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# Industry 5.0: Tracking Scientific Activity on the Most Influential Industries, Associated Topics, and Future Research Agenda

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**Abstract:** Industry 5.0 arrived and sounded the alarms, warning entrepreneurs to adopt it as quickly as possible; the advantage is that this industry is still in its preliminary stages. However, there is little research on this model in the literature. In this context, the objective of this study was to analyze the current state of industry 5.0 in 215 publications from the Scopus database during the period 2019–2022. The applied methodology was quantitative analysis, with a bibliometric approach supported by the VOSviewer and RStudio software, in addition to the Microsoft Excel application. The results showed: (1) an exponential growth of article and conference paper publications in 2022, all indexed in journals of subject areas such as engineering and computer science; (2) four more industries influenced by i5.0, where the electronics sector leads well above manufacturing, energy and public service; (3) seven research topics associated with i5.0 that deal with the transition from industry 4.0 to 5.0; and (4) six little-explored research topics that would help i5.0 move to a new stage and which are related to environmental sustainability, social sustainability, cobots, bioeconomy, smart cities, and sentiment analysis. This study found a gap in the industry 5.0 literature; therefore, this document serves as a guide for future research.

**Keywords:** sustainability; artificial intelligence; internet of things; resilience; industry 5.0

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## 1. Introduction

While many organizations are still absorbing the meaning of Industry 4.0 (i4.0), Industry 5.0 (i5.0) is just around the corner, forcing us to be ready to face new challenges [1,2]. Industry 5.0 establishes a new orientation that complements the criteria established by Industry 4.0 and tries to go beyond profitability and economic productivity by considering three pillars, including the well-being of people, resilience, and sustainability [3–5]. During i4.0 an attempt was made to control human activity favoring the automation of processes by making man compete with the machine, displacing the human from many scenarios. But in i5.0, there is an intention to reach a middle ground where human-machine interaction brings maximum benefits, including cost optimization due to efficient processes, greener solutions, and creative customization demanded by customers [6–9]. It can be said that i4.0 integrates innovative technologies to change the value chain, while i5.0 integrates those technologies with the ability to solve the problems of a person.

Industry 5.0 can be defined as the recent technological revolution whose intention is to transform industry into intelligent structures supported by cognitive computing and the Internet of Things. It tries to put artificial intelligence at the service of people by connecting machines with humans [6,10,11]. This industrial model promotes the economic productivity of the business sector, ensuring the sustainability of the environment, therefore, the high energy consumption of this sector, due to the use of innovative technologies, obliges a progressive show of rational and favorable parameters within this medium [12,13].

For the optimal operation of i5.0 two fundamental elements are required, viz., specialized personnel in human-machine interaction for safe decision making, and technology designed to make interaction with humans simple and intuitive [14]. With industry 5.0 there will be a significant strengthening of artificial intelligence, making it possible to have virtual assistants that are smarter than a person, and who will support decision-making and identify the competitive advantage of a worker in their job [14–16]. In the same way, it will facilitate the development of customized merchandise, since today there are endless products that are about to adapt to individual needs with the deployment of cobots. For all the above to be effective, the assistance of collaborative robots is essential [17–19].

On the other hand, production control systems are always more intuitive and friendly, and are extremely helpful for industrial sectors in the face of the shortage of specialized personnel [20]. Several industries, especially from privileged sectors such as technology (Apple), automotive (Tesla Motors), and aviation (Boeing), took the lead and defined a new way of seeing the world with the new changes. The automotive sector was one of the leaders in incorporating cobot technologies, integrating them as key elements within assembly lines. Dangerous and repetitive activities such as assembly, painting, and welding were automated, while humans took care of the more elaborate activities and maintenance of the robots [7].

Various studies on i5.0 were identified in the literature. For example, Nahavandi [21], Özdemir, and Hekim [22], Javaid and Haleem [23], and Martynov et al. [24] developed studies around "artificial intelligence". As for studies on the "internet of things", these were conducted by Sarma et al. [9], Aslam et al. [25], Maddikunta et al. [26], and Elim and Zhai [27], among others. With reference to research on "sustainable development", these were elaborated by Saniuk et al. [2], Sindhwani et al. [4], and ElFar et al. [28], among others. On the other hand, the authors Doyle-Kent and Kopacek [10], Xu et al. [6], Demir and Cicibaş [29], and Gürdür Broo et al. [30] studied the "industrial revolutions". In contrast, the studies of Huang et al. [31], Rožanec et al. [32], Ivanov [33], and Tropschuh et al. [34], addressed the "human-centric".

Grabowska et al. [5], Johri et al. [14], Chin [35], and Mladineo et al. [36], among others, addressed "sustainability". On the other hand, Thakur and Kumar Sehgal [37] and Verma et al. [38] oriented their studies to "embedded systems". Regarding research on "technology", there are those developed by Alvarez-Aros and Bernal-Torres [39], Rupa et al. [40], and Zizic et al. [41]. In contrast, Akundi et al. [42], Jabrane and Bousmah [43], Monteiro et al. [44], and Sachsenmeier [45] preferred to analyze "big data". There are also studies associated with "cyber-physical systems", including those developed by Fernandes et al. [46], Garcia et al. [47], Martins et al. [48], Patera et al. [49], and Sverko et al. [50].

Several review-type studies in the i5.0 literature were also identified and analyzed to pinpoint what was studied from a scientometrics perspective [51–55]. Each of these studies was found to be focused on a particular topic, but none made a comprehensive identification of the topics associated with i5.0, nor did they identify the most influential industry sectors. For these reasons, a bibliometric review was carried out to map the studies carried out in this field, in addition to identifying existing gaps in knowledge. It is important to highlight that this bibliometric exploration is accompanied by a bibliographic approach to find out the perceptions of the group of authors involved in the elaboration of the documents chosen in this analysis. From this point of view, this study formulated the following research questions:

- RQ1. How does the core knowledge of the Industry 5.0 field evolve over time?
- RQ2. What are the most influential industries in the field of knowledge of Industry 5.0?
- RQ3. What are the topics associated with Industry 5.0?
- RQ4. What are the topics associated with Industry 5.0 suggested for future research?

To address the research questions, the Results section is structured as follows: avsummary of the main information, the most influential industrial sectors, associated topics, and future research agenda.

*Literature Review: Industry 5.0*

There is much controversy over the definition of Industry 5.0 within the business and academic sectors. Different reasons offered by researchers give primacy to i5.0. Specifically, Özdemir and Hekim [22] managed to define i5.0 as the gradual evolutionary improvement of i4.0 that can enable "symmetric innovation" to address the shortcomings of the i4.0 innovation ecosystem. On the other hand, researchers such as Nahavandi [21] and Leng et al. [56] have rebuked the productivity-centricity of i4.0, arguing that i5.0 shows the beginning of human-oriented industrial sector activities induced by changes in recent technologies that favor human-machine joint participation. Consequently, productivity, the work environment, and employment are improved.

Despite offering different views on this development, these reviews agreed on two basic aspects of i5.0. First, early research identified i4.0 and the digital transformation behind it as having issues with technology centricity and the digital divide [1]. Recent research such as the Grabowska et al. [5] study describes such drawbacks of i4.0 contrary to sustainability. Second, scholars consider that, although i5.0 builds on technological elements of i4.0 [41], it is linked to technological changes such as energy transitions technologies and smart materials, cognitive artificial intelligence, among others [26].

The evolution of the i5.0 model took a turn when the European Community published a report on Europe's future industrial agenda. This report proposed that i5.0 should be perceived as a continuous evolution of the current i4.0 model and not as a replacement for it. Although this report points out that i5.0 focuses on human beings and sustainability, it proposes that this model should facilitate technological innovation to be profiled for the benefit of social and environmental development [57].

The European Commission published its Industry 5.0 agenda in 2021 with the aim of a sustainable, human-centered, and resilient industry. According to it, i5.0 is a complementary stage extending the i4.0 model to favor recent social and environmental expectations [58]. The European Commission, in early 2022, adopted an attitude towards i4.0, stating that this model should not be considered as a framework conducive to addressing social tensions and the climate crisis [59]. This report proposes that i5.0 is an original approach for the industrial sector, rethinking the task and performance of value chains, digital transformation, and business management models in the hyper-connected industrial sector.

From this European Commission report [59] and recent research [5,26], i5.0 is different from i4.0 in five aspects: (1) i5.0 weighs productivity-driven competitiveness and sustainable development; (2) i5.0 empowers the workforce by strengthening people-centered strategies for technological development; (3) i5.0 relies on effective technologies and standards to increase the scope of application of industrial responsibility within the value chain; (4) i5.0 drives the preeminence of stakeholders in innovation development, technology management, and sustainability performance management; and (5) i5.0 drives technological innovation in the field of environmental sustainability.

At present, there is a general opinion on how the i5.0 model differs from the previous ones. This difference is that i5.0 represents a social and technological event driven by stakeholders who invariably transform conservative business models into resilient, circular, regenerative, and sustainable business models.

## 2. Methodology

This manuscript is based on bibliometric analysis [60]. The five steps that Zupic & Čater recommended in their research were put into practice [61]. Among them are "study design", "bibliometric data collection", "analysis", "visualization" and "interpretation" (Figure 1).




**Figure 1.** Methodological design steps.

### *2.1. Study Design*

This bibliometric study formulated four research questions (RQ1, RQ2, RQ3, and RQ4) in the Introduction section. For RQ1, Microsoft Excel vertical and horizontal column charts were used to show changes in data during 2019–2022 and/or to illustrate comparisons between items (year, country, subject area, document type, and most relevant sources). For RQ2, a bibliometric methodology known as "keyword co-occurrence analysis" in "overlay display" was used to show the terms that allow us to derive the most influential industry sectors in i5.0. For RQ3, the conceptual structure bibliometric method called Thematic Map was used to show the topics associated with i5.0. For RQ4, the bibliometric-type methodology known as "keyword co-occurrence analysis" under "network visualization" was used in order to show the keywords with minimal co-occurrence, which allows us to indicate the topics associated with i5.0 for future studies.

### *2.2. Bibliometric Data Collection*

Scopus was used because it is a very complete database, and many of its articles are also simultaneously indexed in other databases. In the Scopus database, the terms "Industry 5.0" or "i5.0" or "human-centered Industry 4.0" were searched in the search field TITLE-ABS-KEY. The rationale for the selection of the three search terms is that, after a review of the literature, they were found to be the most linked to industry 5.0, i.e., they had a high number of co-occurrences. The search returned 530 documents, then was narrowed down to All Open Access, and the search returned 232 records. To obtain recent literature, it was delimited to the period 2019–2022, obtaining 218 records. The types of documents "Letter" and "Editorial" were excluded because we needed research with results, obtaining 215 records. This search includes all countries/territories and all subject areas (Figure 2). The advanced query was as follows: "TITLE-ABS-KEY ("industry 5.0" OR "i5.0" OR "human-centered Industry 4.0") AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019)) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "re") OR LIMIT-TO (DOCTYPE, "ch"))".

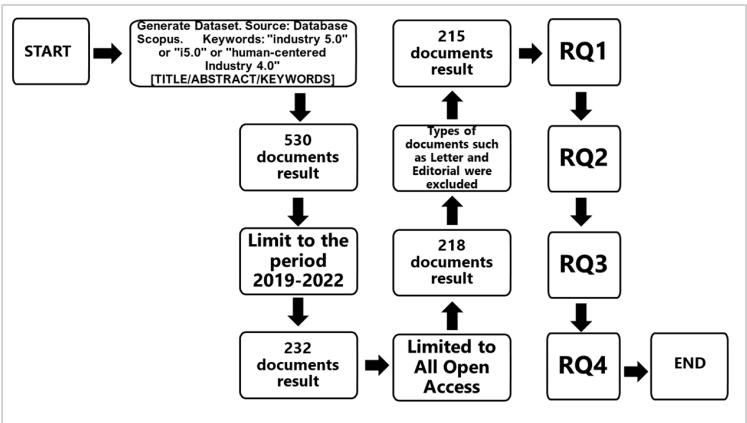



**Figure 2.** Investigation methodology.

### *2.3. Analysis*

In this step the uploaded information went through the conversion process to guarantee its quality and feasibility. The information is derived from Scopus in CSV format to be loaded into the VOSviewer, RStudio and Microsoft Excel 365 software.

### *2.4. Visualization*

This study was developed with vertical and horizontal column charts made by Microsoft Excel 365 to show the evolution of knowledge in the i5.0 field (year, country, subject area, type of document, and sources). On the other hand, it was developed under the Thematic Map of the RStudio statistical package to indicate the clusters of the topics associated with Industry 5.0. In parallel, this review was developed under the "keyword co-occurrence analysis" of the VOSviewer software to show the most influential industries and under-explored i5.0-associated topics.

### *2.5. Interpretation*

In this fifth step, the findings were exposed and interpreted, in line with the four research questions of this study: the results of the knowledge evolution of the i5.0 field over time, the most influential industries in Industry 5.0, the topics associated with i5.0, and the associated topics to i5.0 few explored. The conclusions were developed in accordance with the specific objectives for the construction of the final document.

## 3. Results and Discussions

### *3.1. Summary of Main Information*

Table 1 shows the period registered in Scopus about Industry 5.0, that is, from the year 2019 to 2022. The total number of documents ($n$ = 215) indexed during the indicated period with an annual growth rate of 214.81% is also indicated. The manuscripts cite 15111 references. On the other hand, 790 authors contributed with these documents, managing to index 867 author keywords. The percentage of international co-authorship is 36.74%, where the average number of co-authors per document is 4.01.

**Table 1.** Main information.

| Description | Results |
|---|---|
| Timespan | 2019–2022 |
| Sources (journals, books, etc.) | 121 |
| Documents | 215 |
| Annual growth rate % | 214.81 |
| Document average age | 1.39 |
| Average citations per doc | 9.177 |
| References | 15111 |
| Keywords plus (ID) | 1344 |
| Author's keywords (DE) | 867 |
| Authors | 790 |
| Authors of single-authored docs | 15 |
| Single-authored docs | 15 |
| Co-authors per Doc | 4.01 |
| International co-authorships % | 36.74 |
| Article | 151 |
| Conference paper | 37 |
| Review | 26 |
| Book chapter | 1 |

The table also shows the four document types used by the 790 authors who contributed to the 215 publications in this bibliometric study. "Article" leads with 151 documents [62–71]. It is followed in second place by "Conference paper", with 37 publications [72–80]. In third place is "Review", with 26 studies [52–55,81,82]. "Book chapter" occupies the fourth position with 1 document [83].

It should be noted that both articles and conference papers add up to 188 documents; that is, they represent 87.44% of original studies that have valuable information for the preparation of this bibliometric study.

3.1.1. Annual Scientific Production and Average Citation Per Year

According to Figure 3, 2019 registered 5 publications with a high citation average of 24.20 and related to human-robot collaboration. An investigation related to this year is the so-called "Industry 5.0 and Human-Robot Co-working" developed by Demir et al. [17], where conflicts because of shared human-robot work are discussed from the perspective of the human worker and the organization, they also state that these identified conflicts could be key to future research on organizational robotics. Other studies for this year, 2019, were identified [21,24,29,84].

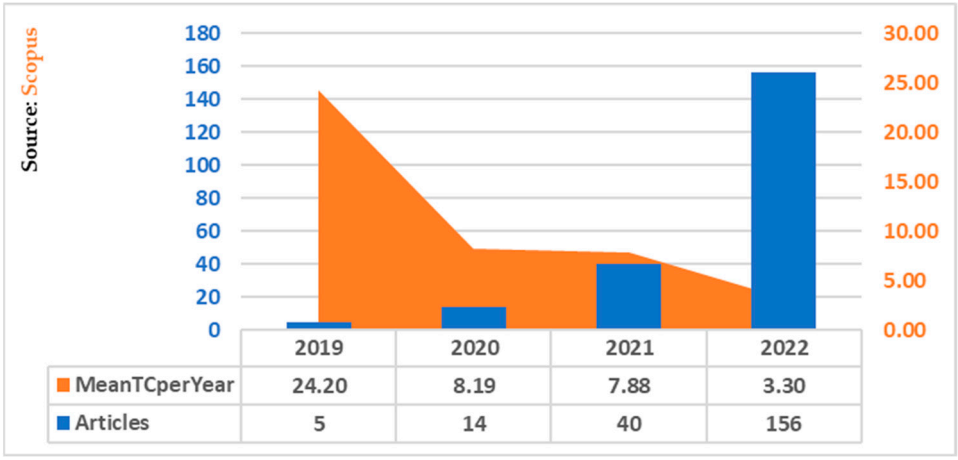



**Figure 3.** Articles per year and citations.

2020 counted 14 studies and a citation average of 8.19; the documents increased by 180% compared to 2019 but its citation average dropped by 66.15%. The 2020 studies focus on the Internet of Things. A study related to this year is one called "Innovation in the era of IoT and Industry 5.0: Absolute Innovation Management (AIM) framework" prepared by Aslam et al. [25], which proposed a novel design to manage innovation called "Absolute Innovation Management (AIM)" in order that innovation can be understood, implemented, and be part of the agenda of organizations to achieve goals, competitiveness and economic growth, on the one hand, and simultaneously addresses the demand for the Internet of Things in the i5.0 era. Other studies were identified for the year 2020 [1,23,27,44,85,86].

In 2021, with 40 documents, there was an increase of 286% compared to 2020, but its citation average remained at 7.88, and here the studies were associated with Artificial Intelligence and sustainability. Among these studies is the paper "Prospects of Industry 5.0 in algae: Customization of production and new advance technology for clean bioenergy generation" prepared by Elfar et al. [28], who affirm that today, clean, sustainable, and profitable energy is required given regulations in the supply of fuels from petroleum. The industrialization of algae is an essential step to realize the high energy demand and thus be able to reach SDGs. Several elements were discussed in this study, among them the environmental and economic valuation of algae-based bioenergy production, the customization of this bioenergy, and the evolutions in the algae harvesting method. Other studies from the year 2021 were identified [6,14,19,40,43,87–89].

Finally, in 2022 it registered 156 manuscripts, showing an increase of 390% compared to 2021, but its citation average dropped 58% to 3.30. This year's investigations were related to the i4.0 to i5.0 transition, the Internet of Things, artificial intelligence, and sustainable development. One of the investigations of the year 2022 was developed by Adel [81] and is called "Future of industry 5.0 in society: human-centric solutions, challenges and prospective research areas". This study affirms that business productivity is increasing

thanks to smart factories. He also points out that customer satisfaction has risen due to the customization of products. The purpose of this research was to analyze the possible applications of i5.0, discuss the definitions of this industry, and analyze the technologies required by it. Other studies registered for the year 2022 were identified [11,16,18,26,30,42,71,90,91].

This exponential growth in publications from 2019 to 2022 makes it clear how the disruptions of COVID-19 accelerated the beginning of the adaptation process from Industry 4.0 to 5.0. In fact, most of the 2022 research is focused on the transition between these two paradigms.

#### 3.1.2. Countries with Scientific Production and Total Citations

A total of 69 countries are involved in the preparation of the 215 documents, so that a manuscript could be recognized by two or more countries. Figure 4 shows the 10 countries with the most documents and total citations (TC). In first place is China ($n$ = 22; TC: 167) [92–94], followed in second place by Italy ($n$ = 21; TC: 159) [63,95,96], in third position and very similar to Italy is the United States ($n$ = 21; TC: 157) [69,97,98], in fourth position is the United Kingdom ($n$ = 20; TC: 93) [72,99,100], fifth place is occupied by India ($n$ = 16; TC: 15) [22,23,84]. In sixth and seventh place are Germany and Spain, with ($n$ = 13; TC: 9) [32,73] and ($n$ = 13; TC: 66) [101,102], respectively, but Spain comes out more favored due to its high TC. In eighth position is Sweden with ($n$ = 12; TC: 13) [47], in ninth place is Poland with ($n$ = 11; TC: 49) [2,62], and South Korea occupies the tenth position with ($n$ = 10; TC: 7) [2,53,62].

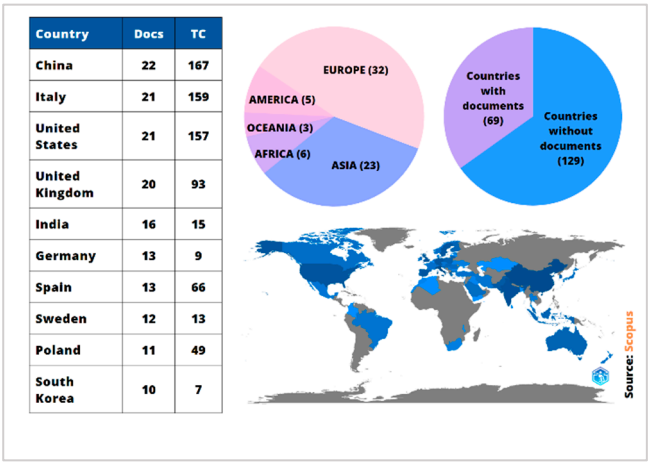



**Figure 4.** Documents and TC by Country/Territory.

Of the 198 countries that make up world geography, only 69 contributed to industry 5.0 research, a global participation of 34.85%. These 69 countries are spread over five continents. The percentage of participation by continent is discussed below. Of the 54 countries that make up Africa, only six contribute, i.e., a 11.11% participation. From America only 5 nations out of 35 contributed for a 14.28% participation. Of the 48 Asian countries, 23 managed to contribute with studies on the variable in question, for a 47.91% participation. For its part, Oceania contributes with three countries out of its fifteen, obtaining a 20% share. On the other hand, Europe achieves the highest participation with 69.57% by obtaining from its 46 nations the contribution of 32 of them. These statistics allow us to infer that there is a limited number of studies on Industry 5.0, the weak points being Africa, America, and Oceania. It should be noted that a manuscript can be registered by one or more nations, therefore, the sum of all the manuscript in this section ($n$ = 336) will never match the total number of documents registered in the main information ($n$ = 215).

3.1.3. Registration of Documents by Subject Area

In the methodological design, it was noted that there was no exclusion of any of the thematic areas. In the same way that the registration of documents by country was counted, so too the registration of documents by thematic area was done; i.e., a manuscript can be counted by two or more subject areas linked in this study. Figure 5 shows the 18 subject areas covered in this study.

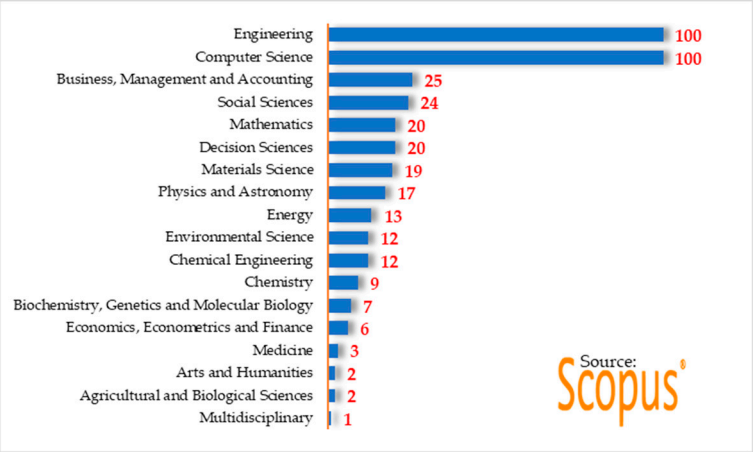



**Figure 5.** Documents by subject area.

Engineering ($n$ = 100) and Computer Science ($n$ = 100) register documents with a total 400% higher than Business, Management and Accounting ($n$ = 25) and Social Sciences ($n$ = 24). Mathematics and Decision Sciences count the same number of documents individually ($n$ = 20). These are followed by Materials Science ($n$ = 19), which is followed by Physics and Astronomy ($n$ = 17), and Energy ($n$ = 13). Environmental Science and Chemical Engineering also share the same number of manuscripts ($n$ = 12). Chemistry ($n$ = 9), Biochemistry, Genetics and Molecular Biology ($n$ = 7), Economics, Econometrics and Finance ($n$ = 6), Medicine ($n$ = 3), Arts and Humanities ($n$ = 2), and Agricultural and Biological Sciences ($n$ = 2) follow. Finally, in last place is Multidisciplinary ($n$ = 1).

Engineering and Computer Science are the subject areas that stand out the most in this analysis, and this is because engineering education, especially industrial engineering, is the one that is best equipped to face the challenges created during the transition to Industry 5.0. For these challenges, they rely on Computer Science, which helps to describe and transform valuable information for this change. An example of a registered study for these two subject areas, i.e., Engineering and Computer Science, is the one entitled "Industry 4.0 and Industry 5.0—Initiation, conception and perception", which was prepared by Xu et al. [6]. This study posits that technology is what drives i4.0, while value is what drives i5.0. For these authors, the presence of these two paradigms requires investigation, therefore, it also needs more debate and details.

3.1.4. Most Relevant Sources, Citation, and Impact Measure (h_Index)

Figure 6 shows the ten most relevant sources of the 121 that contribute to this study. The figure was designed with three bars, the one in blue represents the number of documents indexed for each source, the brown bar indicates the number of manuscripts that have cited the documents represented in the blue bar, and finally, the bar red shows the h_index of each source.

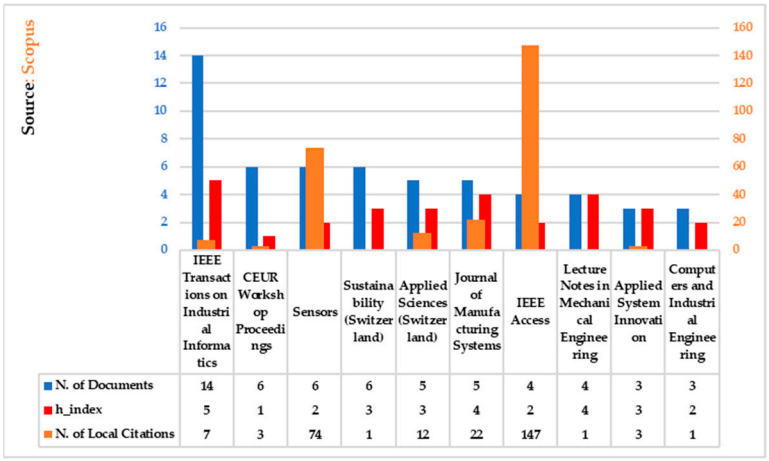



**Figure 6.** Most relevant sources, citation, and impact measure.

The IEEE Transactions on Industrial Informatics source leads with 14 papers and has been cited by 7 manuscripts, retaining an impact measure of (h_index = 5). CEUR Workshop Proceedings records 6 documents being cited by three manuscripts and its impact measure is (h_index = 1). The six documents indexed by Sensors have managed to be cited by 74 manuscripts, leaving with an impact measure of (h_index = 2). Likewise, the source Sustainability (Switzerland) registers six publications, but is only cited by one manuscript, this source shows a (h_index = 3). Applied Sciences (Switzerland) counts 5 documents cited by 12 manuscripts and its impact measure is (h_index = 3). Journal of Manufacturing Systems also totals 5 documents and is cited in 22 articles, showing a (h_index = 4).

IEEE Access indexes four documents and is cited in 147 articles, showing a (h_index = 2). Lecture Notes in Mechanical Engineering records 4 papers cited by a single manuscript, it has a (h_index = 4). Applied System Innovation totals three papers cited by three articles, shows a (h_index = 3). Finally, we have Computers and Industrial Engineering with three papers that were cited by a single manuscript, (h_index = 2) is attributed.

It should be noted that IEEE Access and Sensors are the two most cited sources despite their low document records.

### *3.2. Most influential Industries in Industry 5.0*

Figure 7 shows the terms related to industry 5.0 during 2019–2022. These were loaded into the VOSviewer software to generate the figure. The type of analysis called "co-occurrence" was applied, the unit of analysis was "keywords", the counting method was "fractional counting", with a minimum number of "occurrences" of a keyword ($n$ = 3).

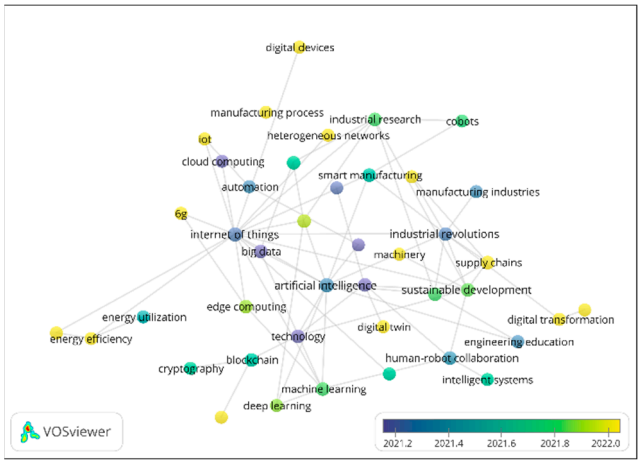



**Figure 7.** Industry 5.0 terms during 2019–2022.

All the terms obtained were ordered in Table 2 according to the weight of the "occurrences", the average year of publication and the most influential industrial sector. Below the table, influential industry sectors are discussed.

**Table 2.** Influential industry sectors.

| Label/Term | Weight <Occurrences> | Score <Avg.Pub.Year> | Industry Sector |
|---|---|---|---|
| big data | 9 | 2020.33 | Electronics |
| cloud computing | 3 | 2020.33 | Electronics |
| robotics | 8 | 2020.88 | Electronics |
| technology | 10 | 2021.00 | All Industry |
| manufacturing | 7 | 2021.14 | Manufacturing |
| software | 4 | 2021.25 | Electronics |
| human-robot collaboration | 7 | 2021.29 | Electronics |
| artificial intelligence | 27 | 2021.33 | Electronics |
| engineering education | 3 | 2021.33 | Public Service |
| industrial revolutions | 18 | 2021.33 | All Industry |
| internet of things | 27 | 2021.33 | Electronics |
| manufacturing industries | 3 | 2021.33 | Manufacturing |
| automation | 7 | 2021.43 | All Industry |
| energy utilization | 4 | 2021.50 | Energy |
| smart manufacturing | 9 | 2021.56 | Manufacturing |
| blockchain | 8 | 2021.62 | Electronics |
| cobots | 3 | 2021.67 | Electronics |
| cryptography | 3 | 2021.67 | Electronics |
| cyber-physical systems | 9 | 2021.67 | Electronics |
| intelligent systems | 3 | 2021.67 | Electronics |
| virtual reality | 3 | 2021.67 | Electronics |
| machine learning | 8 | 2021.75 | Electronics |
| industrial research | 9 | 2021.78 | All Industry |
| manufacture | 9 | 2021.78 | Manufacturing |
| sustainable development | 19 | 2021.79 | All Industry |
| deep learning | 6 | 2021.83 | Electronics |
| edge computing | 8 | 2021.88 | Electronics |
| embedded systems | 10 | 2021.90 | Electronics |
| 5G mobile communication systems | 3 | 2022.00 | Electronics |
| 6G mobile communication | 3 | 2022.00 | Electronics |
| cognitive systems | 3 | 2022.00 | Electronics |
| digital devices | 3 | 2022.00 | Electronics |
| digital transformation | 6 | 2022.00 | All Industry |
| digital twin | 3 | 2022.00 | Electronics |
| digitalization | 4 | 2022.00 | All Industry |
| energy efficiency | 4 | 2022.00 | Energy |
| heterogeneous networks | 3 | 2022.00 | Electronics |
| industrial internet of things | 3 | 2022.00 | Electronics |
| machinery | 4 | 2022.00 | Manufacturing |
| manufacturing process | 3 | 2022.00 | Manufacturing |
| mobile communications | 3 | 2022.00 | Electronics |
| mobile telecommunication systems | 3 | 2022.00 | Electronics |
| smart contract | 3 | 2022.00 | Electronics |
| supply chains | 8 | 2022.00 | All Industry |

According to Table 2, the interest in industry 5.0 between 2020 and 2022 is noted by the increase in publications in this period. The data resulting from the table is categorized to identify the influential industry sectors in Industry 5.0. During the categorization, the industrial sector identified as All Industry was excluded because it has terms that are valid for the rest of the sectors. In total, four industries were specified, from the most influential to the least influential: Electronic, Manufacturing, Energy, and Public Service.

(1) Electronic: the most influential sector in industry 5.0, the related terms are artificial intelligence, internet of things, embedded systems, big data, cyber-physical systems,

robotics, blockchain, machine learning, edge computing, human-robot collaboration, deep learning, software, cloud computing, cobots, etc. An investigation related to this industrial sector is the so-called "Industry 5.0: Ethereum blockchain technology based DApp smart contract" developed by Rupa et al. [40]. This study designed an application supported by the blockchain to manage clinical certificates using the Remix Ethereum blockchain. This application accelerates the analysis of the rate of births, diseases, and deaths according to location and date. Five other studies related to this sector were identified [18,21,22,25,26].

(2) Manufacturing: the second most influential sector, the related terms are smart manufacturing, machinery, manufacturing industries, and manufacturing process. This sector is experiencing changes because of the COVID-19 pandemic; in fact, research on this sector begins to stand out from the beginning of 2021 to 2022. A document linked to this industrial sector is the so-called "Retrofitting-Based Development of Brownfield Industry 4.0 and Industry 5.0 Solutions" which was developed by Tran et al. [103]. This study provides a systematic description of Brownfield development in the legacy system. The scope of this study focuses on the progression of i4.0 but takes into consideration planning for the imminent i5.0. They propose to manufacturers to modify their installations into smart premises with minimal efforts and costs. Five other documents on this sector were found [3,11,17,38,71].

(3) Energy: the third influential sector in industry 5.0, the related terms are energy utilization and energy efficiency. Energy management in an industry 5.0 model is expected to help in energy efficiency without losing sight of workers and to help increase the conversion ability of the industry. A publication related to this sector is the so-called "NOMA-Enabled Backscatter Communications for Green Transportation in Automotive-Industry 5.0" prepared by Khan et al. [7]. This paper provides a presentation on green displacement and discusses the benefits of using Ultra Low Power Communications and Non-Orthogonal Multiple Access (NOMA) in the automotive i5.0. It also affirms that these are two central techniques of 6G transmissions to expand the spectrum and energy savings in the vehicular network. Four other publications were identified around this sector [8,9,37,104].

(4) Public service: the least influential sector, and the only term related to Industry 5.0 is engineering education. There are few investigations on this sector, and they deal with the education of industrial engineers for the development of skills in the transit of industry 5.0. A document linked to this sector is the so-called "Sustainable Development Competences of Engineering Students in Light of the Industry 5.0 Concept" developed by Mazur and Walczyna [105]. The purpose of this research was to analyze the type and level of expertise around sustainable growth by students at the Lublin University of Life Sciences and the Lublin University of Technology. This study sought to verify through the self-assessment of competencies, the correspondence between the competencies of the students and the type of university. The findings confirmed gaps between students in terms of activity and areas of knowledge. Three other documents related to this sector were found [30,72,106].

It should be noted that there are currently numerous industrial sectors, but this study shows only four; therefore, it is inferred that the transition from industry 4.0 to 5.0 has already begun and is in its initial stages. Figure 8 shows the trend for these four sectors.

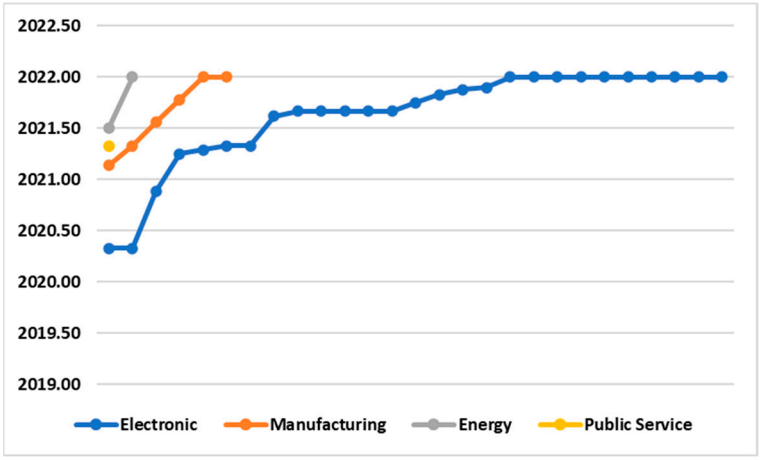



**Figure 8.** Trend of four industrial sectors.

### *3.3. Topics Associated with Industry 5.0*

The "Thematic Map" that is displayed in Figure 9, is divided into four categories called: "Emerging or Declining Themes", "Niche Themes", "Motor Themes" and "Basic Themes". These themes are located within the map according to centrality (degree of relevance) and density (degree of development). For its generation, the "walktrap" grouping algorithm of the RStudio software was applied as default criteria, in addition to the minimum frequency of clustering ($n$ = 5) per thousand manuscripts and the author's keywords ($n$ = 250).

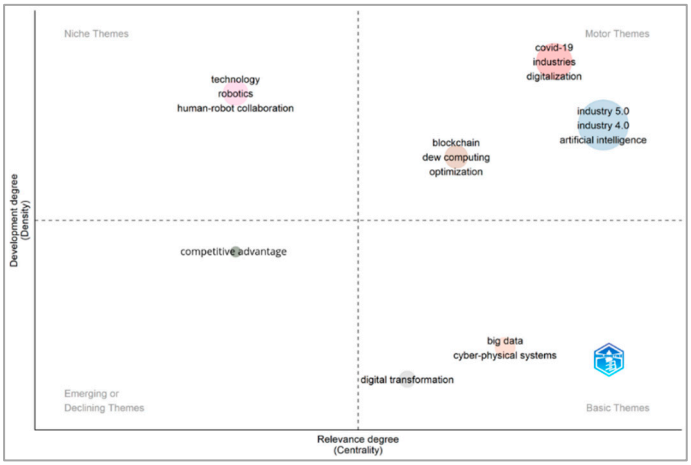



**Figure 9.** Thematic Map.

The thematic map showed seven clusters of the topics associated with industry 5.0 at the date of development of this bibliometric study. Table 3 shows the description, frequency, and categories of each theme together with the degrees of relevance and development. After Table 3, the seven themes are discussed.

(1) Industry 5.0, Industry 4.0, and artificial intelligence: this cluster is categorized as "Motor Themes" and includes studies on industry 5.0 closely related to industry 4.0 and artificial intelligence, that is, how this technological revolution aims to transform the industrial sector 4.0 into intelligent structures supported by development artificial intelligence [14,16,21,65,73,107–110].

(2) COVID-19, industries, and digitalization: categorized as "Motor Themes" according to Table 3 and deals with industry 5.0 studies closely related to digitization in the context of COVID-19, i.e., how digitization contributes to improving production processes, increasing productivity, and optimization of energy, resources, and costs [12,41,54,55,111–114].

(3) Technology, robotics, and human-robot collaboration: classified as "Niche Topics" in Table 3 and deals with Industry 5.0 studies with links to technology and human-robot collaboration, i.e., how Industry 5.0 values human-robotic cooperation with the intention to establish a more participatory horizon centered on humanity [4,17,18,76,91,115,116].
(4) Blockchain, dew computing, and optimization: categorized as "Motor Themes", and covers Industry 5.0 publications intricately linked to blockchain and dew computing. Blockchain is a remarkable database that organizes and stores information in a decentralized and joint manner. As for dew computing, this is a decentralized computerized architecture where data, calculation, registration, and programs are located timely and efficiently within the cloud and the source of information. With blockchain and dew computing the optimization of the industries is sought [10,38,40,54,77,117–120].
(5) Big data and cyber-physical systems: categorized under "Basic Themes", and covers publications on big data and cyber-physical systems in industry 5.0, i.e., the use of digital technologies in the services provided and in industrial production activities to facilitate effective and innovative processes in the generation of goods and services that incorporate digital and conventional techniques [22,31,37,42,43,46,47,49,56,121,122].
(6) Digital transformation: categorized under "Basic Themes" and encompasses studies on how the industry adopts digital technology to digitize analog services or products to increase their value with the help of customer experience, innovation, and invention [30,48,62,67,123,124].
(7) Competitive advantage: this cluster is categorized as "Declining Themes" in Table 3 and includes documents on how one industry overlaps another in the same sector using unspecified methods, managing to innovate in its own way [25,35].

**Table 3.** Research lines most affected by industry 5.0.

| # | Thematic Description | Call on Centrality | Call on Density | Rank Centrality | Rank Density | Cluster Frequency | Thematic Category |
|---|---|---|---|---|---|---|---|
| 1 | "Industry 5.0/Industry 4.0/artificial intelligence" | 2.5 | 61.5 | 11 | 9 | 280 | Motor Themes |
| 2 | "COVID-19/industries/digitalization" | 1.0 | 69.9 | 10 | 11 | 50 | Motor Themes |
| 3 | "technology/robotics/human-robot collaboration" | 0.0 | 65.7 | 3.5 | 10 | 14 | Niche Themes |
| 4 | "blockchain/dew computing/optimization" | 0.2 | 56.3 | 8 | 8 | 11 | Motor Themes |
| 5 | "big data/cyber-physical systems" | 0.4 | 30 | 9 | 2 | 8 | Basic Themes |
| 6 | "digital transformation" | 0.1 | 20 | 7 | 1 | 5 | Basic Themes |
| 7 | "competitive advantage" | 0 | 50 | 3.5 | 5 | 2 | Declining Themes |

### *3.4. Future Research Agenda*

To build a future research agenda, the 867 author keywords were loaded into the statistical software VOSviewer for "keyword co-occurrence analysis" using the "association strength" method. The criteria used was the selection of keywords with less co-occurrence ($n = 2$) associated with industry 5.0. The applied analysis generated six topics associated with i5.0 for future studies (Figure 10), including: environmental sustainability, social sustainability, cobots, bioeconomy, smart city, and sentiment analysis.

The six topics for future research are discussed below.

(1) Environmental Sustainability: studies that deal with the balance that is generated as a consequence of the harmony between humanity and its environment, and that this harmony is maintained over time [12,125].
(2) Social Sustainability: a study theme that deals with how sustainability enhances personal, community and cultural development for the achievement of global living conditions, health, and decent and equal training [88,89,125].
(3) Cobots: a study theme that deals with compact robots that do not take up much space and that were created to work physically with humans in a collaborative environment [11,19,126].
(4) Bioeconomy: a study theme related to various objectives, including clean water and sanitation, responsible production and consumption and sustainable cities. These bioeconomy studies also touch on decent work and economic growth [4,116].

(5) Smart city: a study theme on cities where information and communication technologies (ICT) are put into practice to provide them with a set of structures that ensure sustainable development, favorable living conditions, and a cost-benefit ratio of available resources [20,53].

(6) Sentiment analysis: this subject of study refers to the treatment of natural language, text recognition and computational terminology to individualize and separate subjective information, i.e., it classifies a sentence as positive, negative, or neutral [82,99,102,121].

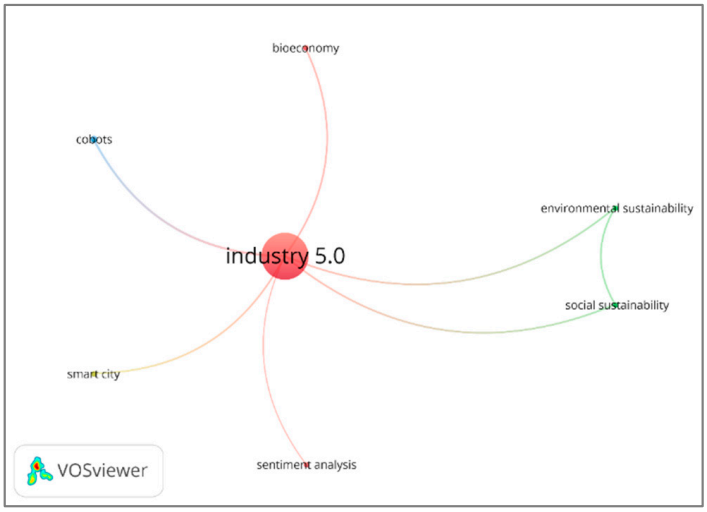



**Figure 10.** Author keywords.

Figure 11 below shows a summary of the results obtained:

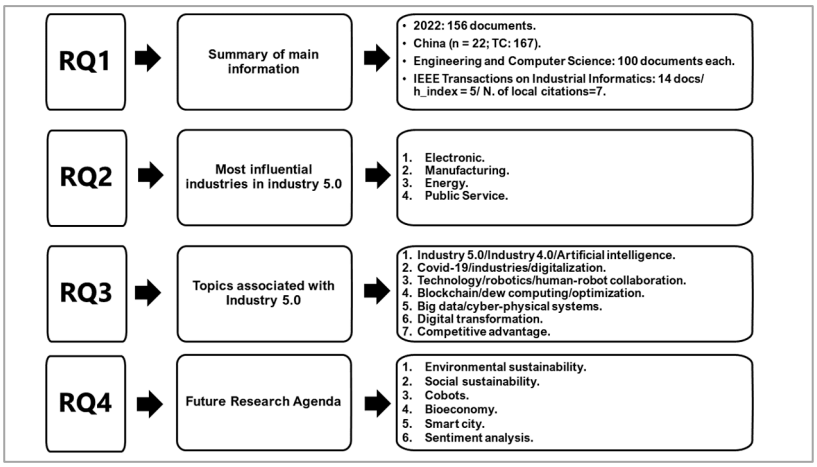



**Figure 11.** Summary of contents in the Results section.

## 4. Limitations

Although the contributions of this study are important, the following limitations cannot be ignored. First, the exclusive use of Scopus to access the information analyzed in this bibliometric study. It is known that the use of several databases guarantees a better scope, but Scopus has many manuscripts that could also be indexed in other databases. Another limitation is the little previous research on i5.0 because it is a recent topic, and this limitation is demonstrated in the registration of articles during the period 2019–2022. The information used in this study is current as of December 2022.

## 5. Conclusions

Industry 5.0 can be defined as the new manufacturing paradigm where the scenario is human-machine interaction. This study identified four industry sectors linked to i5.0, from most influential to least influential. These sectors are Electronic, Manufacturing, Energy and Public Service, which are few compared to the considerable number of existing sectors, which allows us to agree with what many studies affirm, namely that i5.0 is still in its initial stages. Now, Electronics is the most influential industry sector for being the cornerstone of the i5.0. This sector has been the backbone of the third and fourth industrial revolutions and it is also for the fifth. Electronics are key to increasingly precise and powerful machinery (cobots, robots), along with the creative potential of human beings. The Manufacturing sector relies on consumer electronics (chips), which is very necessary in the intelligent production process. Likewise, this electronic support occurs in the Energy sector, which aims to obtain energy performance for the benefit of environmental sustainability, but the findings indicate few studies on this sector, inferring a low use of efficient energy in i5.0. On the other hand, the Public Services sector plays a key role, since education, especially industrial engineering, is vital in the training of professionals with skills for i5.0. But it is the least influential sector, which allows us to agree with what assorted studies have stated, and that is that qualified personnel are needed, therefore, it is necessary to train more professionals to help promote i5.0.

The topics associated with i5.0 identified in this research are driven by artificial intelligence, digitization and digital transformation, key elements for human-robot collaboration; undoubtedly these elements would not work without the help of the electronics sector. Further, recommended topics for future research were identified, such as environmental sustainability, social sustainability, cobots, bioeconomy, smart cities, and sentiment analysis. These aim to consolidate this industrial model and focus on its three pillars: the human being, resilience, and sustainability. This study makes an important contribution, since 72.56% of the total literature analyzed is from the year 2022, i.e., recent literature. In addition to the above, 87.44% of the 215 manuscripts are articles and conference papers, i.e., primary source information that translates into valuable information for this study. A low participation of countries with studies in i5.0 was found; i.e., 129 nations (65.15%) of the 198 have not registered studies in Scopus, showing a considerable scientific gap from a geographical point of view.

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**Conflicts of Interest:** The authors declare no conflict of interest.

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