more appropriate applicability as National Innovation System (NIS), Regional Innovation System (RIS), Sectoral Innovation System (SIS) and Technological Innovation System (TIS), being these the most known in the literature, varying among them according to a specific analytical framework, system limits and components, dimensions and perspectives [12]. In NIS and RIS, the territory is emphasized (within national and regional geographical boundaries, respectively) [13], being this considered as an influential and active factor, becoming the center of attention, whereas for SIS the focal point is set on a particular productive sector and in the case of TIS, on a particular technological area, both having no limits regarding the territorial dimension. All the above mentioned IS types coexist and complement each other [14]. However, by 2007, NIS and RIS concepts dominated IS literature comprising about 75% of its content ([15] as cited in [16]); among the reasons for this, can be found that contemporary contributions and proposals are oriented towards development and growth models (especially in economics), in which, territory is a relevant driver [17, 18].

IS approach (specifically, NIS and RIS) is often considered

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useful as a framework to understanding differences between territories, e.g., through NIS it is possible to inquire into the question of why countries with similar resources, structures and patterns may differ in terms of capabilities (scientific, technological, economic) [19]; commonly, among nations different strategies are established, therefore, results vary. Thus, NIS is considered suitable for evaluation and monitoring studies aimed at decision and policy-making actions regarding nations.

B. Bibliometrics Tools and Methods: Analyzing and Mapping the Scientific Literature

In the opinion of Salinas-Rios & Garcia-López [20], bibliometrics is a branch of scientometrics, the latter being defined as a discipline aimed at analyzing, measuring, comparing and evaluating scientific activity (such as research), specifically oriented to the study of scientific literature; the word *bibliometrics* is composed of two Greek terms, *biblos* and *metron* (meaning, book and measure, respectively) ([21] as cited in [20]). Scientific literature (hereafter, just referred to as literature) is characterized as a body of documents (including journal and conference articles, books, reviews, among others), which frequently, requires a peer review process before publication; academics, researchers, along with other agents, habitually materialize and communicate their findings and achievements in documents, adding, modifying or refuting ideas and thoughts, creating over time, a mass of knowledge, which is expected to increase in volume and scope; thus, this type of literature is considered, in essence, evolutionary and cumulative. In a general way, through bibliometrics methods, from a collection of related documents, a set of bibliographic variables (indicators, indexes) are identified, scrutinized and interpreted to provide insights and comprehension about the composition, organization and development of a field of study. Antonio de Souza *et al*. [22] also pointed out the difference between bibliometrics and scientometrics, adding that each should be applied according to the objectives and purposes of study.

There are five main bibliometrics methods [23]: citation analysis, co-citation analysis, bibliographical coupling, co-word analysis and co-author analysis; the latter uses co-authorship data to measure the interaction activity occurred in a document by associating and connecting authors referenced in the same document (i.e., co-authors): interaction activity in co-authorship is considered as a social bond between individuals, e.g., if two authors are referenced quite frequently in several documents, it can be interpreted that they have a strong social tie, i.e., high relatedness. Thus, through co-author analysis it is possible to address the social structure and organization of a given field of study [24]. Additionally, co-author analysis can be oriented at different levels (depending on the selection of the units of analysis); co-authorship data can be defined in terms of author name (two or more authors identified by name are related, because they appeared together in a document, e.g., Author A and Author B), but also, considering institutional affiliation (two or more institutions are related, because two or more authors that appeared together were affiliated in different institutions, e.g., A is affiliated with Institution X and B is affiliated with Institution Y, as a result, X and Y are related), or country affiliation (A is affiliated with X located in Country J and B is affiliated with Y located in Country K, as a result, J and K are related). Therefore, different aspects of a field of study can be analyzed, e.g., by conducting a co-author analysis (taking as units countries), the international dimension can be explored [24]. In this respect, works oriented to study co-authorship patterns at the international level, generally, become the focus of interest and attract more attention compared to others (e.g., between institutions and/or authors from a single country) ([25] as cited in [26]).

Furthermore, when performing a co-author analysis to inquire into certain research questions, often this will require considering other bibliometrics variables in order to measure the impact in relation to interaction activity such as number of documents, cites per document, to name a few [23]; also, considering a longitudinal frame, through multiple observations, to identify changes in patterns and trends over time [24]. Interaction activity in literature (also, commonly referred as scientific collaboration or linkage) has been the subject of interest, since according to some authors [22, 27], this has many effects and outcomes: it is positively correlated with knowledge diffusion (e.g., authors are incentivized to collaborate to access to supplementary resources and capabilities, such as funding, equipment, technical skills) and the promotion of innovation activities (e.g., in the field of bioenergy, collaboration activity stimulates the initiation of new research trends). Moreover, authors are prone to collaborate seeking to obtain academic recognition.

Habitually, in a complementary manner, science mapping analysis (also known as bibliometric mapping, depending on the aim and object of study [24]) is implemented, enabling to depict graphically, the structure, organization and development of knowledge and research areas through the application of bibliometrics methods [23, 24]. One of these, is network analysis, which has gained relevance among researchers [28], in particular Social Network Analysis (SNA), properly designed and oriented to the inquiry in social aspects, such as collaboration activities. According to the latter author, SNA is a network (graph) arranged by a set of nodes related by a specific type of bond; basically, it is formed by three components [22]: 1) nodes, which represent people (individually or collectively); 2) links, which make the connections between the nodes, displaying the interactions among them; 3) Flows, which point out the direction (unidirectional or bidirectional) of the links, regularly by means of arrows. One of the most widely used indicators to characterize a SNA is the centrality indicator (CI) proposed by Freeman [29]: for an entire network, CI indicates to what degree, there are predominant nodes within the network. When a network has a CI value of 1 (100%), it means that one node is dominant, and the rest of nodes are linked and depend on it, existing no links between them. Also, for a single node, the higher the CI value, the greater influence it exerts on a network ([30] as cited in [31]). Often, researchers make use of CI indicator in three ways: Degree centrality (DCI), Between centrality (BCI) and Closeness Centrality (CCI), to establish the influences of nodes within a network:

DCI: measures the number of links that each node has with others, indicating to what extent, a specific node participates

in a particular network [31, 32]. If a node has a high DCI value, it can be interpreted as this having a high exposure within the network, therefore, being easily reachable for others [28].

BCI: measures the intermediation of a node between other node(s) within the network, indicating the frequency with which a node is placed on the shortest path/distance between any other node(s) [31]. A node that has a high BCI value can be considered to exert certain level of control over other nodes in terms of flow, therefore, it has the capacity to restrict communication, even preventing them from reaching others [32]. On the contrary, when the BCI value of a node is equal to 0, it means that this is not on the (shortest) path between other node(s). BCI denotes to what extent, a node is needed as a linker within a network [28].

CCI: measures the inverse of the average length of the shortest distances between nodes in a network [31, 32]. If a node requires several nodes to reach others, it means that this has a higher farness value in the network, on the contrary, if a node requires less, it has a higher closeness value (i.e., CCI value) which means that this is more independent without relying on intermediaries, being able to stablish links with others by itself [28, 32].

In general, specifically speaking about SNA, where the interaction activity between authors involved in literature production is addressed and displayed, the DCI points out how many authors have published documents with others, the BCI indicates which authors are functioning as "brigdes" among others and the CCI reveals the authors' possibility to reach out to others ([33] as cited in [23]). Taking in consideration this information, interesting results, discussions and conclusions can be established, shedding light on the different angles of authors ´practice in science and research in a particular field of study [31, 32]. Additionally, some software applications have been developed for the purpose of building and analyzing science and bibliometric maps (even some precisely for SNA), proving a wide range of methods, processing and visualization techniques, such as Pajek, Ucinet, VantagePoint, VOSViewer, to name a few [24]; nevertheless, frequently, for an appropriate and extensive study, it is required to use of different tools and programs, complementing the features and advantages of each, as suggested by Cobo *et al*. [24].

C. IS Approach and Bibliometrics: Previous Studies

In the opinion of Teixeira [19], IS literature has a multidisciplinary complexion, this due to the many contributions made from various and distinct research fields (such as economics, management, governance), therefore, it is possible to find a wide range of concepts, ideas, methodologies and perspectives related to it. The study of IS literature is of interest for several reasons, e.g.: to comprehend and discern how these contributions have shaped the IS approach, which topics and issues have already been addressed through research and which are emerging. However, as this author stated, there is a small number of works based on bibliometrics analysis and methods concerning IS, and even fewer those focused on studying IS literary corpus. Taking the above on account, in 2014 [19], Teixeira presented a work exploring NIS approach by making use of bibliometrics analysis (considering 356 documents published up to December 2010), essentially aimed at describing the roots, evolution and influence of its literature: among the most relevant findings is that, NIS literature is geographically centered in United Kingdom, Denmark and United States; moreover, these countries have influenced others which are relatively near in proximity, such as Netherlands, Germany, Italy and Spain, as well as those located in Asia and Latin America. On the other side, Lee & Su [31] focused on RIS and bibliometric mapping (by processing 432 documents), constructed two types of network maps: co-word and co-author (at three levels: author ś name, institution and country), determining and analyzing their properties (DCI, BCI and CCI).

In 2016 [8], Arias *et al*. addressed the relationship between IS and industry by conducting a bibliometric analysis on 751 documents (published between 2001-2014); the state and development of IS and industry research (in two scopes: global and Latin America) is established, as well as identifying the main agents and other bibliometric variables involved (such as authors, institutions, countries, keywords). In a similar vein, Jurowetzki *et al*. [34] performed a bibliometric analysis (bibliographic coupling and citation) along with a qualitative review on a body of literature (initially consisting of 5,000 documents) related to two topics: IS and global value chains; these authors suggested that the combination of these two may be convenient and beneficial for understanding issues concerning economic development and socioeconomic processes. In addition, seven clusters of documents containing references to both topics were identified. By 2020 [35], Dahesh *et al*. presented an overview of IS literature (establishing the current status and structure, as well as evolution over time), by performing bibliometric analysis and mapping (bibliographic couple, co-words, co-citation), taking into account 3,250 documents published in the period 1988-2018. However, collaboration activity, specifically between authors, was not contemplated, neither at individual, institutional or country level.

Besides the aforementioned works, there are others that also have applied bibliometrics and scientometrics analysis and mapping, but these were not oriented to explore the IS literature, e.g.: Cantner *et al*. [36] made use of them to quantify and evaluate three RIS (agents and activities) located in Europe; in a similar way, Antonio de Souza *et al*. [22] focused on different IS concerning the generation and use of ethanol; in this regard, also [1, 37, 38], among others.

After presenting the conceptual and referential framework, as well as some previous researches conducted on the subject in section I, the objectives and methodology of this study are stated. Then, the results are presented in section IV, and finally, discussion and conclusion are described in section V.

II. Research Objectives

Considering the conceptual and referential framework on the IS approach mentioned in the previous section, as well as the variety of existing studies regarding bibliometric analysis and mapping, different areas of opportunity of contribution for this work were identified; consequently, research

objectives were established.

General objective: To study the development and current setting of the IS literature (in its general conceptualization), through performing bibliometric analysis and mapping, with emphasis on the interaction activity of the countries involved.

Specific objectives: 1) To identify and analyze bibliometric variables (number of papers, citations, links, collaborations) corresponding to the countries; 2) To map, characterize and interpret the interaction activity between the countries through SNA (measurement of centrality indicators); 3) To establish and examine changes of trends and patterns over time.

III. Research Methodology

In the first place, a search was performed in the Scopus database on February 13th, 2022, employing the following instruction: "TITLE-ABS-KEY ("innovation system*" OR "system* of innovation", to retrieve records related to the term IS (referenced in the title, abstract and keywords sections). 7,605 documents were identified, which were published in the period of 1990-2021 (from these, 885 documents were published between 1990-2005), corresponding to the type of: 75.35% journal article, 17.68% conference article, 4.69% review and 2.28% books; in addition, 92.79% were written in English. There records were exported into spreadsheets, thus, constituting the database for study.

Subsequently, through Analyze search results and Refine results tools provided by the Scopus website, VosViewer software (1.6.18 version) and spreadsheet manipulation, the information contained in the database was processed, determining the bibliometrics variables of number of documents, cites, links and collaborations (in regards of interaction activity in authorship) of each country (as a result, setting the unit of analysis at country level); the latter two, were defined and measure as follow: link is the relationship between two or more countries, e.g., in a network composed by 20 countries, each country has the possibility of being linked to other 19 countries in terms of co-authorship (if they appeared together in one document, at least); collaboration is the strength of links, in this case, in terms of number of documents they appeared together, for example, Canada can be linked to Italy, China and Russia (link value is equal to 3 for Canada), but the collaboration degree can be different for each country, for example, Canada collaborated five times with Italy, two with China and four with Russia (collaboration value is equal to 11 for Canada).

A total of 107 countries were identified (with more than two documents, by 2021), corresponding to the following territories: five continents (Africa: 22 countries, America: 14, Asia: 33, Europe:36 and Oceania: 2) and five regions (Latin America: 12, European Union: 26, Middle East: 13 and Association of Southeast Asian Nations – ASEAN: 8). However, for practical reason and to maximize the scope of this work, just representative countries of these territories are considered for study. The procedure to determine which countries are representative is this: the countries from each territory were organized from larger to smaller in terms of number of documents published by 2021, and the first ones composing above the 80% of the total number of documents of each territory were chosen. For example, by 2021, in the case of Asia, 33 countries published 2,013 documents, but about 81% of this production were published by six countries, China, South Korea, Japan, Taiwan, India, Iran, as consequence these are the representatives countries of Asia. As a result, 42 countries were established as representative (Table I). Their bibliometrics variables of each country were grouped according to two periods of time: documents published from 1990 to 2005 and from 1990 to 2021.

Finally, SNA were carried out using the software Ucinet 6 (version 6.742), creating two networks related to co-authorship of countries on IS literature (1990-2005 and 1990-2021). Before this, it was necessary to build symmetrical matrix for each period (employing the bibliometrics variables previously generated), since Unicet 6 is not capable of exacting bibliometric data from documents: these were elaborated in spreadsheets and served as the input data for Ucinet 6. Once, the two networks were created, Unicet 6 also displayed information related to the characteristics of the networks (as CI value) and other measures, as centrality indicators, thus, in this way, the values of DCI, BCI and CCI of each country for the two periods was obtained.

IV. Results

A. Bibliometric Variables of IS literature

From 2005 to 2021 (Fig. 1), there have been an enormous growth in the number of documents related to IS approach (it has multiplied its size more than 8 times), however this has not occurred consistently, having ups and downs through the years; in the last decade, since 2011 (in which it was reported a high growth rate), the average annual growth rate has been moderate (around 5%). In respect to the distribution of the documents in geographical terms, this has been presented unevenly, with a high concentration in 2021 in the countries belonging to Europe (56.80% of the total number of documents), followed by Asia (26. 47%), America (19.12%), Africa (5.93%) and Oceania (3.54%); in the case of regions, those forming part of the European Union (40.12%), followed by Latin America (7.86%), the Middle East (2.41%) and ASEAN (3.05%).

Considering the countries separately, China, UK, US, Netherlands, Germany, Russia, Sweden, Spain, Italy, Brazil, France and the Canada were the most productive countries in terms of documents published by 2021 (Table I); together contributed about 66% of the literature. In addition, taking into account the period 1990-2005, it was observed that this concentration effect also occurred in a similar way, with twelve countries (UK, US, Germany, Netherlands, Canada, France, Sweden, Italy, Japan, S. Korea, Australia and Austria) leading in document production, accounting for 66.78%.). In this regard, it was identified that in the period 2005-2021, Brazil, China, Spain and Russia reported significant changes in document growth, multiplying the number of documents: 17.8 times, 64.4, 20.22 and 82 respectively, thus achieving, at present, to be part of the countries with the highest document production. In these fifteen years, other countries showed

high growth ratios (above the medium value of 10.1) such as Indonesia (65), Malaysia (62), Ghana (32), Kenya (25), Uganda (23), Nigeria (21), Thailand (16.25), Mexico (15.5), S. Africa (13.23), Turkey (12.33), Norway (12.24) and Egypt (11); however, in most of these countries, document production has still been limited. On the other hand, in respect to the citation of documents (Table I), it was found that the following countries reported the highest citation/document ratios (above the median value of 15.6) in 2021: Netherlands (52.9), Zimbabwe (49.5), Egypt (49.3), UK (48.7), Sweden (47.7), US (45.2), Austria (41.9), Norway (40.8), Italy (37.1), Germany (30.9), Canada (29.1), Ethiopia (27.5), Benin (25), Finland (25.1), Ghana (24.8), Australia (19.8), Tanzania (19.5), Spain (19.0), Taiwan (17.2) and S. Korea (16.1). In 2005, this was as follows (medium value of 2): UK (15.6), US (9.5), Italy (12.5), Sweden (10.9), Spain (10.6), Netherlands (7.8), Norway (7.1), Austria (7), Germany (5.7), Israel (4.8), Canada (4.6), Finland (4.0), Indonesia (4), France (3.4) and India (3).

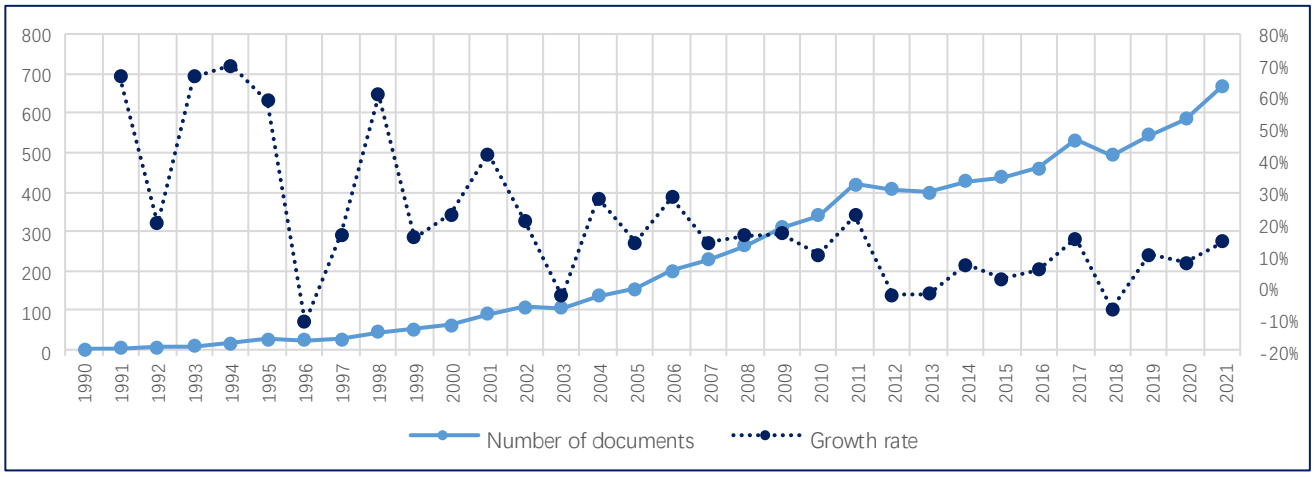

Fig. 1. Development of scientific literature on innovation system approach.

In regards to collaboration activity (Table I), the proportion of documents from each country that are published collaboratively (i.e., in co-authorship with other country), by 2021 the median value was set at 45%, with the following performing above this: Burkina Faso (93%), Uganda (91%), Benin (88%), Ethiopia (86%), Zimbabwe (85%), Kenya (78%), Ghana (66%), United Arab Emirates (65%), Tanzania (63%), Netherlands (60%), Austria (58%), Norway (55%), US (53%), UK (51%), Israel (50%), Australia, Spain and Sweden (47% each). By 2005, the median value was 30%, and those above were: Egypt (100%), Indonesia (100%), Zimbabwe (100%), Thailand (75%), Kenya (100%), India (50%), Japan (42%), Norway (41%), Italy (38%), Netherlands (38%), US (38%), Sweden (36%), Colombia (33%), S. Korea (33%), Turkey (33%), UK (31%), France and Germany (30% each). In the case of linkages between countries (Table I), for 2021, the median value of the proportion of linkages was 44% (considering that if a country obtains a value of 100%, it means this has links with all the others; a value of 50% indicates that this has links with half of them), with the following performing above this value: Netherlands (93%), United Kingdom (90%), United States (85%), France (78%), Australia (73%), Sweden (71%), Germany (66%), Italy (66%), South Africa (66%), Canada (63%), China (61%), India (59%), Russia (56%), Spain (56%), Japan (49%), Ethiopia, Finland, Kenya and South Korea (46% each). In 2005, the medium value was 9%, with the following countries obtaining a higher value: the United States (57%), the United Kingdom (34%),
the Netherlands (34%), Germany (34%), Sweden (29%), Canada (23%), South Korea (23%), Italy (20%), Japan (20%), France (17%), India (17%), Finland (14%), Thailand and Zimbabwe (11% each).

B. Social Network Analysis and Mapping: Centrality Indicators

By employing Ucinet 6, two social network maps were built, displaying the linkages and collaborations of co-authorship among countries in the IS literature, one from 1990–2005 and the other from 1990–2021(Appendix A), also SNA was performed, and values of the centrality indicators for each country were calculated automatically through this software (Table I). In addition, some relevant and general characteristic of these networks were set through Ucinet 6: for the first network (1990–2005), among the 35 nodes (countries), 79 links occurred, however, the number of possible links was 595, so, the network density (number of links/possible links) was 13.27%, thus on average, 2.25 links per country was established; moreover, the CI value was 48.31%. For the second network, these values were: links: 392, possible links: 820, density: 47.8% and CI: 49.62%. Next, briefly, some relevant results regarding the centrality indicators of countries are mentioned (Table I): By 2005, according to the DCI value, Germany, Netherlands, UK, Sweden, Canada, S. Korea, Japan and Italy were located in the center of the network (these scored above 0.20), having easy access to it and also, capable of disseminate knowledge to others, this was reflected in the high BCI values of these, except for the Asian countries (which did not performed well in BCI), on the contrary, despite Zimbabwe not being central, it was able to connect others. By considering the CCI values, it was noted countries placed in a central position were independent to interact with others; this was not the case of the African, Latin America, Middle East and ASEAN countries, which needed intermediaries since in general, these remained with not much interaction activity.

TABLE I: BIBLIOMETRIC VARIABLES AND CENTRALITY MEASURES OF COUNTRIES INVOLVED IN INNOVATION SYSTEM LITERATURE

Country	Documents		Citation		Linkages[1]		Collaborations[2]		Degree Centrality[3]		Closeness Centrality[3]		Betweenness Centrality[3]	
	2005	2021	2005	2021	2005	2021	2005	2021	2005	2021	2005	2021	2005	2021
Argentina[B,F]	5	44	3	469	0	11	1	15	0.00	0.28	0.00	0.05	0.00	0.19
Australia[E]	23	229	52	4537	3	30	4	107	0.09	0.75	14.47	0.05	0.62	3.21
Austria[D,G]	22	172	154	7211	2	14	4	99	0.06	0.35	13.77	0.05	0.00	0.08
Benin[E]		25		624		12		22		0.30		0.05		0.10
Brazil[B,F]	15	267	30	2075	1	18	2	64	0.03	0.45	13.93	0.05	0.00	0.29
Burkina Faso[A]		15		175		17		14		0.43		0.05		0.63
Canada[B]	46	231	211	6728	8	26	12	104	0.23	0.65	14.91	0.05	7.23	2.42
China[C]	15	966	32	7100	2	25	3	164	0.06	0.63	14.11	0.05	0.00	1.83
Colombia[B,F]	3	86	2	191	3	14	1	35	0.09	0.35	12.64	0.05	0.00	0.31
Egypt[A,H]	1	11	0	542	1	3	1	5	0.03	0.08	13.28	0.05	0.00	0.00
Ethiopia[A]		35		964		19		30		0.48		0.05		0.91
Finland[D,G]	22	207	89	5191	5	19	5	77	0.15	0.48	14.47	0.05	0.29	0.65
France[D,G]	46	266	155	3113	6	32	14	137	0.18	0.80	14.66	0.06	1.35	3.75
Germany[D,G]	79	501	452	15467	12	27	24	204	0.35	0.68	15.39	0.05	22.56	2.17
Ghana[A]	1	32	0	792	0	15	0	21	0.00	0.38	0.00	0.05	0.00	0.47
India[C]	18	130	54	1605	6	24	9	38	0.18	0.60	14.47	0.05	0.73	1.33
Indonesia[C,I]	1	65	4	331	3	11	1	14	0.09	0.28	14.05	0.05	0.00	0.18
Iran[C,H]		75		466		9		18		0.23		0.05		0.02
Israel[C,H]	5	14	24	210	0	6	1	7	0.00	0.15	0.00	0.05	0.00	0.00
Italy[D,G]	42	315	525	11692	7	27	16	139	0.21	0.68	14.78	75.47	0.41	2.61
Japan[C]	36	153	50	1972	7	20	15	66	0.21	0.50	14.47	66.67	0.68	0.48
Kenya[A]	2	50	4	778	3	19	2	39	0.09	0.48	14.23	65.57	0.00	0.93
Malaysia[C,I]	1	62	0	611	0	12	0	19	0.00	0.30	0.00	58.82	0.00	0.21
Mexico[B,F]	6	93	6	905	3	15	1	31	0.09	0.38	12.64	61.54	0.00	0.44
Netherlands[D,G]	56	563	434	29776	12	38	21	335	0.35	0.95	15.18	95.24	7.14	9.04
Nigeria[A]	2	42	3	349	0	18	0	15	0.00	0.45	0.00	64.52	0.00	0.57
Norway[D]	17	208	120	8476	2	17	7	114	0.06	0.43	14.11	63.49	0.00	0.28
Russian [D]	6	492	2	2971	2	23	1	73	0.06	0.58	14.11	70.18	0.00	1.39
South Africa[A]	13	172	7	1240	2	27	2	54	0.06	0.68	13.66	75.47	0.00	1.98
South Korea[C]	36	196	47	3146	8	19	12	63	0.23	0.48	14.85	65.57	2.31	0.32
Spain[D,G]	18	364	190	6904	2	23	5	172	0.06	0.58	14.11	70.18	0.00	1.02
Sweden[D,G]	44	368	479	17564	10	29	16	172	0.29	0.73	15.04	78.43	4.94	2.70
Taiwan[C]	18	133	16	2377	3	16	3	38	0.09	0.40	13.88	62.50	0.14	0.37
Tanzania[A]		24		467		13		15		0.33		59.70		0.22
Thailand[C,I]	4	65	0	307	4	18	3	30	0.12	0.45	14.11	64.52	0.13	0.90
Turkey[C,H]	3	37	3	292	2	6	1	15	0.06	0.15	14.11	54.05	0.00	0.00
Uganda[A]	1	23	1	343	3	16	0	21	0.09	0.40	12.64	62.50	0.00	0.34
U. Arab E.[C,H]		17		125		9		11		0.23		55.56		0.09
U. Kingdom[D]	130	828	2029	40352	12	37	40	426	0.35	0.93	15.18	93.02	5.93	6.62
U. States[B]	117	690	1113	31186	20	35	44	366	0.59	0.88	15.74	88.89	26.83	5.71
Zimbabwe[A]	3	13	5	643	4	15	3	11	0.12	0.38	13.99	61.54	13.90	0.39

Territorial affiliation: continent: A= Africa, B= América, C= Asia, D= Europe, E= Oceania; region: F=Latin America, G=European Union, H=Middle East, I=ASEAN. Gray box indicates no data available.

1. Linkages: Number of countries which appeared referenced at least in one document.
2. Collaboration: Number of documents published in co-authorship.
3. Measures were calculated automatically through Ucinet 6, upon network building.

By 2021, the most notable changed was that the most of countries scored a DCI value above 0.20, nevertheless, almost the same countries that were presenting the highest values were the same (with little change), except for the Asian countries, which lost position as centrals and were replaced by China, now becoming the most central country in Asia. In respect to BCI value, it was remarkable how due to the growth in density of the overall network, in general, the countries obtained a low score, so countries acting as bridges among others are not that required. However, even the evident development of the network (in terms of linkages), some countries have remained in the center and although the countries in general have made efforts improve its interaction activity, some are located far within the network; one outstanding case of this is China.

V. CONCLUSION

The great growth of IS literature in recent decades reflects the relevance and usefulness that has remained over time in the IS approach as a field of study and research. For this reason, several countries have made efforts to strengthen scientific research in IS, with some of them registering important changes in terms of document production. However, not all countries act or have the same conditions to carry out their research work, especially those considered undeveloped or developing (which are often located on the periphery of the center of knowledge): while some have opted to maintain their research activity at the local level with little interaction activity (for example, China); others have required leverage mainly from developed countries to generate knowledge in the field of IS and subsequently establish their networks at the local level (as is the case of African countries). It was estimated that this is due to the high concentration and centralization effect (taking into account the production and citation of documents, with emphasis on Europe) that has remained almost the same over time. Although, at present,

there is a high connectivity between countries, it is necessary to seek to foster links and collaboration, especially with developed and prominent countries in the IS literature, whose resources can be useful. Possibly, in the interaction activity between countries there are influences of several factors, economic (funding), cultural (such as language), institutional (administrative cohesion), among others. Among the limitations of this work is that it is possible to find other documents in different databases, so the results may vary. It is recommended as a future area of research to add other bibliometric variables, as well as others of a different nature (economic, social, to mention a few), to deepen and strengthen the results presented here.

APPENDIX

Social Networks on IS Literature

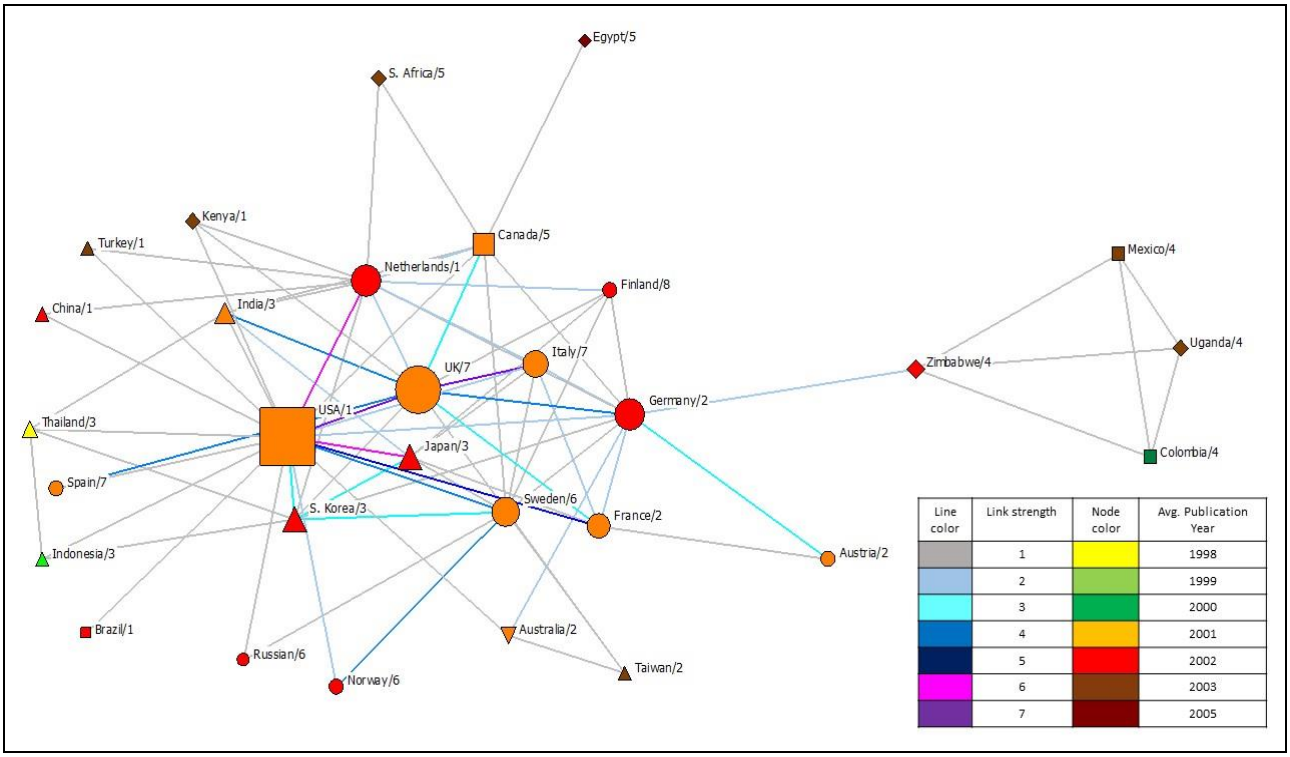

Fig. A1. Social network on innovation system literature (1990–2005).

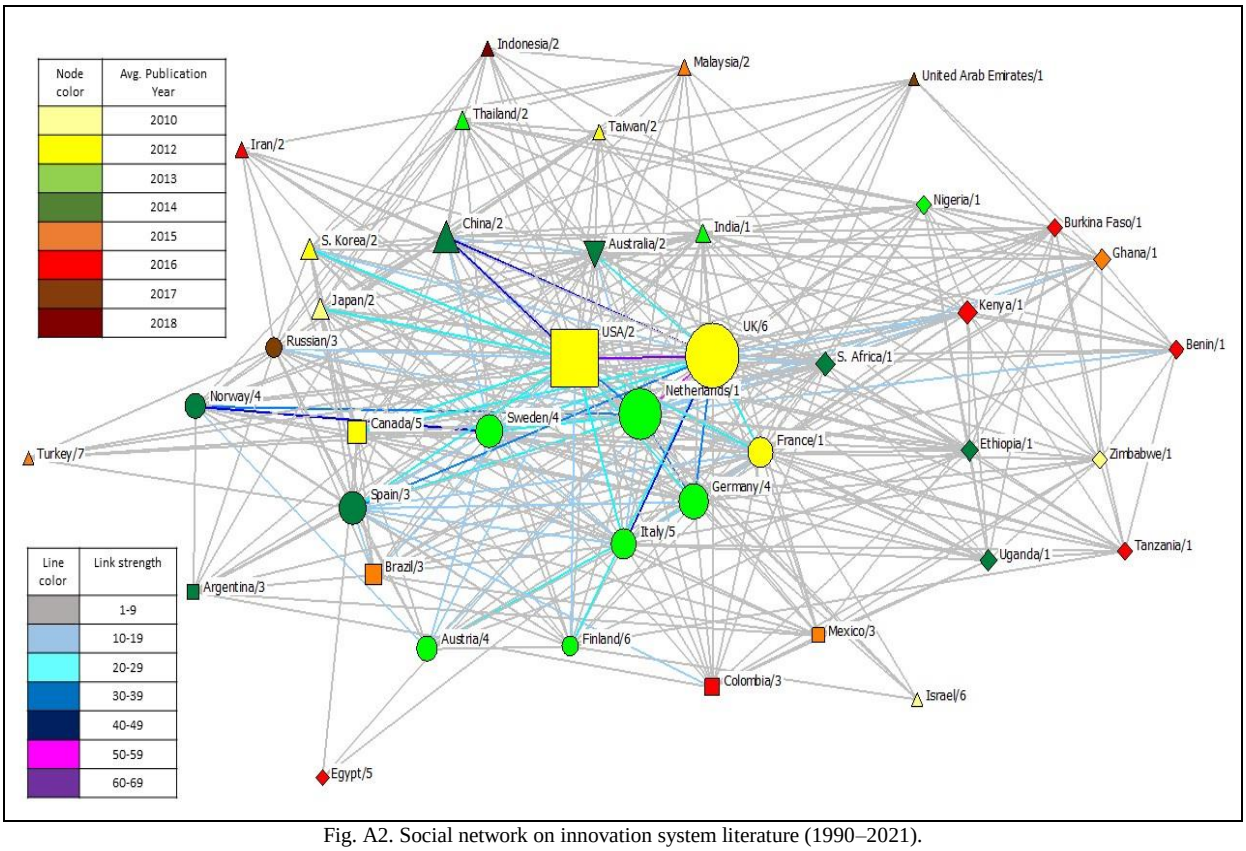

Fig. A2. Social network on innovation system literature (1990–2021).

Continent affiliations are shown according to the shape of the node: Circle=Europe; Square= America; Up Triangle=Asia; Down triangle=Oceania; Diamond=Africa; Number next to country's name, indicates the group of belonging according to VosViewer clustering process. Groups can be interpreted as groups of research, because there are grouped together considering links and link strength between countries; Size node is accordingly to the number of documents of each country; Link strength color refers to the number of collaborations between two countries, for example, Korea is linked to Sweden, having a link strength of 3, i.e., three documents were published between both; Avg. Publication Year is automatically calculated by VosViewer, it indicates the sum of the publication year of each document related to one country / number of documents of that country.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

T ález-L ópez made the research design, as well, conducted and managed the activities related to this study, as bibliometrics analysis and mapping. Don Juan Lerma gave support, performing specific tasks, as literature research, translation and editing. Ba ñuelos acted mainly, as adviser and reviewer along the development of this work.

All the authors approved the final version of this document.

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