

## Research Trends in the Fifth Industrial Revolution Field

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### Abstract

The present study investigates the transformative developments associated with the Fifth Industrial Revolution, with particular emphasis on the emergence and evolution of fifth-generation industrial technologies globally. The research examines not only the technological shifts themselves but also their broader implications for societies, products, and industrial systems. In doing so, the present investigation addresses research trends concerning Industry 5.0, leading countries in scientific output, the subject categorisation in Industry 5.0 research, and related emerging topics in this field. To achieve these aims, the study employs a scientometric methodology. All relevant documents-including peer-reviewed articles, books, manuscripts, and conference papers-were retrieved from the Web of Science database for the period 2014–2023 using a comprehensive search strategy targeting the field of fifth-generation industry (using the search term TS= “Industry 5.0”). In total, 3,502 publications were identified. The dataset was subsequently analyzed using SPSS and CiteSpace to uncover publication trends, collaboration networks, and topical structures within the field. The findings reveal a marked increase in scholarly output on fifth-generation industrial technologies, from 184 publications in 2014 to 1,430 in 2023. China stands out as the most productive contributor, accounting for 798 studies over the past decade. Moreover, China and the United States were among the earliest countries to initiate systematic research on fifth-generation industry, indicating their leading role in shaping the field's intellectual foundations. Among disciplinary areas, food science and technology constitutes the most prominent category with 453 studies, followed by environmental sciences with 325 publications, and biotechnology and applied microbiology with 301 publications-highlighting the multidisciplinary nature of fifth-generation industrial research.

Topical analyses further demonstrate that themes such as Industry 5.0, systems thinking, sustainable development, and digital twins have remained consistently central since the introduction of the fifth-generation industry concept. The findings underscore that, in the context of the Fifth Industrial Revolution, technological paradigms have undergone substantial reconfiguration. Emerging innovations—including 4D printing, collaborative robots (cobots), and cognitive computing—have fundamentally reshaped production processes, service delivery mechanisms, and the broader industrial ecosystem.

**Keywords:** Fifth Industrial Revolution, Research Trends, Co-Citation Analysis, Web of Science.

### Introduction

The trajectory of industrial productivity has consistently been shaped by the accelerating pace of technological advancement. In recent years, this progression has assumed particular significance, as technologies such as 4D printing, collaborative robots (cobots), augmented and virtual reality, and digital twins have evolved rapidly and intelligently. Collectively, these developments have converged to form what is now recognized as the Fifth Generation of Industry—commonly referred to as Industry 5.0. Understanding the position and implications of Industry 5.0 requires revisiting the historical evolution of industrial revolutions. The First Industrial Revolution (1760-1840) marked the transition to mechanized production powered by water and steam, fundamentally transforming manufacturing processes (Ardito, Petruzzelli, Panniello & Garavelli, 2019; Rajput & Singh, 2020). The Second Industrial Revolution emerged with the introduction of electric power in the early twentieth century, enabling industrial automation and mass production—developments that facilitated the post-World War II population boom (Dalenogare, Benítez, Ayala & Frank, 2018). The Third Industrial Revolution, beginning in the 1960s, incorporated computers and robotics, thereby reducing reliance on manual labor. Subsequently, the Fourth Industrial Revolution in the early twenty-first century centered on the integration of information and communication technologies, significantly enhancing digital connectivity and industrial flexibility (Vaidya, Ambad & Bhosle, 2018; Khoshseper, Alimohammadlou, Mohammadi & Ranaei Kordshouli, 2023).

Industry 5.0 builds on the foundations of Industry 4.0 but extends beyond digitalization to address broader societal, ecological, and human-centered priorities. It reflects both the extent of national technological development in the early twenty-first century and the strategic pathways through which countries can enhance their industrial resilience in the decades to come. Industry 5.0 not only seeks to maintain stable employment within the manufacturing sector but also emphasizes ecological sustainability through “green production” practices, carbon neutrality, and energy efficiency (Berg, Knoll, & Petridis, 2021). Whereas Industry 4.0 primarily focused on digitalization and AI-driven efficiency (Shi, Xie, Xue, Chen, Fu and Xu, 2020), Industry 5.0 is distinguished by its emphasis on research, innovation, and the long-term integration of technology to serve human well-being. It aims to fulfill the promises of advanced digitalization, big data, and artificial intelligence while ensuring that these technologies address emerging industrial, societal, and environmental needs (Kipper, Furstenu, Hoppe, Frozza & Iepsen, 2020).

This vision positions Industry 5.0 as a framework for enhancing production resilience during periods of transformation and for strengthening industrial value chains through greater adaptability and responsiveness. Within the European context, Industry 5.0 places strategic

emphasis on dimensions that will shape the future position of industry-economic, technological, environmental, and social. The model envisions industries that benefit not only corporate productivity but also workers' well-being (Xu, 2020; Narkhede, Pasi, Rajhans & Kulkarni, 2024). These benefits include attracting and retaining skilled talent, optimizing energy use, and strengthening overall industrial resilience. Although the initial investments required for the Industry 5.0 transformation may temporarily challenge European competitiveness relative to countries that have not yet transitioned, coordinated and timely investment strategies are essential for mitigating such risks. Failure to adopt people-centered, sustainable, and resilient industrial models could ultimately undermine Europe's global competitiveness. Accordingly, technology and innovation constitute core elements of Europe's path toward a new industrial paradigm-one in which resilience, environmental responsibility, and worker welfare are embedded within industrial processes (Zhou, Zhang, Zhao, Zheng & Song, 2021).

The rapid emergence of Industry 5.0 and the widespread dissemination of its concepts across organizational sectors have resulted in an increasingly fragmented body of research. This fragmentation makes it difficult for scholars to gain a clear understanding of the technological and organizational transformations induced by Industry 5.0. To achieve comprehensive insight into these developments, a systematic scientometric approach is essential. Scientometric analysis enables the structured examination of global research activity, providing a clear, integrated, and purpose-driven overview of the factors shaping Industry 5.0. Accordingly, the present study seeks to analyze research trends in the Fifth Generation of Industry through a scientometric lens.

### **Research Questions**

1. What have been the research trends in the field of Industry 5.0 from 2014 to 2023?
2. Which countries have contributed the most to scientific production related to Industry 5.0?
3. What topics and technologies have been the focus of research in Industry 5.0?

### **Literature Review**

This section synthesizes domestic and international research related to the Fifth Generation of Industry (Industry 5.0). Paschek, Mocan and Draghici (2019) evaluated the commercial implications of the emerging industrial paradigm, referred to as the fifth generation of industry. Their findings indicate that industries characterized by innovation capacity and responsiveness to market fluctuations are more likely to achieve competitive success. They further argue that Industry 5.0 represents a shift away from mass automation toward enhancing the capabilities and decision-making power of human workers. In a scientometric analysis, Alves, Lima, and Gaspar (2023) reported a continuous increase in research on Industry 5.0 between 2019 and 2023. Their findings highlight China as the most prolific contributor in terms of scientific output and international research collaboration during this period. Moreover, they observed that "Industry 5.0" and "digital twin" were the most frequently occurring and enduring themes across publications.

Barata and Kayser (2023), in their study titled *Industry 5.0: Past, Present, and Near Future*, identified four thematic clusters shaping the intellectual structure of Industry 5.0. The first cluster encompasses foundational concepts, including Industry 4.0, manufacturing, personalization, digital transformation, the Society 5.0 vision, and sustainability. The second

cluster concerns the future of the work environment, whereas the third emphasizes the growing relevance of digital twin technologies. The fourth cluster comprises core-enabling technologies, including blockchain, the Internet of Things, augmented reality, and next-generation communication systems (5G and 6G). Their analysis additionally reveals that research published after 2022 has increasingly focused on smart cities and digital twin applications. The authors also identify India, China, and the United States as the global leaders in Industry 5.0 scientific production, followed by prominent European contributors such as Italy, Spain, and the United Kingdom.

In another significant contribution, Zamany, Khamseh, and Iranbanfard (2024) examined the key variables influencing the international transfer of advanced technologies in the context of Industry 5.0. Their research identified five core clusters: (1) advanced technologies (e.g., artificial intelligence and the Internet of Things), (2) technology transfer mechanisms, (3) defining characteristics of Industry 5.0, (4) implementation challenges such as cybersecurity risks and high operational costs, and (5) regulatory frameworks and opportunities. Their study underscores the strategic role of international technology transfer in facilitating the transition to Industry 5.0 and highlights the centrality of human collaboration and competency development in guiding policymaking and implementation.

Similarly, Zulkifli and Wasesa (2024) observed a substantial increase in Industry 5.0 publications since 2018. However, their scoping review revealed that research remains disproportionately concentrated in the manufacturing and service sectors, with limited attention to fields such as agriculture and retail. Among the three core pillars of Industry 5.0—sustainability, resilience, and human-centeredness—the resilience dimension has received the least scholarly attention. They emphasize the need to develop operational frameworks that integrate advanced technologies (e.g., artificial intelligence and the Internet of Things) with sustainability-driven and human-centered principles. Additionally, they identify the development of sector-specific resilience indicators and models as an essential direction for future research.

Overall, the literature indicates that most existing studies adopt theoretical or conceptual orientations, relying heavily on content analysis and thematic clustering techniques such as VOSviewer. In contrast, comprehensive scientometric analyses and systematic reviews of long-term research trends remain limited. Among the reviewed studies, only the works of Alves et al. (2023) explicitly examine the longitudinal growth trajectory of Industry 5.0 research. This gap highlights the need for more integrated and data-driven evaluations of research patterns in the field—an issue that the present study aims to address.

### **Conclusion and inference from the literature review**

A review of previous research indicates that Industry 5.0 represents a significant shift from Industry 4.0, transitioning the focus from technology-driven productivity to human-centricity, sustainability, and resilience. While Industry 4.0 emphasizes digitalization, automation, and smart technologies, Industry 5.0 integrates these advancements with a stronger focus on improving human well-being, reducing environmental impact, and developing flexible industrial systems.

Key findings from the reviewed studies reveal that:

1. **Human-Centricity:** Industry 5.0 prioritizes the role of humans in production processes and utilizes technologies such as collaborative robots (cobots) and advanced human-machine

interfaces to enhance creativity, decision-making, and employee satisfaction.

2. Sustainability: The integration of circular economy principles and technologies such as 4D printing and digital twins drives efforts to reduce waste, conserve resources, and minimize environmental footprint.

3. Resilience: Industry 5.0 aims to create industrial systems that are better equipped to handle crises, ensuring continuity and adaptability in the face of global challenges.

However, the existing literature also highlights several gaps:

1. Lack of Attention to Implementation Challenges: While the theoretical framework of Industry 5.0 is well articulated, few studies have addressed the practical challenges of implementing these technologies.

2. Geographical Imbalance in the Distribution of Industry 5.0 and Related Technologies: Most research has been conducted in countries such as China, the United States, and Germany, with limited studies focusing on developing countries.

### Materials and Methods

The present study is applied, seeking to expand knowledge on the subject and provide explanations and clarifications. Additionally, the results obtained from this research facilitate decision-making and the planning of future research in the context of Industry 5.0. The method of this research is scientometric. SPSS and CiteSpace were employed for data analysis. CiteSpace is a tool for analyzing co-citation in research. The validity and reliability of the data were assessed using specific formulas. The research data encompass all outputs produced by researchers in Industry 5.0 from 2014 to 2023. The stakeholders of this research include a range of experts in technology and innovation. Accordingly, stakeholders are categorized into several groups. The first group comprises university faculty members, while the second group includes technology and innovation experts from research centers and science and technology parks. The third group consists of master's and doctoral students whose theses are focused on Industry 5.0 technologies.

The main steps for collecting and analyzing documents related to Industry 5.0 are as follows: In the first step, existing data in the Web of Science Core Collection (WOSCC) database were searched using the keywords listed in Table 1 and saved in plain text format to ensure compatibility with CiteSpace. In the next step, synonyms and irrelevant words were removed. Subsequently, the search results were imported into CiteSpace, and the desired outputs were obtained, presented as figures and tables for analysis. This research evaluated the centrality parameter using below equation

$$BC_t = \sum_{i \neq j \neq k} \frac{n_{st}^t}{g_{st}} \text{ (Freeman, 1977).}$$

In this Equation,  $g_{st}$  indicates the number of shortest paths between nodes, while  $n_{st}^t$  represents the number of paths passing through node  $iii$ . The significance of each node can be assessed using the centrality index. Any node with a centrality value of  $\geq 0.1$  or greater is considered a pivotal point (Zhang et al., 2020).

Table 1

Search query

Subject	Keyword	Number of Records
Industry 5.0	TS= (industry 5.0 OR "industry 5.0" OR I5.0 OR "I 5.0" OR "fifth industr* revolution" OR "industr* revolution 5.0" OR "Industr*5.0 Revolution") and py=2014-2023	3502

## Results

After cleaning, data extracted from the Web of Science were imported into CiteSpace, and the studies were examined with respect to publication output, leading journals, country collaborations, subject classifications, keywords, and related variables.

### Characteristics of publication outputs

As shown in Figure 1, research on Industry 5.0 has increased from 2014 to 2023.

According to Web of Science data, 3,502 studies have been conducted on Industry 5.0 technologies, up from 184 in 2014 to 1,430 in 2023.

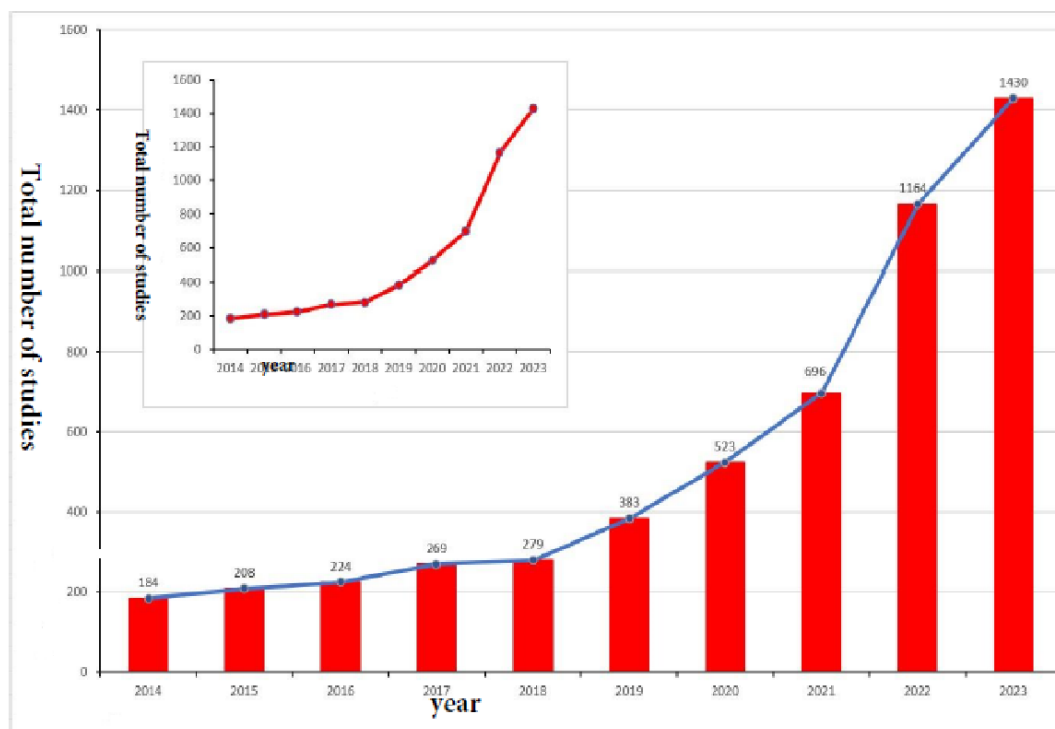


Figure 1: The number of published papers in the fifth-generation industry

### Country collaborations

China has conducted the most research in Industry 5.0 over the past decade, with 798 studies. India ranks second with 401 studies, while the United States ranks third with 346 studies (Figure 2). Recent trends indicate that China, India, and the United States have made more rapid advances in this area. The Islamic Republic of Iran ranks 15th globally in scientific output on Industry 5.0, placing it ahead of countries such as Turkey, France, and Russia.

According to a 2023 report by UNCTAD, one reason for the success and leadership of countries such as the United States, China, and India is their industrial policy and support for domestic production. These countries have established their leading positions in the world by supporting an internal production system and innovation that combine public- and private-sector players, as well as by supporting and regulating research institutions. In China, the Renewable Energy Law, enacted in 2006, encouraged Chinese companies and research institutions to collaborate with foreign partners, enabling them to enter international markets through this cooperation. Another specific program implemented by Chinese policymakers is the "Thousand Talents Plan," which aims to attract global experts and retain top Chinese researchers in industrial technologies. In India, Indian policymakers prioritized lower prices over building internal production capacity, seeking to maximize the transfer and acquisition of technology. Overall, there has been limited emphasis on research and development and on the creation of domestic capabilities and production capacity.

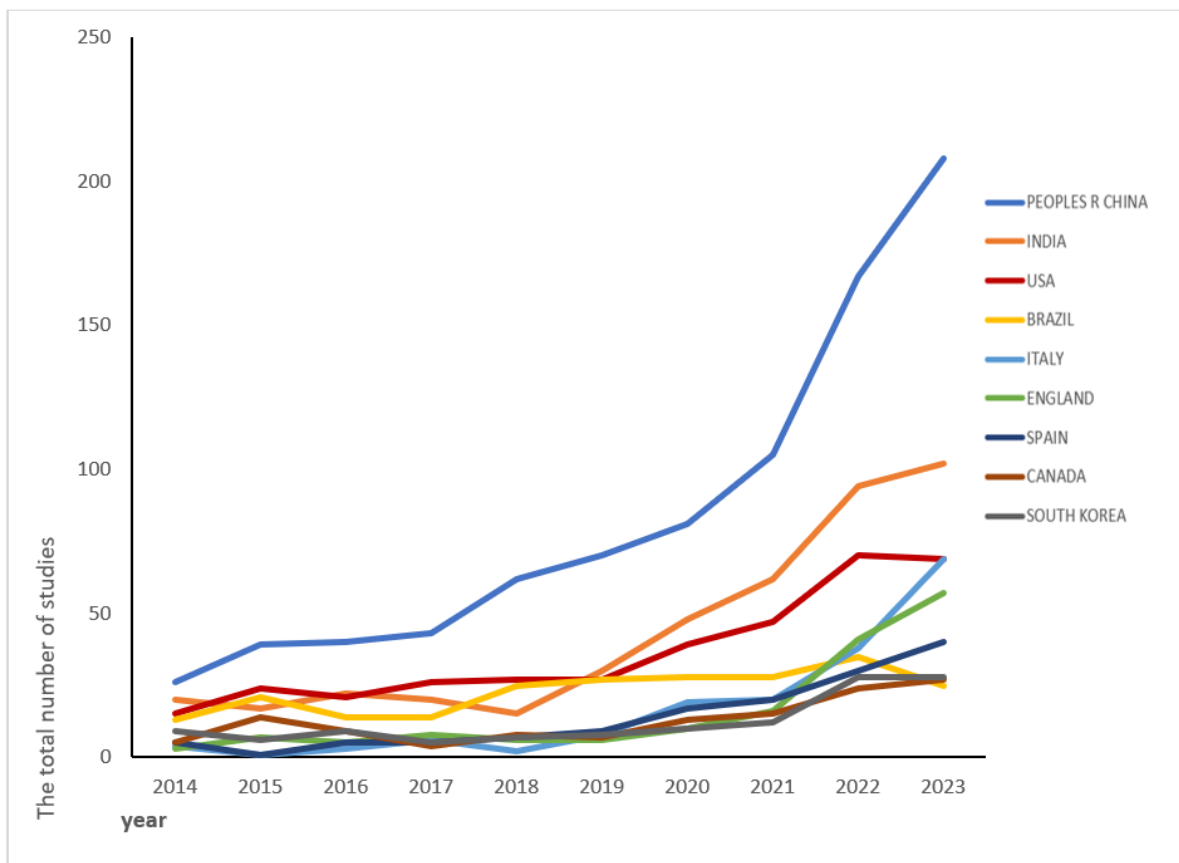


Figure 2: Leading countries in global scientific production related to Industry 5.0

This Figure consists of nodes and connections, where the color of each ring surrounding the countries and their relationships corresponds to different years. The central nodes representing China and the United States indicate that these two countries were the first to conduct research on Industry 5.0 (Figure 3). Furthermore, in 2016, countries such as Argentina, Portugal, and Iran had the strongest collaborative relationships among them.

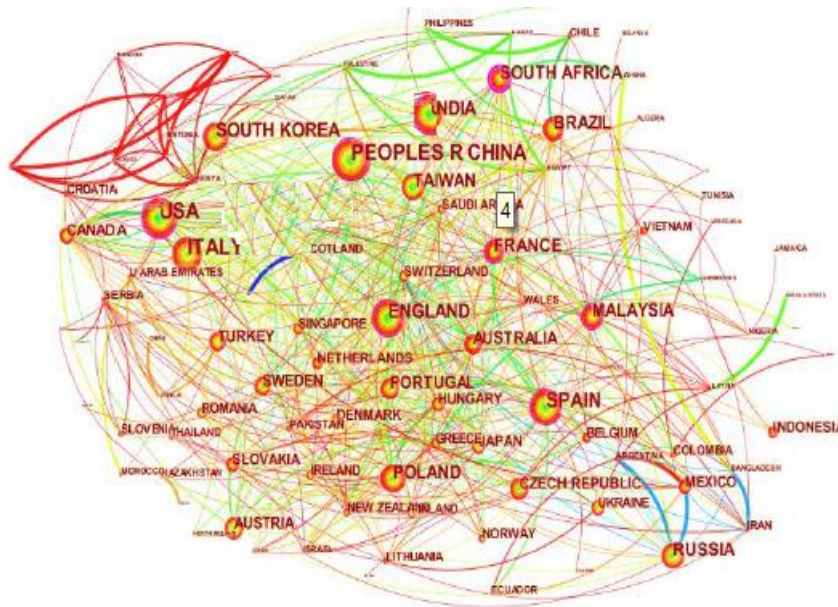


Figure 3: Collaboration relationships between countries in Industry 5.0

**Topic classification in industry 5.0**

Each article indexed in the WOSCC belongs to one or more subject categories. It is evident that Industry 5.0, as an interdisciplinary research area, encompasses multiple fields of study. Research in Industry 5.0 is multifaceted and encompasses a wide range of interests. According to Table 2, among the classifications made, the category of Food Science Technology, with 453 records, is the largest category, followed by Environmental Sciences, with 325 records, as the second category, and Biotechnology and Applied Microbiology, with 301 records, making it the third significant category in Industry 5.0 research.

Table 2  
Top topic category in Web of Science

Rank: (2014-2023)	Web of Science topic category	Number of documents
1	Food science technology	453
2	Environmental science	325
3	Biotechnology and Applied Microbiology	301
4	Chemical engineering	265
5	Electrical and electronic engineering	220
6	Material engineering	210
7	Interdisciplinary chemistry	201
8	Applied Chemistry	185
9	Molecular biology	164
10	Environmental engineering	153

**High frequency keywords**

In this study, the most frequently occurring keywords in Industry 5.0 for different periods are presented in Table 3. A comparison of keyword frequencies indicates that certain topics, such as Industry 5.0, Systems, Sustainable Development, and Digital Twins, have persisted

since the introduction of the Industry 5.0 concept in research discussions. Additionally, from 2021 to 2023, there was increased attention to foundational concepts and themes such as resilience and sustainability.

*Table 3*  
*High-Frequency Keywords of the 5<sup>th</sup> generation industry*

2014-2016		2017-2020			2021-2023
Keywords	Frequency	Keywords	Frequency	Keywords	Frequency
Industry 5.0	30	Industry 5.0	225	Industry 5.0	1205
System	8	Virtual Reality	215	Virtual Reality	656
Collaborative Robot	8	System	110	Augmented Reality	455
Digital Twin	8	Management	70	Collaborative Robot	344
4D Printing	3	Collaborative Robot	67	System	340
Internet of Things	3	Intelligent System	39	Management	320
Cognitive Computing	3	Sustainable Development	37	Digital Twin	209
Additive Manufacturing	2	Digital Twin	25	Additive Manufacturing	201
Intelligent System	2	Cooperation	18	Resilience	148
Big Data	2	Internet of Things	14	Sustainable Development	145

### Knowledge mapping

To determine the evolution of studies on Industry 5.0, a knowledge mapping tree was designed with a timeline representation. In Figure 4, each cluster illustrates the temporal distribution from left to right. These clusters exhibit a gradient of colors from warm to cool as you move from top to bottom. As the gradient shifts from warm colors to cooler tones, the size of the clusters and the number of references within each category decrease. Each cluster displays arcs with varying color gradients. The warmer the color spectrum, the more recent the clusters are. The same principle applies to the nodes; larger node sizes indicate a greater number of citations, while moving from cooler to warmer color gradients signifies the novelty of citations. Furthermore, the new cluster group includes all currently active clusters, indicating the research frontiers. These indicators typically reflect high citation rates, high activity levels, or centrality within the co-citation network.

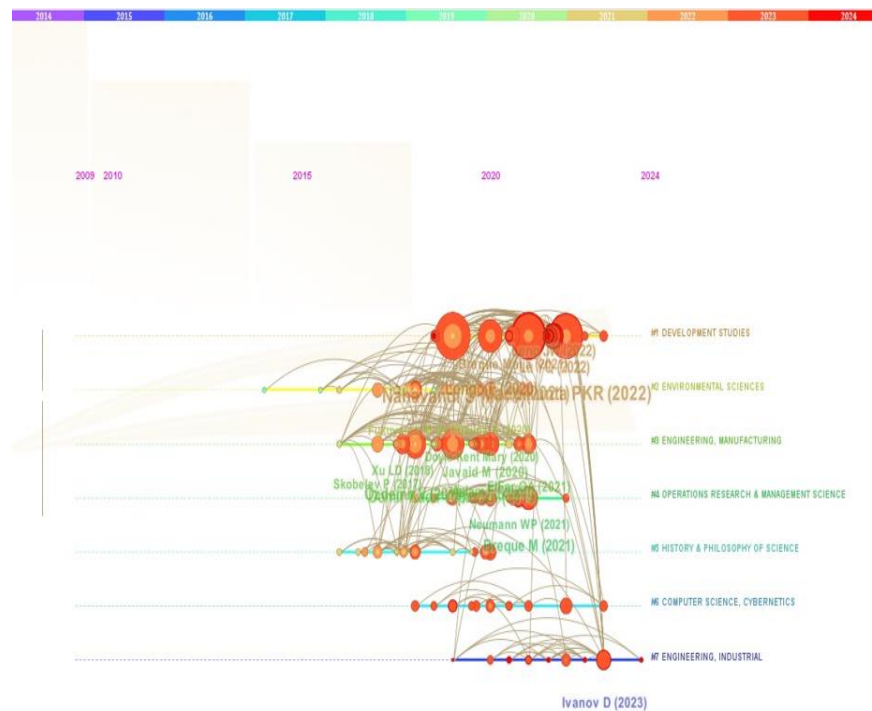


Figure 4: Co-citation analysis timeline

### Discussion

The purpose of this study was to examine global developments in Industry 5.0 and its associated emerging technologies. To achieve this objective, relevant keywords were employed to retrieve scientific documents from the Web of Science database. Following data extraction, CiteSpace software was used to analyze publication trends, country-level contributions, and thematic hotspots. The findings of the study address the following research questions:

What has been the growth trend of research conducted in the field of fifth-generation industry from 2014 to 2023?

Which countries have played leading roles in the global scientific production related to Industry 5.0, and what patterns of international cooperation exist among them?

What are the dominant thematic categories and emerging hot topics within Industry 5.0 research on the Web of Science?

To answer these questions, scientific literature published between 2014 and 2023 was reviewed to identify major research areas and the interests of leading countries in Industry 5.0, both globally and in the Islamic world.

The findings show that publications in the field of Industry 5.0 increased from 184 in 2014 to 1,430 in 2023, indicating a clear upward trend. These results corroborate the findings of Alves et al. (2023), both of which highlight the significant global expansion of research in this field. Unlike earlier studies that primarily focused on Industry 4.0, the present findings emphasize Industry 5.0's distinctive orientation toward human-centricity, sustainability, and resilience, signaling a paradigmatic shift in industrial and technological research.

Over the past decade, China, India, and the United States have emerged as the most active contributors to scientific output in Industry 5.0. Notably, the Islamic Republic of Iran, ranked 15th globally, surpasses countries such as Turkey, France, and Russia—an outcome consistent

with the reports of Alves et al. (2023). These studies similarly indicate the rapid growth of Industry 5.0 research from 2019 to 2023, with China exhibiting the highest levels of international collaboration. During the same period, Industry 5.0 and digital twin technologies were the most frequently recurring topics across global publications.

Analysis of national strategies in leading countries indicates that progress in Industry 5.0 is strongly shaped by the alignment of technological priorities with domestic needs and global trends. For example:

China has emphasized targeted international cooperation and large-scale industrial digitalization.

India has prioritized low-cost technological solutions to support governmental and societal needs.

The United States has pursued innovation-driven policies to maintain its competitive advantage.

These strategically differentiated approaches have enabled all three countries to secure substantial influence in the scientific and technological development of Industry 5.0. With its current ranking, Iran has demonstrated considerable potential for further advancement. Strengthening innovation-driven industrial policies, supporting domestic production capacity, and expanding international scientific cooperation—especially in key areas such as digital twins, sustainable development, and resilience—can significantly enhance Iran’s position in the global Industry 5.0 landscape.

The findings further reveal that national strategies have a profound influence on the broader development of advanced technologies, including those that underpin Industry 5.0. This underscores the importance of coherent policy frameworks in facilitating technological adoption and industrial transformation.

In terms of thematic distribution, food science and technology emerged as the largest research category within Industry 5.0, followed by environmental sciences, and then applied biotechnology and microbiology. Additionally, conceptual themes such as Industry 5.0, systems thinking, sustainable development, and digital twins have remained central to scholarly discourse since the inception of the Industry 5.0 paradigm. Between 2021 and 2023, interest in resilience and sustainability increased significantly, reflecting global concerns related to environmental challenges, supply chain disruptions, and industrial adaptability.

Emerging technologies—including cobots, 4D printing, and digital twin systems—have gained increasing attention in recent years. These findings are consistent with the studies of Barata and Kayser (2023) and Zulkifli and Wasesa (2024). However, the present study further emphasizes that the shift toward sustainability and human-centric design is more pronounced in Industry 5.0 than in Industry 4.0, a dimension that earlier research often overlooked or underemphasized.

### **Conclusion**

The remarkable surge in scholarly publications on Industry 5.0 between 2014 and 2023 underscores the growing strategic significance of this emerging paradigm. Industry 5.0 represents more than a technological evolution; it signals a profound transformation in industrial philosophy—one that places human-centricity, sustainability, and resilience at the forefront of future industrial systems. These foundational pillars collectively shape the trajectory of contemporary and forthcoming research.

The prominence of China, India, and the United States as leading contributors to scientific output in this domain highlights the decisive role of well-designed national strategies in shaping industrial and technological advancement. Iran's fifteenth-place global ranking reflects substantial national potential in this field. To translate this potential into tangible advancement—particularly toward achieving a single-digit global ranking—it is imperative for Iran to strengthen strategic investment, policy integration, and long-term planning aligned with the priorities of Industry 5.0.

The findings of this study further reveal that developments associated with the Fifth Industrial Revolution have fundamentally reshaped the technological landscape. Emerging technologies such as 4D printing, collaborative robots (cobots), and cognitive computing are already transforming production and service systems. Consequently, the future research frontier is expected to expand into advanced domains such as Virtual Reality (VR), Augmented Reality (AR), and Digital Twins, which will play increasingly critical roles in knowledge-intensive and interconnected industrial ecosystems. A defining feature of Industry 5.0 is its explicit shift toward a human-centric framework, moving beyond earlier technology-driven orientations. This paradigm requires industries to account for societal considerations, including worker well-being, environmental constraints, and ethical concerns, as integral components of industrial design and operation. By prioritizing human value creation, ecological boundaries, and workplace safety, Industry 5.0 reinforces the vision of a resilient and adaptive industrial model—one that aligns technological innovation with broader socio-environmental imperatives (Ivanov, 2023).

As demonstrated in this research, scientometric analyses provide essential insights into global research trajectories, intellectual structures, and emerging thematic clusters. In line with prior studies, such evaluations contribute valuable evidence for policymakers, planners, and researchers, offering a strategic foundation for enhancing quantitative and qualitative research outputs. By identifying prevailing trends, conceptual frameworks, and areas of high momentum, these analyses support informed decision-making to achieve balanced and sustainable scientific and technological development within the context of Industry 5.0.

### Research Limitations

1. Limitations of the Web of Science Database: This study has used only data from the Web of Science database and has not considered other databases.
2. Time Limitations: The data in this research only covers up to the year 2023 and does not include the year 2024.
3. Focus on English-Language Articles: This study has not taken other languages into account.

### Suggestions for Future Research

1. The impact of Industry 5.0 technologies on specific industries should be investigated.
2. The obstacles and challenges of implementing Industry 5.0 should be explored.
3. Comparative studies between leading countries (such as China and the United States) and developing countries (such as Iran) should be conducted to identify the strengths and weaknesses of developing countries.

### Practical Recommendations Based on Research Findings

1. Organizations should focus on developing technologies that enhance employee well-being and safety, such as collaborative robots and virtual reality systems.
2. Industries should adopt technologies that help reduce energy consumption, such as 4D printing and digital twins.
3. Countries and organizations should expand their international collaborations in Industry 5.0.
4. To succeed in Industry 5.0, investing in workforce training and developing skills related to advanced technologies is essential.

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