

Review

# Bibliometric Trends in Industry 5.0 Research: An Updated Overview

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**Abstract:** The emergence of Industry 5.0 took place in the mid-2010s, presenting a novel vision for the future of an industry that places emphasis on human involvement in the production process. Following the outbreak of the COVID-19 pandemic, there has been a substantial surge in the popularity of this concept, gaining traction not only in the business realm but also within academic circles. This increased attention can be attributed to a heightened focus on crucial aspects such as sustainability and resilience. The objective of this study is to present an updated overview of key bibliometric trends in Industry 5.0 research. The findings indicate a remarkable expansion of research activities in the field of Industry 5.0, as evidenced by a substantial increase in the number of publications and citations. Concurrently, the growth of Industry 5.0 research has led to the emergence of diverse perspectives and the exploration of related research themes such as artificial intelligence, big data, and human factors. In summary, this study enhances our understanding of the Industry 5.0 concept by providing an updated overview of the current state of research in this area and suggesting potential avenues for future investigations.

**Keywords:** Industry 5.0; bibliometric review; literature review; management trends



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## 1. Introduction

Industry 5.0 (I5.0) is a new, innovative concept aimed at making the industry more “sustainable, human-centered, and resilient” [1]. As Di Nardo and Yu [1], p. 1, point out, “while a significant number of companies around the world are still trying to adapt to Industry 4.0, the discussion about Industry 5.0 has already begun”. The concept of Industry 5.0 originated from mid-2010s social media posts by Michael Rada and others [2–5] and in the years thereafter these ideas were picked up by the academic community, with the first academic article published in 2016 [6]. Since the outbreak of the pandemic, I5.0 has received increasing levels of attention in business and society [7,8]. In 2021, the academic literature on I5.0 was still in an embryonic phase but on a clear upward trajectory [9].

Therefore, in this study, we provide an updated overview of bibliometric trends in the I5.0 literature. While there have been a few prior bibliometric analyses mapping different aspects of the early phase of I5.0 [9–12], this research field is very fast-moving and is rapidly expanding. Therefore, it is useful to establish an updated picture, explore the scientific landscape, and develop an understanding and overview of the trajectory and hot topics in the scientific literature on I5.0. This is interesting because I5.0 resonates with the concept of sustainability through its broad stakeholder-oriented approach. As such, it intersects two influential contemporary trends in business and society: sustainability and digitalization.

The structure of the paper is as follows: Section 2 offers a brief background on the concept of I5.0 and summarizes the findings of prior bibliometric studies, which provide a

context for comparison with the current study's results. Section 3 outlines the bibliometric methods and data used for the analysis. Section 4 presents the results of the citation-based bibliometric analysis, including overall trends and identification of key sources, documents, authors, and countries. Section 5 provides a thematic analysis of the I5.0 research field and an analysis of the evolution of research themes. Section 6 delves into the findings of the study and outlines potential avenues for future research. Lastly, Section 7 concludes the paper by emphasizing its contributions and reflecting on the study's limitations.

## 2. Related Work

### 2.1. Industry 5.0

I5.0 represents the next phase of industrialization that builds on the foundations of Industry 4.0 (I4.0). However, there are disagreements about whether I5.0 is an evolutionary step or something completely new [3,13–15]. For example, Özdemir and Hekim [13] (pp. 71–72), characterize it “as an evolutionary, incremental (but critically necessary) advancement that builds on the concept and practices of Industry 4.0”. I5.0, in contrast to I4.0, places a greater emphasis on human participation in the manufacturing process [2,13]. While I4.0 is defined by the integration of advanced digital technologies such as automation, big data, artificial intelligence, and the Internet of Things (IoT) into manufacturing processes [16,17], I5.0 shifts its focus to areas that demand creativity, problem-solving, and decision-making, where human involvement is crucial.

I5.0 aims to merge the advantages of automation with the creativity and ingenuity of human workers to create more innovative and sustainable production processes. Achieving this requires the development of new technologies that support human–machine collaboration, including augmented reality, virtual reality, and collaborative robots [18]. In other words, proponents of I5.0 recognize the critical role of humans in manufacturing and seek to leverage their skills and abilities to drive innovation and growth.

The objective of I5.0 is to create a more balanced and sustainable approach to manufacturing that considers both the efficiency and profitability of production processes, as well as the impact on workers and the environment. The European Commission [19] (pp. 3–4), argues that I5.0 “complements the existing ‘Industry 4.0’ paradigm by having research and innovation drive the transition to a sustainable, human-centric and resilient European industry. It moves the focus from solely shareholder value to stakeholder value, for all concerned”.

In summary, while I4.0 and I5.0 utilize many of the same technologies, the two approaches differ in several ways. For example, Madsen and Slåtten [20] summarize these main differences, and point out that I5.0 is considerably more human-centric than its predecessor. I5.0 also shifts the emphasis from productivity to sustainability, and from shareholders to a more comprehensive approach that considers the concerns of a diverse group of stakeholders.

### 2.2. Prior Bibliometric Studies

In this section, we provide an overview of existing bibliometric studies on Industry 5.0 and summarize the key findings from these studies. This will serve as a backdrop and baseline against which to compare the results of the updated analysis.

Grabowska, Saniuk and Gajdzik [12] conducted a bibliometric analysis to shed light on the transformation of the I4.0 concept into the I5.0 concept. The data were collected in May 2021, a time when there were still relatively few indexed I5.0 studies in the Web of Science, noting that the first publication appeared in 2020, with 17 in 2022 and another 5 published during the first four months of 2021.

Coelho, Bessa, Landeck and Silva [11] looked at the rise of the term I5.0 in the scientific literature, collecting data from Scopus data in March 2021, which yielded 37 documents, finding that Özdemir and Hekim [13] and Nahavandi [21] were two most cited papers. Madsen and Berg [9] collected the data a few months later (September 2021) and used the Scopus database, which has a broader coverage than the Web of Science. In total, there

were less than 100 documents in Scopus, but the findings suggested a strong growth in the volume of publications in the years 2020 and 2021. The analysis showed that the most cited articles as of 2021 were Özdemir and Hekim [13], Nahavandi [21], Abdel-Basset et al. [22], Demir et al. [23] and Sachsenmeier [6].

So while there have been a few prior bibliometric analyses mapping different aspects of the early phase of I5.0 [9–12], the development has been rapid and therefore it would be useful to establish an updated picture taking into account the most recent publications on the topic of I5.0.

### 3. Methodology

#### 3.1. Bibliometric Methods

Bibliometric methods are statistical techniques used to analyze scientific publications and measure scholarly production in a specific field [24]. In addition, bibliometric methods can be used to assess the impact of research, identify research gaps, and understand the structure and dynamics of scientific communities. In recent years, bibliometric methods have gained popularity in business and management studies [25], and several resources exist to guide their use [26].

#### 3.2. Data Sources and Selection Criteria

In this section, we describe the sources of data used in the study, including the databases, search terms, and inclusion/exclusion criteria.

This study obtained bibliometric data from the Scopus database ([www.scopus.com](http://www.scopus.com)) accessed on 4 February 2023. Scopus was chosen for its broader coverage compared to the Web of Science [27]. As noted by Zupic and Čater [25], p. 42, “broader coverage is useful for mapping smaller research areas”. The broad coverage provided by Scopus is arguably crucial in the context of I5.0 as early publications on new concepts may appear outside of leading journals in a field, such as in conference proceedings that widely used in some academic fields (e.g., engineering and computer science) [28] that are highly relevant to research on I5.0. In the realm of computer-related fields, it is worth noting that certain conference proceedings are regarded as being more timely, cutting edge, and rigorously peer-reviewed than certain journals [29] (pp. 661–662). Although the Web of Science has a longer history of coverage, this feature was not relevant to this study due to the relatively short history of Industry 5.0 that only goes back to 2015 [3].

Only the search term “Industry 5.0” was used, and documents explicitly mentioning “Industry 5.0” in the abstract, title, or keywords were included to avoid excluding any potentially relevant publications. The study covers the time period from 2015 to 2023, since it is documented in the literature that the concept was first mentioned on social media in 2015 and in a scientific article from 2016 [9].

Table 1 summarizes the considerations and choices made in this study. The search query used was: “TITLE-ABS-KEY (“Industry 5.0”) AND PUBYEAR > 2014”, meaning documents containing the term “Industry 5.0” in the title, abstract, or keywords were searched for, published between 2015 and 2023.

**Table 1.** Overview of search procedure and choices made (Source: own elaboration).

Aspect	Choice
Database	Scopus
Search query	TITLE-ABS-KEY (“industry 5.0”) AND PUBYEAR > 2014
Time period	2015–2023
Date of query	4 February 2023
Categories	All
Sources	All
Languages	Any
Number of documents	532

### 3.3. Data Analysis

The extracted Scopus data were imported into Biblioshiny, which is a web-based R-tool for bibliometric analyses [30]. While there are many alternative software packages that can be used to conduct bibliometric analyses and science mapping [31], the use of Biblioshiny can be justified on several grounds, such as the ability to carry out comprehensive analysis, visual representation, and ease of use.

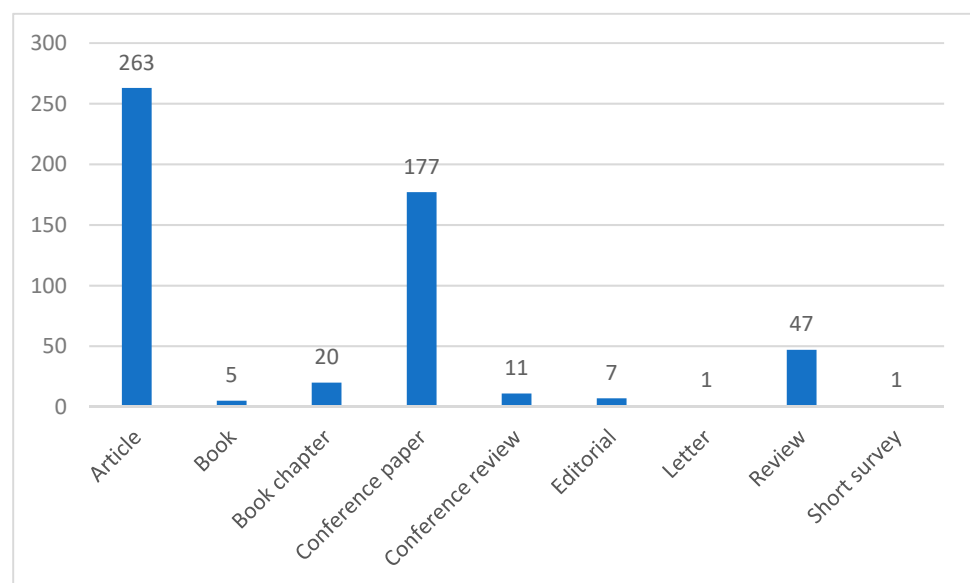
We used the software to analyze publication trends and perform citation-based and thematic analyses. The citation-based analyses provide an overview of key publication trends on I5.0 in terms of overall growth trajectory and influential authors, sources, documents and countries. The thematic analysis provides an overview of the conceptual structure of the I5.0 research field. According to Aria and Cuccurullo [32], a thematic analysis provides insight into “what science talks about, the main themes and trends”. Therefore, we will present two visualizations: (1) a thematic map and (2) a diagram of thematic evolution.

### 3.4. Data Set

Table 2 displays the main information about the data set. The analyzed data encompass a collection of 532 documents spanning from 2016 to 2023, sourced from 278 different journals, books, etc. The collection has an annual growth rate of 70.57%. On average, the documents are 1.35 years old and have received 6.617 citations. There are 28,109 references in total. Figure 1 shows that data set includes various types of documents such as 263 articles, 5 books, 20 book chapters, 177 conference papers, 11 conference reviews, 7 editorials, 1 letter, 47 reviews, and 1 short survey.

**Table 2.** Main information about the data set.

Description	Results
Timespan	2016:2023
Sources (Journals, Books, etc.)	278
Documents	532
Annual Growth Rate %	70.57
Document Average Age	1.35
Average citations per doc	6.617
References	28,109



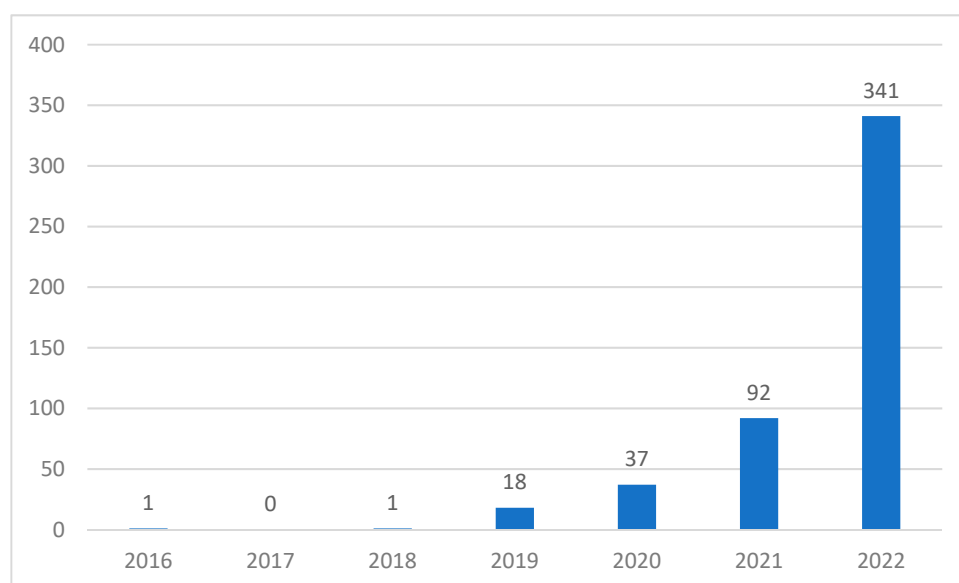
**Figure 1.** Overview of document types.

#### 4. Citation-Based Analysis of Industry 5.0 Research

This section provides an overview of the landscape of the I5.0 literature, by examining overall publication trends and identifying the most productive authors, institutions, and the most cited articles and journals.

##### 4.1. Publication Trends

Figure 2 displays the volume and growth trajectory of research related to I5.0 during the period 2016 to 2022. The first article on I5.0 indexed in Scopus was published by Sachsenmeier [6]. Since then, there has been a significant and steady rise in the number of publications per year in the field of I5.0. This trend is highlighted by Table 2, which demonstrates an annual growth rate of approximately 70%. Particularly noteworthy is the substantial increase in publications starting from 2019, which further accelerated during the COVID-19 pandemic. From 2021 to 2022, the annual number of publications has more than tripled, suggesting that the current growth can be characterized as exponential, a pattern similar of growth similar to what was observed in research on Industry 4.0 during the 2010s [33].



**Figure 2.** Volume and growth trajectory of Industry 5.0 research in the Scopus database 2015–2022 (Note: 2023 publications not displayed due to partial year data).

##### 4.2. Most Relevant Sources

The presented Table 3 showcases the key sources in I5.0 research, based on the number of published articles on the subject. It is evident from the table that these sources comprise a combination of journals and conference proceedings. The prominence of conference proceedings as platforms for I5.0-related research is to be expected, considering that a significant portion of this research is conducted by scholars from engineering and computer science disciplines, which typically favor conference proceedings as publication outlets more than fields such as business and management [28].

The table shows the number of articles published in different sources. The top source is *IEEE Transactions on Industrial Informatics* with 24 articles, followed by *Sustainability* with 17 articles. The rest of the sources have fewer than 17 articles, with the lowest being *Communications in Computer and Information Science* with 9 articles. Overall, the table shows that I5.0 research is published across a wide spectrum of outlets. It is noteworthy that MDPI, an open-access publisher, publishes three of the top four journals (*Sustainability*, *Sensors*, and *Applied Sciences*). A possible reason for the concentration of I5.0 research in these journals could be that researchers publishing on fast-moving and “hot” topics (which

I5.0 undoubtedly currently is) often prefer journals with shorter review times to establish authorship as soon as possible and/or to avoid being “scooped” [34,35].

**Table 3.** Most relevant sources in I5.0 research.

	Sources	Number of Articles
1	IEEE Transactions on Industrial Informatics	24
2	Sustainability	17
3	Sensors	15
4	Applied Sciences	13
5	CEUR Workshop Proceedings	13
6	IFAC-PapersOnLine	13
7	IFIP Advances in Information and Communication Technology	11
8	Journal of Manufacturing Systems	10
9	Communications in Computer and Information Science	9
10	Lecture Notes in Mechanical Engineering	9

Table 4 provides an overview of the 10 most impactful sources in I5.0 research. The table provides an overview of the following metrics: h-index, total citations (TC), number of papers (NP), and the starting year of publication (Start year).

**Table 4.** The 10 most impactful sources in I5.0 research.

	Source	h_Index	TC	NP	Start Year
1	IEEE Transactions on Industrial Informatics	7	137	24	2021
2	Journal of the Knowledge Economy	6	114	8	2021
3	Sustainability	6	357	17	2019
4	Journal of Manufacturing Systems	5	248	10	2021
5	Lecture Notes in Mechanical Engineering	5	53	9	2020
6	Applied Sciences	4	134	13	2020
7	Computers and Industrial Engineering	4	46	8	2021
8	Energies	4	44	8	2021
9	Sensors	4	57	15	2021
10	Applied System Innovation	3	64	4	2021

The top 10 sources are ranked according to h-index. The h-index is developed to assess the research output of individual researchers [36] but can also be used to evaluate the performance of journals. In this case, an h-index of 5 means that the journal has published 5 articles that have received at least 5 citations. While h-index is widely used to measure research performance, it has some limitations since it, for example, does not account for very highly cited articles [37].

The table shows that *IEEE Transactions on Industrial Informatics* ranks first with an h-index of 7, followed by the *Journal of the Knowledge Economy* and *Sustainability*, both with h-indexes of 6. In terms of total citations, the picture is slightly different, with *Sustainability* in the lead, followed by *Journal of Manufacturing Systems*. Both of these journals have published two of the highest-cited articles on I5.0 [15,21]. In terms of number of articles on I5.0, *IEEE Transactions on Industrial Informatics* leads with 24, followed by the three aforementioned open-access journals (*Sustainability*, *Sensors*, and *Applied Sciences*).

#### 4.3. Most Impactful Documents

Table 5 displays the top 10 most impactful articles on I5.0. The columns provide details on the article’ DOI (Digital Object Identifier), publication year, local citations (LC), global citations (GC), and the LC/GC ratio. The highest local citations count (96) belongs to Nahavandi [21]. This article also has the highest global citations count (281), which indicates that it has had considerable influence in other fields as well. The highest LC/GC ratio (56.9%) is associated with Aslam et al. [38].

**Table 5.** Top 10 impactful documents in I5.0 research.

Rank	Document	DOI	Year	LC	GC	LC/GC Ratio (%)
1	Nahavandi [21]	10.3390/su11164371	2019	96	281	34.16
2	Demir, Döven and Sezen [23]	10.1016/j.procs.2019.09.104	2019	66	153	43.14
3	Xu, Lu, Vogel-Heuser and Wang [15]	10.1016/j.jmsy.2021.10.006	2021	61	170	35.88
4	Longo et al. [39]	10.3390/APP10124182	2020	56	101	55.45
5	Özdemir and Hekim [13]	10.1089/omi.2017.0194	2018	45	185	24.32
6	Aslam, Aimin, Li and Ur Rehman [38]	10.3390/info11020124	2020	33	58	56.9
7	Maddikunta, Pham, Prabadevi, Deepa, Dev, Gadekallu, Ruby and Liyanage [18]	10.1016/j.jii.2021.100257	2022	30	195	15.38
8	Lu et al. [40]	10.1016/j.jmsy.2022.02.001	2022	23	40	57.5
9	Javaid and Haleem [41]	10.1142/S2424862220500141	2020	22	59	37.29
10	Romero and Stahre [42]	10.1016/j.procir.2021.11.183	2021	19	38	50

**4.4. Most Impactful Authors**

An overview of the 25 most influential authors who have made significant contributions to the scientific literature on I5.0 is presented in Table 6. The table lists various metrics for these researchers: h-index, total citations (TC), number of articles published (NP) and start year. The h-index is a measure of a researcher’s productivity and impact. H-index is defined as the highest number h such that h of a researcher’s papers have at least h citations each. TC represents the total number of citations for a particular researcher, NP represents the number of papers that a researcher has published, whereas start year represents the year the researcher started publishing on I5.0.

**Table 6.** Most impactful authors in I5.0 research.

	Author	h-Index	TC	NP	Start Year
1	Nahavandi S	2	284	3	2019
2	Wang L	4	240	6	2021
3	Lu Y	3	216	3	2021
4	Xu X	2	210	2	2021
5	Dev K	2	205	3	2022
6	B P	1	195	1	2022
7	Deepa N	1	195	1	2022
8	Gadekallu TR	1	195	1	2022
9	Liyanage M	1	195	1	2022
10	Maddikunta PKR	1	195	1	2022
11	Pham QV	1	195	1	2022
12	Ruby R	1	195	1	2022
13	Hekim N	2	188	2	2018
14	Özdemir V	2	188	2	2018
15	Vogel-Heuser B	1	170	2	2021
16	Demir KA	2	158	3	2019
17	Haleem A	4	154	5	2019
18	Javaid M	4	154	4	2019
19	Döven G	1	153	1	2019
20	Sezen B	1	153	1	2019
21	Carayannis EG	6	117	7	2021
22	Chang V	3	103	3	2020
23	Longo F	1	101	1	2020
24	Padovano A	1	101	1	2020
25	Umbrello S	1	101	1	2020

The authors are ranked by total number of citations (TC). Nahavandi S has the highest citations and has published three articles, including the highly cited 2019 article [21]. Wang L follows in second place with 240 citations across six articles, while Lu Y in third place has 216 citations across three articles. It is notable that both Wang L and Lu Y started publishing on I5.0 as recently as 2021. Several of the coauthors on the Maddikunta, Pham, Prabadevi, Deepa, Dev, Gadekallu, Ruby and Liyanage [18] article are also in the top 15. The researchers with the longest careers in I5.0 research started in 2018 and 2019. It is notable that the researcher with the earliest published article [6] is missing from the top 25.

4.5. Most Relevant Countries

Table 7 provides an overview of the 10 most productive countries in the scientific literature on I5.0. The countries with the highest production of research are India, China, Italy and the USA. The rest of the countries in the top 10 are all European countries.

Table 7. Ten most productive countries in I5.0 research.

Rank	Country	Frequency
1	India	180
2	China	138
3	Italy	80
4	USA	62
5	Portugal	55
6	United Kingdom	51
7	Germany	39
8	Poland	35
9	Spain	35
10	Ireland	31

In a previous bibliometric analysis carried out in 2021, Germany was absent from the top 10 [9]. This was somewhat surprising since Germany has been a dominant country in terms of I4.0 research [33]. However, as of early 2023 the data indicate that I5.0 is starting to attract more attention in the academic community in Germany as well, e.g., [43,44], and the country has climbed to 8th position.

Table 8 provides an overview of the 10 most impactful countries in I5.0 research. The countries are ranked according to total citations (TC). The highest-ranked countries in terms total citations are China with 356, followed by Australia with 341. Then, follows a group of countries that have attracted approximately 200 citations each (e.g., New Zealand, Italy and Republic of Korea). In terms of average article citations, Turkey has the highest average (77.5), followed by New Zealand with 54. The countries with lower average article citations are China (8.68), India (4.58), the United Kingdom (7.13), Italy (7.39), and the United States (17.64). However, these averages should be interpreted with caution due to the relatively low total volume of articles and the fact that some of these articles have had little time to accumulate citations.

Table 8. The most impactful countries in Industry 5.0 research.

	Country	TC	Average Article Citations
1	China	356	8.68
2	Australia	341	48.71
3	New Zealand	216	54
4	Italy	207	7.39
5	Korea	203	25.38
6	Canada	200	22.22
7	India	197	4.58
8	USA	194	17.64
9	Turkey	155	77.5
10	United Kingdom	107	7.13

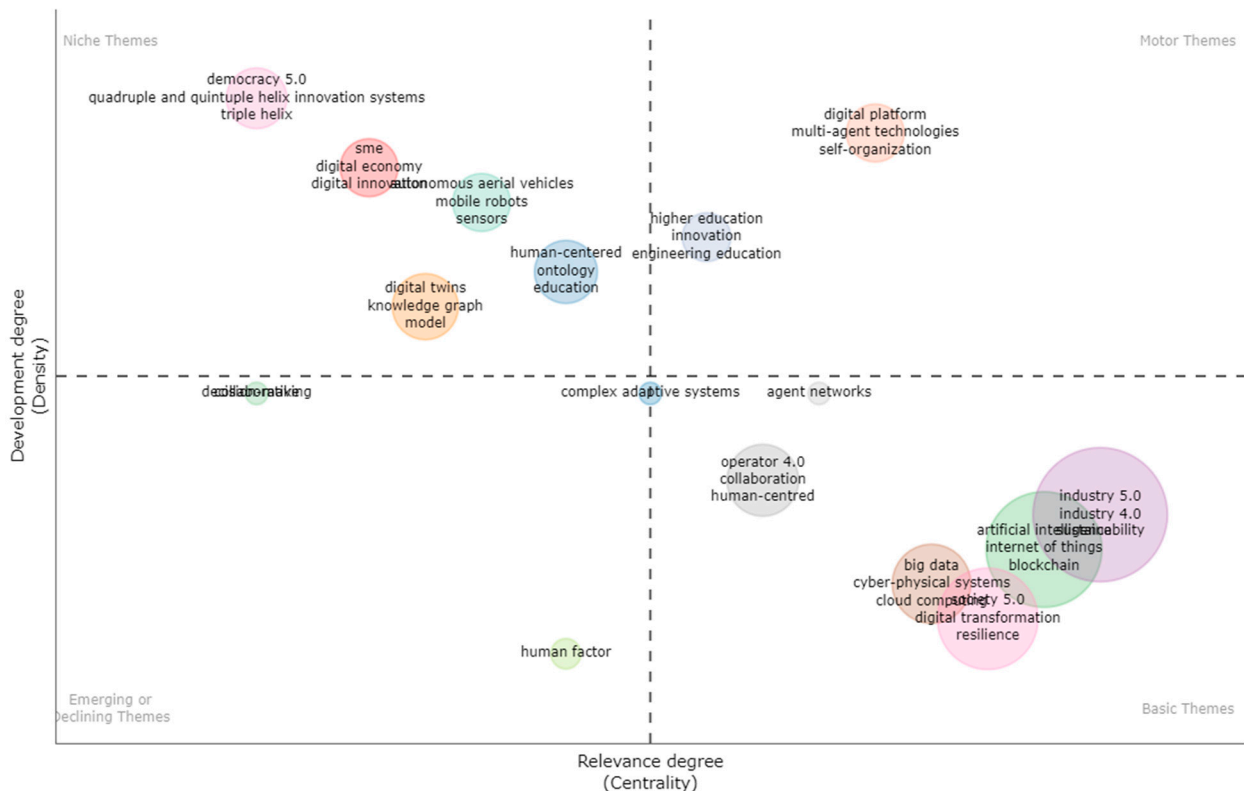


## 5. Thematic Analysis of Industry 5.0 Research

This section provides a thematic analysis of I5.0 research, which focused on the conceptual structure of the I5.0 research field. The section is divided into two parts: (1) a thematic map of themes in I5.0 research, and (2) an analysis of the evolution of research themes in the I5.0 literature.

### 5.1. Thematic Map

A thematic map allows for visualizing important themes in a research field [45]. Based on author keywords, we constructed a thematic map (Figure 3). This analysis generates clusters of keywords and identifies the themes in the research field. The map has two dimensions: centrality (x-axis) and density (y-axis). Centrality refers to how important a particular theme is, while density refers to the development of the theme. The  $2 \times 2$  matrix in the thematic map yields four quadrants, where the size of the bubble refers to the occurrence of the keywords.



**Figure 3.** Thematic map (Source: Biblioshiny).

In the upper right quadrant, we find the motor themes that are the most discussed topics in the field. The map shows that these are related to digital platforms, multi-agent technologies, self-organization, innovation, higher education, and engineering education.

The upper left quadrant contains the niche themes, which are well-developed but isolated (niche) themes. There are many niche themes in the I5.0 literature, which could reflect that the concept currently is applied to many diverse areas such as research on innovation systems (triple helix), democracy, digital economy, and digital innovation.

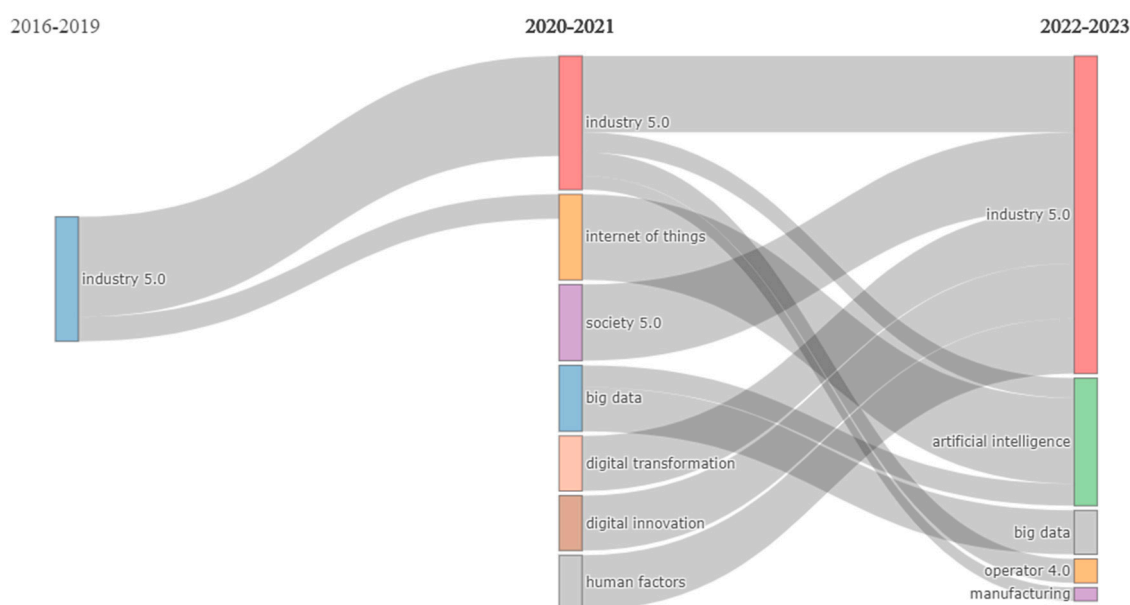
In the lower right quadrant, we find the themes that are considered basic and transversal, with low levels of development but high levels of centrality and relevancy to the I5.0 literature. As can be seen from the map, most of the themes can be considered basic, including I4.0/I5.0-related technologies such as artificial intelligence, big data, internet of things, blockchain and cyber-physical systems. We also can find themes related to Operator 4.0, digital transformation, as well as sustainability and resilience.

In the lower left quadrant, we find the emerging or declining themes. There are few themes in this quadrant and only one that is solidly within the quadrant (“human factor”). Since I5.0 is a field of research that has grown rapidly in recent years, these themes are likely emerging. Several recent studies have focused specifically on the role of human factors and the human–machine interaction in I5.0 [10,46,47].

### 5.2. Thematic Evolution

In this section, we present an analysis of the thematic evolution in I5.0 research literature based on author keywords. An examination of the thematic evolution of the I5.0 field provides an interesting broad picture of the development of the field. Such longitudinal analyses allow for highlighting how topics merge or split into several themes [32].

Figure 4 presents an alluvial diagram, which can be described as a type of flow diagram. This type of graph is useful for visualizing the thematic evolution of a research field [32]. The figure shows the thematic evolution of the I5.0 research field in the period 2016–2023, by dividing it into three time slices or subperiods. Accordingly, we are looking at the evolution of keywords during three different time periods (2016–2019; 2020–2022; 2022–2023). The reason for choosing these time slices was that there was an uptick in the volume of research in 2020, coinciding with the COVID-19 pandemic, which some commentators suggested has fueled the shift towards I5.0 [7,8]. Therefore, exploring whether these surges were associated with the emergence and development of new research themes is interesting.



**Figure 4.** Thematic evolution (Source: Biblioshiny).

In the first phase (2016–2019), I5.0 is the dominant theme, which can be explained by the fact that this is the embryonic phase where studies were attempting to define and explain the concept. During the second phase (2020–2021), it is clear that research on the concept splits up into several themes, and studies on I5.0 relate to concepts such as Internet of Things, Society 5.0, big data, digital transformation, digital innovation, and human factors [15,38,48,49].

In the third phase (2022–2023), we see the continuation of some themes such as big data, but also the emergence of additional themes such as artificial intelligence [50–52]. Another emerging theme is the link between Operator 4.0 and I5.0 [12,53,54].

## 6. Discussion

The analysis carried out in this paper offers valuable insights into the evolution of I5.0 since its inception in the mid-2010s and serves as a foundation for identifying future

research directions in this field. The bibliometric trends revealed in this paper clearly show that I5.0 is an upward trajectory, with an exponential growth in publication volume in recent years, with 2022 having almost four times as many publications as 2021. One reason for the growth and expansion of the I5.0 literature is that the concepts' popularity has been fueled by the COVID-19 pandemic [7,8] and a shifting zeitgeist towards a much stronger focus on resilience and sustainability [20]. These are aspects of the I5.0 concept that have been heavily promoted by the European Commission in the last few years [19,55,56].

In addition, the study offers an overview and a snapshot of the current research landscape around I5.0, which could be valuable for researchers contemplating research in this field. It also serves as a quick reference guide to help authors identify publication avenues in different fields that are more likely to be welcoming of research on this concept. Through our bibliometric analysis, we have provided a preliminary "reading list" of sorts for this area [25]. Our analysis reveals that the top three most cited articles are Nahavandi [21], Demir, Döven and Sezen [23], and Xu, Lu, Vogel-Heuser and Wang [15], while the most relevant journals are *IEEE Transactions on Industrial Informatics, Sustainability*, and *Sensors*.

The thematic analysis presented in Section 5 allows a combination of looking at the field's evolution using a combination of quantitative and qualitative insights. This type of analysis can be useful for identifying future research areas since it provides indications about what is currently happening on the research front and could be interesting areas for future work. The thematic map shows that there is a heavy concentration of basic themes in I5.0 research, which are central themes in need of more development. Additionally, many of the themes can be characterized as niche themes, which means that they are specialized or peripheral, and in need of stronger connection to the broader I5.0 literature. Since the I5.0 literature is growing rapidly, it is likely that some of the current basic, emerging, and niche themes will move to the upper right quadrant and become motor themes.

## 7. Conclusions

The aim of the current paper has been to provide an updated overview of the state of I5.0 research. While there have been a few prior bibliometric analyses mapping different aspects of the early phase of I5.0 [9–12], our updated bibliometric analysis shows that the field of I5.0 is very fast-moving and is rapidly expanding.

In summary, our bibliometric analysis has allowed us to identify the general publication trends and the overall trajectory and hot topics in the scientific literature around I5.0. We have identified the most impactful documents, sources, authors, and countries in the field of research on I5.0. Despite the limited size of the literature on I5.0 at present, the overall publication trend suggests that this area of research is expanding quickly. Several of the most impactful articles have been published recently, suggesting that I5.0 is still an area in flux and rapid development. Therefore, our study provides more insight into the evolutionary trajectory of the I5.0 concept. By undertaking this endeavor, we actively contribute to enhancing our comprehension of a significant contemporary phenomenon within the realm of business and organizations [20].

In closing, it is important to reflect on the study's limitations. The study's heavy reliance on bibliometric data from Scopus implies a strong emphasis on scholarly discourse on I5.0 published in academic journals. Furthermore, while Scopus is one of the largest bibliographic databases available, it does not cover all scientific publications. Bibliometric studies are subjective and can be influenced by the choices we made related to search terms and the inclusion criteria. Moreover, there may be potential issues related to using author keywords for thematic analysis since they may have only been chosen to provide general background.

In the future, researchers could combine bibliometric data with other types of data from electronic magazines, newspapers, or social media platforms [57–59]. Another potential avenue for future research would involve conducting longitudinally oriented analyses

that examine different time periods, with the aim of revealing shifts in the structure and dynamics of the academic research field concerning I5.0.

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