Conceptual structure of innovation systems, a systematic approach through qualitative data analysis

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Abstract

This article analyzes the conceptual structure of the field of study of innovation systems through the establishment of subfields of knowledge using text mining. The data was sourced from the Web of Science in a search through Boolean operators under the concept "innovation systems" obtaining 6,706 articles in august 2020. For the analysis, a dictionary of categories has been constructed that agglomerate conceptually close families of words comprising keywords, theoretical and geographical approaches. Additionally, the QDA Miner & Wordstat software has been used to exploit the data. As results, it is possible to identify the central role of the concepts of triple helix and open innovation in the field of study of innovation systems; in the same way, it is possible to identify that the concepts of quadruple and quintuple helix related to the greater relevance of social and environmental issues on the agenda emerge strongly. And although the most discussed issues correspond to knowledge transfer, the science, and the economic development; the hottest issues result from the dynamics of innovation systems, its performance, and collaboration actions. Socio-technological changes in the innovation systems, mainly in North America, become less relevant as research interest, while new discussions arise in Europe and Africa on social and environmental sustainability issues. Public policies for innovation systems, management associated with new business models, and sustainability are topics of greatest interest for research. In this way the conceptual structure of the field and subfields of study of innovation systems is explained from the different visualizations through word clusters, the graphic representation of matrices and dendrograms.

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1. Introduction

Freeman (1997) defines a national innovation system as the "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Atkinson, 2014), while to Carlsson (2002) a "Innovation systems can be defined in a variety of ways:

they can be national, regional, sectoral, or technological. They all involve the creation, diffusion, and use of knowledge. Systems consist of components, relationships among these, and their characteristics or attributes". Anyway, national innovation systems and regional innovation systems are concepts associated with the competitive capacity of a region or territory (Lundvall et al., 2002), which is linked to the search for economic development (Fagerberg & Srholec, 2008) through regional development challenges (Edquist, 2010).

The analysis of the scientific literature for the case of the study of innovation systems has taken several directions: some works use bibliometric studies on innovation systems such as Chao et al. (2018), Uriona-Maldonado et al. (2012), Lopez-Rubio et al. (2020), or Lopez-Rubio et al. (2021). Other studies address the analysis of innovation systems through a literature review. Some examples are the ones conducted by Geels (2004) or Negro et al. (2012). Finally, other research in interdisciplinary studies outside innovation systems have deepened into the conceptual structure to improve the understanding of a given field of study such as Furrer et al. (2008), González-Loureiro et al. (2015) or López-Duarte et al. (2016).

This paper explores the use of data mining to study the conceptual structure of innovation systems using QDA miner and Wordstat, to find and explain the subfields of study and their relationships, based on existing data in the Web of Science.

Thus, the objective of this papers is to identify the role of the triple helix and open innovation in the conceptual structure of innovation systems, as well as identify how new concepts such as the quadruple and quintuple helix are positioned. Also, identify what are the new topics, or emerging topics in the discussions on innovation systems, as well as identify what are the hottest topics in the debates on innovation systems. Finally, identify how discussions about innovation systems change in response to geographic location in continents and subcontinents. This allows understanding the basic theories of the field of study, new trends or emerging topics, and mature or widely studied topics. With the aim of analyzing the conceptual structure associated with innovation systems, a set of concepts organized around three axes have been used: the axis of theoretical approaches; the axis of key elements, understood as the infrastructure for innovation, the macro aspects, processes, activities, and actors of innovation; and the axis of geographic associations classified by continents. The detailed development of the three axes mentioned above is described below.

This document is organized as follows: first, the theorical framework is built; then, the methodology used is reviewed, explaining the source of the data, the methods and the characteristics of the software used. Subsequently, a theoretical analysis of the correlations between the various concepts involved in the discussion on innovation systems is developed. As a next step, data mining software has been used to produce a set of tables and graphs, which facilitate the interpretation of the conceptual structure underlying the search for innovation systems. Finally, the conclusions of the article are outlined.

2. Theoretical framework

As theoretical approaches, the concepts of open innovation, social innovation, and triple helix, together with the term socio technology, which seeks to group different types of connections between technological and social issues. The concept of Open Innovation (Chesbrough, 2006; Christensen et al. 2005), fruit of innovation as a field of study, explores the open use between two or more organizations of resources, knowledge and capital in order to achieve common benefits, which is regulated by some kind of distribution agreement (Dahlander & Gann, 2010; Cooke, 2005) where this way of generating innovation is far from the individual innovator who generates with his own resources the creative destruction enunciated by Schumpeter (1976). Open Innovation thus overcomes the concept of individualism and leads to collective and organizational efforts.

The Triple helix, and later the Quadruple helix, explores the interaction of institutions such as the university, government, state and society (Geels, 2004) in the generation of initiatives that seek innovations linked to new interactions between actors (Etzkowitz & Leydesdorff, 2000; Etzkowitz et al., 2005) and which materialize in structures such as science and technology parks, incubators, and offices for the transfer of research results –although they could also exist through networks of companies in the so-called clusters. The three main agents included by the Triple Helix are the government, industry, and university. The Quadruple

Helix includes to the last three agents of the Triple Helix knowledge and civil society (knowledge society). Finally, the Quintuple Helix adds society's natural environments (sustainability), while the Sextuple Helix integrates entrepreneurship.

Thus, the triple helix theories are at the center of the discussion on innovation systems. The interlinkages between actors are explained in the literature through the interaction between industry and science (Kaufmann & Tödtling, 2001), while other discussions focus on the interactions between public policies and investments made by the state, with research and development, and knowledge transfer by universities (Meyer-Krahmer & Schmoch, 1998; Schartinger, et al. 2006).

On the other hand, a set of new concepts emerges associated with the relationship between technological change, environmental sustainability and the interplay between innovation and society (Carayannis and Morawska-Jancelewicz, 2022; Carayannis et al., 2019; López-Rubio et al., 2021). Thus, the first concept linked here is socio-technical (Geels, 2004), which explores the interaction between society and technology, where the use of technologies are conditioned by the society receiving this technology but at the same time technology can change the structure of society (Geels, 2005). Some approaches to this topic are the connections with social theories (Geels, 2010), the conceptual relationship of socio-technological systems with innovation systems (Coenen & López, 2010), the interaction between technology and institutions (Fuenfschilling & Truffer, 2014), and the dynamics of socio-technical transition (Geels, 2012).

An important role on innovation systems is the transition towards sustainable practices (Markard et al. 2012) in order to generate technological changes (Hekkert et al., 2007) that promote adjustments in activities and processes in companies, in line with the protection of the environment. In this sense, the studies of policies that induce the transition are relevant (Rogge & Reichardt, 2016). Köhler, et al. (2019) makes a review of transitions towards sustainability based on nine axes of analysis that include roles of society, business, and public policies, among others. In turn, social innovation (Phillips et al., 2015; Cajaiba-Santana, 2014) has taken on an important role in analyzing the purpose of actors in the development of society. These roles include new forms of interaction between actors, particularly civil society. In social innovation, the search for solutions and the social impact of solutions goes beyond the mere generation of wealth. This aim of generating not only economic but also social value leads to a new field of study for innovation issues (Van der Have & Rubalcaba, 2016). For the business world, the generation of new business models, linked to social innovation and its connection with sustainable development is a growing topic (Boons & Lüdeke-Freund, 2013).

The elements described above have been explained from the perspective of innovation in the literature through the concept of the quadruple helix, developed in a systematic literature review by Miller et al, (2018), as well as in discussions around the processes of production and transfer of knowledge, studied by Carayannis and Campbell (2012), Miller et al. (2016), or Del Giudice et al. (2017). In the quadruple helix, the role of society has been relevant as a new axis added to the triple helix. Regarding the concept of the quintuple helix, we turn to the works of Carayannis et al., (2018) and Grundel and Dahlström (2016) which imply the introduction of the socio-ecological transition, as a broader and more comprehensive way of adding the natural environment of society. This implies that sustainable development in a knowledge economy must co-evolve with the knowledge society (Carayannis et al. 2012).

Key elements in national and regional innovation systems

For Tödtling and Trippl (2005), innovation systems imply a set of differentiated innovation policies on a given territory. These innovation policies can include various types of instruments (Borrás & Edquist, 2013) where innovation is driven or promoted through the application of investment, the simultaneous presence of actors of the triple helix and the application of knowledge (Asheim et al., 2011). An example of the application of these policies is developed through different structures such as districts, science and technology parks, or others (Moulaert & Sekia, 2003). Specifically, it is common the specialization in certain fields or activities such as industries or industrial sectors particularly intensive in knowledge and where it is sought that the actors in that territory act under the logic of systems.

In this sense, the regional aspect related to the location of knowledge-based companies, the organization in sectoral clusters, the industrial specialization, and the establishment of focused policies are of vital importance to generate the development of innovation systems as part of national innovation capacity

(Furman et al., 2002). In turn, regional systems are also a derivation of national systems (Cooke et al., 1998) that implies different varieties of regional innovation systems (Asheim,2007) that go through institutional learning, culture building and financial capabilities (Cooke et al., 1997), and the design and implementation of policy (Uyarra,2010; Uyarra & Flanagan,2010). Regional systems transform sectoral systems that have common characteristics such as technological base, technologies, inputs and demands (Malerba, 2002); comprehensively Asheim et al, (2016) analyses the past present and future of regional innovation systems.

Innovation systems seek localized development in a territory or region (Freeman, 1995) through intensive dynamics in science, the promotion of entrepreneurship, the search for economic, environmental, and social sustainability, with dynamics associated with technological change (Smith et al., 2010; Coenen et al.,2012; Hekkert et al., 2007).

Regarding public policies, Bergek et al. (2008) have criticized the lack of practicality in the design and implementation of these policies, particularly applied to regional innovation systems (Acs et al., 2002), although some other authors point out that it is possible to help policy makers and decision makers in the design, analysis and evaluation of policies applied to innovation systems (Woolthuis et al., 2005).

Thus, national, regional, sectoral, or technological innovation systems (Carlsson et al., 2002) involve a set of science, technology, and innovation activities (Ribeiro et al., 2010) that require structures in order to generate innovation dynamics and results in terms of the creation of new technologies, as well as attracting investment and the generation of wealth (Rodriguez-Pose & Crescenzi, 2008). In this sense, numerous organizations have emerged to provide a global network for scientific and innovation institutions and businesses, contributing to regional and local development. Some well-known international associations are the International Association of Science Parks and the World Technopolis Association, which also contribute to the publication of grey literature made available to society.

Based on the characteristics of innovation systems, it is important to include in the analysis the distribution of activities, organizational boundaries, coordination mechanisms, processes, and the final effectiveness of the systems for the development of technological innovations (Liu & White, 2001), i.e., the consolidation of structures and dynamics of the systems in order to achieve the expected performances, through network activities (Pittaway et al., 2004) where knowledge is produced and transferred (Asheim &; Coenen, 2005) as part of the cluster dynamics.

Under the concepts described above, the industry and industrial sectors developed through clusters become relevant, some of them explained in scientific articles such as tourism clusters (Hjalager, 2010), renewable energies (Jacobsson & Johnson, 2000), knowledge-intensive services (Muller & Zenker, 2001), or the analysis of clusters in countries (Wolfe & Gertler, 2004) or through business development understood from the perspective of the firm as new business models and strategies (Teece, 2010).

Entrepreneurship also has an important role in the discussion on innovation systems so we inquire about the effectiveness of incubators in entrepreneurship (Colombo & Delmastro, 2002), best practices (Bergek & Norman, 2008), the role of ecosystems in terms of their structure and influence (Spigel, 2017), as well as the studies on entrepreneurship that are at the center of this discussion (Acs et al., 2014; Autio et al., 2014).

For the purposes of this article, the countries have been classified by continent (Europe, Asia, Latin America, North America, and Africa). This analysis is important because of the different degrees of interest and maturity of regions in innovation systems and the importance of territory and region in innovation systems studies (Freeman, 2002). The discrimination of regions in developed and developing countries has also been analyzed from the perspective of bibliometric studies on innovation systems (Schmutzler et al., 2017; Toivanen & Ponomariov, 2011).

There are also studies associated with the interest of individual countries analyzed individually in studies of innovation systems, as in the case of Mexico (Solleiro & Castañón, 2005), or continental studies, as in the case of Europe (Cooke, 1992). However, Morgan (2004) dismisses the importance of geographical proximity in the discussion of innovation systems, while introducing other considerations of distance and proximity beyond geographical ones, such as socio-economic distances (Berry et al., 2010).

Over the last decades, the discussion of territorial or geographic aspects associated with regional or national innovation systems has been studied in great depth. More recently, discussions have focused on the role of

knowledge in the development of clusters and the promotion of entrepreneurship.

For this article, the research and interest questions are the following:

• What is the role of the Triple Helix theory and Open Innovation in the conceptual structure of innovation systems?

• How are the new concepts of the quadruple and quintuple helix understood in the conceptual structure of innovation systems?

• How does the conceptual structure of innovation systems integrate with territorial logics in terms of continents and subcontinents of the globe? • What are the new discussions in the field of innovation systems and what are the most intense debates on innovation systems issues?

3. Methods and data

For the present work, a search was carried out in the Web of Science Core Collection as of July, 2020, using the respective Boolean operators and the various uses of the term "Innovation Systems" in the period 1900- 2020. The search yields a database consisting of information on scientific articles yielding a total of 6,706 documents structured by title, author, keywords, and abstract. This database grows at a rate of approximately 500 articles per year in the Web of Science database by observing the average annual production of the last decade.

QDA Miner is a qualitative methodological software that allows to study visual, graphical, and textual data, providing categorical and numerical information. This information is examined through exploratory, comparative, and descriptive analyses that determine coding patterns, regularities, relationships, and other properties (Watt, 2015). In this sense, WordStat can add value to the paper by analyzing text content and quantitative content through graphical and statistical tools (Udoh & Rhoades, 2006). The data processing is done by generating a dictionary of categories obtained which correspond to a set of keywords that describe that category following Tranfield et al. (2003). That allows to analyze the conceptual structure of the innovation systems in attention to the emerging topics and gaps, relevant gaps for future, hot topics with relevant gaps, and research of low interest for quality studies according to the figure 4 explained below.

The categories in turn are structured into key elements, theoretical approaches, and geographic location, thus building a dictionary with twenty-nine categories of analysis. As key elements we have used keywords frequently used in articles on innovation systems such as performance, knowledge, cluster, and others. A first filter to select these keywords has been to visualize the connections through the VoS viewer software, and to prioritize the keywords, and subsequently group them into categories or groups of conceptually similar families for analysis. For theoretical approaches, Open Innovation, Socio-technical, Social Innovation and Triple helix have been used. Open Innovation and triple helix have been selected for their relevance in the discussions on innovation systems (Huizingh, 2011; Cooke, 2005), while the transitions approaches (Markard, et al. 2012) here analyzed from the socio-technical transition and social innovation (Howaldt & Schwarz, 2011) have been chosen for their emerging character in the literature of the last two decades, hoping to understand the relationship of these theories with the concepts of quadruple and quintuple helix.

For geographical locations, groups of countries related to continents or subcontinents have been used, thus working with Europe, Asia, Latin America, Australia and Oceania, North America, and Africa. North America has been separated because of its long tradition and high production of scientific articles on the subject.

In this document, for the visualization of the results, the correlation matrices, the tables of principal factor extractions, the frequency distribution and the proximity graphs represented in the dendrograms have been used.

• Frequency distributions show the absolute and relative weight of the various categories in the volume of all words in the 6706 articles referring to the content of the title, abstract, keywords and abstract.

• The tables of extractions executed by means of the factorization analysis of non-negative matrices allow us to extract the main clusters that explain the behavior of the input data. In this case, a set of factors or word clusters, with their respective percentage weights that can explain the analyzed sample.

• The dendrograms show graphically how the words representing the various categories constructed for the dictionary are grouped according to the Jaccard index. The Jaccard index measures the similarity of sets, in this case articles that contain or do not contain a given word or category (word family).

• Correlation matrices show the location on a Cartesian plane of the various words or categories following a matrix factorization analysis, which can be graphically organized through word clusters.

4. Results

In the following paragraphs, the Dictionary of Categories is presented, as well as the various exploitations of the data through dendrograms, frequency distributions, the extraction of factors and, finally, the presentation of matrices, where these tables and graphs allow the conceptual structure of the innovation systems to be explained.

The dictionary of categories was constructed from the use of the key elements, theoretical approaches, and geographic locations described above, resulting in Table 1 in consolidated form as well as in Table A of the annex in detailed form, listing the words included in each category. The letters T and G are placed before the name of the category to indicate respectively Theory and Geography and are thus used in the following graphs and tables.

Number	Category
No.	**Key Elements**
1	Cluster
2	Collaboration
3	Dynamic
4	Development
5	Enterprise
6	Entrepreneurship
1	Cap_Inno (Innovation Capacity)
8	Industry
9	Knowledge
10	Management
11	National innovation
12	Performance
13	Policy
14	Regional innovation
15	Science
16	Sustainability
17	System
18	Transfer
No.	**Theories**
1	T Social innovation
2	T__Open innovation
3	T__Socio technological
4	T__triple helix
No.	**Geography**
1	G__Africa
2	G__Asia
3	G__Australia and Oceania
4	G__Europa

Number	Category
5	G__Latam

Table 1: Dictionary of Categories

Data mining

Below is a set of visualizations resulting from the exploitation of Web of Science data through data mining, with their respective analyses.

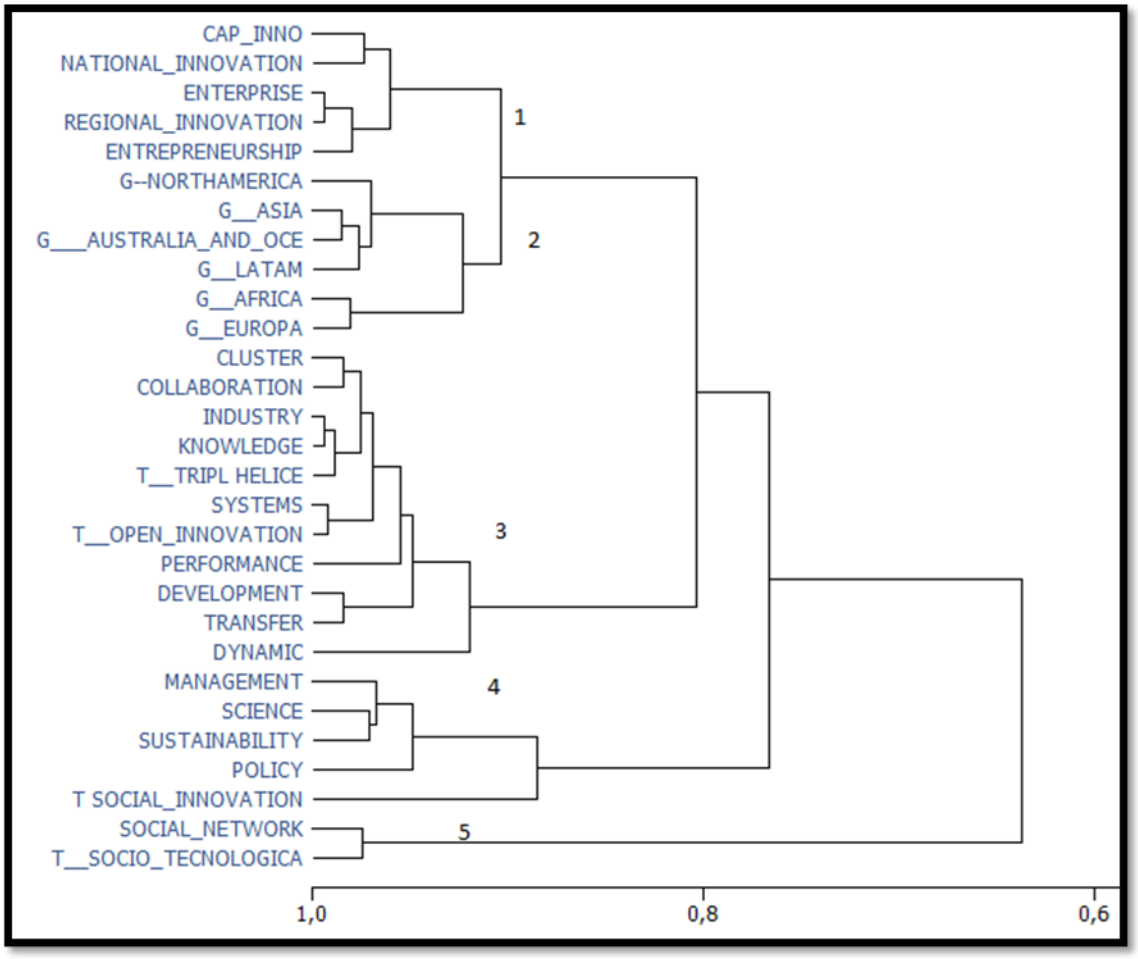

Figure 1: Dendrogram based on Similarity Index. Source: Own elaboration. (Wordstat/ Heatmap / Keyword dendogram).

Figure 1 presents a dendrogram extracted from QDA & Wordstat showing the groupings of the different categories of the dictionary of word families based on the Jacaard similarity index. The dendrogram shows large clusters numbered from 1 to 5 where it is possible to understand the word clustering logic. Thus, it is worth highlighting a grouping associated with the geographical themes indicated in the dendrogram with the number 2. This cluster agglutinates Africa, Europe, Asia, Australia and Oceania and Latin America. It is interesting to note that North America, which includes only the United States and Canada, is found in this cluster 2 separately, which can be explained by the high volume of scientific articles located in these two countries and the maturity of the studies since the initial articles by Freeman (1995) or Furman et al. (2002). In North America (Canada and the United State), discussions have evolved to other topics more related to the dynamics and performance of innovation systems that involve the cluster 1. This Cluster on the other hand, concentrates on topics associated with entrepreneurship and regional and national

innovation systems. It is understandable then that, for most of the countries of the different continents and subcontinents, innovation systems, are strongly linked to entrepreneurship and entrepreneurs from the perspective of national and regional systems.

Cluster 4, which includes new trends, comprises the topics of sustainability and social innovation as new discussions around innovation systems and has articles where the main exponents are Markard et al. (2012) and Coenen et al. (2012). The presence of the management category is also coherent, being understood as the search for new business models associated with this trend. The Policy category, on the other hand, explains the interest of public policies to generate more sustainable and inclusive technological changes.

Cluster 5 shows the social issues related to social networks, as well as socio-technical changes, which have the lowest Jacaard index of the various clusters with an index of approximately 0.65. These two topics are more dissociated than the other clusters in terms of the field of study of innovation systems. Although the value of 0.65 is relevant, the social issues related to socio-technical transitions are not fully articulated with the central discussion of innovation systems. The reason for this situation is that it is an emerging issue. It is interesting to note that sustainability issues, on the other hand, do have a correlation level above 0.9, which indicates that the term appears with a very high frequency with the other key terms that explain innovation systems. Thus, transitions towards sustainability are closer to the discussion of innovation systems than discussions of social issues.

Clusters 1, 2 and 3 represent the categories that explain the processes and expected results of innovation systems and show the heart of the discussion of innovation systems, with Jacaard indices above 0.9, indicating a very high level of correlation. In this sense, the described themes explain with a high level of correlation or connection to the field of study of innovation systems, which in turn indicates how unified the conceptual structure of innovation systems is.

Clusters 1, 2, 3 and 4 together concentrate a large part of the scientific literature on innovation systems with a Jaccard index close to 0.9, leaving out clusters 5, which implies social clusters that are still far from the heart of the discussion on innovation systems.

Frequency distributions

Table 2 shows the frequency distribution for the different words that make up the dictionary of categories previously shown in Table 1.

By drawing an imaginary line in this frequency distribution of Table 2 corresponding to the median value of 6%, it is observed that the most relevant categories are: Cap_Inno (12.56%), industry (10.47%), transfer (7.74 %), development (7.01 %), management (6.30%), systems (6.46%), performance (6.79%). The triple helix as a theoretical approach also appears in this block of categories with the highest frequency with a value of 7.17 %. On the other hand, below this 6%-line, theoretical approaches and geographical locations described by continents and subcontinents are generally less relevant than the other categories of families in the dictionary.

Figure 2 is constructed, which is referred to in the following subsection, by combining the dendrogram in Figure 1 with the frequency Table 2 of the dictionary categories.

Number	Category	Frecuency	% Relative
1	CAP_INNO (Innovation Capacity)	30018	12,56%
2	INDUSTRY	25016	10,47%
3	TRANSFER	18503	7,74%
4	T__TRIPL HELICE	17134	7,17%
5	DEVELOPMENT	16751	7,01%
6	PERFORMANCE	16234	6,79%
7	SYSTEMS	15432	6,46%
8	MANAGEMENT	15046	6,30%
9	SCIENCE	12145	5,08%
10	REGIONAL_INNOVATION	11424	4,78%

Number	Category	Frecuency	% Relative
11	KNOWLEDGE	9262	3,88%
12	SUSTAINABILITY	6647	2,78%
13	G__ASIA	5868	2,46%
14	G__EUROPA	5749	2,41%
15	ENTREPRENEURSHIP	5432	2,27%
16	NATIONAL_INNOVATION	4594	1,92%
17	POLICY	4403	1,84%
18	COLLABORATION	3854	1,61%
19	DYNAMIC	2779	1,16%
20	T__OPEN_INNOVATION	2751	1,15%
21	T SOCIAL_INNOVATION	2379	1,00%
22	ENTERPRISE	2285	0,96%
23	CLUSTER	2199	0,92%
24	G__AFRICA	1315	0,55%
25	G__LATAM	1052	0,44%
26	T__SOCIO_TECNOLOGICA	263	0,11%
27	G___AUSTRALIA_AND_OCE	165	0,07%
28	G—NORTHAMERICA	148	0,06%
29	SOCIAL_NETWORK	138	0,06%

Table 2: Frequency distribution for the categories

For the construction of the figure, the words of each category corresponding to the different branches of the dendrogram have been added, according to the clusters established there. In this way, cluster 1, obtains a percentage of 44.64%, which is obtained by adding the data corresponding to Cap_Inn (Innovation Capacity), National Innovation, Enterprise, Regional Innovation, Entrepreneurship, which as shown in Table 2, have a percentage of participation of 12.56%, 1.92%, 0.48%, 4.78%, and 2.27% respectively.

The figure also shows the corresponding sums to indicate the cumulative percentages of each of the branches and clusters of the dendrogram, as explained in the previous paragraph.

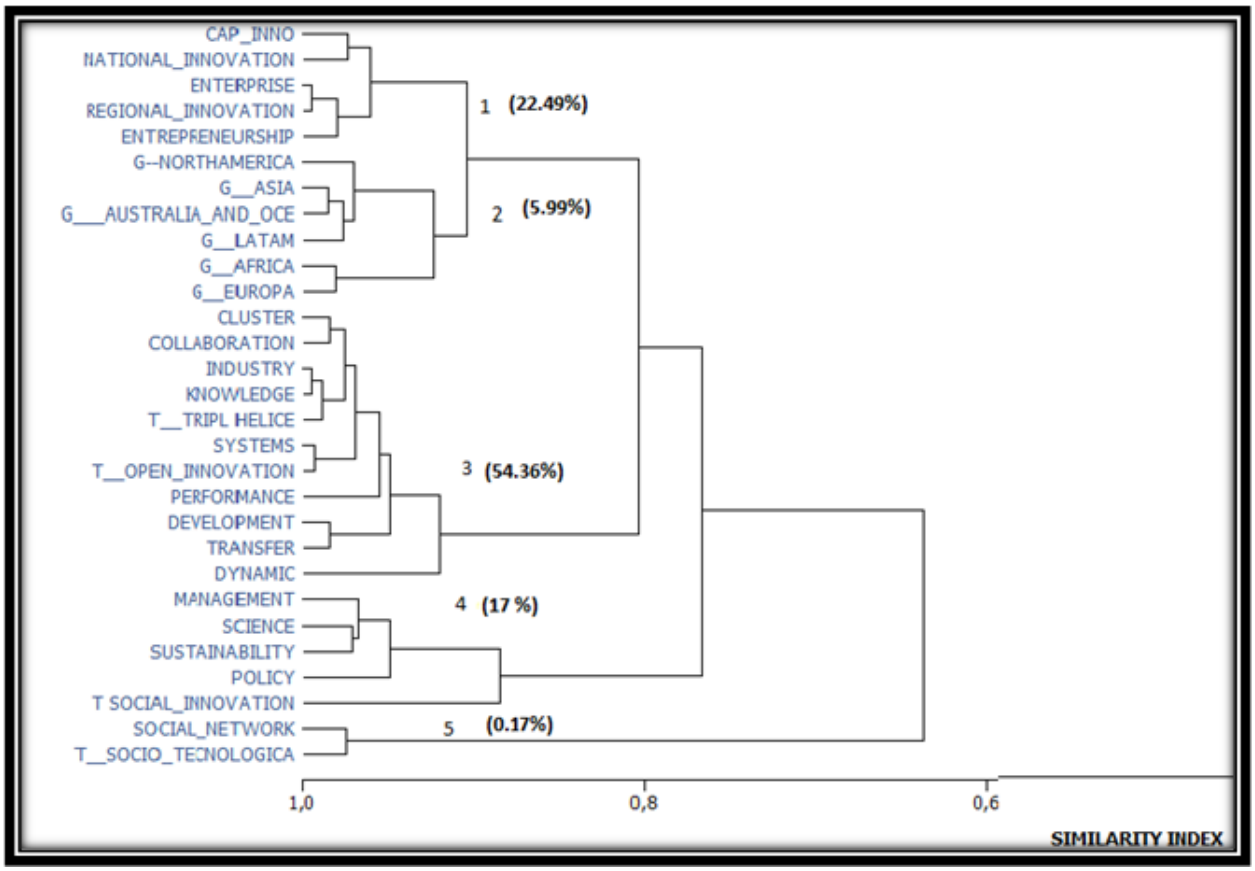

Figure 2: Combined dendrogram and frequency distribution analysis. Source: Own elaboration. (Wordstat/ Heatmap / Keyword dendogram).

Cluster 1 with 22.49%, cluster 3 with 54.36% and finally cluster 4 with 17% should be highlighted. These four clusters represent 93.85 % of the frequencies, which could amply explain the field of study. From the Non-negative matrix factorization (NMF or NNMF) analysis, executed for the dictionary of categories shown in Table 3 using QDA & Wordstat software, an extraction of the main topics shown in Table 2 has been performed. The resulting extraction comprises 5 main topics which have been nominated for the present article as "New trends", "Collaboration", "Knowledge & regional economy", "Science and Technology & triple helix", and finally Innovation Systems, and which fully correspond to clusters 1, 2,3, 4 and 5 explained above. Thus, the Table 3 indicates the clusters (extracted with QDA miner & Wordstat) that includes the name assigned by the authors to each cluster, the dictionary categories (see Table A) include in each cluster, the frequency and number of cases included, the coherence and the % of the corresponding cases. The presence of these five clusters is explained below, where the "Innovation System" cluster is the result of the search for "innovation systems" in WoS described in the methodology section of this article and therefore comprises 98% of the cases. • The "new trends" cluster explains the current interest in sustainability issues and social change, which comprises about 25 % of the cases in this database. • The word Cooperation (36%) has been used to name this cluster to differentiate it from the word Collaboration, which is already in the dictionary of categories. • "Knowledge & regional economy" is a cluster that comprises 83% of the cases and includes all the families of words related to Regional Innovation, Performance, Entrepreneurship and Development overlapped with the cluster named "Cooperation". • The cluster "Science and Technology, & triple helix", comprises in the center of the cluster the word triple helix, and an associated group of words related to science, technology, and innovation. This corresponds to a value of 93 % of the cases.

With the presence of these four-word clusters, it is possible to explain the structure of the innovation systems, where it is relevant to show the percentage or relative weight of each cluster. The presence of

the cluster of words "Science and technology & triple helix" and "Knowledge & regional economy" is consistent with the findings of Cooke (2005) who identifies the triple helix and regionalization as elements of approximation in the discussion of regional innovation systems. Similarly, "new trends" is a word cluster consistent with Markard et al.'s (2012) transitions to sustainability. The cluster of words called "cooperation" is consistent with the logic of the logic of open innovation, but clearly includes other types of cooperation such as social innovation and social networks, among others.

No	Topic	Keywords	Coherence	Freq	Cases	% Case
1	Innovation systems	SYSTEMS; CAP_INNO; PERFORMANCE; INDUSTRY; DEVELOPMENT; INNOVATION SYSTEMS; REGIONAL INNOVATION SYSTEMS; NATIONAL INNOVATION SYSTEMS; SYSTEMS OF INNOVATION	0,399	55978	6538	97,49%

No	Topic	Keywords	Coherence	Freq	Cases	% Case
2	Science and technology & triple helix	SCIENCE; TRANSFER; NATIONAL_INNOVATION; G_ASIA; PERFORMANCE;"T_TRIPL HELICE"; DEVELOPMENT; INDUSTRY; SCIENCE AND TECHNOLOGY; ECONOMIC DEVELOPMENT; TECHNOLOGY TRANSFER; INNOVATION SYSTEM; RESEARCH AND DEVELOPMENT; KNOWLEDGE TRANSFER; INNOVATION PERFORMANCE; SUSTAINABLE DEVELOPMENT	0406	38301	6246	93.14%

No	Topic	Keywords	Coherence	Freq	Cases	% Case
3	Knowledge & regional economy	REGIONAL_INNOVATION; G__EUROPA; ENTREPRENEURSHIP; DEVELOPMENT; PERFORMANCE; ECONOMIC DEVELOPMENT; RESEARCH AND DEVELOPMENT; SUSTAINABLE DEVELOPMENT; INNOVATION PERFORMANCE; REGIONAL DEVELOPMENT; INNOVATIVE DEVELOPMENT; INNOVATION AND ENTREPRENEURSHIP; TECHNOLOGY DEVELOPMENT; INNOVATION DEVELOPMENT; TECHNOLOGICAL	0,354	22310	5522	82.34%

No	Topic	Keywords	Coherence	Freq	Cases	% Case
4	Cooperation	COLLABORATION; SOCIAL_NETWORK; T__OPEN_INNOVATION; KNOWLEDGE; CLUSTER; KNOWLEDGE TRANSFER; KNOWLEDGE ECONOMY; KNOWLEDGE CREATION; KNOWLEDGE BASES; KNOWLEDGE PRODUCTION; KNOWLEDGE FLOWS; KNOWLEDGE MANAGEMENT	0,328	6705	2400	35.79 %
5	New trends	T__SOCIO_TECNOLOGICA; SUSTAINABILITY; DYNAMIC; SUSTAINABILITY TRANSITIONS	0,277	3804	1646	24.55 %

Table 3: Five clusters according to the main topics in the innovation systems literature (drawn from the QDA miner & Wordstat software)

Word Cluster Matrix

Figure 3 shows the 4 clusters mentioned above: "New trends", "Cooperation", "knowledge & regional economy", and finally "Science and technology & triple helix".

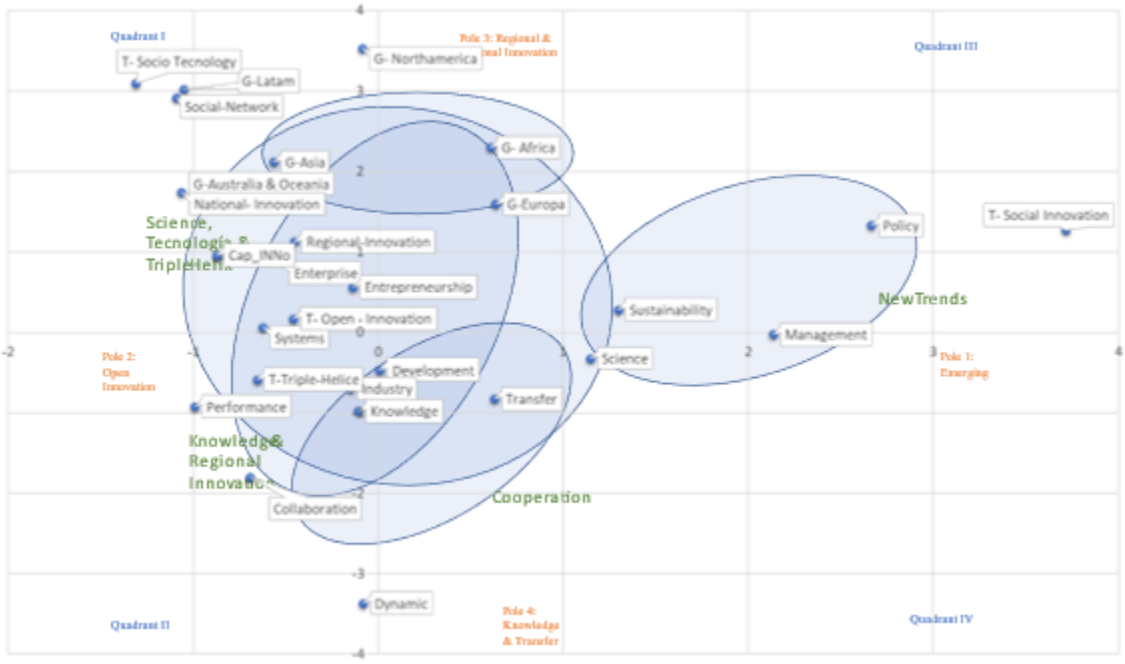

Figure 3: Word Cluster. Source: Own elaboration.

These clusters are complemented in Figure 1 by the presence of the theoretical approaches corresponding to Triple Helix, Open Innovation, Social Innovation and Socio Technical. Thus, it is observed that the concepts Triple Helix and Open Innovation are close in the Cartesian diagram due to their high concurrence in the scientific literature, which in turn is since the development of Open Innovation involves in practice the interaction with various business, state, university, or social actors, in collaboration schemes that correspond to the triple helix approach. Similarly, these two theoretical approaches (Triple Helix and Open Innovation) are located at the center of three of the large clusters in Figure 3.

The topics of transition to sustainability and social innovation are more closely associated with the "new trends" cluster due to their emerging nature, which explains their separation from the other three clusters in Figure 3. This is consistent with the fact that the literature shows that scientific production on these topics corresponds to the last two decades.

On the other hand, the approaches associated with "Socio-technical" transitions appear closer to the concepts of national innovation and regional innovation, since innovation systems are characterized by their focus on technological change.

In Figure 3 we have also added the geographical focus represented by the continents or subcontinents, in this case, Latin America, Europe, Asia, Australia and Oceania, and finally North America. Additionally, the four poles or extremes of the Cartesian diagram have been added, called Pole 1 "Emerging", Pole 2 "Open Innovation", Pole 3 "Regional & National Innovation", and finally Pole 4 "Knowledge &Transfer". Finally, in Figure 2, quadrant designations such as I, II, III and IV have also been added. The above to develop the explanation that follows:

In relation to developments based on geographical aspects, it is possible to identify that Latin America, Australia and Oceania, as well as Asia, are located in quadrant I y IV, which can be understood by the search of these regions to implement and use innovation systems to mobilize innovation indicators. They are also very close to the "Science and Technology, & triple helix" cluster, which is characterized by the development of regional and national innovation systems, the triple helix and innovation structures.

North America is in quadrant IV, closer to the words National Innovation and Regional Innovation, explained by the profusion of research in this field of study in this particular region and by interests closer to the performance of innovation systems.

Europe and Africa appear to be very close. One explanation for this proximity could be the fact of being halfway between the issues of sustainability and social innovation corresponding to the emerging issues of social and environmental concerns, and on the other hand the search for performance and knowledge-intensive industrial clusters. Although in the case of Europe, important developments in innovation systems have been developed in the last decades in contrast to Africa and its underdeveloped countries.

In relation to the extremes or poles of the Cartesian diagram, these have been denominated on the x-axis, "Emerging" and "open innovation", which reflects a tension between the new themes and interests represented here by Social Innovation and Sustainability, and the tradition of innovation systems represented by the theoretical approach of Open Innovation.

On the other hand, the y-axis represents on one side the discussion of regional and national innovation systems dominated by discussions of technological change, and on the other side the expected results or products of the innovation systems measured in knowledge, transfers, and dynamics of the innovation systems that appear loose from the word clusters and very close to the end of the negative axis of the ordinates.

Gaps in qualitative analysis

Figure 4 shows the matrix for detecting gaps in qualitative research that according to González- Loureiro et al, (2015) allows identifying topics of interest for future studies (Quadrant IV), topics of current debate (Quadrant III), and topics in decline (Quadrant I), and emerging topics (Quadrant II). In this way, the various categories can be organized according to this matrix as shown in Figure 4.

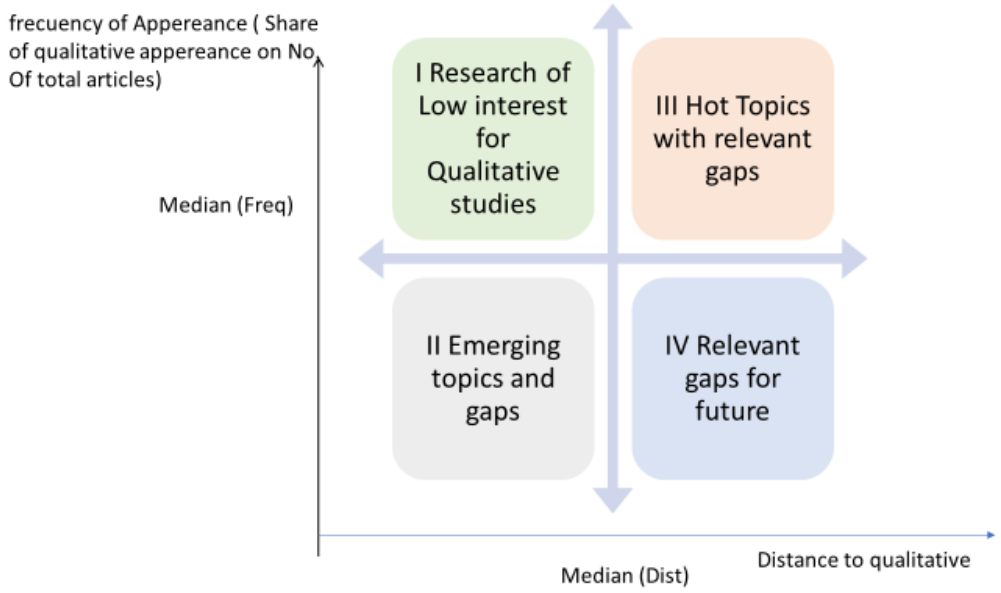

Figure 4: The matrix to detect. Source: Adapted from González-Loureiro et al, (2015).

Through Figures 3 and 4, some conclusions are reached:

• The topics that could be of greatest interest in the future, located in quadrant III, are Policy, Social innovation, Management issues, as well as Sustainability. Additionally, studies associated with Europe and Africa should be considered.

• The topics on which there is currently most debate, corresponding to quadrant IV, are Science, Development, and Transfer.

• The topics of little interest are those associated with North America and related to Socio Technology. These appear in quadrant I.

• Emerging topics include, Performance, Industry, Dynamic and Collaboration. Quadrant II.

It is interesting to observe the central role of the concepts of open innovation and triple helix in the discussions of innovation systems, as result of the efforts of university, enterprise and state interaction, and multiple collaboration schemes. Likewise, it is observed that the discussions on innovation systems move towards aspects of environmental and social sustainability, related to the implementation of public policies for sustainability, and the development of new business models in the logic of the quadruple and quintuple helix. On the other hand, it is observed that socio-technological transitions lose strength, while the central discussions spin around economic development related to the performance and dynamics of innovation systems, in accordance with the essence of innovation systems derived from the transfer of knowledge and the intensive use of science. While discussions in North America on socio-technological issues lose strength, in Europe and Africa sustainability issues are of greater interest in research.

5. Conclusions

According to previous work, the use of data mining software allows the exploitation of data from the Web of Science or other databases through the generation of various types of reports such as dendrograms, factor extraction using the non-negative matrix factorization technique as well as the visualization of word clusters in the Cartesian plane.

In the case of the field of study of innovation systems, the conceptual structure is understood in essence through three large word clusters, which in this article have been called "Cooperation", "Science & technology, & triple helix", and finally "Knowledge & regional innovation". These clusters individually represent 36%, 83% and 93% of the words used respectively with overlaps. The combined cluster of these three clusters explains 97% of the discussions on innovation systems studies. A fourth cluster, called "New Trends" in this article, which represents 24% of the discussions on innovation systems, corresponds to the topics of sustainability and social innovation, which could be understood in association with the "Management" category, linked to new business models in the markets for sustainable and socially responsible products and services, where a meeting point of these terms is found around the circular economy.

Innovation systems pivot around the discussion of the triple helix as a tradition and emerging issues linked to sustainability and socio-technical transition. In this sense, open innovation, and the triple helix form part of the theoretical heart of this field of study, while emerging issues focus on environmental sustainability and social issues. Similarly, innovation systems are torn between regional and national tensions on the one hand, and issues of knowledge transfer and generation on the other.

The link between the socio-technical transition and the socio-ecological transition gives meaning to the presence of the quadruple and quintuple helix in the conceptual structure of innovation systems. Notwithstanding the above, transitions towards sustainability are fully integrated into the discussion of innovation systems, while social issues are emerging.

Entrepreneurship and economic development are anchored in the discussion of innovation systems as the expected end of innovation systems, and therefore at the center of the field of study, consistent with studies since Schumpeter's time.

In relation to geographical issues, discussions in Latin America, Asia, Australia, and Oceania focus on the importance of regional and national innovation systems, possibly linked to the effort to develop innovation systems to boost innovation indicators and regional development. In the case of Latin America, the weak infrastructure in terms of innovation systems makes it necessary to generate enabling conditions and consolidate capacities, so the concern is focused on these terms.North America, a region that has been

extensively researched in terms of innovation systems, debates revolve around Enterprise, Entrepreneurship, Regional and National Innovation. Unlike Latin America, Asia, Australia and Oceania, the focus is on the performance of innovation systems, rather than on the enabling conditions of innovation systems.

In the case of Europe, it is moving towards new discussions on environmental and social issues, probably linked to the Paris Agreement on climate change, the Circular Economy and social innovation agendas. Finally, and related to the emerging issues of socio-technical and socio-ecological transition.

Africa, tied to underdevelopment, is likely to seek to initiate innovation systems based on sustainability agendas and social issues, given the importance of sustainability in a continent with simultaneous abundance and scarcity of natural resources, as well as deep poverty.

It is interesting to note that the role of the theoretical approaches associated with technological transitions or changes remains distant from the three major clusters that define the field of study of innovation systems, which can be interpreted as the gradual abandonment of these approaches, and how the shift towards new social and environmental transitions, explicit in the quadruple and quintuple helix, has been explained. In this way, the importance of technological change, by itself, has been replaced by the emergence of changes or transitions focused on the environmental and social.

In terms of the research question posed in the article, the triple helix and open innovation are at the intersection of the three major word clusters, whereby these theories individually explain each and every one of the major clusters. This places these theories at the center of discussions of innovation systems. Nevertheless, the emergence of the quadruple and quintuple helix concepts linking society and sustainability issues respectively to the old triple helix concept is observed in the conceptual structure as a new layer that is being integrated into the body of knowledge on innovation systems. In this way, the transitions towards sustainability and the social end up being an expected projection of the discussions on innovation systems.North America as Socio Technological change are not of major interest among academics because of the depth of research.

Future topics of interest could be related to Africa, Europe, social innovation, and public policies all related to socio-technical and environmental transition –Africa topics are understood in terms of the low real implementation of innovation systems and related to the low production of scientific articles. Europe is very interesting in terms of the transition of innovation systems towards new sustainability and social issues. Finally, the issues of social innovation and its incorporation into innovation systems in the territories, and the regional could be very interesting.

Another interesting analysis could be how public policies are integrated with innovation systems, especially in relation to the emerging issues of sustainability and social issues, or how public policies feed the impulse of innovation systems based on the quadruple and quintuple helix.

Sustainability is a topic of great discussion and interest, and numerous studies can be foreseen in this field, as well as the social innovation.

However, a new field of discussion is emerging around public policy and management as drivers to achieve sustainability transitions. In the field of management, it could be configured around new business models and strategies, while for public policies, longer-term approaches to include environmental sustainability and inclusive approaches to respond to social demands on productive apparatuses represented by companies and industrial clusters nested in innovation systems.

Footnotes

1. Vos Viewer. https://www.vosviewer.com/

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Appendix

CATEGORY Mental construct	WORDS Family of related words
CLUSTER	Cluster, industrial cluster.
COLLABORATION	Innovation network, network.

CATEGORY Mental construct	WORDS Family of related words
DEVELOPMENT	Advanced economies, develop, developing countries, economic develop, economic growth, emergence, emerging, factors, economic geography, globalization, integrated, patterns, regional economics, regional level, sectoral systems, socio economic, underdevelopment, world, world development.
DYNAMIC	Dynamic, evolution, transformation, transition.
ENTERPRISE	Model, small and medium, business services, enterprise.
ENTREPRENEURSHIP	Creation, creative, entrepreneurial, entrepreneurship ecosystem, entrepreneurship, innovative, start up, venture capital, business services, enterprise, small and medium.
CAP_INN (Innovation Capacity)	innovation process, innovation, innovation activities, innovation and production, innovation capacity, innovation process, innovative capacity, learning process, market formation, potential, process, role, sources, structural, structure, innovative activities.
G__ AUSTRALIA AND OCEANIA	Australia, Micronesia, New Zealand, Papua_ new Guinea, Samoa.
G__AFRICA	Africa, Africa, Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, democratic republic of the Congo, Djibouti, Egypt, equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Ghana, Guinea, Guinea-Bissau, ivory coast, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, south Africa, south Africa, south Africa, south Sudan, Tanzania, the Gambia, Tunisia, Uganda, western Sahara, Zambia, Zimbabwe.
G__ASIA	Afghanistan, Armenia, Asian, Azerbaijan, Bahrein, Bangladesh, Brunei, Bhutan, Cambodia, china, Chinese, Cyprus, Georgia, India, Indonesia, Iran, Iraq ,Israel, Japan, Japanese, Jordan, Kazakhstan, Korea, Kuwait, Kyrgyzstan, Laos, Lebanon, Malaysia, Maldives, Mongolia, Myanmar, Nepal, north Korea, Oman, Pakistan, Palestine, Philippines, Qatar, Russia, Russian, Saudi Arabia, Singapore, south Korea, Sri Lanka, Syria, Taiwan, Taiwan, Taiwanese, Tajikistan, Thailand, Timor-Leste, turkey, Turkmenistan, United Arab Emirates, Uzbekistan, Vietnam, Yemen.

CATEGORY Mental construct	WORDS Family of related words
G__EUROPA	Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Denmark, Dutch, Estonia, EU, Europe, European, European, European countries, European union, Finland, France, France, Georgia, German, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Malta, Moldavan, Monaco, Montenegro, Netherlands, north Macedonia, Norway, Poland, Portugal, Romania, Russia, san Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, turkey, UK, Ukraine, United kingdom.
G__LATAM	Argentina, Bolivia, Brazil, chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, el Salvador, Guatemala, Honduras, México, Nicaragua, Panamá, Paraguay, Perú, Uruguay, Venezuela.
G—NORTHAMERICA	Canada, United States.
INDUSTRY	Agricultural, agriculture system, Agriculture, conservation agriculture, Biotechnology, Business service, companies, creative industries, energy, energy policy, energy system, firm, generation, industrial, industries, industry, manufacturing, manufacturing firm, nanotechnology, oil, patent, product, production research and development, sector, sectoral, service, small and medium, software, software industries, transformation transition.
KNOWLEDGE	Information, innovation studies, innovation theory, intensive, knowledge creation
Knowledge _network, knowledge transfer, knowledge, knowledge base, knowledge based economy, knowledge bases, knowledge creation, knowledge diffusion, knowledge economy, knowledge exchange, knowledge exchange, knowledge flows, knowledge intensive, knowledge interactions, knowledge management, knowledge networks, knowledge production, knowledge spillovers, knowledge transfer, regional knowledge, tacit knowledge, tacit knowledge, transfer	
MANAGEMENT	Adaptative management, administration, advantage, business model, challenge, competitive advantage, complex, cooperation, cost, decision, external, forecasting, future, goals, innovation management, management of technology, market, modelling, organization, organizational, organization, resource, specialization, stakeholders, strategic, strategic management, strategies, technology management
NATIONAL_INNOVATION	Nation, national, National innovation, National innovation system, nation level, national system of innovation

CATEGORY Mental construct	WORDS Family of related words
PERFORMANCE	Competition, competitive, competitive advantage, competitiveness, demand, efficiency, efficient, gap, impact, indicator, innovation performance, market, performance, productivity, results, role, success, successful, update
POLICY	Energy policy, innovation policy, Policy maker, Policy implication, policy instrument, policy making, politic, public, public policy, research policy, technology policy
REGIONAL_INNOVATION	Geographical proximity, local, local innovation, proximity, region, region development, regional innovation system, regional system, regional, regional advantage, regional development, regional innovation, regional innovation system, regional level, regional science, regional studies, regional system of innovation, territorial, region
SCIENCE	Research, research and development, science, science and technology, science based, scientific, researchers,
SUSTAINABILITY	Climate, climate change, eco innovation, ecological, ecosystem, environment, environmental, environmental innovation, environments, green, nature, renewable, renewable energy, renewable energy technologies, selection environments, sustain develop, sustain transit, sustainability transitions, sustainable, sustainable development,
SYSTEM	Function, innovation system, innovation system approach, system, system function, system of innovation, systemic, systems of innovation, technological innovation system
T SOCIAL_INNOVATION	Social, social innovation
T__OPEN_INNOVATION	Collaboration, Collaborative, collaborative innovation, open innovation, open
T__SOCIO_TECNOLOGICA	socio technical, socio technical system, socio technical transition
T__TRIPL HELICE	Actor network, actor strategies, actor, actor and institution, actors involved, firm, governance, government, helix, institution, institutional, institutional change, interaction, political, public sector, society, triple helix, triple helix model, universities, university industry, university industry government
TRANSFER	

Table A: Dictionary of Categories. Source: Own elaboration.