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Industria 4.0 dentro de la innovación: Análisis bibliométrico
Industry 4.0 whithin Innovation: Bibliometric Analysis

Ricardo Salazar-Velázquez [1] 0000-0002-5755-988X
Juan Mejía-Trejo [1] 0000-0003-0558-1943

[1] Universidad de Guadalajara, Centro Universitario de Ciencias Económico Administrativas
✉ ricardo.salazar7842@alumnos.udg.mx

Palabras clave: análisis bibliométrico; innovación; industria 4.0; administración; negocios; contabilidad; internet de las cosas; desarrollo sustentable; innovación tecnológica; bibliometría; Scopus; Web of Science
Keywords: bibliometric analysis; innovation; industry 4.0; management; business; accounting; internet of things; sustainable development; technological innovation; bibliometrics; Scopus; Web of Science

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Resumen

Introducción: el propósito de esta investigación es analizar las relaciones y tendencias de crecimiento del concepto de *Industria 4.0* dentro del universo global de la literatura sobre Innovación, limitada al área temática de *empresa*, *administración* y *contabilidad*, mediante un análisis bibliométrico.

Método: se utiliza Scopus como base de datos para el análisis de 513 documentos para el período comprendido de 1998 a 2021. De igual modo, se emplea el *software* VOS Viewer para el procesamiento de bases de datos de Scopus, y para la elaboración de figuras que representan las relaciones entre las muestras de documentos.

Resultados: la cantidad de documentos está creciendo exponencialmente, comenzando con una tendencia en 2016 y aumentando desde entonces. La fuente más dinámica es *Technological Forecasting And Social Change*. El autor con más documentos es Voight, K. L., con 10 publicaciones, y la institución más destacada es la Universidad de Johanesburg con 14 documentos. El país con más documentos es Italia con 69. El 69 % del total de documentos son artículos, y el 23,4 % son ponencias. El número de documentos en el área de Negocios, Gestión y Contabilidad, con 513, supera con creces a cualquier otra área, representando el 42 % del total de documentos. El patrocinador de financiamiento con más documentos es la Fundación Nacional de Ciencias Naturales de China con 13 archivos. Algunas de las organizaciones más actualizadas son el Department of Mechanical & Industrial Engineering y The center for digital labor markets. El país con más documentos es Reino Unido, con 50 documentos y 584 citas, seguido de Estados Unidos,

con 1 110 citas. Estados Unidos tiene principalmente vínculos con China, Australia, Reino Unido, Alemania e Italia. Reino Unido tiene principalmente enlaces con Francia, Italia, Alemania y Estados Unidos. Las principales relaciones de China son Australia, Estados Unidos, Pakistán, Taiwán, Turquía, Brasil y Corea del Sur. Los principales enlaces de Italia son Francia, España, Brasil, Federación de Rusia, Reino Unido, Austria y Portugal. Se pudo determinar que los países se agrupan en su mayoría en 6 grupos.

Conclusión: si bien aún no hay muchas publicaciones, se puede inferir que el término *Industria 4.0* dentro de la literatura disponible sobre innovación seguirá aumentando exponencialmente a lo largo del tiempo, reforzando las relaciones entre autores, instituciones y países. Con base en el estado actual de la literatura, el área temática de *negocios, administración y contabilidad* seguirá siendo la que englobe la mayoría de los documentos disponibles.

Abstract

Introduction: the purpose of this research is to analyze the relationships and growth trends of *Industry 4.0* within the global universe of current literature on innovation, limited to the subject area of *business, administration, and accounting* by means of a bibliometric analysis.

Method: Scopus is used as a database for the analysis of 513 documents for the period from 1998 to 2021. VOS viewer was used for processing Scopus database and elaboration of figures representing the relationships between samples.

Results: the number of documents is exponentially growing, starting with a trend in 2017 and increasing ever since. The most dynamic source is *Technological Forecasting And Social Change*. The author with most documents is Voight, K. L. with 10, and the most distinguished institution is the University of Johannesburg with 14 documents. The country with more documents is Italy, with 69. According to the database 69 % of the total documents are articles and 23,4 % are conference papers. The number of documents in the area of Business, Management and Accounting, with 513 documents, exceeds by far any other area, representing 42 % of all documents. The funding sponsor with more documents is the National Natural Science Foundations of China with 13 documents. Some of the most updated organizations are Department of Mechanical & Industrial Engineering, The center for digital labor markets. The country with more documents is United Kingdom with 50 documents and 584 citations, followed by United States with 1110 citations. United States has mainly bonds with China, Australia, United Kingdom,

Germany and Italy. United Kingdom has mainly bonds with France, Italy, Germany and United States. China's main relations are Australia, United States, Pakistan, Taiwan, Turkey, Brazil and South Korea. Italy's main bonds are France, Spain, Brazil, Russian Federation, United Kingdom, Austria and Portugal. It could be determined that countries are mostly grouped in 6 clusters.

Conclusion: Although there are not many publications yet, it can be inferred that the term industry 4.0 within the available literature of innovation will keep increasing exponentially over time reinforcing relations between authors, institutions and countries. Based on the current state of literature, the subject area of *business, management, and accounting* will keep on being the one that encompasses most of the available documents.

Introduction

Since the 1990s, the OECD's perspective on innovations has shifted to include more and more varieties in the Oslo Manual. In the first edition published in 1992, only product and production process innovations were considered as such, it was until 2005, in its third edition, that organizational and marketing variants were introduced, with the purpose of including innovations developed in the service sector; this was one of the most notable changes to the Manual since its first edition. In its third edition, the Manual divides innovations into four groups: Organizational, Marketing, Product, and Process as seen in table 1.

Table 1. Innovation types.

Innovation type	Definition
Organizational	Introduction of methods never used by the company, with the function of organizing work management routines and procedures
Marketing	Implementation of new marketing methods that do not have been used before by the company, which may include changes in the packaging and in the design of the presentation of the products, in the promotion, and methods of marketing of goods and services
Product	Changes are introduced in materials, components, or other characteristics with the purpose of having a greater reception of the market or a different use.
Process	Changes in production techniques, as well as in the components and tools that are used with the purpose of improving quality and productive efficiency.

Source: own elaboration based on OECD, 2005.

The fourth and latest version provides a set of guidelines that extend measurement of innovation from companies to other organizations and individuals, as well as updates in basic definitions and taxonomies to facilitate reporting and interpretation across the business sector, it takes more account of globalization and digital trends and also guidance on measuring internal and external factors influencing business innovation, integrating prior guidance in developing countries on measuring innovation (OECD, 2018). In accordance to these changes in the conception of innovation, new technology changed the scope and context of mayor sectors in global industry witch encompassed concepts such as computerization, digitization and intelligentization in the term Industry 4.0 or also called The Fourth Industrial Revolution (Lin, Shyu, & Ding, 2017).

Industrial revolutions can be divided in 4 stages: Industry 1.0, Industry 2.0, Industry 3.0, and finally Industry 4.0. Each industrial revolution has contributed in the advancement of today's development (Alaloul, Liew, Zawaw, & Kennedy, 2020). Industry's 1.0 main attribute was the use of water and steam engines combined with manpower to operate machinery in production back in the 18th century (Hitpass & Astudillo, 2019); Industry 2.0 was characterized by mass producing goods and services with electricity starting in early 20th century, also enabling chain production for the first time (Baygin, Yetis, Karakose, & Akin, 2016); Industry 3.0, starting in the 1950's up to 2010, is identified by higher level of automation and digitalization powered by Information Technology (IT) and electronics (Agolla, 2018); Industry 4.0 is distinguished by the implementation of Cyber-physical Systems, the use of smart industry, Internet of Things, the rise of Big Data and hyperconnectivity (Pereira & Romero, 2017; Hitpass & Astudillo, 2019).

The term was first introduced in 2011, at the Hannover Fair presented under the title of intelligent production, used in a technological strategy project of the German government (Baygin, Yetis, Karakose, & Akin, 2016; Glistau & Coello Machado, 2018). Industry 4.0 is the most powerful driver of innovation, triggering trends in organizations in terms of new strategies, organizational models, operation and technologies and human resources management practices (Ghobakhloo, 2018; Ibarra, Ganzarain, & Igartua, 2018). The technical innovations that are associated with Industry 4.0 offer the possibility of adapting existing business models or developing new ones (Müller & Däschle, 2018, p. 5). As stated in Velásquez, Estevez, & Pesado (2019), it is the transformation through the use of information and communication technologies in line with digital evolution based on transfer of knowledge and generating customized products at relatively lower costs and delivery times.

However, adoption of Industry 4.0 initiatives is not so easy due to existence of many challenges (Luthra & Mangla, 2018). For example, although flexibility, cost reduction, efficiency, quality and competitive advantage are some of the benefits to Industry 4.0 adoption in SMEs, financial and knowledge constraints have been mayor barriers (Masood & Sonntag, 2020). According to Schröder (2016), small and medium-sized enterprises lack the resources, methodological approaches, and general standards to join value creation networks related to industry 4.0, unlike large companies.

Do to the dynamic change in the concepts of innovation and industry 4.0 and relatively new sources of knowledge in both comes the interest to acknowledge the relationships and growth trends of Industry 4.0 within innovation by carrying out a bibliometric analysis limited to the subject area of business, administration and accounting.

Methods

The internet is by far the fastest growing technology in the history of the world starting with 7 % of adults in USA online in 1995 to 60 % by the year 2000, therefore causing the migration of scientific publications to electronic formats in searchable databases, and large datasets, lowering publishing barriers and obtaining worldwide electronic exposure at a lower cost (Wren, 2005; Hewson & Stewart, 2014).

Bibliometrics, a branch from scient metrics, statistically measures the output side of science allowing to understand the continuous flux of scientific and technical research (Godin, 2006; Leydesdorff & Milojević, 2012). Bibliometric methods are used mainly for research evaluation and the two most common data sources are Web of Science (WoS) and Elsevier's Scopus, which is one of the largest curated abstract and citation databases indexed through rigorous content selection making it a source for many types of different bibliometric studies around citation analysis and correlations, essentially of highly cited articles on indicators (Mongeon & Paul-Hus, 2016; Baas, Schotten, Plume, Côté & Karimi, 2020).

Elsevier's Scopus database was used in order to carry out this study. VOS viewer is used for organizing, visualizing, and interpreting Scopus database. "VOS viewer can be used to construct maps of authors or journals based on co-citation data or to construct maps of keywords based on co-occurrence data. The program offers a viewer that allows bibliometric maps to be examined in full detail" (Van Eck & Waltman, 2010, p. 524).

The documents considered where based on the search of the term “Innovation” appearing in 431, 357 document results, filtered out by searching within results the term “Industry 4.0” resulting in 3,431 documents, limited to the subject area related to business, management and accounting, reducing the results into 1130 documents. Finally, limiting the results to the exact keywords “industry 4.0”, “Innovation”, “Internet of things”, “Sustainable Development”, and “Technological Innovation” resulting in 513 document results. Analyzing a number greater than 513 samples would result in taking into account documents not pertinent to the study subject. For example, not having included the industry 4.0 variable, in addition to having included all the subject areas and also the keywords "digital transformation", "manufacturing", "competition", and "business model innovation", the outcome would’ve been a total of 430,846 additional documents not related to the investigation, this was avoided with the previous filter. Likewise, analyzing a number less than 513 results would generate dynamics in the graphic displays that would make their interpretation more difficult. The keyword “industry 4.0” contained only 232 documents, hence based on the literature reviewed, the previously mentioned keywords were considered, avoiding an information bias. Also, Scopus only allows downloading a maximum of 2000 documents.

Results

Documents by year

There is a pronounced change starting in the year 2016, increasing from 3 documents the year before to 22, and exponentially growing starting a trend in 2017 and increasing ever since. By this running year 2020 there are already almost 60 more documents than last year as seen in fig. 1. The trajectory can be analyzed in three stages: 1- The consolidation of the preceding literature up until the conception of the term “industry 4.0”; 2- The exponential growth in 2016 that enables the development of the research area caused by consolidated literature in the first stage; 3- A growth trend from 2017 onwards, where during this period the largest number of documents has been generated. It is the stage with the largest reserve of literature. Exponential growth is accelerating rapidly.

2021	7
2020	200
2019	141
2018	87
2017	32
2016	22
2015	3
2014	1
2013	0
2012	2

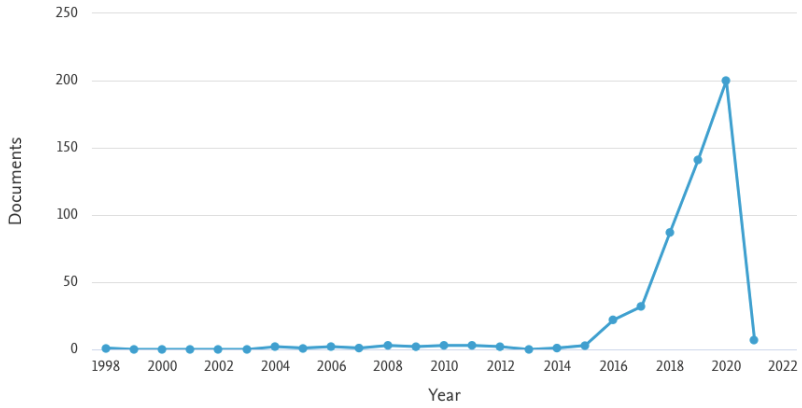

Fig. 1. Documents by year.
Source: Scopus database, 2020.

Documents per year by source

Fig. 2 shows that the three sources with more documents are Technological Forecasting And Social Change with 43, followed in second place by Journal Of cleaner Production with 19, and finally International Journal of Production Economics. The most dynamic source is Technological Forecasting And Social Change starting with 1 document in 2017, then 12 documents in 2018, followed by 5 in 2019, and a sudden change in 2020 with 22 documents, making it the source with the biggest number of documents. Although it is difficult to know the particular reasons of what generates dynamics in the documents per year for each source, it can be inferred that there is a certain correlation between the growth trend observed in fig. 1 and the fact that Technological Forecasting And Social Change has had an exponential growth in that same period in relation to the other sources. The three least dynamic sources are: Polish Journal of Management Studies, Journal of Manufacturing Technology Management and Cogent Business and Management.

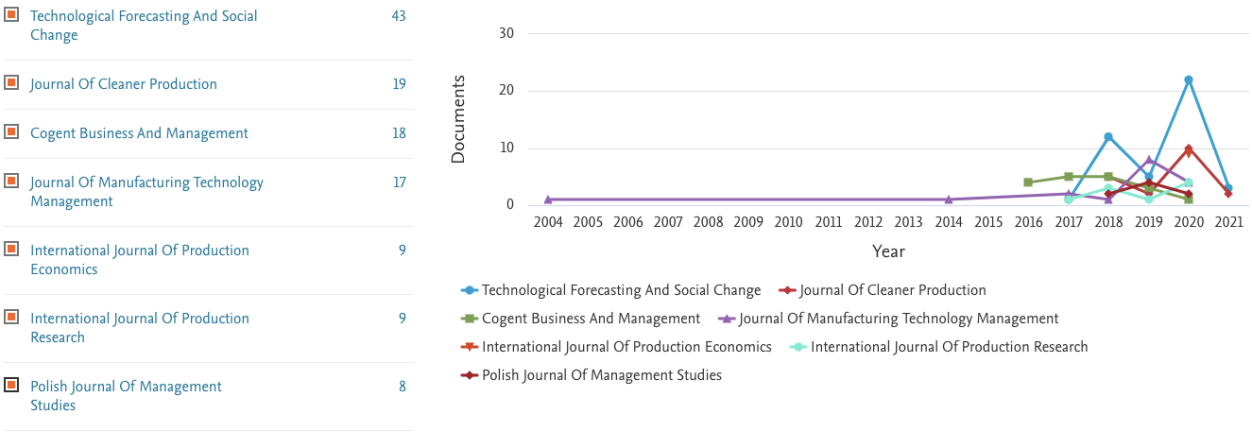

Fig. 2. Document per year by source.
Source: Scopus database, 2020.

Documents by authors

Fig. 3 shows that the author with most documents is Voight, K. L. with 10 documents, followed by Muller, J.M. with 6 documents and finally followed by Arnold, C. with 5 documents.

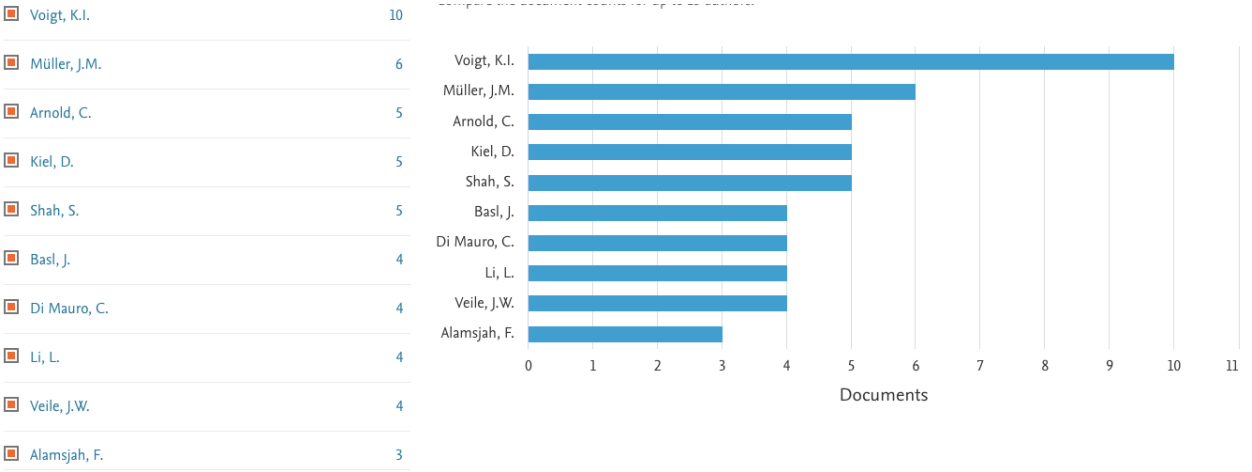

Fig. 3. Documents by authors
Source: Scopus database, 2020.

Although Muller, J has double the documents that Lau, A, this last one has more citations as seen in table 2.

Table 2. Author by citations.

Author	Citation	Documents
Voigt, K.	324	10
Lau, A.	296	3
Muller, J.	242	6
Li, L.	225	4
Arnold, C.	119	5
Kiel, D.	114	5
Idiagbon-Oke, M.	102	3
Oke, A.	102	3
Chen, C.	102	3
Frank, A.	88	3

Source: own elaboration based on Scopus database, 2020.

Documents by affiliation

Fig. 4 shows that the 5 most distinguished institutions are University of Johannesburg with 14 documents, Friedrich-Alexander-Universitat Rrlangen-Nurnberg with 11 documents, Universita Degli Studi Di Padova with 8 documents and Old Dominion University and University of Cambridge both with 6 documents.

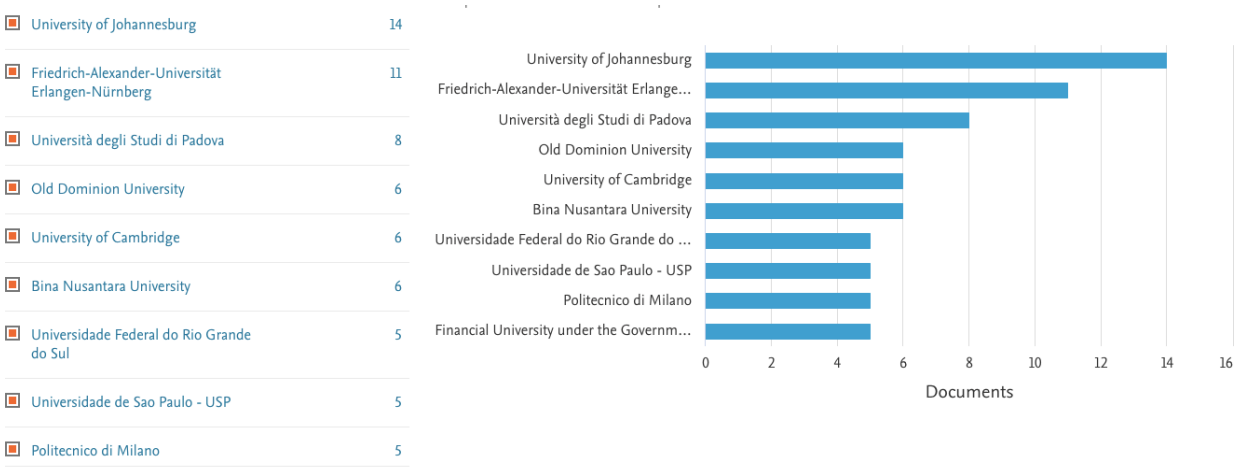

Fig. 4. Documents by affiliation
Source: Scopus database, 2020.

Documents by country

As can be seen in fig. 5, the country with more documents is Italy with 69 documents, followed by Germany with 55 documents, in third place, United Kingdom with 50, United States is in 4th place with 46 documents and China is below with 39.

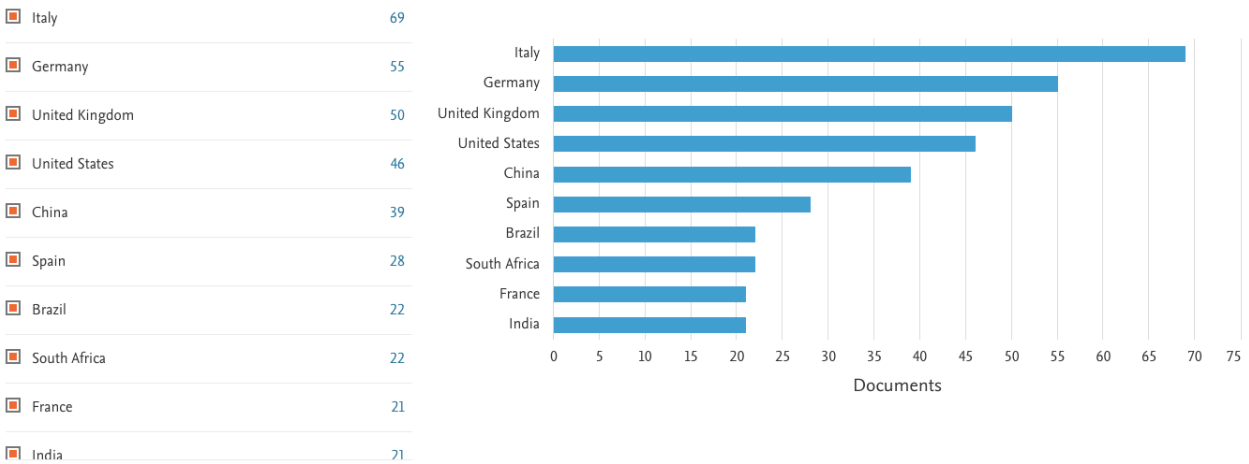

Fig. 5. Documents by country
Source: Scopus database, 2020.

Documents by type

It can be observed in fig. 6,69 % of the total documents are articles and 23,4 % are conference papers, and the remaining 7,6 % is distributed in reviews, book chapters, editorials, book, and short survey.

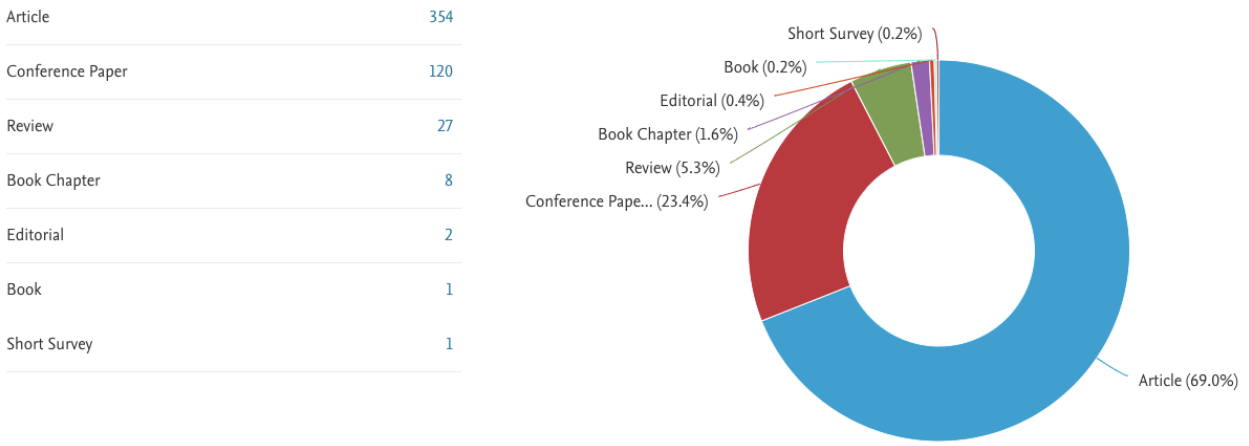

Fig. 6. Documents by type.
Source: Scopus database, 2020.

Documents by subject area

As it can be seen in fig. 7, the number of documents in the area of Business, Management and Accounting with 513 documents exceeds by far any other area. This represents the 42 % of all documents, followed by Engineering with 14,4 %.

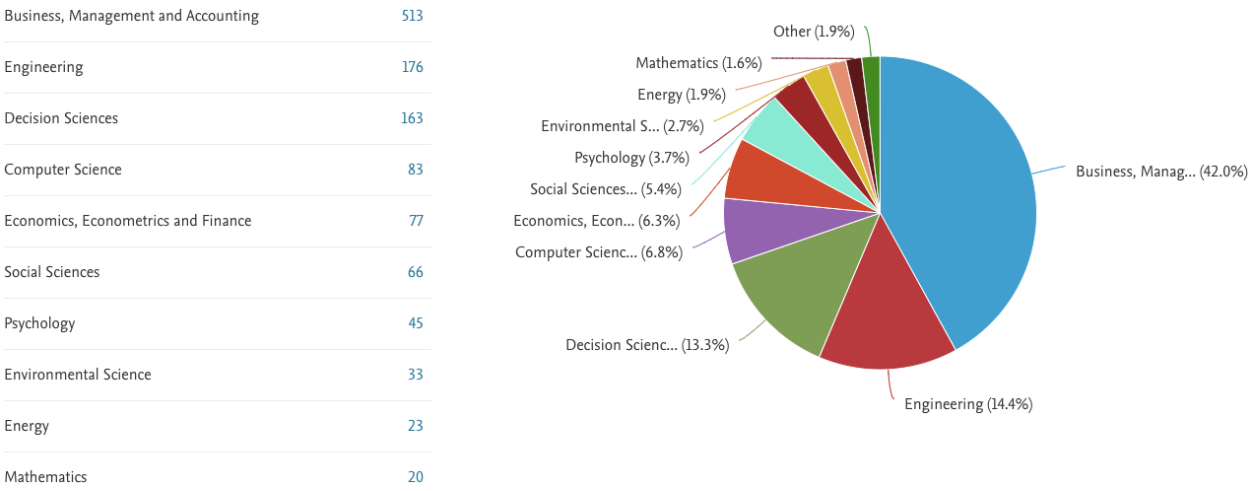

Fig. 7. Document by subject area.
Source: Scopus database, 2020.

Documents by funding sponsor

As can be seen in fig. 8, the funding sponsor with more documents it the National Natural Science Foundations of China with 13 documents, the second place is for the European Commission with 7 documents, in third place Coordenação de Aperfeiçoamento de Pessoal de Nível Superior and Conselho Nacional de Desenvolvimiento Cientifico e Tecnológico both with 5 documents

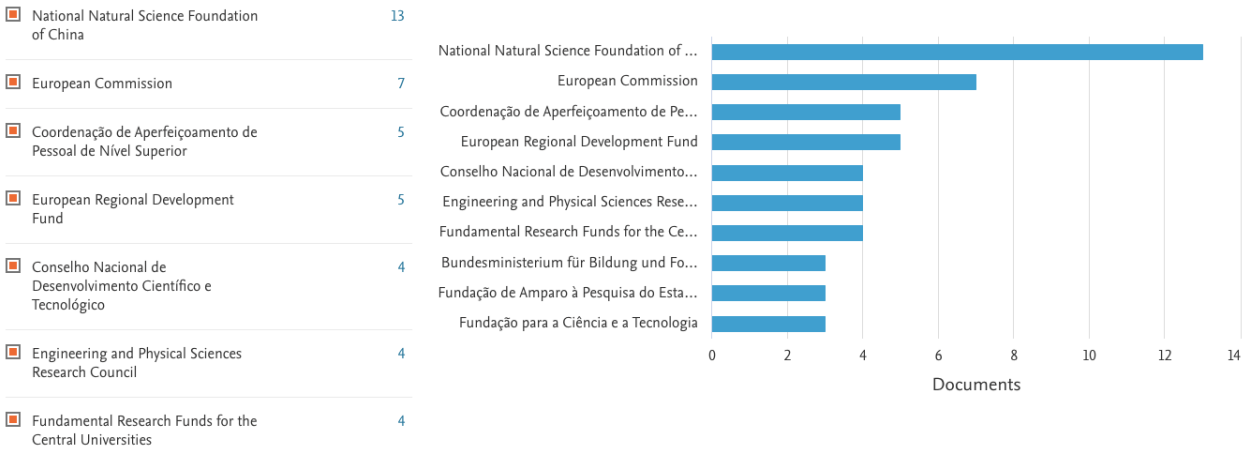

Fig. 8. Documents by funding sponsor.
Source: Scopus database, 2020.

Although there are different methodological tools to measure science and knowledge, including different bibliometric indicators to those considered, the analysis by means of VOS Viewer particularly allowed the development of co-authorship maps based on bibliographic data considering the units of measurement "Author", "Organizations" and "Countries". The resulting

maps were network, overlay, and density visualizations. Specifically, fig. 9 was developed through an analysis of co-authorship by authors with a network visualization. Documents with a maximum of 10 authors were ignored. Of the 4288 authors, only 1286 passed the filter of a minimum of 1 document per author and a minimum of 1 citation per author. VOS Viewer suggested to select only 1000 authors with the greatest total link strength. For fig. 10, a co-authorship analysis was developed by Organization with an overlay visualization. And fig. 11 was developed by means of a co-authorship analysis by organization with a density visualization. In both figs. 10 and 11: documents with a maximum of 10 organizations were ignored; Of 3852 results, only 48 passed the filter of a minimum of 2 documents and a minimum of 1 citation; For the total of organizations, VOS Viewer suggested to select all 48 do to link strength in the sample. A co-authorship analysis was developed by countries represented in a network visualization in fig. 12 and a density visualization in fig. 13. In both figs. 12 and 13: documents with a maximum of 10 countries were ignored; Of the 139 countries, only 56 passed the filter of a minimum of 4 documents per author and minimum 2 citations by author; For the countries, VOS Viewer suggested to select all 56 do to link strength in the sample.

Co-authorship by authors

In spite of the fact that there are 4 clusters represented in Red, Green, Yellow and Blue, there are 3 main clusters represented in fig. 9: 1- “Arnold C”, “Kiel D”, “Muller J”, “Veile J”, “Voigt K”; 2- “Chen c”, “Chen Y”, Li L; 3- “Ancarani A”, “Di Mauro C”. It can be observed that the cluster with more representation is the one highlighted in red, this means that it encompasses most of the documents and citations available in the literature. It’s also visible that the clusters are fairly separated from each other, indicating no close interrelation.

Fig. 9. Network visualization of Co-authorship by authors
Source: own elaboration based on Scopus database, 2020.

Co-authorship by organization

Based on the overlay visualization in fig. 10, some of the most updated organizations are Department of Mechanical & Industrial Engineering, the center for digital labor markets, Department of Economics and Management, financial university under the government of the Russian Federation, University of Pretoria South Africa and Suleman Dawood School of business marked in yellow. Followed by School of Engineering and Sciences of Sacramento, Department of Agricultural Food and Resource Economics Michigan State University, Czestochowa University of Technology, School of Economics Huazhong University of Science and Technology, Department of IT and Decision Sciences, all marked in green. These are followed by Cardiff School

of Management, Department of Manufacturing Engineering Anna University, Friedrich-Alexander-Universität Erlangen-Nürnberg, marked in purple.

Fig. 10. Co-authorship by organization.
Source: own elaboration based on Scopus database, 2020.

A low density is perceived and no overlapping in fig. 11 meaning there is no significant coexistence between cited organizations meaning that there is no outstanding organization in relation to the others in terms of documents and citations. Although the dispersion of the organizations is homogeneous and in the mostly unrelated to each other, it is observed that University of Primoska is one of the most noticeable do to is position in relation to others.

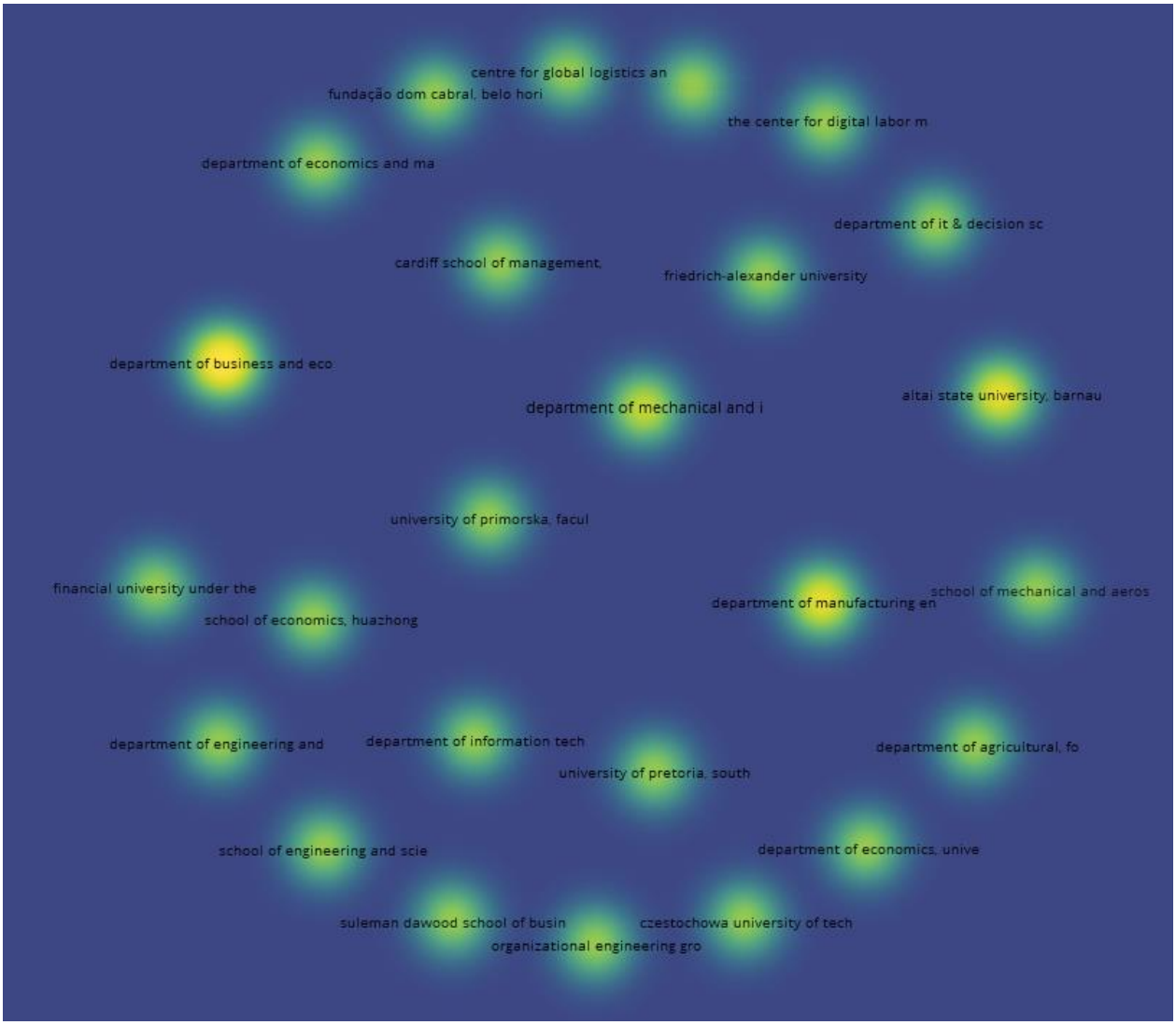

Fig. 11. Co-authorship by organization Density.
Source: own elaboration based on Scopus database, 2020.

Co-authorship by countries

Table 3 represents countries with their respective documents and citations. The country with more documents is United Kingdom with 50 documents and 584 citations, followed by United States with 1110 citations and in third place China with 39 documents and 180 citations. Although the UK has barely more documents, United States has practically two times the number of citations.

Table 3. Countries by documents and citations.

Country	Documents	Citations
United Kingdom	50	584
United States	46	1110
China	39	180
Spain	28	49
Brazil	22	222
South Africa	22	116
France	21	146
India	21	117
Russian Federation	20	41
Malaysia	19	45

Source: own elaboration based on Scopus database, 2020.

Fig. 12 represents the relations between Co-authorship by Countries. United States has mainly bonds with China, Australia, United Kingdom, Germany and Italy. United Kingdom has mainly bonds with France, Italy, Germany and United States. China's main relations are Australia, United States, Pakistan, Taiwan, Turkey, Brazil and South Korea. Italy's main bonds are France, Spain, Brazil, Russian Federation, United Kingdom, Austria and Portugal. Countries are represented in 6 main clusters: 1- Some of the visible countries that represent the red cluster are Czech Republic, Malaysia, Pakistan, Indonesia, Russian Federation and Canada; the green cluster main representative countries are Australia, India and Taiwan; the light blue cluster is represented by United States, China, and Turkey; The dark blue cluster is represented by Germany, Sweden and Finland; the yellow cluster's representatives are United Kingdom, France, and Italy; and finally the purple cluster is represented by Brazil, Spain and México.

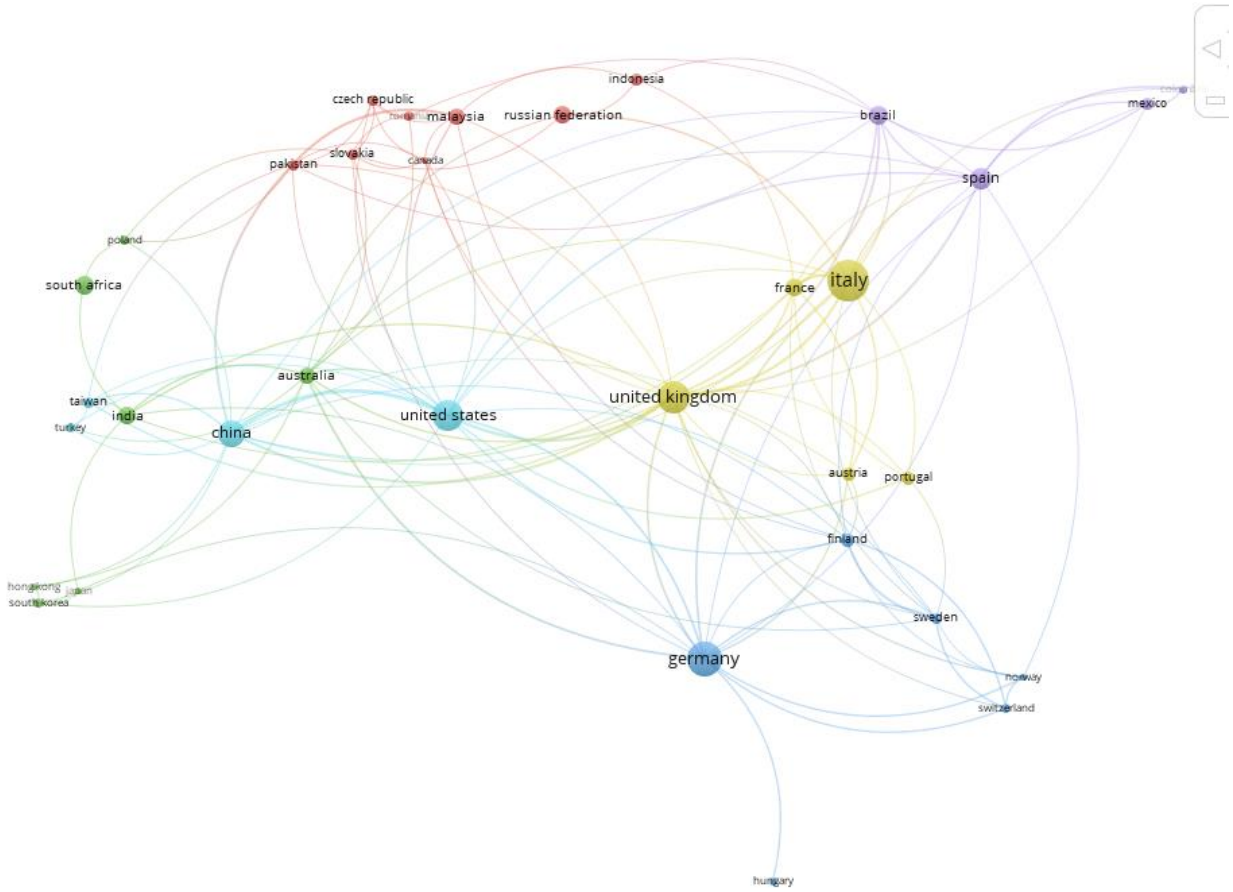

Fig. 12. Network Visualization of Co-authorship by Countries.
Source: own elaboration based on Scopus database, 2020.

By visualizing fig. 13 it could be determined that countries are mostly grouped in 6 clusters: 1- Canada, Czech Republic, Indonesia, Malaysia, Pakistan, Romania, Russian Federation, Slovakia; 2- Australia, Hong Kong, India, Japan, Poland, South Africa, South Korea; 3- Finland, Germany, Hungary, Norway, Sweden, Switzerland; 4- Austria, France, Italy, Portugal, United Kingdom; 5- Brazil, Colombia, Mexico, Spain; 6- China, Taiwan, Turkey, United States.

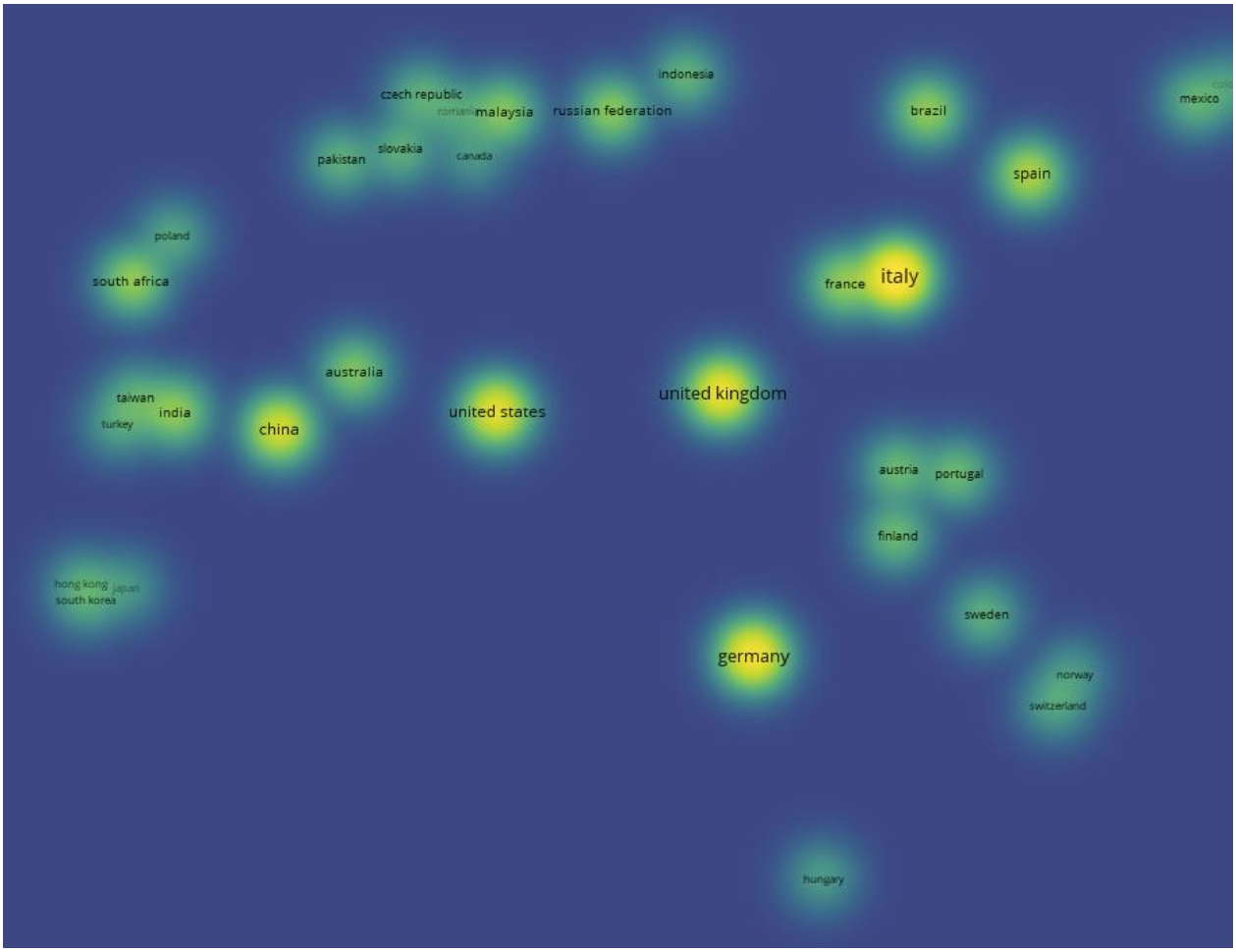

Fig. 13. Density Visualization of Co-authorship by Countries
Source: own elaboration based on Scopus database, 2020.

Conclusions

There is a pronounced increase in documents and exponential growth starting a trend in 2016 and increasing ever since. By this running year 2020 there are already almost 60 more documents than last year with a total of 200 documents. The three sources with more documents are Technological Forecasting And Social Change with 43, followed in second place by Journal Of cleaner Production with 19, and finally Cogent Business And Management. The author with most documents is Voight, K. L. with 10 documents and although Muller, J has double the documents that Lau, A has, this last one has over 120 more citations. The 2 most distinguished institutions are University of Johannesburg with 14 documents and Friedrich-Alexander-Universitat Rrlangen-Nurnberg with 11 documents. The country with more documents is Italy with 69 documents, followed by Germany with 55 documents. 69 % of the total documents are articles and 23,4 % are conference papers making a total of 92.4 % of all documents. The number of documents in the area of Business,

Management and Accounting with 513 documents exceeds by far any other area. The funding sponsor with more documents it the National Natural Science Foundations of China with 13 documents, the second place is for the European Commission with 7 documents.

The institution with the most citations is the Department of Manufacturing Engineering and Engineering Management University of Hong Kong encompassing 227 citations. A low density is perceived and no overlapping meaning there is no significant coexistence between cited organizations. The country with more documents is United Kingdom with 50 documents and 584 citations, and although the UK has barely more documents, United States has practically two times the number of citations. In reference if relationship between countries: United States has mainly bonds with China, Australia, United Kingdom, Germany and Italy; United Kingdom has mainly bonds with France, Italy, Germany and United States; China's main relations are Australia, United States, Pakistan, Taiwan, Turkey, Brazil and South Korea; Italy's main bonds are France, Spain, Brazil, Russian Federation, United Kingdom, Austria and Portugal. It could be determined that countries are mostly grouped in 6 clusters.

The bibliometric analysis contributed to recognize the authors, organizations and countries where science and knowledge currently concentrates on the term industry 4.0 within the Innovation literature in Scopus. This makes it possible to point out areas of research opportunity for authors, organizations and countries that are not among the indicators. It could be inferred based on the results, that it is a fairly recent and little explored topic, countries will keep demanding literature in order to know the state of the art for public policy management, taking into account that it is a topic that will continue to be relevant to the next years. In fact, according to Oztemel & Gursev (2020), the literature has a gap in assessment methodologies. The theorems and definitions have not been settled for real life implementations and are urgently required for those who are intending to speed this transformation up.

It is important to take into account that this type of analysis may have certain restrictions. For example: the fact that a document is cited multiple times is not a synonym of its quality, therefore some complementary qualitative methodology would be required to be able to evaluate it in that sense; The way the data is collected does not take into account all the available information sources since, according to Bornmann & Leydesdorff (2014), bibliometrics can only be applied in disciplines that are represented in adequate databases. According to the author, while the natural sciences are represented in databases, the technical, social and humanities sciences are only

partially included; the information over time will tend to vary, such as the indicators of documents, authors, organizations, and countries.

Limitations

This study managed to extract articles only from the Scopus database in relation to Industry 4.0 within the global universe of current literature on Innovation limited to the subject area of business, administration and accounting and only considering exact keywords “industry 4.0”, “Innovation”, “Internet of things”, “Sustainable Development”, and “Technological Innovation. Also, the research only encompasses documents from 1998 to 2021.

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