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Societal Technological Megatrends: A Bibliometric Analysis from 1982 to 2021

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Abstract: This article presents a bibliometric analysis of scientific publications investigating technological megatrends at the societal level, through the parallel analysis of 549 documents from Scopus and 291 documents in Web of Science (WoS) using the VOSviewer software and the Excel component of the MS Office 365 package. The main purpose of this study was to obtain an overview of the evolution of the research on the subject of technological megatrends from the perspective of interest, domains, geographical areas, sources, authors and cocitation networks, research clusters of countries, and cluster-related concepts. The results showed that publications on technological megatrends started in 1982, but from a scientific point of view they started in 1983 (Scopus) and 1984 (WoS), and that they display an increasing trend after 2010. *Technological Forecasting and Social Change*, *Nature*, *SAE Technical Papers*, *VDI Berichte*, *Harvard Business Review*, *Advances in Intelligent Systems and Computing*, and *Sustainability* represent the most important sources, and Gibbs, Kraemer, Dedrick, Kim, Chmiela, Sauceda, Müller, Tkatchenko, Pratt, Sarmiento, Montes, Ogilvie, Marcus, Perez, Brownson, D. Mourtzis, M. Doukas, and Bernidaki are the most notorious researchers in the field. At the societal level, technological megatrends are closely related to foresight, globalization, industry 4.0, the internet of things, digitalization, technology, artificial intelligence, innovation, the future, and sustainability. This study is original and useful for researchers in the context of the lack of similar studies on this subject.

Keywords: forecasting; societal changes; digital transformations; internet of things; industry 4.0

1. Introduction

Change is the essential characteristic [1,2] of the actual economy. As suggested by Taylor [3] in his attempt to formulate a theory of change, the rapid changes of global society generate opportunities and threats that can be managed properly only if they are approached from a predictive perspective. These concerns, which have been highlighted for thousands of years in China through books and guides dedicated to change [4], have reached a high level of accuracy over time and constitute the basis for numerous academic studies, as well as numerous special reports of renowned consulting firms, such as PricewaterhouseCoopers [5], Deloitte [6], McKinsey [7], and Gartner [8]. We would like to highlight the fact that some concerns in this field were meant to shape an increasingly dynamic reality [9], including the creation of certain intelligent learning algorithms for change impact prediction [10]. It is believed that changes at the global society level (societal changes, also known as megatrends [11]) are generated by macroeconomic forces that manifest themselves in cycles ranging between 20 and 50 years and that act on extended geographical areas by generating an important shift in the progress of a society.

The objective of this study consists in the accomplishment of a bibliometric analysis of megatrends as an effect of technological evolution at the societal level, in order to clearly highlight the main directions and characteristics of the research in this field. Following Aria and Cuccurullo [12], who consider that in a bibliometric analysis we find questions related to the identification of the knowledge base, the examination of the research fund, and the revelation of the social networks, with reference to the scientific community, and in corroboration with the methodologies described by Schepers and Wetzel [13] and Stopar and Bartol [14], corresponding to the assumed objective, we established the following research questions: (Q1) How has the research interest in this topic evolved over time? (Q2) What are the main research areas? (Q3) Which are the countries that pay more attention to research in the field of megatrends? (Q4) What are the main sources in the field of megatrends? (Q5) What are the main papers and the main authors in the field of megatrends? (Q6) What are the source and the author cocitation networks? (Q7) What are the coauthorship clusters by country? and (Q8) What are the clusters of megatrend-related concepts?

Each of these eight abovementioned research questions were formulated in accordance with the practices of the field and were systematized and recommended by Zupic and Čater [15].

2. Technological Megatrends in Society

Although *The Oxford English Dictionary* [11] attributes the earliest use of the concept of Megatrends to *The Christian Science Monitor* (CSM) in the early 1980s, our searches in the CSM article database led to the identification of the use of the term, for the first time, in the article "Where America is rehearsing for the 21st century", published by Ruth Walker on 23 March 1983 [16], given that John Naisbitt's book "Megatrends. The new directions transforming our lives" had already been published in October 1982. We acknowledge that after 1982, megatrends became a concept established by Naisbitt [17], which referred to the "general changes in thinking or approach, which affect countries, industries and organizations", given that *The Oxford English Dictionary* defined it as "an important shift in the progress of a society or of any other particular field or activity; any major movement" [11].

The last decade abounds with authors [18,19] who paid special attention to the concept of megatrends from a scientific perspective. Megatrends are essentially considered to be either global changes in individual, social, and technological structures, which are expected to have a major impact in the future on the markets as a whole [20], on society, the economy, and the natural world in the long run [21]; or macroeconomic and geostrategic forces [22], transformative on the global level [23] and sustainable from the synergistic development perspective [24], which shape our world and our collective future in profound ways associated with both opportunities and significant risks and which have a significant impact on business, the economy industry, society, individuals, culture, and even technology (including information and communication technology). Munters and Marx [25] comprehend megatrends in time and space by reference to key areas of society, such as politics, economics, technology, social values, and relations at all levels of society, and Chism [26] even sees them as solutions available to governments to solve emerging problems. From a unique perspective, it is intriguing to observe the opinion of the authors Vidyasekar, Kolhapur, and Amarnath [27], who examine the impact of transformative forces on the global level and also on the personal lives of individuals, as components of society, enterprises, economies, and cultures.

In summary, we conclude that there is a definition of megatrends in terms of individual research interests and directions [28], which highlights three essential features [24]: the length of megatrends' impact over a period of at least fifteen years, their influence on the global context of the business and social environment, and the transformation of socio-economic strategies. In contrast to the above, we argue that megatrends represent global forces which are manifested over large geographical areas; over long periods of time; with a major impact on the economy, society, and the lives of individuals; and which influence the evolution of humanity as a whole.

In this context, megatrends are manifested in human society as a result of the technology–society relationship [29] amid the changes that dominate society as a whole [2,30], with a predominant emphasis on the technological side [31]. Thus, our attention is drawn to the study of R. Pęciak [18], entitled "Megatrends and their Implications in the Globalised World", in which an inventory of the authors in the field is made, with references to the main socio-technological megatrends for the period of 1982–2016, starting with Naisbitt [17] and concluding with Retief et al. [32]. The study does not take into consideration the futuristic approaches highlighted by the renowned futurologists [33] of the World Future Society (WFS). We highlight, in the same fashion, a similar approach undertaken by Siscan [34], who insisted on the economic and social impact of megatrends.

A revision of the scientific literature is also found in the paper "Global megatrends and their implications for environmental assessment practice" published in 2016 by Retief et al. [32], which focuses on identifying the key megatrends for environmental impact assessment. Thus, the authors conclude that the term megatrends is frequently spotted in reports, periodicals, or other documents created by forecasting institutions or by specialized research centers and consulting firms, but is less incidental in the field of academic databases. Two years later, P. J. Batt [19] departed from this conclusion in the article "Responding to the challenges presented by global megatrends", and conducted a review of the specialized literature focused on the impact of megatrends on the global food industry, having as sources of analysis mainly the reports of the experts of consulting firms. Another critical study of the specialized literature was conducted by Malik and Janowska [28] in the paper "Megatrends and their use in economic analyses of contemporary challenges in the world economy megatrendy", in which they analyzed the use of megatrends as an analytical framework on various economic and social levels. Thus, their research highlighted the conceptual use of megatrends in the forecasting studies of different specific industries, as well as the analysis of changes produced or anticipated in the management of various socioeconomic areas.

Our research has also identified an interesting analysis of the impact of megatrends, at the level of organizations, from the perspective of the relationship between megatrends and disruptive elements, by the authors Linthorst and de Waal [35] in their study "Megatrends and Disruptors and Their Postulated Impact on Organizations", by means of which 13 megatrends were identified, along with one disruptor mentioned in the academic literature, in relation to the topic of "the future of work", and "the occurrence of a pandemic disease" in particular.

The conclusions of the aforementioned studies [18,19,24,28,32,34,35] fully motivate a mapping of the specialized literature assigned to megatrends, which represents an approach with a high degree of originality, being preceded only by a few revisions of the literature in the field. At the same time, the usefulness of this study is proven by the clear highlighting of the main directions and characteristics of the research in this field.

3. Method

For our research approach, we conducted a bibliometric analysis of research resources in the Web of Science and Scopus databases. In this regard, the bibliometric analyses of citations and cocitations are based on purely quantitative approaches and are supported by the premise that citations represent a valid and reliable indicator of the scientific interaction between researchers and research institutions [36]. From the same perspective, Zupic and

Čater [15] consider that one of the most tangible and best-documented forms of scientific collaboration is the coauthorship. In turn, Glänzel and Schubert [37] demonstrate that by means of bibliometric methods almost all aspects of scientific collaboration networks can be reliably followed by analyzing the coauthorship networks. Thus, Aria and Cuccurullo [12], along with Orastean, Marginean, and Sava [38], summarize the structural pattern of a bibliometric analysis, which, in summary, involves the following steps: the research design, data collection, data analysis, and visualization of results. All these are used to identify, for a particular topic, the groups of publications and the authors or the related journals, as well as to interpret the results obtained. In the practice of these bibliometric analyses, the authors of [39] highlight the fact that clustering techniques, which are developed in other fields, are used with predilection in fields such as statistics, informatics, and networking science. By their means, publications are added to a cluster, in order to maximize the qualitative function (1):

$$Q(x_1, \ldots, x_n) = \sum_{i=1}^{n} \sum_{j=1}^{n} \sigma(x_i, x_j) \left(a_{ij} - \frac{\gamma}{2n}\right), \tag{1}$$

where n is the number of publications, a_{ij} represents the correlation of the publication i with j, γ is the resolution parameter, and x_i is the cluster to which the publication i is associated. The function $\sigma(x_i, x_j)$ returns the value 1 if $x_i = x_j$ and the rest is 0.

Consequently, the relationship of the publication i with the publication j is given by:

$$a_{ij} = \frac{c_{ij}}{\sum_{k=1}^{n} c_{ik}}, \tag{2}$$

where c_{ij} has the value 1 if the publication i cites the publication j or if the publication j cites the publication i, and, in other cases, c_{ij} takes the value 0.

Regarding the construction and visualization of the bibliometric maps, the analysis tool we used is represented by VOSviewer, which was developed in 2009 by van Eck and Waltman [40]. Unlike other bibliometric software tools, VOSviewer attaches great importance to large bibliometric maps, which are created in a clear and easy to manage and use format. The aforementioned functional advantages, as well as its distribution in the open-source system, make VOSviewer one of the most frequently used software for bibliometric analyses [41].

The research model suggested by us in order to achieve the purpose of our research is illustrated in Figure 1, with the remark that the study design constituted the subject of the previous paragraphs, where we established the eight research questions and presented the conceptual aspects assumed by the bibliometric method.

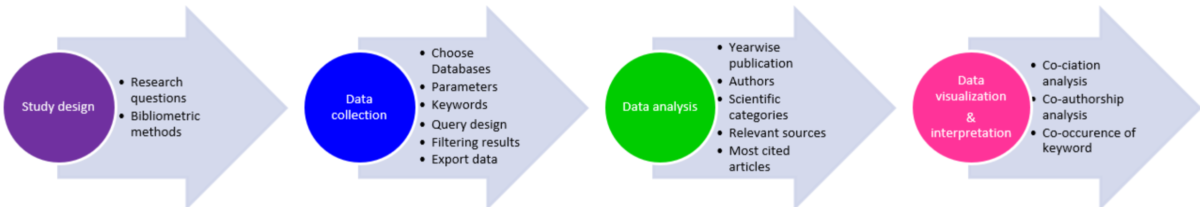

Figure 1. The research model of literature mapping.

4. Data Collection

In consonance with Saunders, Lewis, and Thornhill [42], who consider that data collection requires the definition of the search parameters, the keywords, the establishment of the databases used, and the definition of the filtering criteria, supported by Aria and Cuccurullo [12], who regard data collection as only the processes of obtaining, uploading, converting, and refining the data, we opted for selecting the academic databases, setting the bibliometric search parameters, selecting the keywords, designing the bibliometric database queries, and establishing the criteria for filtering the results (Figure 1). By default, it was understood that the results obtained would be exported so that they could be analyzed, interpreted, and viewed.

4.1. Setting Academic Databases and Additional Sources of Documentation

In our research, we used two databases, Web of Science (WoS) and Scopus, known as the most representative for academic research [43,44]. The Web of Science Core Collection is one of the most important research databases in the world [23], providing access to records through the Clarivate Analytics core platform. In turn, Scopus is the largest database of abstracts and quotes in the world, covering over 24,600 active serial titles and over 194,000 books from over 5000 publishers [45], offering the most comprehensive picture of international research in the fields of science, technology, medicine, sociohumanities, and arts.

4.2. Setting Search Parameters

The search parameters used may included the subject area, the language of publication, the geographical area, the period of publication, and the type of literature used. We mainly looked for specialized literature in English, with technological, economic, and societal accents. Regarding the time interval, our search began with publications from 1982, the year of the introduction of the concept of megatrends in the literature, and ended with the reference date of our research (October 2021).

4.3. Setting Keywords and Designing the Queries

The selection of the keywords represents an important step [42] in a bibliometric analysis of a research topic—in our case, of societal technological megatrends. The motivation behind the selection of words is anchored in the definition offered by us for the concept of a megatrend, as well as in the synthesis idea according to which megatrends, of whatever nature they may be, are based on technological evolution and the key relationship between society and technology [29], which requires change to be the main constant at the societal level [2,3,31]. Because we were talking about change at the societal level, a change that involves large scale technological innovation, our focus was directed to the technological waves, motivated by technological transformations at the socioeconomic level, detected by Almgren and Skobelev [46] at the level of production methods and technological paradigms, against the background of the long waves or long cycles theory suggested by N.D. Kondratiev as early as 1922, and later developed by J.A. Schumpeter [47,48]. All such issues motivated us to focus our attention on the following keywords: megatrends, technological waves, and global forces. In order to emphasize the papers with technological content, we included in our search for the topic of articles (i.e., in the title, abstract, and author keywords) the string "tech", followed by "*", to cover contextual areas with terms such as tech, technological, and techno. In accordance with the aforementioned matters, along with the requirements imposed by each of the two bibliometric databases, we designed and generated the following queries, which led to the results in Table 1 for Scopus and WoS.

Table 1. Scopus and WoS queries and results.

	Query Criteria: Scopus	Results
A	TITLE-ABS-KEY (megatrend * AND tech *) AND PUBYEAR AFT 1982	463
B	TITLE-ABS-KEY ("technological waves") AND PUBYEAR AFT 1982	94
C	TITLE-ABS-KEY ("global forces" AND tech *) AND PUBYEAR AFT 1982	226
Total	TITLE-ABS-KEY (megatrend* AND tech *) OR TITLE-ABS-KEY ("technological waves") OR TITLE-ABS-KEY ("global forces" AND tech *) AND PUBYEAR AFT 1982	781

Table 1. *Cont.*

	Query Criteria: Web of Science	Results
A	TS = (megatrend * AND tech *) AND PY = (1982–2021)	245
B	TS = ("technological waves") AND PY = (1982–2021)	24
C	TS = ("global forces" AND tech *) AND PY = (1982–2021)	80
Total	TS = (megatrend * AND tech *) OR TS = ("technological waves") OR TS = ("global forces" AND tech *) AND PY = (1982–2021)	346

As can be seen in the table above, we proceeded to the cumulation of the searches in the application, using the OR disjunctive logic connector, and the results, visible in Table 1, constituted 781 articles for the Scopus database and 346 articles for the Web of Science database.

4.4. Refining by Filtering the Initial Results

Ensuring a high degree of accuracy for our mapping involved resorting to filtering the articles from the list of those obtained in the previous stage. Consequently, at this stage, we filtered the articles that had been obtained in order to provide a high degree of accuracy to our mapping. The previous queries generated results that covered a wide spectrum, such as articles, proceedings papers or conference papers, conference reviews, editorials, notes, letters, business articles, books, book chapters, reviews, short surveys, and early access articles. In accordance with the structures related to the types of scientific papers, in corroboration with our aim to include in our research the aspects directly related to the research results, we refined the results obtained in the previous stage to the papers of the article and proceedings paper or conference paper type. Therefore, the structure of the results according to the type of documents is presented in Figure 2, with 86.83% of the WoS database results represented by articles and proceedings papers and 75.58% of the results of the Scopus database illustrated by articles and conference papers. In addition, we filtered the results from this refining stage according to the language of publication, i.e., English.

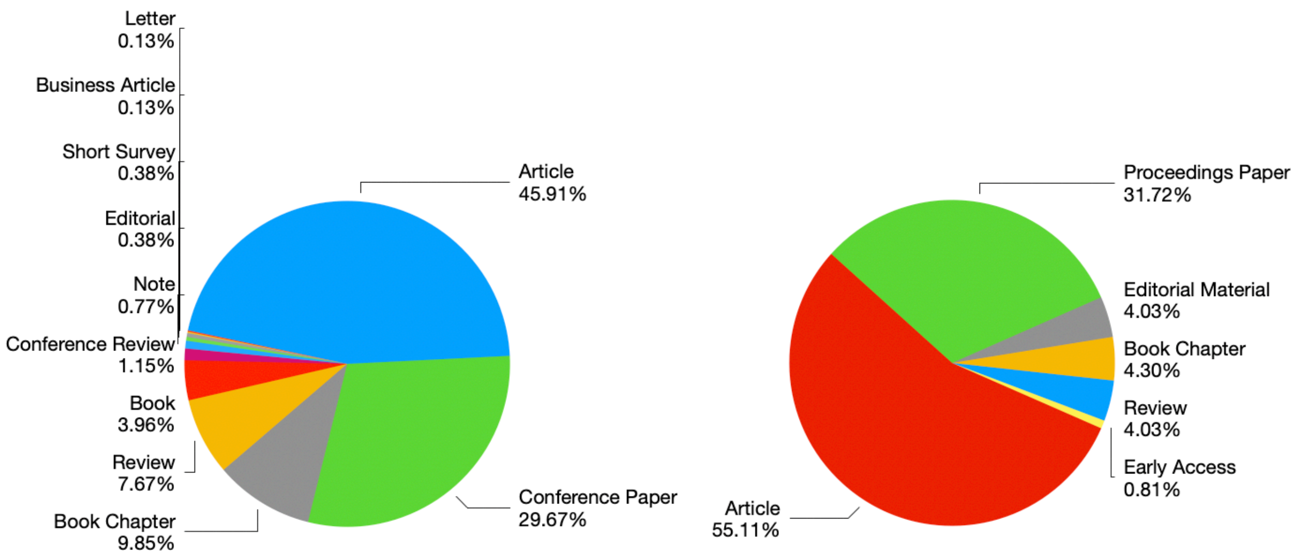

Figure 2. Type of documents (Scopus left, WoS Right).

An important task of the refinements relates to the consistency of the records in the databases [49] obtained in the previous stage, as part of the minimum data cleaning procedures (data cleaning Rahm and Do [50]). Because of the fact that the database was a simple one, with a single table, we noticed that this consistency refered, in principle, to the completion of all table attributes with complete and correct information. Regarding the accuracy, it was not possible for us to perform any test, so we had to rely on the correctness of the data provided by the rules imposed by the two specialized platforms, WoS and Scopus. As far as the provision of complete data is concerned, this aspect demanded that we adjust the visualization of the results only for the fully defined articles. Therefore, we specified the possible deletions or completions of articles when they were detected after passing the tests to visualize the results.

Consequently, for WoS we refined the data by “DOCUMENT TYPES: (article OR proceedings paper) AND LANGUAGES: (English)”, which resulted in 291 articles. We acted correspondingly when we refined the results for Scopus, which meant that we continued refining by (LIMIT-TO (DOCTYPE,“ar”) OR LIMIT-TO (DOCTYPE,“cp”)) AND (LIMIT-TO(LANGUAGE,“English”)), which generated 549 records.

The refinement results, attributable to the filters performed on both WoS and Scopus, were exported in “txt” format (in the case of WoS) and in “csv” format (in the case of Scopus) to VOSviewer. It has to be stressed that for the data export, the operating system used (Windows or Mac) was taken into account, through appropriate selections provided by the VOSviewer interface.

5. Data Analysis

In order to obtain answers to the research questions assigned to our research objective in the field of technological megatrends and their societal manifestation, with reference to the evolution of the research interest in this topic over time (Q1), the main research areas in which the subject has been researched (Q2), the countries where more attention is paid to research in this field (Q3), the main publications in this field (Q4), and the main papers and authors in the field of megatrends (Q5), we organized the analysis of the data from the refined results up to this stage into the following sections: year of publication, scientific category, corresponding authors’ countries, most relevant sources/journals, and most cited articles and authors.

5.1. Year of Publication

This section is dedicated to obtaining an overview of the dynamic evolution of the research direction between 1982 and 31 October 2021. This clarification is necessary in order to ensure the replication of the research, with explicit reference to the possibility that additional papers will appear after 31 October 2021, due to the prepublication (online version) and postpublication gaps, to which the indexing delays are added. The graphical situation of the dynamic evolution of the number of papers per year is illustrated in Figure 3.

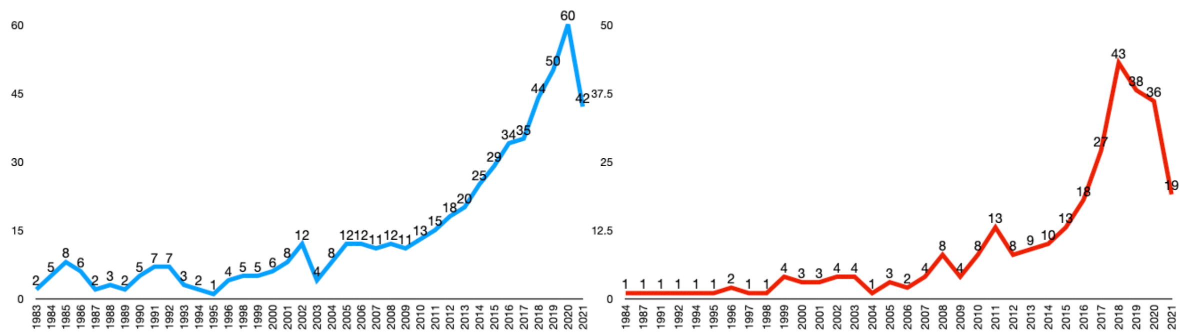

Figure 3. Dynamic evolution of Scopus (**left**) and WoS (**right**) publications between 1982 and 2021.

In Scopus, we noticed that the first papers on this topic were issued in 1983, when two papers were published; that until 2001, a maximum of eight papers per year were published, provided that there were years with one paper only (see 1995) but also years without any publications (see 1997); that, between 2002 and 2010, the annual number of papers on this topic ranged between 10 and 13, except for the years 2003 and 2004, when there were 4 and 8 papers, respectively; that since 2011, there has been a continuous increasing trend from 15 to 60 papers per year; and that in the first ten months of 2021, there have been 42 papers, which indicates that this year will not exceed the maximum value of 60 papers in 2020. We can acknowledge that 2010 was the year when the volume of papers on the megatrends topic expanded and that, after 2016, the threshold of 30 papers per year was crossed.

In WoS, we noticed that the first issuance of a paper on this topic was in 1984, i.e., two years after the concept was proposed; that in the period of 1984–1998 one paper per year was published or even none at all (see 1985, 1986, and 1993), except in 1996, when two papers were published; that from 1999 to 2007, three or four papers were published per year, with the specification that in 2004 only one was published and in 2006 only two; that since 2008, there has been a continuous upward trend from 8 papers to 43 papers, except in 2009, when there were only 4 papers; that after 2018, there was a slow decrease towards 36 papers in 2020, with only 19 papers in the first ten months of 2021. In addition, concerning the data in WoS, we can acknowledge that 2010 was the year when the volume of papers on the topic of megatrends increased, and that after 2015 the threshold of 10 articles per year was crossed.

5.2. Scientific Categories

From the perspective of the analysis by scientific categories, in Figure 4 we identified that the following fields in Scopus contained over 100 papers: engineering (241), computer science (136), and social science (133). These were followed by business management and accounting (83) and environmental science (51).

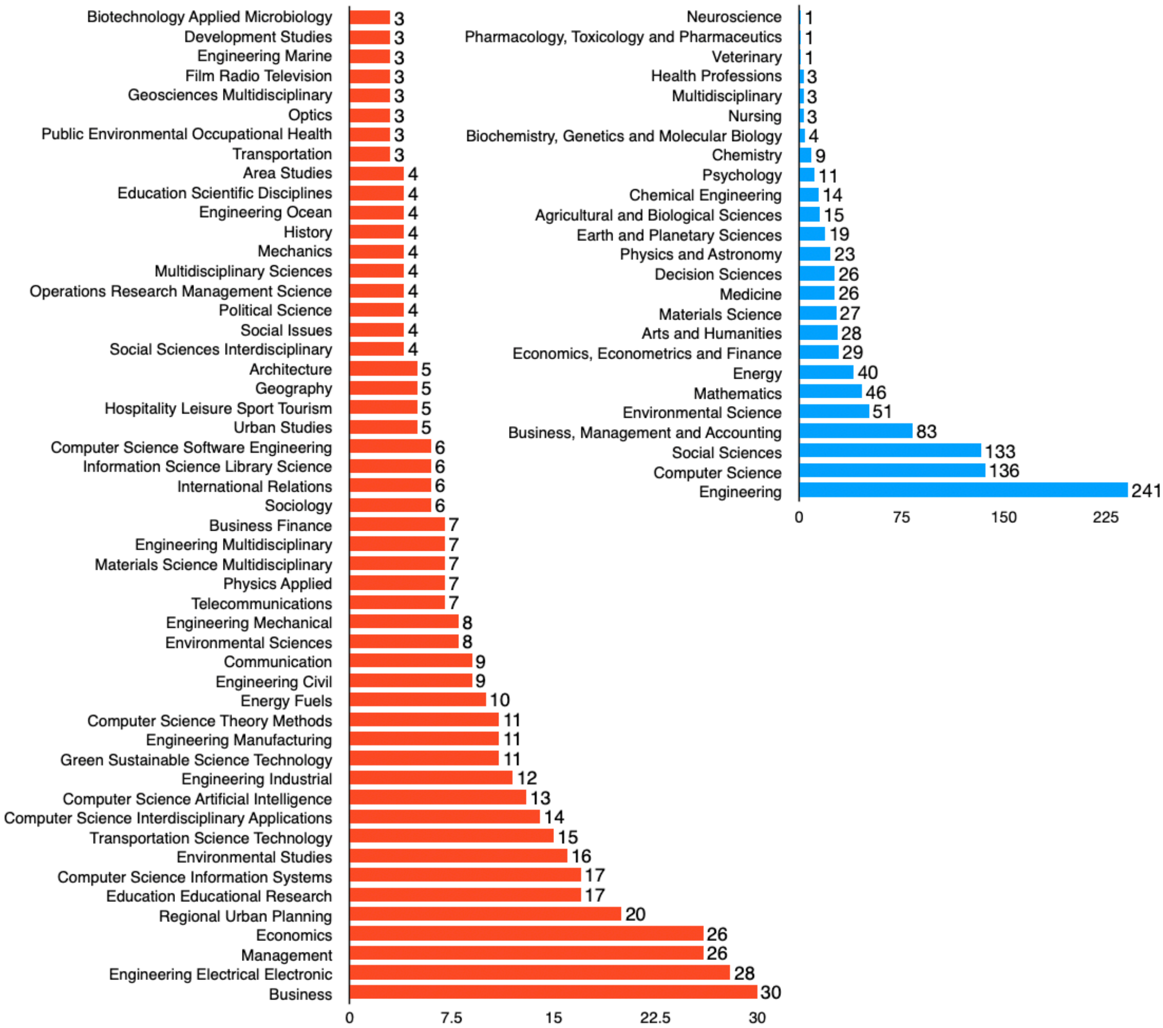

Figure 4. Scopus (**right**) and WoS (**left**) scientific categories between 1982 and 2021.

Between 20 and 50 papers were represented by the fields of mathematics (46), energy (40), economics, econometrics and finance (29), arts and humanities (28), materials science (27), decision sciences (26), medicine (26), and physics and astronomy (23). Between 10 and 19 papers were listed in such fields as Earth and planetary sciences (19), agriculture and biological sciences (15), chemical engineering (14), and psychology (11). Less than 9 papers were itemized in the fields of chemistry (9) and biochemistry, genetics, and molecular biology (4). The studies that were poorly represented in this field, in other words, those included in fewer than three papers, were: nursing (3); health professions (3); multidisciplinary (3); veterinary (1); pharmacology, toxicology, and pharmaceutics (1); and neuroscience (1).

The analysis by category for the WoS database showed the fact that the fields were much more detailed compared to the Scopus database, and that no field exceeded the limit of 30 papers. Thus, with 30 papers we had the field of business; with 28 papers, the field of electrical and electronic engineering; with 26 papers each, the fields of economics and management; with 20 papers, the field of regional urban planning; with 17 papers each, the fields of education, educational research, and computer science information systems; with 16 papers, the field of environmental studies; with 15 papers, the field of transportation science technology; with 14 papers, the field of computer science—interdisciplinary applications; with 13 papers, the field of computer science—artificial intelligence; with 12 papers, the field of industrial engineering; with 11 papers each, the fields of green sustainable science technology, engineering manufacturing, and computer science theory and methods; and with 10 papers, the field of energy fuels. The other 35 fields, each comprising less than 10 papers, were represented by: civil engineering (9), communication (9), environmental sciences (8), mechanical engineering (8), telecommunications (7), applied physics (7), multidisciplinary materials science (7), multidisciplinary engineering (7), business finance (7), sociology (6), international relations (6), information science—library science (6), and computer science—software engineering (6).

5.3. Corresponding Authors' Countries

We acknowledge that obtaining an overview of the countries where more attention is paid to research in the field of technological megatrends at the societal level, based on the metadata provided by the two databases, Scopus and WoS, was possible by targeting the research using the criterion of the country of origin of the corresponding author. Of course, there may be changes in the affiliation of the corresponding author over time, including the country of affiliation, but our research had as a reference date the date on which the paper was submitted and/or accepted for publication, which was mostly related to the funding of that research.

Therefore, from the perspective of analyzing the country of the corresponding author criterion (Figure 5), we noticed that in Scopus, the ranking of the first 15 countries was led by the United States of America with 116 papers, followed by Germany (87), Italy (30), the United Kingdom (29), Australia (20), and Finland (20). With less than 20 papers were: South Korea (19), China (19), Canada (17), Austria (16), the Netherlands (16), the Russian Federation (16), France (15), Spain (15), and Poland (11).

The analysis of the country of the corresponding author criterion detected that in WoS, the ranking of the first 15 countries was also led by the United States of America with 62 papers, followed by Germany (55), the United Kingdom (20), and Italy (20). The ranking continued with the Netherlands (15), Spain (13), South Korea (11), Australia (11), Finland (10), Poland (9), Hungary (8), India (7), China (7), Austria (6), and Sweden (6).

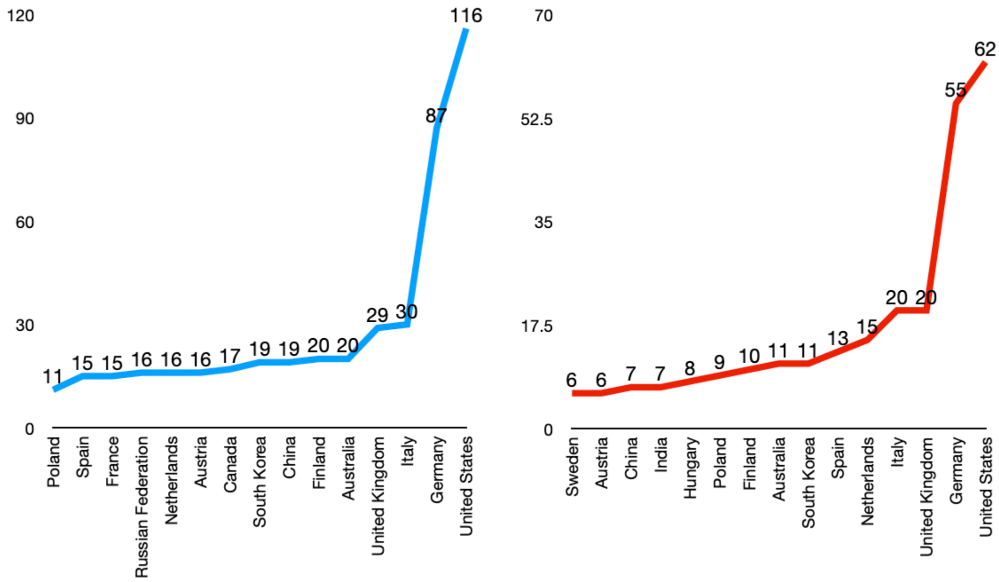

Figure 5. Distribution of publications by country, Scopus (**left**) and WoS (**right**), between 1982 and 2021.

5.4. The Most Relevant Sources

The criteria established through the selection and filtering of the results helped us to establish the most relevant journals in which articles on the topic of megatrends were published. In order to obtain an overview of the journals with a high degree of relevance to our research topic, we proceeded to make a top-10 list of the journals with the most numerous publications in the field. The top 10 journals indexed in Scopus and WoS are presented in Table 2.

Table 2. Top 10 most relevant sources between 1982 and 2021.

Scopus		**Web of Science**	
SAE Technical Papers	11	*VDI Berichte*	7
Advances in Intelligent Systems and Computing	10	*Technological Forecasting and Social Change*	6
VDI Berichte	9	*Advances in Intelligent Systems and Computing*	4
Lecture Notes in Computer Science, including the subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics	5	*International Conference on Traffic and Transport Engineering* (ICTTE) 2018	3
Technological Forecasting and Social Change	5	*Lecture Notes in Computer Science*	3
Campus-Wide Information Systems	4	*Procedia CIRP*	3
Sustainability	4	*Sustainability*	3
AIP Conference Proceedings	3	*2019 IEEE 23rd International Conference on Intelligent Engineering Systems* (INES) *2019*	2
Aistech Iron and Steel Technology Conference Proceedings	3	*Acta Horticulturae*	2
Communications in Computer and Information Science	3	*Communications in Computer and Information Science*	2

Our analysis highlighted that in Scopus, the first position was held by SAE Technical Papers with 11 papers, followed by Advances in Intelligent Systems and Computing with 10 papers and VDI Berichte with 9 papers. Additionally, with 5 papers each, we acknowledge the journals Lecture Notes in Computer Science, including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics, and Technological Forecasting and Social Change. The journals Campus-Wide Information Systems and Sustainability were also included in the Scopus top 10, with 4 papers each. The next group was formed by AIP Conference Proceedings, Aistech Iron and Steel Technology

Conference Proceedings, and Communications in Computer and Information Science, with 3 papers each.

Regarding the top 10 journals in WoS, the first position was held by VDI Berichte, with 7 papers, followed by Technological Forecasting and Social Change with 6 papers and Advances in Intelligent Systems and Computing with 4 papers. The top 10 was continued by International Conference on Traffic and Transport Engineering (ICTTE) 2018, Lecture Notes in Computer Science, Procedia CIRP, and Sustainability, with 3 papers each. Finally, with 2 papers each, the last group was formed by 2019 IEEE 23rd International Conference on Intelligent Engineering Systems (INES) 2019, Acta Horticulturae, and Communications in Computer and Information Science.

5.5. Most Cited Articles and Authors

The credibility and prestige of the journals have a considerable impact on how researchers appreciate and use articles published in a particular field [51]. Thus, in order to carry out this component of the bibliometric analysis, we created a top-15 list of the most cited articles for each of the databases: Scopus (Table A1) and Web of Science (Table A2).

From our queries in the Scopus database using the criteria established in consensus with the objective of our research, as previously defined, on the topic of technological megatrends at the societal level, we notice that the first three positions in the top 15 presented in Table A1 were held by the paper Environment and policy factors shaping global e-commerce diffusion: A cross-country comparison by J. Gibbs, K.L. Kraemer, and J. Dedrick [52] in Information Society (2003), with 234 citations, followed by Cloud computing: Today and Tomorrow by W. Kim [53], in The Journal of Object Technology (2009) with 212 citations and Towards exact molecular dynamics simulations with machine-learned force fields by S. Chmiela, H.E. Sauceda, K.R. Müller, and A. Tkatchenko [54], in Nature Communications (2018), with 195 citations. In this list of the top 15 most cited papers and authors, we discovered that the most cited sources were Information Society (234), The Journal of Object Technology (212), and Nature Communications (195). From the perspective of corroborating the importance of the journals included in the top 15 most cited papers in Scopus, we detected that only two journals appeared in the top 10 most relevant sources, namely, Technological Forecasting and Social Change, with five papers, and Sustainability, with four papers.

From our queries in the WoS database using the criteria established in consensus with the objective of our research, as previously defined, on the topic of technological megatrends at the societal level, we noticed that the first two positions in the top 15 presented in Table A2, were held by the paper The implications of megatrends in information and communication technology and transportation for changes in global physical activity by M. Pratt, O.L. Sarmiento, F. Montes, D. Ogilvie, B.H. Marcus, L.G. Perez, and R.C. Brownson [55], in The Lancet (2012), with 165 citations, followed by Environment and policy factors shaping global e-commerce diffusion: A cross-country comparison by J. Gibbs, K.L. Kraemer, and J. Dedrick [52] in Information Society (2003), with 157 citations, and by Simulation in Manufacturing: Review and Challenges by D. Mourtzis, M. Doukas, and D. Bernidaki [56], in Procedia CIRP (2014), with 124 citations. In this top-15 list of the most cited papers and authors, we discovered that the most cited sources were The Lancet (165), Information Society (157), and Procedia CIRP (124). From the perspective of corroborating the importance of the journals included in the top 15 most cited papers in WoS, we detected that only two journals appeared in the top 10 most relevant sources, namely, Technological Forecasting and Social Change, with 6 papers, and Procedia CIRP, with 3 papers.

6. Data Visualization

Consistent with the research model proposed by us in the above methodology, data visualization and interpretation represented the final stage of our research. This stage of data visualization was specifically designed to identify the set of answers to the last two research questions, with reference to the source and the author cocitation networks (Q6), the coauthorship clusters by country (Q7), and the clusters of megatrend-related concepts (Q8). For this purpose, we conducted a visual analysis of the source and author cocitations, the coauthorship clusters, and the co-occurrence of the keywords. It is important to understand that throughout these visual analyses, a special importance was given to the analysis of the cocitations [57], taking into account the fact that, currently, the citation impact indicators play an important role in evaluating research [51], in conjunction with the great attention paid to bibliometric and scientometric literature.

All these analyses were made possible by considering the attributes attached to each document in the database (such as the authors, keywords, and publication date), which are connected to each other by way of the document. According to Aria and Cuccurullo [12], the connections between various attributes can be represented by a matrix (marked with A) of the type $Document \times Atribute$.

At the basis of these bibliometric analyses was the analysis of the relations between articles and papers by means of the bibliographic references. This started with bibliographic coupling, a term that was invented by Kessler [58], based on the so-called bibliographic coupling unit, which involves coupling two articles by means of a third article that was found in the list of the bibliographic references of each of the two articles. The idea of bibliographic coupling, as Kessler [58] points out, is older and was suggested in 1956 by R. M. Fano (in *Documentation in Action*, 1956. Chapter XIV-e, pp. 238–244. Reinbold Publishing Corp., New York, NY, USA) and later by M.M. Kessler in 1958 (in *Concerning some problems of intrascience communication*, 1958, Lincoln Laboratory Group Report pp. 45–85, 8 December). In other words, we say that two articles are bibliographically coupled if at least one cited reference appears in the bibliography or the reference list of both articles, in which case we can talk about the formation of a network of bibliographic couples, for which Aria and Cuccurullo [12] suggest the following equation:

$$B_{cup} = A \times A' \tag{3}$$

where A is the matrix $Document \times Cited\ reference$ for the document i, A' is the matrix $Document \times Cited\ reference$ for the document j, and the element b_{ij} indicates the number of the bibliographic couples between the document i and the document j.

Similarly, from Equation (3), Aria and Cuccurullo [12] suggested Equation (4) for a network of cocitations, Equation (5) for a network of coauthorship/collaboration, and Equation (6) for a network of keyword co-occurrences, as follows:

$$B_{cocit} = A \times A' \tag{4}$$

where element b_{ij} specifies how many citations there are between the document i and the document j, and the main diagonal of the matrix B_{cocit} contains the number of citations of a reference in the given collection.

$$B_{coll} = A \times A' \tag{5}$$

where element b_{ij} illustrates the number of collaborations between the authors i and j.

$$B_{coocc} = A \times A' \tag{6}$$

where A and A' are matrices of the type $Document \times Word$, where $Word_i$ for A and $Word_j$ for A' can alternatively take the following values: keywords, authors' keywords, or terms extracted from the title or the abstracts of the articles. The element b_{ij} illustrates the number of occurrences between $Word_i$ and $Word_j$.

The use of a computer tool for bibliometric analyses offers the possibility of filtering and selection in order to create a bibliometric network of only those sources, references, and authors that exceed a minimum threshold of bibliometric coupling [14], with the aim of highlighting the essential aspects specific to each type of analysis. In the case of VOSviewer, this threshold is implicitly defined at a value depending on the type of analysis, i.e., we could update this threshold depending on the domain for which the analysis was performed.

6.1. Cocitation Analysis

Within bibliometric networks, the cocitation of two articles occurs when both articles are cited by a third, which, in the opinion of Stopar and Bartol [14], leads to the emergence of a cocitation network of the cited references and/or sources as well as the cited authors. Even if the number of cocitations is equal to the number (degree) of couplings, as Alt and Kirsch [59] pointed out in their analysis, similarly to bibliographic coupling networks, Aria and Cuccurullo [12] establish Equation (4) for the cocitation network.

From a functional perspective, VOSviewer offers the possibility to make three types of cocitation, namely, the cocitation of bibliographic references, the cocitation of sources (in other words, by journals in which the bibliographic references were published), and the cocitation of authors. In our cocitation analysis, our attention was focused on journals and authors.

In order to perform a cocitation analysis of the cited sources, we chose as the threshold of our analysis the value of 10 citations per source/journal (compared to the default value of 20 citations of VOSviewer), motivated by the fact that the field for which we were performing the analysis is niche. Our analysis discovered that the threshold of 10 cocitations was exceeded by 65 of the 10,373 unique sources identified for the Scopus database, while for the WoS database, of the 7.647 unique sources identified, only 85 exceeded this threshold, of which one source was removed due to the mishandling of the source title (No title captured—see the cleaning data). In Figure 6, we present a VOSviewer-generated view of the bibliometric network of cocitations in Scopus journals that exceeded the threshold of 10 citations.

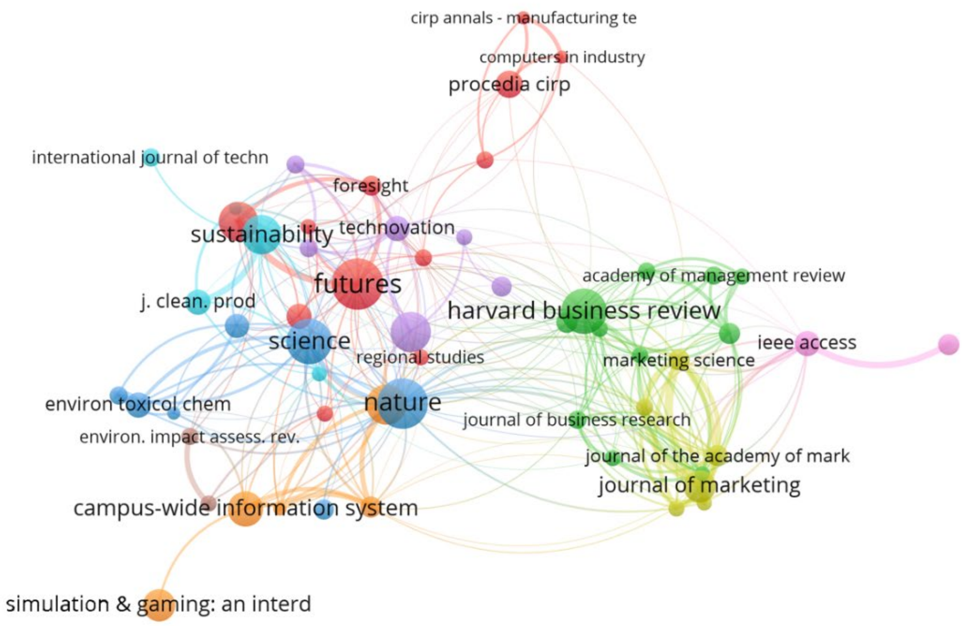

Figure 6. Cocitation analyses between 1982 and 2021 for journals—Scopus.

From the perspective of the cocitation analysis of sources, we noticed that the central places of the network of the bibliometric cocitations in Scopus were held by journals, such as: Futures, Nature, Science, Harvard Business Review, Sustainability, and Campus-Wide Information Systems.

In Figure 7, we present a VOSviewer-generated view of the bibliometric network of cocitations in WoS journals that exceeded the threshold of 10 cocitations.

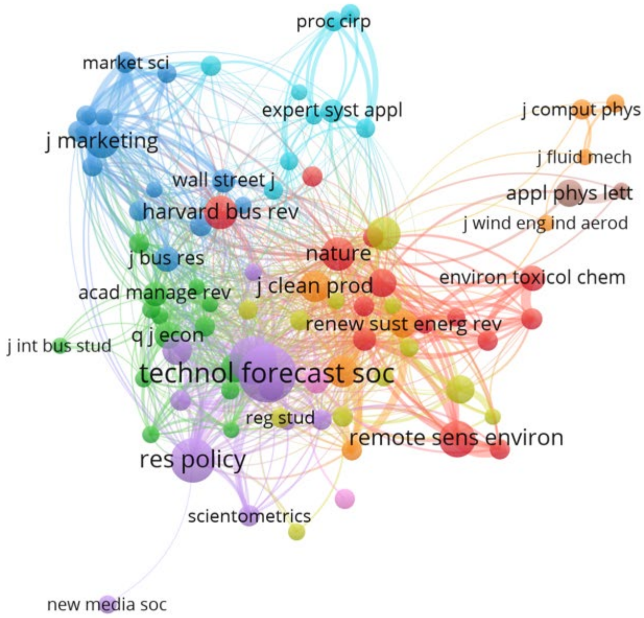

Figure 7. Cocitation analyses between 1982 and 2021 for journals—WoS.

The cocitation analysis, according to the journal criteria, highlighted that the central places of the network of the bibliometric cocitations in WoS were held by Technological Forecasting and Social Change, followed in the second position by Remote Sensing of Environment and Research Policy, and in the third position by Harvard Business Review, Nature, and The Journal of Marketing.

Regarding the cocitation analysis of authors, we proceeded to establish a threshold of five minimum citations for each author. Consequently, our analysis highlighted that for the Scopus database, of the 21,764 authors of bibliographic references, 463 authors met the minimum citation requirement of five citations, and for the WoS database, of the 8858 authors of bibliographic references, only 125 were above this threshold.

From the perspective of the cocitation analysis of the cocited authors, we noticed that in Figure 8 the central places of the bibliometric network in Scopus were dominated by Ahamer, G. (62); Nijkamp, P. (58); Franke, J. (34); Hakalehto, E. (29); Czarneki, I. (29); Kourtit, K. (28); Wang, Y. (24); Zhang, I. (23); and Naisbitt, J. (18).

From the perspective of the *cocitation analysis* of the cocited authors, we noticed that Figure 9 the central places of the bibliometric network in WoS were dominated by Czarnecki, I. (23); Naisbitt, J. (22); OECD (20); Geels, F.V. (19); Porter, M.E. (19); World Bank (18); Nijkamp, P. (18); Acemoglu, D. (16); PWC (16); and Aghion, P. (14).

6.2. Coauthorship Analysis

According to Glänzel and Schubert [37], who argue in particular that a scientific network of authors is a network in which the nodes constitute the authors that can be grouped by country and the links between the nodes of the network represent the collaborative relationships between the authors, i.e., the coauthorships, similarly to the bibliometric coupling network, an author's collaboration network can be obtained, generally, by using Equation (5) [12].

The coauthorship analysis, in our case, highlighted the links between the authors with a distribution of these collaborations according to the countries in which they operate. Our analysis, performed with the help of VOSviewer, for the 549 records in the Scopus database identified 91 countries associated with the collaborating authors, of which only 25 countries were tightly interconnected, in the sense that they exceeded our minimum threshold of five documents. In the same vein, of the 291 records in the WoS database, VOSviewer identified 59 countries associated with the collaborating authors, of which only 21 countries were tightly interconnected. The graphical representation of the coauthorship network of the interconnected countries for Scopus is shown in Figure 10 (left).

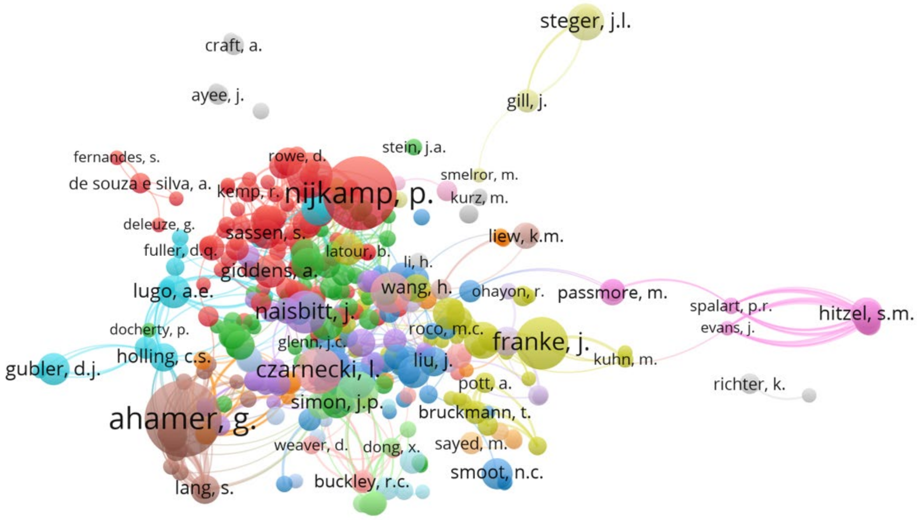

Figure 8. Cocitation analyses between 1982 and 2021 for authors—Scopus.

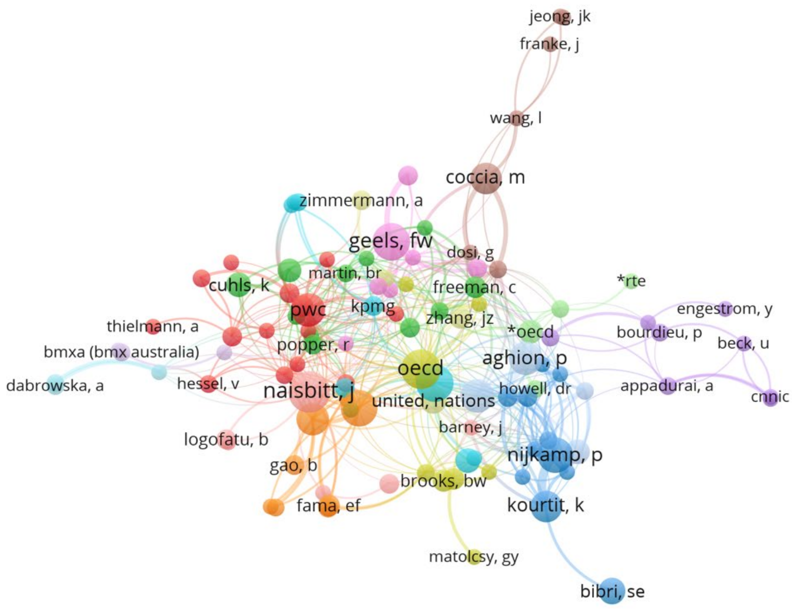

Figure 9. Cocitation analyses between 1982 and 2021 for authors—WoS.

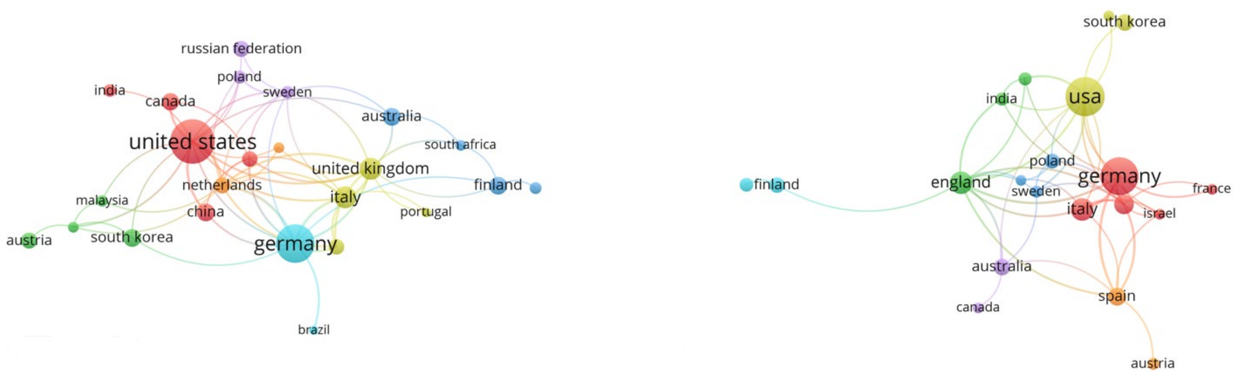

Figure 10. Coauthorships between 1982 and 2021 by countries—Scopus (**left**) and WoS (**right**).

The coauthorship analysis of the subject of technological megatrends at the societal level highlighted the fact that for the Scopus database there was intense collaboration initiated by authors from the United States, Germany, Italy, the United Kingdom, Australia, and Finland. The bibliometric analysis highlighted, in this case, the existence of seven collaboration clusters of authors from the following countries: (1) Canada, China, France, India, and the United States; (2) Austria, Japan, Malaysia, and South Korea; (3) Australia, Finland, Hungary, and South Africa; (4) Italy, Portugal, Spain, and the United Kingdom; (5) Poland, the Russian Federation, and Sweden; (6) Brazil and Germany; and (7) the Netherlands and Switzerland. The centralized situation of these clusters by country is represented in Table 3. The graphical representation of the coauthorship network of the interconnected countries for WoS is shown in Figure 10 (right).

Table 3. The clusters of the countries between 1982 and 2021.

Scopus Clusters	*WoS Clusters*
Canada, China, France, India, United States.	*France, Germany, Israel, Italy, Netherlands.*
Austria, Japan, Malaysia, South Korea.	*England, India, China.*
Australia, Finland, Hungary, South Africa.	*Poland, Portugal, Sweden.*
Italy, Portugal, Spain, United Kingdom.	*Russia, South Korea, United States.*
Poland, Russian Federation, Sweden.	*Australia, Canada.*
Brazil, Germany.	*Finland, Hungary.*
Netherlands, Switzerland.	*Austria, Spain.*

The coauthorship analysis showed that for WoS there was intense collaboration initiated by authors from the United States, Germany, Italy, and England. The bibliometric analysis highlighted, in this case, the existence of seven collaboration clusters of authors from the following countries: (1) France, Germany, Israel, Italy, and the Netherlands; (2) England, India, and China; (3) Poland, Portugal, and Sweden; (4) Russia, South Korea, and the United States; (5) Australia and Canada; (6) Finland and Hungary; and (7) Austria and Spain. The centralized situation of these clusters by country is shown in Table 3.

6.3. Co-Occurrence of Keywords Analysis

The co-occurrence analysis of the keywords did not start with the analysis of the bibliographic references, but was focused on highlighting the relationships between the keywords that the authors considered to be the essence of their research, also called Author Keywords (AKs). In turn, this analysis can be extended to consider what the editorial team considered the paper to be focused on, i.e., the addition of the Keyword Plus (KP) to the AKs. Thus, an overview was obtained of the connection between the common keywords of the papers that were the object of the bibliometric analysis through a graphical visualization of the coword network. In this context, the objective of the keyword analysis was to outline a conceptual structure of the domain of megatrends through the co-occurrence of the keywords as a network which, similarly to the bibliometric coupling networks [12], could be obtained using Equation (6).

In the case of the co-occurrence analysis of keywords, in Figure 11 and Table 4 our attention was focused on the words introduced by the authors of the 549 papers in Scopus and the 291 papers in WoS. Thus, for the 549 records in the Scopus database, there were 1500 unique keywords suggested by the authors; above the threshold of three occurrences of the keyword set by the VOSviewer algorithm, 51 eligible keywords were obtained, of which the first seven, in order of their occurrence, were: megatrends, globalization, industry 4.0, technology, internet of things, artificial intelligence, and digitalization. Our bibliometric analysis for the co-occurrence of the keywords offered by the authors of the 549 papers in Scopus highlighted nine clusters of keywords (Table 4), namely: (1) digital transformation, digitalization, ecosystems, industry 4.0, internet of things, smart city, trends, and virtual reality; (2) artificial intelligence, automation, future of work, machine learning, manufacturing, robotics, and simulation; (3) energy, foresight, megatrends, strategic management, strategic planning, technology assessment, and uncertainty; (4) connectivity, education, innovation, megatrend, strategy, sustainability, and urbanization; (5) future, future studies, globalization, higher education, information technology, and technological change; (6) big data, globalization, India, leadership, and management; (7) climate change, Delphi method, sustainable development, and technology; (8) service-oriented computing, evaluation, and web service discovery; and (9) autonomous driving and security.

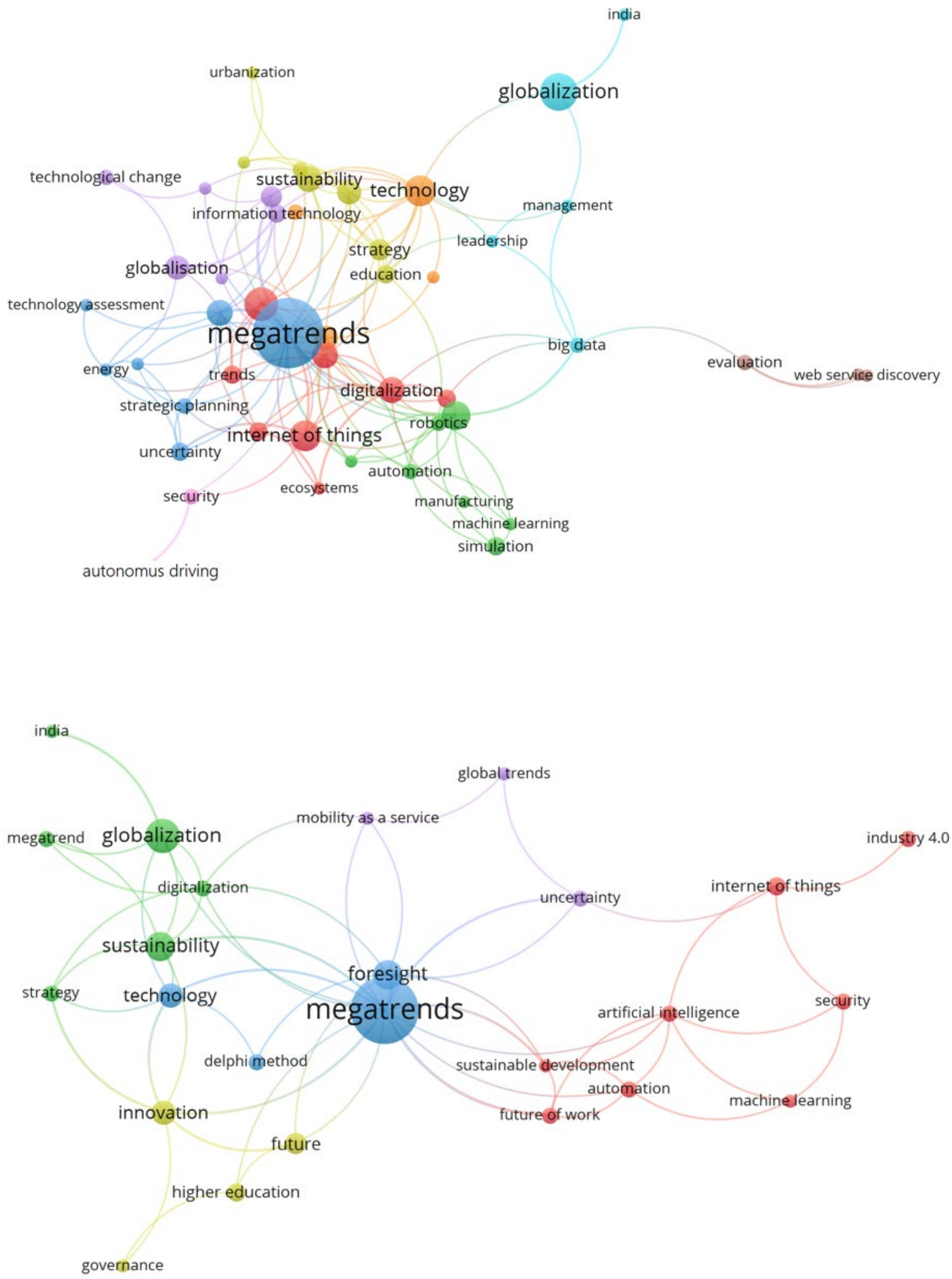

Figure 11. The occurrence of the keywords between 1982 and 2021—Scopus (**above**) and WoS (**below**).

Table 4. The clusters of keywords between 1982 and 2021.

Scopus Clusters	WoS Clusters
Digital transformation, digitalization, ecosystems, industry 4.0, internet of things, smart city, trends, virtual reality.	Artificial intelligence, automation, future of work, industry 4.0, internet of things, machine learning, security, sustainable development.
Artificial intelligence, automation, future of work, machine learning, manufacturing, robotics, simulation.	Digitalization, globalization, India, megatrend, strategy, sustainability.
Energy, foresight, megatrends, strategic management, strategic planning, technology assessment, uncertainty.	Delphi method, foresight, megatrends, technology.
Connectivity, education, innovation, megatrend, strategy, sustainability, urbanization.	Future, governance, higher education, innovation.
Future, future studies, globalization, higher education, information technology, technological change.	Global trends, mobility as a service, uncertainty.
Big data, globalization, India, leadership, management.	
Climate change, Delphi method, sustainable development, technology.	
Service-oriented computing, evaluation, web service discovery.	
Autonomous driving, security.	

For the 291 records of the second database, Web of Science, there were 990 unique keywords proposed by the authors; above the threshold of three occurrences of the keyword set by the VOSviewer algorithm, 26 keywords were noted as eligible, of which the first seven, in order of their occurrence, were: megatrends, globalization, foresight, sustainability, innovation, technology, and future. Our bibliometric analysis for the co-occurrence of the keywords offered by the authors of the 291 papers in WoS highlighted five clusters of keywords (Table 4), namely: (1) artificial intelligence, automation, future of work, industry 4.0, internet of things, machine learning, security, and sustainable development; (2) digitalization, globalization, India, megatrend, strategy, and sustainability; (3) Delphi method, foresight, megatrends, and technology; (4) future, governance, higher education, and innovation; and (5) global trends, mobility as a service, and uncertainty.

7. Discussions

In the context of continuous change at the societal level, highlighted with predilection at the beginning of the 21st century [1] as a characteristic of contemporary society, which requires the efficient management of the resultant opportunities and threats on a global scale [3] in a predictive manner, our research focused on the idea of bibliographically mapping the literature associated with the concept of societal technological megatrends, beginning with the emergence of the concept of megatrends in 1982 [17] and ending in October 2021. By referring to reputable studies in the field of bibliometric analysis [12–15] in order to achieve our research objective, a set of eight research questions was established, for which answers were obtained by applying an appropriate research methodology in accordance with a research model built by reference to the views of several authors, such as Andrade-Valbuena, Merigo-Lindhal, and Olavarrieta [36]; Zupic and Čater [15]; Glänzel and Schubert [37]; Aria and Cuccurullo [12]; and Orastean, Marginean, and Sava [38]. In addition to Microsoft Excel, which was used frequently for the graphical representation of the results of our queries during the data analysis, VOSviewer, which is one of the most commonly used software for bibliometric analysis [41], was employed for the visualization and interpretation of the data. In the following paragraphs, we discuss the answers obtained for each of the research questions.

When it comes to the evolution in time of the research interest in the field of technological megatrends (Q1), our analysis highlighted the modest start of the present topic of megatrends in the years following 1982, especially regarding WoS, stating that the volume of articles on the topic in Scopus was significantly greater than in WoS, along with the fact that after 2010, a continuous upward trend in the megatrends topic was registered. Between the two academic databases, Scopus and WoS, we noticed that the journals indexed in

Scopus were more eager to accept papers on this topic, but also that the authors were more oriented towards the indexed Scopus journals.

Touching upon the main research areas in which papers on this topic have been identified (Q2), our analysis demonstrated that in Scopus the domains were more aggregated compared to WoS, where the domains were more fragmented; that in both databases, we could find the fields of engineering, business and management, and economics (social science) in the top five research areas; and that some fields appeared in only one of the two databases, such as computer science and environmental science, which were spotted only in Scopus, while the field of regional urban planning was discovered only in WoS.

As far as the countries that pay more attention to research in the field of megatrends (Q3) are concerned, our analysis highlighted the fact that in both Scopus and WoS the first positions were given to the United States, Germany, Italy, and the United Kingdom (England). What drew our attention regarding this distribution was that countries such as Canada, the Russian Federation, and France appeared only in Scopus, and countries such as Hungary, India, and Sweden appeared only in WoS. In other words, researchers interested in funding opportunities and collaborations on this topic should focus on the countries in the highest positions on these lists; however, the topic can be disseminated and capitalized in journals published in countries that are not found in this ranking.

Pertaining to the main publications in the field of megatrends (Q4), from the perspective of the number of published articles, we highlighted the fact that there were journals that ranked among the highest in both academic databases, namely: Advances in Intelligent Systems and Computing ($10_{\mathrm{SCOPUS}}/4_{\mathrm{WoS}}$), VDI Berichte ($9_{\mathrm{SCOPUS}}/7_{\mathrm{WoS}}$), Lecture Notes in Computer Science ($5_{\mathrm{SCOPUS}}/3_{\mathrm{WoS}}$), Technological Forecasting and Social Change ($5_{\mathrm{SCOPUS}}/6_{\mathrm{WoS}}$), Sustainability ($4_{\mathrm{SCOPUS}}/3_{\mathrm{WoS}}$), and Communications in Computer and Information Science ($3_{\mathrm{SCOPUS}}/2_{\mathrm{WoS}}$). The most acknowledged Scopus indexed journal on this topic was SAE Technical Papers, with eleven papers, and in WoS it was VDI Berichte, with seven papers. In corroboration also with the answer to Q1, the WoS indexed journals presented a smaller number of papers, even in the case of journals that appeared in both databases, such as the case of the journals Advances in Intelligent Systems and Computing ($10_{\mathrm{SCOPUS}}/4_{\mathrm{WoS}}$) and Lecture Notes in Computer Science ($5_{\mathrm{SCOPUS}}/3_{\mathrm{WoS}}$); this led us to the idea that access to and/or interest in indexing journals in WoS is either more restricted (including financially) or more reduced.

In connection with the main papers and authors in the field of megatrends (Q5) according to our analysis, we noticed that nine papers were found only in the Scopus database, that another nine papers were found only in the Web of Science database, and that six papers were common to both databases. From the comparative analysis of the rankings for both academic databases, we detected that six papers were shared between the two; that the papers in WoS were less frequently cited than those in Scopus; that the paper Environment and policy factors shaping global e-commerce diffusion: A cross-country comparison by J. Gibbs, K.L. Kraemer, and J. Dedrick [52] in Information Society (2003) was the highest ranked in both databases, with 234 citations in Scopus and 157 citations in WoS; and that from the perspective of corroborating the importance of the journals included in the top-15 most cited papers in WoS, we detected that only two journals appeared in the top-10 most relevant sources, namely, Technological Forecasting and Social Change with six papers and Procedia CIRP with three papers. Each of the authors ranked among the highest in either database appeared only once, with a single paper.

While corroborating the importance of the journals included in the top-15 most cited papers in Scopus and WoS, we discovered that in Scopus only two journals appeared in the top-10 most relevant sources, namely, Technological Forecasting and Social Change with five papers and Sustainability with four papers, while in WoS it was only two journals, Technological Forecasting and Social Change with six papers and Procedia CIRP with three papers. Consequently, we detected the presence of the journal Technological Forecasting and Social Change in the highest rankings of both databases (with five papers in Scopus and six in WoS) for both performance criteria, namely, "the most relevant sources" and "the most cited papers".

In relation to the most cited authors in Scopus on the topic of technological megatrends at the societal level, we noted J. Gibbs, K.L. Kraemer, and J. Dedrick 234 times [52]; W. Kim 212 times [53]; and S. Chmiela, H.E. Sauceda, K.R. Müller, and A. Tkatchenko 195 times [54]. In WoS, the most cited authors on the same topic were M. Pratt, O.L. Sarmiento, F. Montes, D. Ogilvie, B.H. Marcus, L.G. Perez, and R.C. Brownson 165 times [55]; J. Gibbs, K.L. Kraemer, and J. Dedrick 157 times [52]; and D. Mourtzis, M. Doukas, and D. Bernidaki 124 times [56]. Here, we noticed that the authors J. Gibbs, K.L. Kraemer, and J. Dedrick ($234_{\text{SCOPUS}}/157_{\text{WoS}}$), with their paper Environment and policy factors shaping global e-commerce diffusion: A cross-country comparison, published in Information Society, appeared in both Scopus and WoS in the top three positions. We were particularly surprised by the fact that J. Naisbitt, the author who launched the concept of societal and technological megatrends [17], did not appear in the list of the most cited articles with his studies or, implicitly, in the list of the most cited authors in the two databases, although his papers appeared in the results of both our queries and, moreover, he is present on Google Scholar with papers in the field of societal technological megatrends with a large number of citations.

Our analysis clearly showed that the papers in Scopus were much more frequently cited than the papers in WoS, which entitles us to underline the fact that from this perspective authors have a greater inclination to research the topic of megatrends in the Scopus indexed journals in comparison with the WoS indexed journals.

Regarding the source and the author cocitation networks (Q6) of the two bibliometric databases, the most cocited journals on the subject of technological megatrends at the societal level were Futures, Technological Forecasting and Social Change, Nature, Science, Harvard Business Review, Remote Sensing of Environment, Research Policy, Sustainability, The Journal of Marketing, and Campus-Wide Information Systems, while the cocitation analysis of authors detected that the most cocited authors were Naisbitt, J. ($18_{\text{SCOPUS}}/22_{\text{WoS}}$); Nijkamp, P. ($58_{\text{SCOPUS}}/18_{\text{WoS}}$); and şi Czarneki, I. ($29_{\text{SCOPUS}}/23_{\text{WoS}}$). However, the most cocited author in Scopus was Ahamer, G. (62), and in WoS it was Czarneki, I. (23).

With reference to the coauthorship clusters by country (Q7) of the two bibliometric databases, we detected from the visual analysis of the coauthorship network that the most active authors for coauthorship on the subject of technological megatrends at the societal level were those from the USA, Germany, Italy, and Great Britain. The analysis identified the existence in the Scopus database of seven collaboration clusters between authors, namely: (1) Canada, China, France, India, and the United States; (2) Austria, Japan, Malaysia, and South Korea; (3) Australia, Finland, Hungary, and South Africa; (4) Italy, Portugal, Spain, and the United Kingdom; (5) Poland, the Russian Federation, and Sweden; (6) Brazil and Germany; and (7) the Netherlands and Switzerland. There were also seven clusters found in WoS, namely: (1) France, Germany, Israel, Italy, and the Netherlands; (2) England, India, and China; (3) Poland, Portugal, and Sweden; (4) Russia, South Korea, and the United States; (5) Australia and Canada; (6) Finland and Hungary; and (7) Austria and Spain.

In terms of the identification of the clusters of megatrend-related concepts identified via the analysis of keywords (Q8), we noticed that the results obtained for the two databases were adjacent, in the sense that a central place was occupied by the concept of *megatrends*, with close links to keywords such as: foresight, globalization, industry 4.0, internet of things, digitalization, technology, artificial intelligence, innovation, future, and sustainability. In the Scopus database, we delimited nine research clusters on megatrend-related concepts, namely: (1) digital transformation, digitalization, ecosystems, industry 4.0, internet of things, smart city, trends, and virtual reality; (2) artificial intelligence, automation, future of work, machine learning, manufacturing, robotics, and simulation; (3) energy, foresight, megatrends, strategic management, strategic planning, technology assessment, and uncertainty; (4) connectivity, education, innovation, megatrend, strategy, sustainability, and urbanization; (5) future, future studies, globalization, higher education, information technology, and technological change; (6) big data, globalization, India, leadership, and management; (7) climate change, Delphi method, sustainable development, and technology; (8) service-oriented computing, evaluation, and web service discovery; and (9) autonomous driving and security. Contrastingly, in WoS we found only five clusters on megatrend-related concepts, namely: (1) artificial intelligence, automation, future of work, industry 4.0, internet of things, machine learning, security, and sustainable development; (2) digitalization, globalization, India, megatrend, strategy, and sustainability; (3) Delphi method, foresight, megatrends, and technology; (4) future, governance, higher education, and innovation; and (5) global trends, mobility as a service, and uncertainty.

8. Conclusions

Through the answers formulated for the eight research questions, we detected that our research objective, namely, to perform a bibliometric analysis of technological megatrends at the societal level, had been met and that a bibliographic mapping of the scientific research in the field of megatrends had been achieved, which meant that we gained an overview of this topical issue which is of great importance at the societal level.

Our research revealed that so far, from the literature we analyzed in the Scopus and Web of Science databases, there are a small number of articles of the literature review type on the topic of technological megatrends with implications at the societal level, and we noted several articles in nonindexed journals in the two databases, as was highlighted in the first section of our paper. However, we also noticed that the literature entirey lacks bibliometric mappings on this topic, which led us to the justified assessment that our study is of potentially high interest, with a high degree of originality that will contribute to the coverage of a gap in the specialized literature. In this way, we also highlighted the useful side of our research for guiding future researchers interested in this topic, in the sense of identifying possible collaborations, funding, research, and guidance for future investigations.

It is important to understand that our study took into account research papers in the scientific databases Scopus and WoS which had been independently reviewed and had met the scientific criteria to be accepted for publication in indexed scientific journals. Therefore, our analysis did not cover sources that were not indexed in the two databases and that could bring to attention some interesting aspects; the research of Retief et al. [32] explicitly underlined this aspect, and Malik and Janowska [28] noticeably stated that the opinions of authors, including those of consulting firms, are influenced by their own research directions. Consequently, we include these aspects under the heading of research limits, and these are serious points to consider in our future research in the field.

One of the big challenges for our research approach was the design of the query intended to decide the selection of the articles related to sociotechnological megatrends in particular. Consequently, we included in our search derivatives of the words technological and societal, as well as corelated concepts, such as technological waves. We conclude that the results obtained highlight the fact that there is a relatively large number of articles related to megatrends, but that these articles are extremely dispersed according to their subdomain or category of scientific research in Scopus compared to WoS. Thus, the results of our query also covered areas such as: optics, history, cultural studies, criminology and penology, architecture, nursing, neuroscience, and pharmacology (though with only two or three articles for each subcategory). Our analysis highlights the fact that the major subfields of research on the subject of technological megatrends at the societal level are those of engineering, business, management, economics, computer science, and the environment.

In order to distinguish the main trends of sociotechnological megatrends, we performed an analysis of the occurrence of keywords, using VOSviewer as a software tool to visualize the results of the bibliometric analysis, which led to the identification of nine clusters for the Scopus database and five clusters for the Web of Science database. The analysis of these clusters highlighted an extremely important aspect of our research, namely the idea that from a futurological perspective the term megatrends is closely related to predictions of developments in various fields at the societal level, in the following research directions: foresight, globalization, industry 4.0, internet of things, digitalization, technology, artificial intelligence, innovation, future, and sustainability. Therefore, we encourage the prospect of future research related to the assimilation of megatrends with sustainability, technological advancement in close correlation with connectivity and industry 4.0, and—why not?—in the long run, with technological singularity as a global technological evolution [60].

It is easy to see that in the last two decades of the 20th century, the subject of megatrends was commonly approached by well-known futurologists (John Naisbitt, Alvin Tofler, Ray Kurzveil, etc.) and less so by organizations/companies interested in this topic (CSM, the Club of Rome, the Association for Computing Machinery (ACM), etc.). In the first two decades of the 21st century, we noticed a greater interest from organizations/companies (World Future Society (WFS), Gartner, PricewaterhouseCoopers, Delloitte, McKinsey, etc.) to get involved in launching predictions through annual reports that also include technological megatrends with influence at the societal level.

In closing, we appreciate that the current paper represents a rigorously grounded and original approach, achieved through the acquisition of answers to all our research questions related to the most relevant scientific sources, the most important authors, the most cited papers, and the geographical distribution by country. Additionally, we believe that our research could be complemented by a similar analysis of periodic (almost annual) reports developed by consulting groups around the world, from prestigious firms such as: De Gruyter, PwC, EY, Gartner, KPMG, Delloit, Rolland Berger, Frost and Sullivan, FIRES, OECD, and EEA. To all this, we add the utility and necessity of continuing to systematically review the research on the subject of technological megatrends at the societal level through analyses of the concepts and ideas it refers to.

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Appendix A

Table A1. The most cited Scopus articles.

SCOPUS Titles	Authors	Source Tiles	YR	CIT
Environment and policy factors shaping global e-commerce diffusion: A cross-country comparison	Gibbs, J.; Kraemer, K.L.; Dedrick, J. [52]	*Information Society*	2003	234
Cloud computing: Today and Tomorrow	Kim, W. [53]	*Journal of Object Technology*	2009	212

Table A1. *Cont.*

SCOPUS Titles	Authors	Source Tiles	YR	CIT
Towards exact molecular dynamics simulations with machine-learned force fields	Chmiela, S.; Sauceda, H.E.; Müller, K.-R.; Tkatchenko, A. [54]	*Nature Communications*	2018	195
Simulation in manufacturing: Review and challenges	Mourtzis, D.; Doukas, M.; Bernidaki, D. [56]	*Procedia CIRP*	2014	162
The globalization of technological innovation: Definition and evidence	Archibugi, D.; Iammarino, S. [61]	*Review of International Political Economy*	2002	145
Developing breeding schemes to assist mitigation of greenhouse gas emissions	Wall, E.; Simm, G.; Moran, D. [62]	*Animal*	2010	120
Bridging tractions in mode I delamination: Measurements and simulations	Sorensen, L.; Botsis, J.; Gmür, Th.; Humbert, L. [63]	*Composites Science and Technology*	2008	107
What is 5G? Emerging 5G mobile services and network requirements	Yu, H.; Lee, H.; Jeon, H. [64]	*Sustainability* (Switzerland)	2017	88
The "New Urban Europe": Global Challenges and Local Responses in the Urban Century	Nijkamp, P.; Kourtit, K. [65]	*European Planning Studies*	2013	80
A hard slog, not a leap frog: Globalization and sustainability transitions in developing Asia	Rock, M.; Murphy, J.T.; Rasiah, R.; van Seters, P.; Managi, S. [66]	*Technological Forecasting and Social Change*	2009	79
Barriers and bridges to prevention and control of dengue: The need for a social-ecological approach	Spiegel, J.; Bennett, S.; Hattersley, L.; Zielinski-Gutiérrez, E.; Gubler, D. [67]	*EcoHealth*	2005	79
Sport, Tribes, and Technology: The New Zealand all Blacks Haka and the Politics of Identity	Jackson, S.J.; Hokowhitu, B. [68]	*Journal of Sport & Social Issues*	2002	66
Guide to the literature on convective heat transfer augmentation.	Bergles, A.E.; Webb, R.L. [69]	*American Society of Mechanical Engineers, Heat Transfer Division, (Publication)* (HTD)	1985	60
Urbanization and the global perspective	Smart, A.; Smart, J. [70]	*Annual Review of Anthropology*	2003	58
Global megatrends and their implications for environmental assessment practice	Retief, F.; Bond, A.; Pope, J.; Morrison-Saunders, A.; King, N. [32]	*Environmental Impact Assessment Review*	2016	54

Table A2. The most cited Web of Science articles.

Web of Science Titles	Authors	Source Tiles	YR	CIT
The implications of megatrends in information and communication technology and transportation for changes in global physical activity	Pratt, M.; Sarmiento, O.L.; Montes, F.; Ogilvie, D.; Marcus, B.H.; Perez, L.G.; Brownson, R.C. [55]	*The Lancet*	2012	165
Environment and policy factors shaping global e-commerce diffusion: A cross-country comparison	Gibbs, J.; Kraemer, K.L.; Dedrick, J. [52]	*Information Society*	2003	157
Simulation in manufacturing: Review and challenges	Mourtzis, D.; Doukas, M.; Bernidaki, D. [56]	*Procedia CIRP*	2014	124
Recent progress in high performance and reliable n-type transition metal oxide-based thin film transistors	Kwon, J.Y.; Jeong, J.K. [71]	*Semiconductor Science and Technology*	2015	123

Table A2. *Cont.*

Web of Science Titles	Authors	Source Tiles	YR	CIT
Developing breeding schemes to assist mitigation of greenhouse gas emissions	Wall, E.; Simm, G.; Moran, D. [62]	*Animal*	2010	120
The globalization of technological innovation: definition and evidence	Archibugi, D; Iammarino, S. [61]	*Review of International Political Economy*	2002	112
Trends in global protected area governance, 1992-2002	Dearden, P.; Bennett, M.; Johnston, J. [72]	*Environmental Management*	2005	99
What Do We Learn From Schumpeterian Growth Theory?	Aghion, P.; Akcigit, U.; Howitt, P. [73]	*Handbook of Economic Growth*	2014	84
Varying methods of state violence	Ron, J. [74]	*International Organization*	1997	73
Global megatrends and their implications for environmental assessment practice	Retief, F.; Bond, A.; Pope, J.; Morrison-Saunders, A.; King, N. [32]	*Environmental Impact Assessment Review*	2016	51
The science of food security	Cole, M.B.; Augustin, M.A.; Robertson, M.J.; Manners, J.M. [75]	*Npj Science of Food*	2018	49
The "New Urban Europe": Global Challenges and Local Responses in the Urban Century	Nijkamp, P.; Kourtit, K. [65]	*European Planning Studies*	2013	48
A methodology of technological foresight: A proposal and field study	Battistella, C.; De Toni, A.F. [76]	*Technological Forecasting and Social Change*	2011	40
Pediatrics in the Year 2020 and Beyond: Preparing for Plausible Futures	Starmer, A.J.; Duby, J.C.; Slaw, K.M.; Edwards, A.; Leslie, L.K. [77]	*Pediatrics*	2010	40
Spaceborne Imaging Spectroscopy for Sustainable Agriculture: Contributions and Challenges	Hank, T.B.; Berger, K.; Bach, H.; Clevers, J.G.P.W.; Gitelson, A.; Zarco-Tejada, P.; Mauser, W. [78]	*Surveys In Geophysics*	2019	37

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