Lisbon School of Economics & Management
Universidade de Lisboa

MASTER

MASTER IN ECONOMICS AND MANAGEMENT OF SCIENCE, TECHNOLOGY AND INNOVATION

MASTER´S FINAL WORK

DISSERTATION

A BIBLIOMETRIC ANALYSIS OF THE COVID-19 PANDEMIC IMPACT ON STI LITERATURE

BERNARDO MOTTA MONTEIRO

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SUPERVISION:
MANUEL MIRA GODINHO

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GLOSSARY

STI – Science, Technology and Innovation

R&D – Research and development

JEL – Journal of Economic Literature

SARS – Severe acute respiratory syndrome

ABSTRACT, KEYWORDS AND JEL CODES

This study investigated how the COVID 19 pandemic impacted the STI literature. We addressed this question by comparing the contents of the STI literature before COVID-19 and since the pandemic's beginning, using bibliometric and clustering techniques as well as a systematic qualitative review of key publications. We find that the concentration in the top ten countries was lower in the Covid Publications than in the non-Covid ones and that the countries hit hard by the pandemic had a higher participation rate in the Covid publications set. Of the 27 selected journals, only 18 had Covid-related publications, and of these, only six journals had a higher participation rate in the Covid set. For the non-Covid publications set, the bibliographic coupling of the journals revealed a clear distinction between two groups, a management/business related one and one of core STI journals. For the 2019 and 2020_21 non-Covid publications set, we obtained a similar result of four clusters that were interpreted as representing the following topics: Firm Innovation, Innovation Management, Scientometrics, and Gender, respectively. With regard to the Covid publications, the cluster analysis revealed that the Covid related STI literature can be divided into four different thematic clusters: Economic Dynamics and Entrepreneurship; New Innovation Models; Scientometrics and Education. The overlay map analysis revealed that most of the shared terms between the non-Covid and Covid sets belonged the Scientometrics cluster, a research theme identified as central by clusters in both sets. Also, we found an intersection in the "Firm Innovation" cluster of the non-Covid publications centered around small business and entrepreneurship topics. However, the publications within the Covid set focused on their role in the economic dynamics and recovery. The Covid pandemic will have lasting effects on several dimensions of science, technology and innovation-related areas and this research aims to help to identify and gain insight into the potential STI knowledge fields related to the impact of Covid-19

KEYWORDS: COVID-19; Innovation Studies; Bibliometric analysis; Co-word analysis; Emerging research topics

JEL CODES: C80; O30

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ACKNOWLEDGMENTS

First, I wish to express my deepest gratitude to Professor Manuel Mira Godinho for his invaluable and never-ending feedback, support and patience throughout this research, as well as for his advice and guidance in matters beyond this work.

I am also grateful to Prof. José Roberto Afonso for his constant support and counselling, both professionally and personally, over the last five years. I would be remiss in not thanking my fellow graduate students, as well as the entire faculty and staff.

Lastly, I'd like to thank my family and friends for their love, encouragement, and unconditional support while I pursued this project. To my parents, my eternal gratitude, for without them nothing would be possible.

1. INTRODUCTION

The COVID-19 pandemic resulted in a profound global triple crisis, which combines health, social and economic issues impacting all aspects of human activity. By July 2022, the disease (SARS-Cov-2) has reached almost all countries, totalling approximately 540 million cases and 6,3 million deaths (WHO, 2022). Given the severity of the crisis, virtually all social actors mobilized resources and turned their attention to dealing with the pandemic outbreak. As a result, companies had to adapt and reinvent their operations, while governments had to adopt rapid, extraordinary, and sometimes unprecedented policies. Naturally, research on COVID-19 attracted the scientific community.

The pandemic's multidimensionality has implications beyond just medical issues, so it stimulates a multidisciplinary interest in the topic. In this context science, technology, and innovation (STI) studies have dealt with several aspects of the COVID-19 crisis.

To assist governments, multilateral organizations, and researchers, this work aims to be an initial assessment of how the COVID 19 pandemic impacted the STI literature. We will address this question by comparing the contents of STI literature before COVID-19 and since the beginning of the pandemic. We believe that our analysis can help governments, multilateral organizations, and researchers to assimilate existing research and support future ones.

To this end, we carry out a systematic review of STI academic publications, using bibliometric and text-mining techniques to capture how the STI studies literature reacted to the COVID-19 crisis, as well as to identify emerging research themes triggered by that crisis (Colavizza et al., 2020; Kousha and Thelwall, 2020; Glänzel et al. 2019). In addition, we do a qualitative analysis of the topics found by a systemic review of the relevant material to identify relevant research topics.

Beyond the present introduction, this research has three more sections and a conclusion. First, Section 2 presents the motivation behind the current investigation and its objectives, followed by Section 3, where we cover the methodology implemented. Then, in Section 4, we present, analyze and discuss the results. Finally, the paper discusses the usefulness of this study, its limitations, and possible developments for future research.

2. MOTIVATION

The high level of infectiousness of the virus and the consequent possibility of the number of infected people exceeding the health system's supply capacity, together with the increased uncertainty around the speed and actual effects of the dissemination of the virus, led most countries to adopt lockdown measures. Even if partially enforced, social distancing had a harmful and profound impact on economic dynamics by imposing simultaneous restrictions on supply and demand.

The depth of the economic crisis resulting from the Covid-19 pandemic is comparable to that of the Great Depression, with an estimated 3.1 percent contraction in the world economy in 2020 followed by a 6.1 percent growth in 2021 (IMF, 2022). Thus, governments worldwide were forced to adopt rapid and extraordinary measures to respond to the crisis through fiscal, monetary, financial, and credit policies.[1] Likewise, the international scientific community reacted to the situation by focusing its research on finding solutions to this pandemic, understanding its impacts, and all its aspects related to the different fields of knowledge. This universal focus of academic research led to an unprecedented redirecting of researchers' attention to an urgent and single topic, thus generating a significant volume of scientific publications (Brainard, 2020; Apuzzo & Kirkpatrick, 2020). Given these developments, academic journals had to adapt, adopting editorial policies prioritizing the publication of research related to COVID-19 and providing them with open access.

It has not been different in economics and its various subject areas. For example, several researchers have been trying to understand the economic consequences of this crisis and suggesting the best micro and macro policy solutions to minimize its adverse effects and ultimately overcome them (Baldwin and Mauro, 2020; Stiglitz, 2020; Wolf, 2020). Similarly, some studies have dealt with the relation between the COVID-19 crisis and the topical issues of the science, technology and innovation studies literature. However, the emergency level imposed by the pandemic prevented all this knowledge

[1] For fiscal, monetary and other measures see IMF's "Policy Responses to COVID-19" (https://bit.ly/34iZZOA); for the tax measures, "Tracking Economic Relief Plans" by the Tax Foundation (https://bit.ly/3bTrWit); for health, containment and economic measures, OECD's "Country Policy Tracker" (https://bit.ly/2RfZ9wK).

production from being done in an integrated and organized manner. Therefore, the systematization of studies done in that perspective is vital as they provide answers to timely but relatively disparate issues.

The need for systematization in conjunction with the unprecedented nature of the situation has, not surprisingly, made the Covid-19 related knowledge outburst itself a study object. For example, some bibliometric studies like Pal (2021) provide a broad overview of this phenomenon, whereas others have highlighted more specific aspects. Liu, Yuan & Zhu (2022) analysis, for example, focuses on social science research, whereas Fassin (2021) studies the disruptive impact on bibliometric indicators. However, to the best of this author's knowledge, analysis specific to economics and STI studies Covid-19 related literature remains limited and, therefore, presents itself as an interesting research opportunity.

Before proceeding further, it is worth noting that the area of science, technology, and innovation studies is broadly defined. So, we need to specify precisely the definition adopted in the context of this research.

First, one must remember that there is no exact and widely accepted definition for STI studies. In fact, there is not even a consensus about the proper terminology to designate such research field, with different labels being used over time. Although, as Martin (2012) points out, by the 1990s, "innovation policy" was the preferred term, and it was also assumed to comprehend aspects of 'science' and 'technology. However, this term later morphed into the broader label of "innovation studies" to fully contemplate the research carried out on the management and economics of R&D, technology, or innovation.

As evidence of the dissemination and widespread acceptance of the term, of the 1115 respondents to the survey conducted by Fagerberg and Verspagen (2009), 80% answered that their research was in the "innovation studies" area. Regarding its definition, Fagerberg, Fosaas, and Sapprasert (2012) define "Innovation Studies" "as the scholarly study of how innovation takes place and what the important explanatory factors and economic and social consequences are."

Opting for the "science policy and innovation studies" label, Martin (2012) refers to it as the studying of a "subject matter, characterized by the terms innovation, technology, R&D and science (…) using a range of social science disciplines". Namely, he highlights

the elements that make up this set, "the science, technology and innovation-related components" of: economics, economic history and business history, policy, management, organizational studies, and sociology of innovation. However, Martin (2012) explicitly excludes from his definition areas that, in his opinion, tend to have their own research communities and journals, such as: the sociology, history and philosophy of science and technology, scientometrics or bibliometrics research, energy and environment policy research and most literature on economic development.

Despite recognizing and/or agreeing with the justifications of the previous nomenclature and definitions, for this research we opted to use the generic label "Science, Technology and Innovation Studies" (or STI Studies) for believing that the understanding of the extent of its research areas is more straightforward. Regarding the definition of the research area, we adopted an extended version of the one presented in Martin (2012), so that it also includes scientometrics or bibliometrics research.

It is worth pointing out that this discussion is also relevant in the science, technology, and innovation policy dimension, for any definition of STI policy is the product of its historical context and current theoretical framework (Schot & Steinmueller, 2018; Flink & Kaldewey 2018). Furthermore, the evolution of these policies is strongly interlinked with developments within the thinking about innovation processes and their connection with science and research (Boekholt, 2010). For example, the replacement of the linear model of innovation with a more interconnected and systemic approach widened the possibilities for public intervention (Meissner & Kergroach, 2019).[2] Thus, the demarcation of policy responsibilities and taxonomy – for science, research, and innovation policies – is not consensual, with these concepts and terms somewhat used rather arbitrarily and interchangeably (Boekholt, 2010).

[2] Generally, these policies can range from science and research policies to technology/innovation policies, aimed at applying the research and scientific output to different purposes and contexts (Meissner & Kergroach, 2019). The range of public interventions to promote these objectives is large, and can include, for example: R&D funding; tax incentives; public research laboratories and institutes; intellectual property management; technology transfer functions; incubators and science parks; training programs; etc (Tassey, 2007 apud Vonortas & Aridi, 2012).

3. METHODOLOGY

Bibliometric analysis (or bibliometrics) uses quantitative data of published literature (citations, authorship, source, keywords, etc.) to study publication patterns within a research field. This process can be summarised by: the selection of the database(s), setting the extraction parameters, processing of the obtained data, choosing the software, and how to visualize the information.

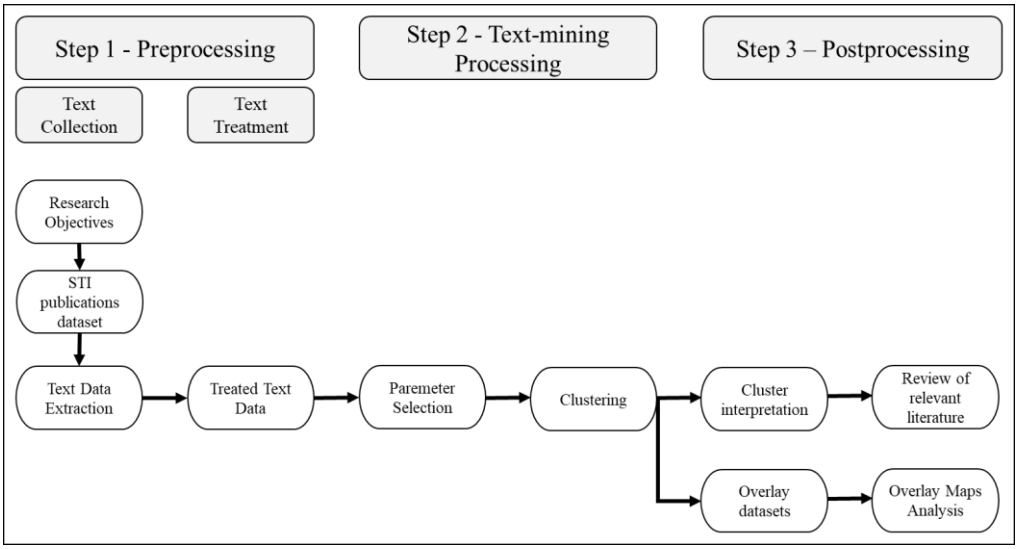


FIGURE 1– The methodological process. Own Elaboration.

Figure 1 shows the methodology adopted in the present study. The first step – Preprocessing – consists of two substeps: Text Collection and Text Treatment. Text Collection begins with defining the study's objective (i.e., identifying the impact of the COVID 19 pandemic in the STI literature) and determining the relevant publications dataset.

The rationale for selecting the elements of each analyzed set of publications was first to determine the collection of journals that most associate with STI topics and, within this set, distinguish which publications are Covid-related. Thus, we end up with two disjoint subsets of STI publications: 1) Articles that do not deal with Covid and 2) Articles that in any way deal with Covid.

For the selection of the relevant universe of academic publications, two distinct strategies were used i) existing literature on the topic and ii) the Journal of Economic Literature (JEL) classification system.

The first approach, the analysis of thematic literature, corresponded to identifying the scientific journals which have been perceived as central to studies of innovation, innovation economics, and STI policy by authors who systematized and performed bibliometric analyses on these areas. This includes the studies of Fagerberg & Verspagen (2009), Fagerberg et al. (2012), Martin et al. (2012) and Landström et al. (2012).

The second approach was based on the classification of JEL codes and consisted of identifying the publications classified in the O3 category or at least one of its subcategories[3]. We downloaded all articles with the document type "article" from the Econlit database with subject codes "O31" to "O39", published between 2015 and 2019[4] [5]. Data was obtained from 224,867 articles, published in 386 journals. Next, we selected the top ten journals with more publications as the relevant subset. It should be noted that since this approach is based on a code system dedicated to classifying economics articles, that may somehow contribute to biasing our sample in that direction.

The grouping of the results of the different approaches resulted in a selection of fifty-two STI-related journals – Annex 1. At first glance, some of the selected journals appear too distant from the STI universe and, therefore, not particularly relevant for this study. The next step was to refine this first selection by using the bibliographic coupling links between the publications of the selected journals.

A bibliographic coupling link is a connection between a pair of publications that cite the same document. That is, it corresponds to the overlap in the reference lists of the publications. Its strength indicates the number of cited references these items have in common (Van Eck & Waltman, 2013). As the unit of analysis is journals, the bibliographic coupling link between two journals is the sum of the links between their publications. For our purposes, we downloaded from the Web of Science[6] all the articles

[3] The O3 category refers to "Innovation, Research and Development, Technological Change, Intellectual Property Rights", and its subcategories are: Innovation and Invention: Processes and Incentives; Management of Technological Innovation and R&D; Technological Change: Choices and Consequences, Diffusion Processes; Intellectual Property and Intellectual Capital; Social Innovation; Open Innovation; Government Policy and Other.

[4] The data was downloaded on 10/10/2020.

[5] Here, it is worth noting that even though the Covid x No Covid analysis is limited to the years 2019 2020 and 2021, we chose to adopt a time period beyond 2019 here in order to ensure greater representation in the selection of the sample of academic journals to be used as a reference.

[6] SCI-EXPANDED, SSCI

published in the pre-selected journals in 2019 and proceeded to do a bibliographic coupling analysis using the VOSViewer software.[7]

This technique yields a score (or "weight") to each journal based on the total link strength of its publications. To refine the pre-selection, we resorted to two indicators: 1) "Total link strength", which reveals the total strength of the links of a journal with other journals, and 2) its relative value per number of publications of the respective journal. Thus, it also incorporates journals that have fewer but influential articles.

Our selection criteria were that at least one of the chosen indicators was higher than the average of the whole set or its respective cluster. With these criteria, we narrowed down our STI selection to twenty-seven journals. Table 1 presents the final selection of STI-related journals.

[7] The data was downloaded on 16/06/2021.

TABLE I

FINAL SELECTION OF INNOVATION JOURNALS

n	Journal	Source
1	Academy Of Management Journal	Fagerberg et al.(2012); Landström et al. (2012)
2	Academy of Management Review	Fagerberg et al.(2012); Landström et al. (2012)
3	Administrative Science Quarterly	Fagerberg et al.(2012); Landström et al. (2012)
4	Economics of Innovation and New Technology	JEL O3; Fagerberg and Verspagen (2009)
5	Human Relations	Fagerberg et al.(2012)
6	Industrial and Corporate Change	JEL O3; Fagerberg and Verspagen (2009); Fagerberg et al.(2012)
7	Industry and Innovation	JEL O3
8	International Journal of Technology Management	Fagerberg et al.(2012); Landström et al. (2012)
9	Journal of Business Ethics	Landström et al. (2012)
10	Journal of Business Research	Landström et al. (2012)
11	Journal of Business Venturing	Landström et al. (2012)
12	Journal Of International Business Studies	Fagerberg et al.(2012); Landström et al. (2012)
13	Journal of Management	Landström et al. (2012)
14	Journal Of Management Studies	Fagerberg et al.(2012); Landström et al. (2012)
15	Journal of Product Innovation Management	Fagerberg and Verspagen (2009)
16	Journal of Technology Transfer	JEL O3
17	Organization Science	Fagerberg et al.(2012); Landström et al. (2012)
18	Organization Studies	Fagerberg et al.(2012); Martin et al. (2012); Landström et al. (2012)
19	R & D Management	Fagerberg and Verspagen (2009); Landström et al. (2012)
20	Regional Studies	JEL O3; Fagerberg and Verspagen (2009); Fagerberg et al.(2012); Landström et al. (2012)
21	Research Policy	JEL O3; Fagerberg and Verspagen (2009); Fagerberg et al.(2012); Martin et al. (2012); Landström et al. (2012)
22	Scientometrics	Martin et al. (2012)
23	Small Business Economics	Fagerberg et al.(2012); Landström et al. (2012)
24	Strategic Management Journal	Fagerberg and Verspagen (2009); Fagerberg et al.(2012); Martin et al. (2012); Landström et al. (2012)
25	Technological Forecasting And Social Change	Martin et al. (2012)
26	Technology Analysis & Strategic Management	JEL O3; Fagerberg et al.(2012); Martin et al. (2012)
27	Technovation	Fagerberg and Verspagen (2009); Landström et al. (2012)

Source: Own Elaboration

With the final selection of journals defined, the Text Collection sub-step continued with the text data extraction. We used the Web of Science (WOS) Core Collection (SCI-

EXPANDED, SSCI) database to access and download the academic articles from 2019,2020 and 2021.[8]

The WOS database is frequently used for bibliometric studies in several subject areas, including economics and policy studies. For this study, all article or review publications in the previously selected STI journals were subjected to a textual descriptor search in their titles, abstracts, and keywords. In line with other bibliometric studies related to COVID-19 the following keywords were chosen: “Covid-19" OR "Covid" OR "Covid 19" OR “COVID 2019" OR "coronavirus 2019" OR "coronavirus disease 2019" OR "2019 nCoV" OR "SARS nCoV" OR "SARS-CoV-2" OR "Wuhan coronavirus" OR "Wuhan pneumonia" OR "novel coronavirus" (Verma & Gustafsson, 2020; Kousha, & Thelwall, 2020). The analysis period ranged from 1 January 2019 to 31 December 2021, and only publications in English were considered.

In summary, we have three primary datasets in this research, which correspond to the combination of the following variables: timeframe and the mention (or not) of Covid, as represented by Figure 2.

	2019	**2020_21**
Non Covid	STI.NCov (2019)	STI.Ncov (2020_21)
Covid	n.a	STI.Cov (2020_21)

FIGURE 2 – Combination of Search Variables and Correspondent Datasets. Own Elaboration.

Table 2 summarizes the queries described.

[8] The data was downloaded on 24/03/2022.

TABLE II

DATA COLLECTION PARAMETERS

Set	Covid Query	Timespan	Database	Language	Scope
2019		01/01/2019 to 31/12/2019	Web of Science	English	Title; abstract and keywords
2020_21 Covid	✓	01/01/2020 to 31/12/2021			
2020_21 N Covid					

Source: Own Elaboration

Regarding the Text Treatment sub-step, although the entire registry was downloaded, only the following information was extracted and loaded into a Microsoft Excel file: publication title, journal title, abstract, publication, and early access date, authors keywords, Keywords Plus, WOS Categories, and research areas. We also removed duplicated entries.

In Step 2 (Text Mining Processing), we opted to perform a co-word analysis to identify the most relevant themes related to COVID-19 in the documents obtained. This was done using the text mining functionality from the VOSviewer software to construct and visualize co-occurrence networks of important terms. The software turns the bibliographic data input into a graphic output by grouping the items into non-overlapping clusters and has been widely used for constructing bibliometric maps in the most varied studies (see, for example, Gaviria-Marin, Merigó, & Baier-Fuentes (2019) and Rafols et al (2012))

We decided to analyze the concatenation of the title and abstract and not the keywords. If, on the one hand, keywords reflect the core content of a publication, regardless of manual or automatic designation, on the other hand, authors carefully choose and write their article's title and abstract to summarize its main idea, topics, and conclusions. However, given the area of study's specificity, the keywords are too broad and may not yield the relevant information we are looking for.

When dealing with the title and abstract analysis, we chose the "binary counting" method, which identifies the presence (or absence) of a given term in a document (Van Eck & Waltman, 2013). This appears to be the best counting method for this research

since our goal is to identify the presence of a given theme in a document, regardless of its relative frequency within it. The threshold limit, i.e., the number of times a word needs to occur to be considered, and the cluster resolution[9] were defined according to each specific case. We also adopted the 60% default relevance score threshold.[10] For the Covid set of publications, all disease-related words were eliminated as they would have no value in the thematic analysis.[11]

Table 3 summarizes the clustering parameters used.

TABLE III

CLUSTERING PARAMETERS

Set	Minimum number of ocurrences	Cluster Resolution	Analysis Unit	Counting method	Normalization Method
2019	10	0,90	Title + abstract	Binary	Association Strenght
2020_21 Covid	5	1,00			
2020_21 N Covid	10	0,90			

Source: Own Elaboration

The third and last step (Postprocessing) consists of two sub-steps: Cluster and Overlay Map analysis.

First, to interpret the meaning of each cluster, we perform a cluster interpretation exercise, followed by selecting and analyzing documents relevant to the identified themes. For this, it was necessary to locate among the publications which were more related to of each cluster. For this, we opted for a more logical approach instead of arbitrarily adopting an ad-hoc selection. First, a score was calculated for each cluster term

[9] According to Van Eck & Waltman (2013, p.23) "This parameter determines the level of detail of the clustering produced by the VOS clustering technique. (...)The higher the value of the parameter, the larger the number of clusters produced by the VOS clustering technique"

[10] "To exclude general terms, VOSviewer calculates for each term a relevance score. Terms with a high relevance score tend to represent specific topics covered by the text data, while terms with a low relevance score tend to be of a general nature and tend not to be representative of any specific topic. By excluding terms with a low relevance score, general terms are filtered out and the focus shifts to more specific and more informative terms. By default, 40% of the terms are excluded based on their relevance score." (Van Eck & Waltman, 2013)

[11] The deleted terms were: "coronavirus"; "coronavirus disease"; "disease"; "health crisis"; "iii"; "novel coronavirus"; "pandemic crisis"; "plain english summary"; "sars cov" and "virus".

based on its relative occurrence (i.e. the occurrence of the term divided by the total occurrences of the cluster terms). Then, the terms of the cluster were searched in the title and abstract of each publication and the sum of the scores of those terms resulted in an indicator of relevance for the publication in that cluster. This procedure was done for all clusters, and at the end of the process, every publication had a relevance indicator for each cluster. Each publication was allocated to the cluster in which it had the highest relevance indicator. Finally, the publications were ordered in descending order by their relevance indicators so that the most relevant publications from each cluster could be identified.

Finally, to further explore the results obtained and compare the different sets we resort to the Overlay Maps technique, based on Rafols, Porter & Leydesdorff (2010). The technique consists of using the units and positions derived from a bibliometric map, but superimposing data from another analyzed set, also obtained by a bibliometric map, over them (Rafols, Porter & Leydesdorff, 2010).

4. RESULTS

This section reports the data and findings obtained through applying the methodology presented above. First, the descriptive statistics of the analyzed sets are presented, highlighting the most relevant countries and journals. Following this, we present cluster results, namely its term maps and their most relevant terms and articles, followed by a thematic analysis of the clusters. In the end, we present the results of the overlay maps analysis.

4.1. Descriptive Analysis

The records of 13.041 articles were downloaded. There were 3.893 non-Covid publications in 2019 and 8.648 in the 2020_21 set[12]. The remaining 284 correspond to Covid-related publications from 2020 and 2021. Tables 4 and 5 present descriptive statistics about the dataset regarding the countries and journals where authors are more active in these areas.

[12] 4.125 in 2020 and 4.739 in 2021.

TABLE IV

PUBLICATIONS PER COUNTRY OF THEIR AUTHORS, AS A PERCENTAGE OF TOTAL PUBLICATIONS – TOP 10

	All Publications					
	2019		2020_21 N Covid		2020_21 Covid	
1	USA	19,2	USA	16,6	USA	14,4
2	GBR	11,5	GBR	10,9	GBR	13,5
3	CHN	7,8	CHN	9,6	ITA	7,6
4	DEU	5,4	DEU	5,5	CHN	6,3
5	ITA	5,3	ITA	5,2	FRA	5,0
6	FRA	5,0	FRA	5,1	ESP	4,4
7	ESP	4,0	ESP	4,1	AUS	4,1
8	AUS	4,0	AUS	3,9	DEU	3,9
9	CAN	4,0	CAN	3,4	IND	3,3
10	NLD	4,0	NLD	3,4	CAN	2,0
	Others	29,9	Others	32,2	Others	35,4

Source: Own Elaboration

TABLE V

PUBLICATIONS PER JOURNALS, AS A PERCENTAGE OF TOTAL PUBLICATIONS – TOP 10

	2019		2020_21N Covid		2020_21Covid	
1	Journal Of Business Research	14,5	Journal Of Business Research	21,3	Technological Forecasting And Social Change	26,4
2	Journal Of Business Ethics	13,4	Technological Forecasting And Social Change	13,9	Journal Of Business Research	19,7
3	Technological Forecasting And Social Change	11,0	Journal Of Business Ethics	9,9	Scientometrics	13,4
4	Scientometrics	7,7	Scientometrics	8,8	R & D Management	9,9
5	Regional Studies	5,4	Small Business Economics	4,6	Small Business Economics	8,1
6	Research Policy	4,9	Technology Analysis & Strategic Management	4,2	Journal Of Management Studies	6,0
7	Technology Analysis & Strategic Management	4,0	Regional Studies	3,7	Journal Of Business Ethics	3,9
8	Small Business Economics	3,7	Research Policy	3,7	Technology Analysis & Strategic Management	2,1
9	Journal Of Management	3,3	Organization Science	2,7	Industrial And Corporate Change	2,1
10	Strategic Management Journal	3,1	Strategic Management Journal	2,4	Regional Studies	1,8
	Other Journals	29,1	Other Journals	24,8	Other Journals	6,7

Source: Own Elaboration

At first glance, when looking at the geographic distribution of publications, we find no significant difference between the sets, which present a concentration in high-income countries (and in China too), a pattern commonly observed in Economics and in STI studies (Merigó, Rocafort & Aznar-Alarcón, 2016; Merigó et al, 2016). This similarity is confirmed by the coefficient of correlation of 0.99 between the non-Covid sets of 2019 and 2020_21 and 0.96 between the Covid and non-Covid publications of 2020_21.

Even so, we can still highlight a few interesting aspects of the sets. First, we find a significant concentration in the top ten countries for all sets, which account for 65% to 70% of the total. It is worth noting, however, that the Covid Publications set has the lowest ratio, indicating that, proportionally, Covid-related topics had a more widespread and worldwide appeal. Nonetheless, eight of the fourteen countries that appeared in at least one of the Top 10 were present in all rankings.

Second, looking individually at the performance of the top-10 countries whose authors have published the most, it is important to highlight that generally, the United States, United Kingdom, and China always occupy first, second and third positions. The notable exception is in the Covid Publications set, in which Italy has the third-largest number of authors, an increase of 32% (or 2.4 p.p.) compared to its performance. This is not surprising, given that the country was among the most affected by the pandemic in the early days of the disease between March and April 2020. Similarly, India, the third country in absolute numbers of deaths from Covid to date, with an increase of 47% (or 1.6 p.p.), jumps from the fourteenth position in the 2020_21 non-Covid set to the ninth place in the Covid set.

It is also interesting that amongst the top-three countries ranked in the 2020_21 non-Covid publications set, only the UK shows an increase (of 19% or 2.6 p.p.) in its relative weight compared with its performance in the Covid Publications set. On the contrary, the US and China participation rate falls by 15% (or 2.2 p.p.) and 53% (or 3.3 p.p), respectively. The other significant decreases belong to Germany (42% or 1.6 p.p.), Canada (68% or 1.4 p.p.), and The Netherlands (66% or 1.3 p.p.)

Moving on to the journal-related data, we find that the non-Covid sets of 2019 and 2020_21 present similar results, with a correlation coefficient greater than 0.94. It should be noted, however, that although the top-3 leading publications are the same in both sets (i.e., Journal of Business Research, Journal of Business Ethics and Technological Forecasting and Social Change) there is a 47% (or 6.9 p.p) increase in the Journal of Business Research's participation rate as well as the exchange of places between Journal of Business Ethics (-26% or -3.5 p.p.) and Technological Forecasting And Social Change (+27% or +2.9 p.p.). This significant increase in the Journal of Business Research's participation rate is the reason why the overall concentration of the 2020_21 non-Covid set rose compared to its 2019 counterpart. This is confirmed by the increase in the participation rate of the top-10 publications (from 71% to 75%) and the higher coefficient of variation (from 1.0 to 1.3).

Regarding the Covid publications set, we have that of the twenty-seven selected journals in our query, only eighteen (64%) had Covid-related publications. In that sense, it is no surprise that the general similarity between sets doesn't occur to the same extent

when comparing the Covid and non-Covid publications of 2020_21, which present a correlation coefficient of 0.83. When comparing their concentration level, we find that 2020_21 sets have a coefficient of variation of 1.3. [13]

Participation performance improvements were limited to a few specific journals. In fact, of the eighteen journals with Covid-related publications, only six of them increased their participation rate in comparison with the non-Covid set: Technological Forecasting and Social Change (of 90% or 12,5 p.p.); R&D Management (of 916% or 8,9 p.p.); Scientometrics (of 53% or 4,6 p.p.); Journal of Management Studies (of 231% or 4,2 p.p.); Small Business Economics (of 76% or 3,5 p.p.) and Industrial and Corporate Change (of 31% or 0,5 p.p.). On the other hand, amongst the journals with a lower participation in the Covid set, the "Journal of Business Ethics" stands out with a 61% decrease (or -6 p.p.) in comparison with its performance in the non-Covid set, making it go from the third most active publication to the seventh. So, we have that from the top-3 leading publications in the non-Covid sets, i.e., Journal of Business Research, Journal of Business Ethics and Technological Forecasting and Social Change, only the publications in the latter revealed an increased interest in Covid-related topics.

It is worth noting, that journals such as "Journal of Management Studies" and "Small Business Economics" held calls for papers specifically aimed at Covid themes, which justifies some of this difference in the performances between journals with regard to covid-related publications.

Finally, it is also possible to analyze the journal dimension of our sets of publications using the previously mentioned bibliographic coupling technique. While the set of covid publications does not yield significant results due to its smaller sample size, the non-Covid publications offer some interesting results. Figure 3 presents the results for the set of the non-Covid-related publications of 2020 and 2021.[14]

[13] One should note that although the Covid publications the top-10 sources amount to 93.3% of the total and the top-10 of its non-Covid counterpart it accounts for only 75.2%, this is mostly due to the reduced size of the first set of only 18 sources, in comparison with the 27 sources of the non-Covid set.

[14] The 2019 publications yield similar results, which can be seen at: https://tinyurl.com/2bm2c2mn

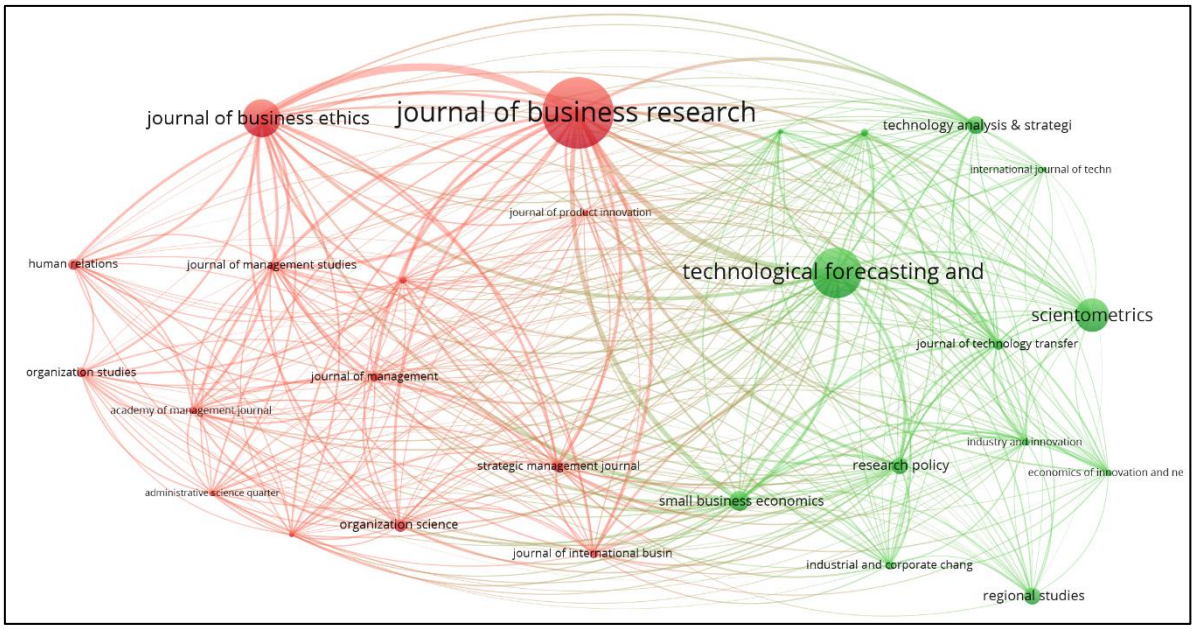


FIGURE 3 – Bibliographic Coupling of Journals: 2020_21 N Covid. Own Elaboration. Available online at: https://tinyurl.com/2aftjs9g

From Figure 3 we can observe a visible distinction between two groups of journals: those more linked to the management and business area, spearheaded, in number of publications, by the "Journal of Business Research" and the "Journal of Business Ethics"; and those other journals more focused on core STI themes, with emphasis on "Technological Forecasting and Social Change" and "Scientometrics".

In summary, having analyzed the descriptive statistics regarding the most active countries of our publication sets, we concluded that although the geographical pattern of the sets is relatively similar, there are some important differences between them. First, we find that the concentration in the top ten countries was lower in the Covid Publications than in the non-Covid ones. Second, the countries that were hit hard by the pandemic had a higher participation rate in the set of Covid publications. And third, we have that for the top-three best-ranked countries in the 2020_21 non-Covid publications set, only the UK increased its participation rate in the Covid-related set.

Regarding the journal analysis, only 18 of the 27 selected journals had Covid-related publications, and, regarding the journals participation rate, this set of publications presented a similar coefficient of variation when compared to the non-Covid set.

However, when comparing the participation rate of each specific journal between the 2020_21 non-Covid and Covid publications, we observe that only six journals had a higher participation rate in the Covid set. More specifically, we have that of the top-3 leading publications in the non-Covid sets, i.e., Journal of Business Research, Journal of Business Ethics and Technological Forecasting and Social Change, only the latter had an increased participation rate in the Covid set. In addition, we also found that for the non-Covid publications, the bibliographic coupling of the journals reveals a clear distinction between management/business and core STI journals.

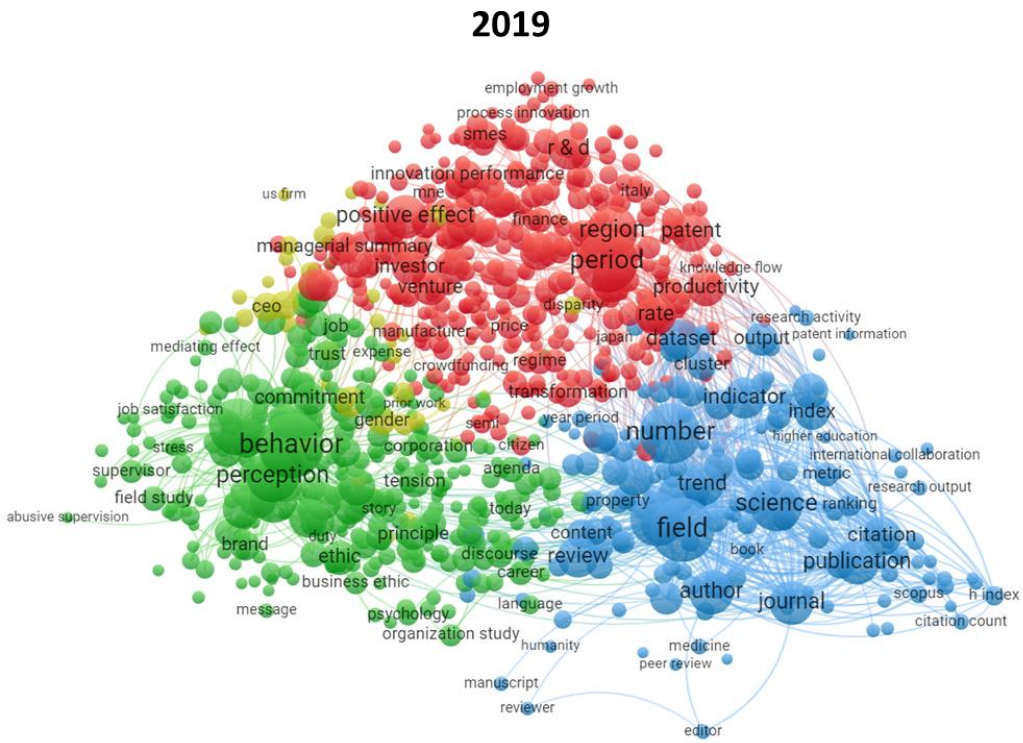
4.2. Cluster Analysis

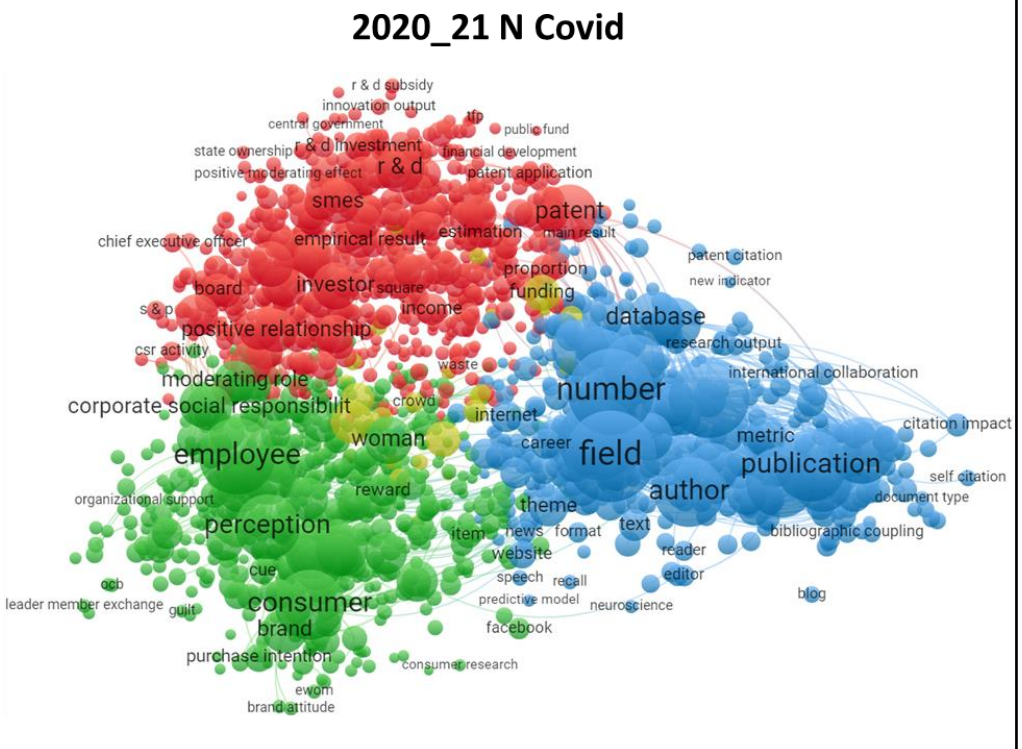
Moving on to the clustering, we obtained the co-occurrence relationships between the thousands of terms using VOSviewer, whose cluster visualization allows us to get detailed information on the relationships between the terms through its zoom and map scrolling functionality. The maps show terms extracted from the titles and abstracts of publications in our datasets. The graphical view of the co-occurrence network clusters is available online.[15]

- ***Non-Covid Related Literature***

First, we will look at the two sets of non-Covid publications. The term map shows four groups of related terms, each with a specific number of terms. Terms grouped in the same cluster are more likely to reflect common topics. Figure 4 presents the co-occurrence maps of the 2019 and 2020_21 sets and some descriptive characteristics of the clusters, while Table 6 presents the five most frequent terms of each cluster of the two analyzed sets.

[15] 2019: https://tinyurl.com/y25y3hzg; 2020_21 N Covid: https://tinyurl.com/y3jd7v9c; 2020_21 Covid: https://tinyurl.com/y2lom9np.





Item	Cluster				
	1	2	3	4	Total
Terms	380 (41,5%)	325 (35,5%)	173 (18,9%)	38 (4,1%)	916 (100%)
Total Term Occurrences	10.757 (37,9%)	9.795 (34,5%)	6.820 (24%)	993 (3,5%)	28.365 (100%)

Item	Cluster				
	1	2	3	4	Total
Terms	805 (41,4%)	706 (36,3%)	406 (20,9%)	28 (1,4%)	1.945 (100%)
Total Term Occurrences	18.677 (35,4%)	17.113 (32,4%)	16.277 (30,8%)	720 (1,4%)	52.787 (100%)

FIGURE 4 – CO-OCCURRENCE MAP: NON-COVID PUBLICATIONS 2019 AND 2020_21. OWN ELABORATION.

2019: HTTPS://TINYURL.COM/Y25Y3HZG; 2020_21 N COVID: HTTPS://TINYURL.COM/Y3JD7V9C

TABLE VI

TOP -5 TERMS (TOTAL OCCURRENCES AND AS % CLUSTER): NON-COVID RELATED

Cluster	2019	2020_21 N Covid
1	period (302; 2,8%) region (205; 1,9%) positive effect (151; 1,4%) patent (130; 1,2%) rate (130; 1,2%)	patent (218; 1,2%) r & d (190; 1%) firm performance (169; 0,9%) investor (160; 0,9%) smes (154; 0,8%)
2	behavior (337; 3,4%) employee (257; 2,2%) perception (211; 2,2%) consumer (180; 1,8%) leader (130; 1,3%)	consumer (490; 2,9%) employee (420; 2,5%) perception (335; 2%) experiment (238; 1,4%) intention (231; 1,3%)
3	field (326; 4,8%) number (292; 4,3%) researcher (227; 3,3%) science (217; 3,2%) author (155; 2,3%)	field (612; 3,8%) number (540; 3,3%) researcher (520; 3,2%) science (444; 2,7%) author (334; 2,1%)
4	woman (75; 7,6%) ceo (67; 6,7%) board (64; 6,4%) gender (62; 6,2%) director (56; 5,6%)	gender (104; 14,4%) funding (90; 12,5%) man (77; 10,7%) signal (74; 10,3%) disparity (40; 5,6%)

Source: Own Elaboration

From Table 6 and the respective co-occurrence maps, we see that the grouping of the two sets in the case of non-Covid publications presented relatively similar clustering results in both the 2019 and 2020_21 sets. A possible interpretation of these clusters is as follows:

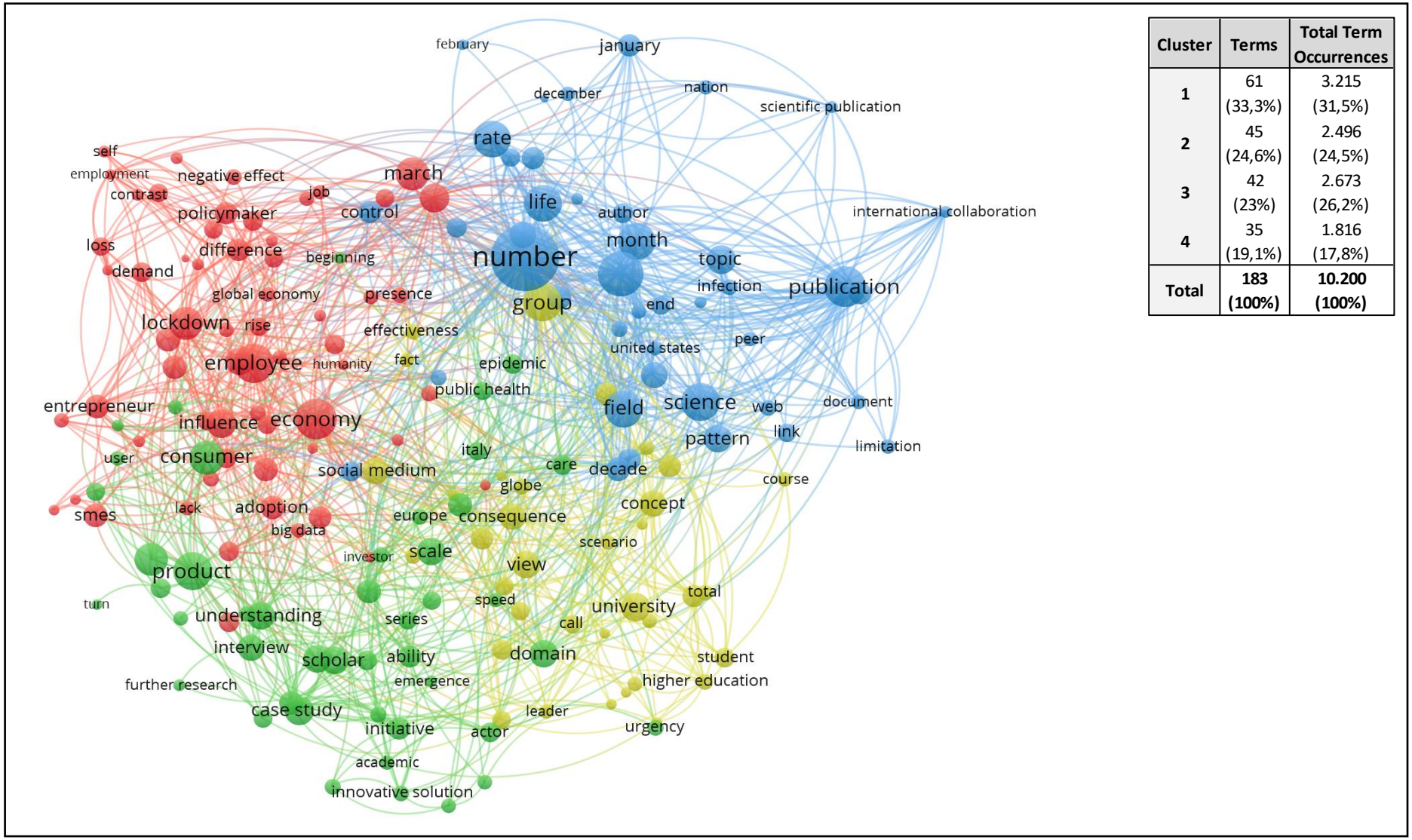
- *Firm Innovation cluster*, visible in red on the co-occurrence maps, which, in addition to the terms shown in Table 6, namely “period”, “region”, “positive effect”, “patent”, “rate”, “r & d”, “firm performance”, “investor” and “smes”,

contains others such as "productivity", "employment", "enterprise" and "innovation performance".

- *Innovation Management cluster*, visible in green on the co-occurrence maps, which, in addition to the terms shown in Table 6, namely "behavior", "employee", "perception", "consumer", "leader", "experiment" and "intention", contains others such as "marketing", "leadership", "brand" and "workplace".
- *Scientometrics* cluster, visible in blue on the co-occurrence maps, which in addition to the terms shown in Table 6, namely "field", "number", "researcher", "science" and "author", contains others such as "publication", "topic", "citation" and "dataset".
- *Gender* cluster, visible in yellow in the co-occurrence maps, which in addition to the terms shown in Table 6, namely "woman", "ceo", "board", "gender", "director", "funding", "man", "signal" and "disparity", contains others such as "male", "female", "pay" and "misconduct".

- ***Covid Related Literature***

Next, we move to the cluster analysis of the Covid publications. Looking at the co-occurrence map (Figure 3), we identify four distinct groups. In the following pages, we will explore these four clusters, highlighting their size and most relevant terms and articles. Also, by reviewing the five most relevant publications in each cluster, we will obtain a qualitative appraisal of the cluster's literature and explore some of the main topics addressed by STI publications throughout the Covid-19 crisis.



Cluster	Terms	Total Term Occurrences
1	61 (33,3%)	3.215 (31,5%)
2	45 (24,6%)	2.496 (24,5%)
3	42 (23%)	2.673 (26,2%)
4	35 (19,1%)	1.816 (17,8%)
Total	**183 (100%)**	**10.200 (100%)**

FIGURE 5 – Co-occurrence map: Covid Publications 2020 and 2021. Own Elaboration.

2020_21 Covid: https://tinyurl.com/2dsebzvr .

The first cluster, visible in red on the co-occurrence maps, accounts for 33,3% of the total identified terms. In addition to the terms presented in Table 7, namely "economy", "employee", "lockdown", "march" and "growth", that cluster contains other terms such as "entrepreneur", "smes", "demand" and "survival". The analysis of both its terms and main articles indicates that the central theme captured by the cluster revolves around *Economic Dynamics and Entrepreneurship* topics.

TABLE VII

2020_21 COVID CLUSTER 1 - ECONOMIC DYNAMICS AND ENTREPRENEURSHIP

Cluster 1 -Economic Dynamics and Entrepreneurship	
Top 5 Terms - Total Occurrences and as % Cluster	
economy (21; 4,3%); employee (20; 4,1%); lockdown (16; 3,3%); march (16; 3,3%); growth (14; 2,8%)	
Top 5 Most Relevant Papers	
Title	***Reference***
Risk of burnout in French entrepreneurs during the COVID-19 crisis	Torrès et al (2022)
The future of entrepreneurship: the few or the many?	Kuratko & Audretsch (2021)
Small firms and the COVID-19 insolvency gap	Dörr, Licht & Murmann (2022)
Self-employment over the business cycle in the USA: a decomposition	Fossen (2021)
Rethinking stabilization policies; Including supply-side measures and entrepreneurial processes	Braunerhjelm (2022)

Source: Own Elaboration

Qualitative appraisal of the cluster #1 literature

The COVID-19 pandemic had a significant impact on entrepreneurial activity, in the world of work and small businesses, in several of their dimensions. From the point of view of the labor market, Fossen (2021) addresses the dynamics of entry rates into self-employment during economic recessions and upswings. Using survey data from the USA for the 2008/09 Great Recession it finds that over this period, the higher entry rate into self-employment can be explained by the higher unemployment rate and that this movement consists primarily of entry into unincorporated self-employment, revealing its strong correlation with necessity entrepreneurship. The author concludes that public policy should enable business creation by the unemployed in response to economic shocks and draws a parallel with the COVID-19 crisis noting after the height of the crisis one can expect a rise in non-innovative self-employment. From a more microeconomic perspective, Torrès et Al (2022) studies the burnout level of entrepreneurs, specifically if it increased during the pandemic and its main drivers, discriminating between health risks, the effect of the lockdown, and/or the perceptions of economic risks. Comparing data of French entrepreneurs collected during the pandemic with samples from before the Covid-19 crisis they found an increased level of burnout in the pandemic, linked to all three threats but with the effects of the lockdown and economic risks

above the health risks. According to the authors, this may indicate that entrepreneurs favor the latter in a choice between personal health and the health of their business. Looking at the long-run effect on entrepreneurial activity, Kuratko & Audretsch (2021) focus on whether post-Covid-19 entrepreneurship will be one of centralization or democratization, i.e. if the current dynamics that favors the unicorns proliferation and disregards smaller ventures and other types of entrepreneurship will persist.

Looking from the policy perspective, Dörr, Licht & Murmann (2022) investigate if the early policy measures to strengthen liquidity positions induced an insolvency gap, defined by the authors as "the deviation of observed insolvency rates during the COVID-19 pandemic and expected insolvency rates based on a counterfactual pre-crisis setting with no policy intervention". The Schumpeterian cleansing effect, i.e. the idea that crisis force unviable firms out of the market and thus reallocate resources to more productive firms, is used as a theoretical framework. The insolvency gap induced by the pandemic-related policy is estimated using firm-specific credit rating data and information on insolvency filings. The authors find that the insolvency gap is more significant in companies with up to 10 employees, gradually decreasing as the size of the firm increases, and in companies with an already more fragile financial situation. The paper concludes that the somewhat indiscriminate liquidity measures hampered the crisis "cleansing effect" and that this can lead to market congestion and hinder entrepreneurial activity. In a broader and more theoretical discussion, Braunerhjelm (2022) argues that traditional macroeconomic stabilization policies cannot handle the effects of the Covid-19 crisis, especially with monetary policy in a close liquidity trap situation. Through a literature review, the paper presents a different framework for stabilization policies, focusing on microeconomic measures targeting the economy's supply side. The author argues that policies dealing with entrepreneurship, firm growth, and innovation, should also play a part in the stabilization process and highlights four micro-level policy areas: knowledge upgrading (e.g., access to financial support conditioned to knowledge-enhancing activities), taxes (e.g., a carry-back system for profit/losses for a more extended period) financing (e.g., well designed state-guaranteed loans), and the labor market (e.g., improved mobility and matching). These measures would strengthen the growth potential and lower the stabilization costs, possibly endogenizing his process.

Next, we move to the second cluster, visible in green on the co-occurrence maps, which accounts for 25% of the total identified terms. In addition to the terms shown in Table 8, namely "product", "consumer", "service", "case study" and "domain", that cluster contains other terms such as "stakeholder", "customer", "open innovation" and "innovative solution". The analysis of both its terms and main articles indicates that the central theme captured by this cluster revolves around *New Innovation Models*

TABLE VIII

2020_21 COVID CLUSTER 2 - *NEW INNOVATION MODELS*

Cluster 2 - New Innovation Models	
Top 5 Terms - Total Occurrences and as % Cluster	
product (19; 4,7%); consumer (17; 4,2%); service (16; 4%); case study (14; 3,5%); domain (13; 3,2%)	
Top 5 Most Relevant Papers	
Title	***Reference***
How can crowdsourcing help tackle the COVID-19 pandemic? An explorative overview of innovative collaborative practices	Vermicelli & Cricelli & Grimaldi (2021)
The fast response of academic spinoffs to unexpected societal and economic challenges. Lessons from the COVID-19 pandemic crisis	Battaglia, Paolucci & Ughetto (2021)
Maker movement contribution to fighting COVID-19 pandemic: insights from Tunisian FabLabs	Abbassi et al (2022)
Open innovation in the face of the COVID-19 grand challenge: insights from the Pan-European hackathon 'EUvsVirus'	Bertello, Bogers & De Bernardi (2022)
How to save the world during a pandemic event. A case study of frugal innovation	Vesci et al (2021)

Source: Own Elaboration

Qualitative appraisal of the cluster #2 literature

Large-scale crises tend to foster innovation developments. In the Covid pandemic case, there was a common trend of adopting open innovation practices, hoping to speed up the response (Chesbrough,2020). This led to the emergence of several initiatives based on collaborative networks of stakeholders, such as crowdsourcing and hackathons. In that regard, Vermicelli, Cricelli & Grimaldi (2021), through searches on the internet, in search engines, and in crowdsourcing databases, identify and detail the development and implementation of 16 crowdsourcing initiatives related to the Covid crisis. By classifying them according to the type of crowdsourcing configuration, they find a greater frequency of some specific combinations of configurations and tasks, suggesting greater suitability of specific crowdsourcing mechanisms for a particular objective. They further highlight the importance of involving both experts and ordinary people in crowdsourcing initiatives. Similarly, Bartello, Bogers & De Bernardi (2022) address another kind of innovation model, the hackathon, investigating how this kind of event works as a tool for open innovation to address the Covid crisis. A hackathon consists of an event, usually lasting around 48–72 h, that brings people together to address a specific challenge through problem-solving, prototyping, designing, coding, etc. The article analyzes the case of the hackathon EUvsVirus, promoted by the European Innovation Council, a 3-day online that involved over 30,000 individuals (innovators, partners, investors, and civil society) and aimed to develop innovative solutions to coronavirus-related problems. Four dimensions of the hackathons are identified as relevant in generating an effective open innovation process in the face of grand challenges that require both urgent action and long-term thinking, being those four dimensions: broad scope; participatory architecture; online setting; and community creation. The authors also highlight the capacity of hackathons to tackle not only well-defined problems but also ill-defined scientific, technological, and societal questions, as well as the importance of knowledge recombination with atypical resources, such as retired experts, graduate students, and the public.

In the production and business field, the open innovation spirit was also present, for example, in companies that had to adapt their pre-pandemic production logic and redirect their activities to demands imposed by the crisis. For instance, Battaglia, Paolucci & Ughetto (2021) deal with the topic of academic spinoff through a case study of the Italian spinoff Omnidermal, which went from developing a device for the assessment and monitoring of ulcers before the pandemic to working on the conversion of manual ventilators to automated ones to be used by COVID-19 patients. The key insight drawn by them from the case study was that although the literature mainly links the growth of academic spinoffs to a technology-push process, this process can at the same time foster basic competencies and practices that can later be recombined in response to an external shock and be used to address new and clear market demands, thus, switching from a technology-push to a market-pull model.

This collaborative and innovative spirit was not limited to major enterprises and also showed up in companies that had to seek others for capabilities they did not possess and were necessary to overcome obstacles imposed by the pandemic. For example, Vesci et al (2021) analyze the role of digital makers in R&D processes set in motion to address unexpected exogenous shocks rapidly and effectively, such as in the Covid-19 pandemic context. As part of their theoretical framework, they adapt the concept of frugal innovation, characterized by them as a bottom-up process to develop effective and low-cost solutions to the basic needs of resource-constrained customers. Their article consists of an exploratory case study of a small Italian innovation services company that, alongside a local doctor, developed a 3D printed version of a disposable respiratory valve in high demand by local hospitals and subsequently went on to make available the technical information needed for reproduction, resulting in the production of 150,000 valves all over the world by the makers community. The article highlights the interaction between frugal innovation principles, open innovation strategies, and the makers community in providing effective solutions for the local community with potential global scalability. Also dealing with the makers' community, Abbassi et al (2022) focus on the relationship between health crisis and new innovation processes in a country of the Global South and how, in a resource-constrained environment, can the maker movement shape the innovation ecosystem in response to a health crisis. Through a qualitative approach based on a case study of 3D printing efforts in the Tunisian capital to provide personal protective equipment to support the public healthcare, the authors present the evolution from fragmented local-level initiatives to a collaborative and structured national ecosystem, highlighting this as a widening of the application of open innovation, typically associated with a high-tech context, new business models and the support of R&D activities. The article identifies five key success factors for crisis-driven innovation processes during a health crisis, namely 'Supply chain Management', 'R&D', 'Production', 'Funding', and 'Communication & Networking'. In conclusion, Abbassi et al (2022) believe that the maker movement in association with new technologies, with its minimal external assistance requirement, represent a significant opportunity for the Global South not only to foster innovation but also to tackle social and economic challenges.

Moving on, we have the third cluster, visible in blue on the co-occurrence maps and accounts for 24% of the total identified terms. In addition to the terms shown in Table 9, namely "number", "researcher", "publication", "science" and "field", that cluster contains other terms such as "topic", "pattern", "journal" and "author". The analysis of

both its terms and main articles indicates that the central theme captured by this cluster revolves around *Scientometrics* topics.

TABLE IX

2020_21 COVID CLUSTER 3 - *SCIENTOMETRICS*

Cluster 3 - Scientometrics	
Top 5 Terms - Total Occurrences and as % Cluster	
number (38; 8,6%); researcher (23; 5,2%); publication (21; 4,7%); science (19; 4,3%); field (18; 4,1%)	
Top 5 Most Relevant Papers	
Title	***Reference***
Coronavirus mapping in scientific publications: When science advances rapidly and collectively, is access to this knowledge open to society?	Belli et al (2020)
Covid-19 pandemic and the unprecedented mobilisation of scholarly efforts prompted by a health crisis: Scientometric comparisons across SARS, MERS and 2019-nCoV literature	Haghani & Bliemer (2020)
Visualizing the knowledge outburst in global research on COVID-19	Pal (2021)
How scientific research reacts to international public health emergencies: a global analysis of response patterns	Zhang, et al (2020)
The sharing of research data facing the COVID-19 pandemic	Lucas-Dominguez et al (2021)

Source: Own Elaboration

Qualitative appraisal of the cluster #3 literature

The magnitude of the health emergency made the academic community turn its attention to studying the pandemic and its consequence, which led to a surge of covid related scientific publications in several research fields. This process became the focus of several researchers, seeking to map, quantify and qualify this unprecedented knowledge outburst. For example, in a more general perspective, Pal (2021) uses scientometric methods and techniques to analyze the scholarly output of 'new coronavirus' research from the first five months of the Covid-19 pandemics, producing a broad view of the new coronavirus research. This article finds that the Covid-19 pandemic led to a surge of coronavirus related publication growth of 1600% when compared to the previous year, when, in comparison, the growth rate in the SARS crisis in 2003 was 577%. Around 80% of the publications were freely available and 93% were in English. This paper finds that the most relevant areas of study were in Medical Science, focusing on virology, immunology, epidemiology, pharmacology, public health, critical care, and emergency medicine. The covid-19 research was primarily located in the US and China, followed by Italy, the UK, India, France, Canada, and Germany, and a high level of scientific collaboration was found (circa 80% of total publications). The publications in their dataset had a total of 58,066 citations, which amounts to a significant mean number of of 10.8 citations per cited publication.

On the other hand, Belli et al (2020) tackled two specific coronavirus publications topics: the international scientific collaboration and their proportion and typology of open

accessibility. For this purpose, the analyze over eighteen thousand coronavirus scientific publications indexed on the Web of Science covering the period from 2001 to 2020, dividing the analysis into the two last decades and two previous years. This paper finds a growing international collaboration in all countries in 2019–2020 and a maintenance of well-established clusters of countries and organizations over the two studied periods, with the US and China as the primary producers, followed by all European countries. Regarding the open accessibility, the paper finds that while for the overall 2001–2020 period the percentage of open access articles on coronavirus was 59.2%, for 2020 it increased to 91.4%, indicating a possible commitment of commercial publishers with the health crisis. When comparing different open access types, they find that the pandemic has sparked the usage of the bronze type, which does not guarantee life-long open access and is subject to the goodwill of commercial publishers. For the authors, this represents that the publishers assumed, at least implicitly, that open access can lead to better and more effective results. Also, regarding accessibility and free dissemination of knowledge, Lucas-Dominguez et al (2021) evaluate the dissemination of research data underlying COVID-19 scientific publications. Through the analysis of supplementary materials and repositories in the PubMed database, they find a total of 5,905 records, but only 804 papers had included relevant research data. Of these, 77.4% contained supplementary material, consisting primarily of PDF and DOC files (42.8% and 32.6%, respectively) typically containing textual or graphic materials. Only 73 files had data in reusable formats, or 1.2% of the total records analyzed. The authors believe this low percentage may be associated with factors such as intellectual property and confidentiality restrictions and lack of incentives for researchers. They also warn that freely available data is crucial for efficient epidemic response, for example, to predict outbreaks and single out the most relevant transmission factors.

In addition to analyzing and characterizing the current crisis, efforts were also made to contextualize and compare it to similar previous crises in search of similarities and/or discrepancies as well as recurring patterns. For example, Haghani & Bliemer (2020) compare and analyze from a scientometric perspective the Covid-19 literature with the ones that emerged from in response to the two previous major coronavirus diseases, SARS and MERS. The authors find that the 2019 Coronavirus outbreak scholarly output was of a different magnitude when compared to the previously existing body of literature since that, within the first five months, the number of publications related to the covid-19 crisis was nearly equal to 70% of the total amount of coronaviruses from the past 50 years. They found that the three outbreaks recurrently generated three distinct clusters of study topics: public health response and epidemic control, the chemical constitution of the virus, and treatment, vaccine, and clinical care. The authors further found that the Covid-19 studies have covered a wider and more diverse variety of journals and subject areas. For example, while for the Covid-19 literature, the economic aspects are represented in the word maps, they are not as clearly identifiable on the SARS and MERS maps. It was also observed a clear link between geographical origins, each outbreak's severity, and the magnitude of research output from these regions. Similarly, Zhang et al (2020) explore how academia generally reacts to an epidemic/pandemic scenario, by analyzing literature related to six virus outbreaks during the last twenty years, including the covid-19 crisis, looking for patterns related to publication features, geographical distribution, institutions, and funding agencies. They found that there is a surge of publications after the issuing of a Public Health Emergency declaration by the World Health Organization, peaking within 2 years after the outbreak. As expected, countries typically devote more attention to epidemics close to their geographic position, even though researchers in North America and Europe also pay attention to outbreaks in other regions via collaborative work with the outbreak center, the exception being the SARS crisis whose research took place mainly on China, with some collaboration with the US. Most papers belonged to the ‘Virology’ and ‘Infectious Diseases’ research areas, although it was noticed that European and American

publications were more focused on public health issues, while the Chinese and Japanese ones paid more attention to biochemistry and pharmacology matters, respectively.

Finally, the fourth and final cluster is visible in yellow on the co-occurrence maps, which accounts for 19,3% of the total identified terms. In addition to the terms shown in Table 10, namely "group", "university", "view", "concept" and "consequence", that cluster contains other terms such as "education", "student", "test" and "teaching". The analysis of both its terms and main articles indicates that the central theme captured by this cluster revolves around Education topics.

TABLE X

2020_21 COVID CLUSTER 4 - *EDUCATION*

Cluster 4 - Education	
Top 5 Terms - Total Occurrences and as % Cluster	
group (19; 6,8%); university (14; 5%); view (13; 4,7%); concept (12; 4,3%); consequence (12; 4,3%)	
Top 5 Most Relevant Papers	
Title	***Reference***
Can online higher education be an active agent for change? - comparison of academic success and job-readiness before and during COVID-19	Alam & Parvin (2021)
Online technology: Sustainable higher education or diploma disease for emerging society during emergency-comparison between pre and during COVID-19	Alam & Asimiran (2021)
Quantifying the publication preferences of leading research universities	Lancho-Barrantes & Cantu-Ortiz (2021)
On the syndemic nature of crises: A Freeman perspective	Dosi & Soete (2022)
Knowledge exploration-exploitation and information technology: crisis management of teaching-learning scenario in the COVID-19 outbreak	Saide & Sheng (2021)

Source: Own Elaboration

Qualitative appraisal of the cluster #4 literature

The lockdown measures put in place to try to reduce the spread of the Covid virus profoundly impacted various dimensions of society, including the forcible migration of millions of students to online classes. Naturally, this unprecedented and abrupt change led to debates and concerns regarding the quality of education and its future impacts. For example, Saide & Sheng (2021) present a broad discussion on knowledge transfer and information technology for the education system in uncertain times, like the Covid pandemic. Using a systematic literature review approach, it classifies the selected articles into six broad categories: internal-external knowledge, tacit-explicit knowledge, knowledge exploration-exploitation, IT

tools for online learning, and knowledge receiver. This paper highlights the importance of supporting the lecturer and learners on properly using online learning tools, especially keeping in mind that online learning requires good Internet access and suitable hardware, which may be especially challenging for lower-income students. The lack of human-touch interaction between instructors and students is also pointed out as problematic since it decreases student feedback and thus requires extra control from the teaching staff.

On the other hand, Alam & Parvin (2021) studied the effectiveness of online mode in higher education through the lenses of academic and job-readiness performance of students. By analyzing two groups of graduates, a pre-COVID19 cohort that had face-to-face teaching and another that experienced the online mode during the pandemic, the authors seek to compare and understand the differences between the groups with regards to academic learning outcomes, academic achievement, and job readiness and investigate the role of the active learning concept in this context. They found that the pre-pandemic group obtained worse academic results for all the knowledge streams (science, business, arts) than their pandemic counterparts. This trend was visible in all the four domains that compose the academic score: theory, practical, class attendance & participation, and presentation. However, when comparing the job-readiness scores, the pre-COVID-19 students achieved better results. For the authors, these results indicate that online learning made education more passive and raise concerns that the online learning model has deepened an already dysfunctional relationship between practice and theory and may tend to lead to fabricated grades. Using the same dataset, Alam & Asimiran (2021) expand the analysis by focusing on the sustainable production of higher education and on the so-called 'diploma disease, that is, the belief that more formal education automatically leads to more professional qualifications and better-paying jobs. From the results presented previously, this article concludes that it seems that the higher education system used the pandemic to extend the "diploma disease crisis and that online learning as a primary delivery mode may threaten the sustainable production of higher education, which ultimately would hinder the relationship with between universities and industry, due to lack of confidence in student training".

With a more theoretical approach, Dosi & Soete (2022) analyze the COVID-19 health crisis by considering the writings of Christopher Freeman on the long-term environmental crisis and its implications for science, technology, and innovation policy. This paper also resorts to the use of the medical anthropological concept of "syndemic", a combination of 'synergy' with 'epidemic' that expresses the dependency between a particular disease and social, political, economic, and environmental conditions as well as other diseases, which is seen as is in line with Chris Freeman's reflections on crises. In that regard, focusing on the growing inequality brought about by the covid crisis, the paper singles out two groups: the youth and the disruption of the traditional learning and education dynamic; and the elderly that faced strict confinement in long-term care facilities along with high mortality rates. In their analysis, the authors highlight the similarity between epidemiology and diffusion, in the sense that the spreading of COVID-19 with its interaction with local socioeconomic conditions is similar to the diffusion process of radical innovation, with the fundamental policy difference that in one case the objective is to slow down the process and in the other the opposite. Dosi & Soete (2022) further point out that governments successfully convinced the public of the need for confinement measures. Still, there is no guarantee that this ability to act rapidly will be used in response to the climate change crisis, namely taking into account the lack of global solidarity seen in the pandemic. The authors advocate for open science as the dominant framework for environmental research, and that the discussion on patent-free vaccine production should lead to a broader debate regarding the patent-free access to green industrial technologies, which are of the utmost importance in facing the environmental crisis, much like the vaccines were essential in controlling the pandemic.

Finally, Lancho-Barrantes & Cantu-Ortiz (2021) focus on the uniqueness of research universities by analyzing their publication profiles, research preferences, collaboration, and influence on the rest of the universities. For this, they gathered the scientific production from a 5-year period of the top (and bottom) 20 institutions ranked in the THE World University Rankings 2020 and applied bibliometrics indicators and clustering analysis. They found that most universities in the top-20 belong to the United States and present many publications in top journals, with high levels of scientific collaboration, and their publications are cited twice more than expected. It is also found that the 20 top and low-ranking universities present similar research preferences. It is noteworthy that in this article the pandemic reference is merely circumstantial, with the word "covid" appearing just once. The article was likely written in the 2nd quarter of 2020, at the height of the pandemic-related uncertainty.

In summary, the co-occurrence map's analysis showed that the covid-related STI literature can be split into four different thematic clusters. The first one covers *Economic Dynamics and Entrepreneurship* topics, specifically those related with entrepreneurial activity and small businesses. The second cluster deals with *New Innovation Models* based on collaborative networks of stakeholders that gained traction with the pandemic, such as crowdsourcing and hackathon. The third cluster encompasses publications related to *Scientometric* analysis, that aimed to map, quantify, and qualify the unprecedented knowledge outburst caused by the pandemic. Finally, the fourth cluster contains publications that focus on analysis of the lockdown measures' impact on the quality of *Education* and its future impacts.

It is worth noting that, in the qualitative appraisal of the Covid literature it is possible to observe a significant number of articles that discuss public policy and government related issues. Given the sheer scale of the pandemic crisis and the sudden need for immediate state action, it makes sense for Covid related texts to be more "policy oriented", whether it is analysing policies put into effect or proposing new ones. In fact, for the 2020 and 2021 publications, when we compare the relative frequency of articles that contain the terms "policy" and/or "policies" in their title or abstract, we find that in the Covid publication set this rate is almost double than in the non-Covid publications set, 27.8% and 14.7% respectively. When it comes to the term "government" the difference in relative frequency is even greater, with 18% of the Covid publications containing the word versus only 5.6% of the non-Covid publications. Likewise, there seems to exist a concern in Covid publications with the long term and with being prepared for the next similar crisis. For example, the term "future" appears in in the title or abstract of 22.5% of the Covid related articles, but just on 11.8% of the non-Covid related.

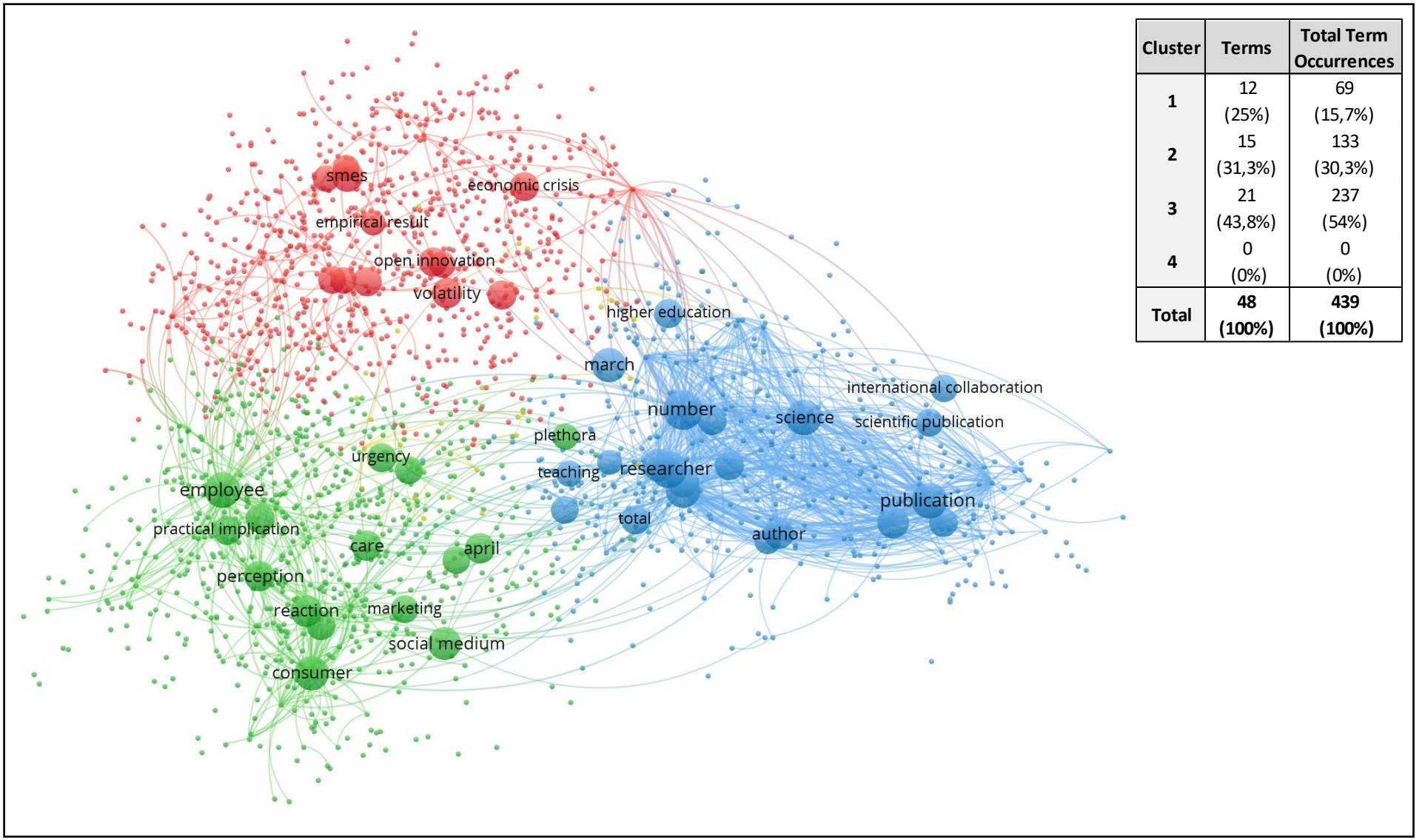
4.2. Overlay Map

To further explore the results obtained and compare the Covid and non-Covid sets, we resort to the overlay maps technique, based on Rafols, Porter & Leydesdorff (2010), which provides a visual structure that makes it possible to make immediate and visual comparisons of the sets' relationships.

The basic idea of an overlay map is to project information from a subset of publications over a global baseline map obtained from different set of publications (Carley et al, 2017; Rotolo et al., 2014). In other words, it consists of using the units and positions from a bibliometric map of a reference set of publications (the basemap), as a base for superimposing data (the overlay) from another analyzed set of publication (Rafols, Porter & Leydesdorff, 2010).

For this study, the term co-occurrence map of the 2020_21 non-Covid publications was chosen as the basemap, and the term co-occurrence map of the 2020_21 Covid publications was used as the overlay layer. The relevant terms (i.e. terms that exist in both sets) appear in this non-Covid baseline map in their original position, but are overlaid with their weight (i.e. number of occurrences) from the Covid publications maps. This is represented by the relative size of the circle of each node. This technique allows us to analyze how much and in what manner each thematic area identified in the non-Covid publications dealt with Covid-related issues.

Figure 4 presents the graphical view of the Overlay Map.



Cluster	Terms	Total Term Occurrences
1	12 (25%)	69 (15,7%)
2	15 (31,3%)	133 (30,3%)
3	21 (43,8%)	237 (54%)
4	0 (0%)	0 (0%)
Total	**48 (100%)**	**439 (100%)**

FIGURE 4 – Overlay Map: 2020_21 Covid x 2020_21 N Covid . Own Elaboration

Available online at: https://tinyurl.com/2oj9ychs

The overlay map shows a total intersection of forty-eight terms between the 2020_21 Non-Covid and Covid sets. With regards to the distribution among cluster we have that cluster # 3 presents the largest share of terms (21 or 43.8%), followed respectively by cluster # 2 with 15 terms (31.3%) and cluster # 1 with 12 (25%). There were no matches in cluster # 4.

It is not surprising that cluster # 3 has the highest number of matches, given that its theme (Scientometrics) was also identified as central to one the clusters of the covid publications set (coincidentally, also cluster # 3). In fact, of the twenty-one terms with correspondence in cluster # 3 of the non-Covid publications set, sixteen belong to cluster # 3 of the covid publications set. The five overlaid terms with the highest occurrences in cluster #3 were “number”, “researcher”, “publication”, “science” and “field”

Likewise, there is a similar relationship between cluster # 1 of both sets. Of the twelve terms matching cluster # 1 of the non-Covid publications set, ten belong to cluster # 1 of the covid publications set. The top-five terms in this cluster were “smes”, “volatility”, “innovative solution”, “open innovation” and “economic crisis”. Among the terms with correspondence in cluster # 2, there is no pattern regarding their origin cluster in the covid publications set and its top five terms with most occurrences were: “employee”, “consumer”, “social medium”, “reaction” and “april”.

In addition to analyzing the words in common, it is interesting to investigate the terms that appear in only one of the sets. On the one hand, relevant terms in non-Covid publications set that do not appear in the covid publications set may indicate themes and areas that did not concern much with issues related to the pandemic. On the other hand, relevant terms in the covid publications set that do not appear in the non-Covid publications set can give clues about emerging research topics.

The analysis of the two sets' shared and unique terms leads to two main conclusions. First, for the Non-Covid publications cluster # 1 (Firm Innovation), the thematic intersection with Covid publications took place around small business and entrepreneurship topics. This is evident both by the sharing of terms such as “smes” and “small business”, and by the absence of occurrence in terms typically more linked to large companies’ context, such as “patent” and “r & d”. It should be noted, however, that in the Covid publications there was a focus on the role of small businesses and entrepreneurship

in the economic dynamics, with the occurrence of terms such as “economy”, “growth”; “recovery”, and “survival”, which does not happen in non-Covid publications.

The second main conclusion is that for the non-Covid publications cluster # 3 (Scientometrics), the intersection occurred around terms of a more technical nature and which are characteristic of scientometric studies such as “researcher”, “publication”, and “science”. In the Covid publications, however, there were terms, such as "life", "increase", "control" and "death”, that point to a more specific research focus linked to public health issues caused by the pandemic.

5. CONCLUSION

This section concludes the research by summarizing its key findings and confronting them with the initial research question. It further addresses what is the contribution and its value. Finally, it closes with a discussion of the study's limitations and possibilities for future research.

This study investigated how the COVID 19 pandemic impacted the STI literature. We addressed this question by comparing the contents of the STI literature before COVID-19 and since the pandemic's beginning, using bibliometric and clustering techniques as well as a systematic qualitative review of key publications.

The descriptive statistics regarding the most active countries of our publication sets, revealed that although the geographical pattern of the sets is relatively similar, there are some important differences between them. First, we find that the concentration in the top ten countries was lower in the Covid Publications than in the non-Covid ones. Second, the countries hit hard by the pandemic had a higher participation rate in the set of Covid publications. And third, we have that for the top-three best-ranked countries in the 2020_21 non-Covid publications set, only the UK increased its participation rate in the Covid-related set.

In the journal analysis dimension, we observed that only 18 of the 27 selected journals had Covid-related publications, and, regarding the journals participation rate, this set of publications presented a similar coefficient of variation when compared to the non-Covid set. However, when comparing the participation rate of each journal between the 2020_21 non-Covid and Covid publications, we observe that only six journals had a higher participation rate in the Covid set. More specifically, we have that of the top-3 leading publications in the non-Covid sets, i.e., Journal of Business Research, Journal of Business Ethics and Technological Forecasting and Social Change, only the latter had an increased participation rate in the Covid set. In addition, we found that for the non-Covid publications set, the bibliographic coupling of the journals reveals a clear distinction between two groups, a management/business related one and one of core STI journals.

Moving on to the cluster analysis, for both the 2019 and 2020_21 non-Covid publications set, we obtained a similar result of four clusters, three being very significant and independent and a fourth one which is statistically less relevant. They were

interpreted as representing the following topics: Firm Innovation, Innovation Management, Scientometrics, and Gender, respectively.

With regard to the Covid publications, the cluster analysis revealed that the Covid related STI literature can be divided into four different thematic clusters: Economic Dynamics and Entrepreneurship; New Innovation Models; Scientometrics and Education.

The *Economic Dynamics and Entrepreneurship* cluster contained terms such as "economy", "employee", "lockdown", "growth", "entrepreneur", "smes" and "survival", and its main research topics were those related to small businesses, entrepreneurial activity relationship with the lockdown, and the overall impact on the global economy.

The *New Innovation Models* cluster contained terms such as "product", "consumer", "service", "case study", "stakeholder", "customer", "open innovation" and "innovative solution", and its main research topics were those related to collaborative networks of stakeholders, such as crowdsourcing and hackathon.

The Scientometric cluster contained terms such as "number", "researcher", "publication", "science" and "field", "topic", "pattern", "journal" and "author", and its main research topics were those related to mapping and quantifying this covid related knowledge outburst.

The *Education* cluster contained terms such as "group", "university", "view", "concept", "consequence", "education", "student", "test" and "teaching", and its main research topics were those related to the lockdown measures' impact on the quality of *Education*.

Finally, in the overlay map analysis we found a total intersection of forty-eight terms between the 2020_21 Non-Covid and Covid sets, with the largest share of these terms belonging to the Scientometrics cluster, a research theme identified as central by clusters in both sets. This intersection between the two Scientometrics clusters took place around more technical terms and highlighted the fact that the Covid publications set Scientometrics cluster also encompassed more specific terms linked to the public health issues caused by the pandemic, such as "life", "increase", "control" and "death".

Similarly, we observed an intersection in the "Firm Innovation" cluster of the non-Covid publications centered around small business and entrepreneurship topics. This was

evident both by the sharing of terms such as “smes” and “small business”, and by the absence of occurrence in terms typically more linked to large companies’ context, such as “patent” and “r&d. However, we find that the publications within the Covid set focused on their role in the economic dynamics and recovery, which did not happen in Non-Covid publications

We believe that the Covid pandemic will have lasting effects on several dimensions of science, technology and innovation-related areas. The co-word analysis based on the title and abstract terms helped to identify and gain insight into the potential STI knowledge fields related to the impact of Covid-19. However, this study has an exploratory nature as it was undertaken to understand the impact of the Covid-19 pandemic on the STI literature. Therefore, it was not intended to yield final results on the topic and should be considered alongside other qualitative and quantitative analyses of STI Covid-19 research.

Naturally, we recognize some limitations to be addressed in future studies. Firstly, the STI journal list was based on previous literature and subjected to our own selection process, which may not be the best one and present some bias. For example, the list could be improved to reflect the research field better, perhaps, being the object of a questionnaire with experts. In second place, the knowledge outburst triggered by the pandemic was not limited to academic literature but also seen in other types of publications, such as grey literature and print media. Including publications of a non-academic nature in the analysis may be interesting and helpful to understand better the impact and issues addressed by the STI literature. Also, since different waves and phases marked the pandemic evolution, it could be of great value to alter the analysed periods to shorter intervals to capture the change of the research topics addressed throughout the pandemic.

Finally, we believe that the article selection technique of a term-based cluster analysis that was used in this study may be useful in another research. For example, in this same context, it could be interesting to distribute the articles of the clusters identified in the non-Covid literature, and then follow with a co-word analysis of articles set in each cluster, in order to refine their thematic interpretation.

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APPENDICES

ANNEX 1

PRE-SELECTION OF INNOVATION JOURNALS

n	Journal	Source
1	Academy Of Management Journal	Fagerberg et al.(2012); Landström et al. (2012)
2	Academy Of Management Review	Fagerberg et al.(2012); Landström et al. (2012)
3	Actual Problems of Economics	JEL O3
4	Administrative Science Quarterly	Fagerberg et al.(2012); Landström et al. (2012)
5	American Sociological Review	Martin et al. (2012)
6	Cambridge Journal Of Economics	Fagerberg et al.(2012)
7	Economics of Innovation and New Technology	JEL O3; Fagerberg and Verspagen (2009)
8	Energy Policy	JEL O3
9	Environment and Planning A	Martin et al. (2012)
10	Human Relations	Fagerberg et al.(2012)
11	Industrial and Corporate Change	JEL O3; Fagerberg and Verspagen (2009); Fagerberg et al.(2012)
12	Industry and Innovation	JEL O3
13	International Journal Of Technology Management	Fagerberg et al.(2012); Landström et al. (2012)
14	Isis	Martin et al. (2012)
15	Journal of Business Ethics	Landström et al. (2012)
16	Journal of Business Research	Landström et al. (2012)
17	Journal of Business Venturing	Landström et al. (2012)
18	Journal of Economic Behavior and Organization	Landström et al. (2012)
19	Journal of Economic Issues	Landström et al. (2012)
20	Journal of Evolutionary Economics	Fagerberg and Verspagen (2009)
21	Journal of Industrial Economics	Fagerberg and Verspagen (2009)
22	Journal Of International Business Studies	Fagerberg et al.(2012); Landström et al. (2012)
23	Journal of Management	Landström et al. (2012)
24	Journal Of Management Studies	Fagerberg et al.(2012); Landström et al. (2012)
25	Journal of Product Innovation Management	Fagerberg and Verspagen (2009)
26	Journal of Research in Science Teaching	Martin et al. (2012)
27	Journal of Technology Transfer	JEL O3
28	Journal of the American Society for Information Science and Technology	Martin et al. (2012)
29	Journal of the Knowldege Economy	JEL O3
30	Management Science	Fagerberg and Verspagen (2009); Fagerberg et al.(2012); Landström et al. (2012)
31	Minerva	Martin et al. (2012)
32	Organization Science	Fagerberg et al.(2012); Landström et al. (2012)
33	Organization Studies	Fagerberg et al.(2012); Martin et al. (2012); Landström et al. (2012)
34	Philosophy of the Social Sciences	Martin et al. (2012)
35	R&D Management	Fagerberg and Verspagen (2009); Landström et al. (2012)
36	Rand Journal of Economics	Fagerberg and Verspagen (2009)
37	Regional Studies	JEL O3; Fagerberg and Verspagen (2009); Fagerberg et al.(2012); Landström et al. (2012)
38	Research Policy	JEL O3; Fagerberg and Verspagen (2009); Fagerberg et al.(2012); Martin et al. (2012); Landström et al. (2012)
39	Science Education	Martin et al. (2012)
40	Science, Technology and Human Values	Martin et al. (2012)
41	Scientometrics	Martin et al. (2012)
42	Small Business Economics	Fagerberg et al.(2012); Landström et al. (2012)
43	Social Science and Medicine	Martin et al. (2012)
44	Social Science Information sur les Sciences Sociales	Martin et al. (2012)
45	Social Studies of Science	Martin et al. (2012)
46	Strategic Management Journal	Fagerberg and Verspagen (2009); Fagerberg et al.(2012); Martin et al. (2012); Landström et al. (2012)
47	Structural Change and Economic Dynamics	Fagerberg and Verspagen (2009)
48	Studies in History and Philosophy of Science	Martin et al. (2012)
49	Technological Forecasting And Social Change	Martin et al. (2012)
50	Technology Analysis & Strategic Management	JEL O3; Fagerberg et al.(2012); Martin et al. (2012)
51	Technology and Culture	Martin et al. (2012)
52	Technovation	Fagerberg and Verspagen (2009); Landström et al. (2012)