

# Industry 4.0 Research in Emerging Economies: A Bibliometric Comparison of Brazil and Globally Leading Countries

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## Abstract:

**Objective:** This study aims to map and analyze the Industry 4.0 research landscape in Brazil, comparing it with leading countries in order to identify dominant trends, research gaps, and Brazil's position and potential contributions to the global knowledge base. **Methods:** A bibliometric approach was adopted based on scientific publications indexed in the Scopus database. Text mining and network analysis techniques were applied using the VOSviewer software to examine publication growth, co-authorship collaboration patterns, and thematic clusters. Comparative analyses between Brazil and leading countries were conducted to identify convergences and divergences in research focus over time. **Results:** The findings indicate strong global growth in Industry 4.0 research, while Brazil exhibits a comparatively slower expansion. Brazilian publications largely align with international research themes, particularly those related to the Internet of Things (IoT), Big Data, and Machine Learning. However, Brazilian studies show a distinctive emphasis on applications aimed at operational efficiency and sustainability. **Conclusions:** The study concludes that, although Brazil follows global Industry 4.0 research trends, differences remain in the scale and pace of scientific production. The results highlight opportunities to strengthen Brazil's position through increased investment in research and development and expanded international collaboration. These insights are relevant for researchers, policymakers, and industry professionals seeking to promote strategic actions that enhance the impact and global integration of Brazilian Industry 4.0 research.

**Keywords:** Manufacturing; Industrial revolution; Artificial intelligence; Decision making; Smart factory.

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## 1. Introduction

The term Industry 4.0 originated from its use in 2011, in an initiative by the German government in collaboration with universities and private companies. It represents a new era in manufacturing that brings together technology for enhancing industrial production and efficiency (Kagermann *et al.*, 2013). Industry 4.0 is based on the concept of advanced or smart manufacturing, which entails adaptable systems with flexible production lines that automatically adjust for the processing of different types of products as well as for variable conditions, thereby enhancing the overall quality, productivity, and flexibility while enabling large-scale sustainable mass customization (Jabbour *et al.*, 2018; Frank *et al.*, 2019; Schuh *et al.*, 2020; Wang *et al.*, 2016b).

In order to achieve its aims, Industry 4.0 integrates core enabling technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, Cyber-Physical Systems (CPS), Multi-Agent Systems (MAS), and Cloud Computing to enable real-time data acquisition, predictive analytics, and autonomous decision-making across the product lifecycle (Dalenogare *et al.*, 2018; Frank *et al.*, 2019; Wang *et al.*, 2016a). Additionally, sociotechnical transformation is required for Industry 4.0, in which activities in the value chain are all carried out through smart approaches based on Information and Communication Technologies (ICT) (Longo *et al.*, 2017; Raguseo *et al.*, 2016; Stock *et al.*, 2018).

Those transformations through Industry 4.0 have a direct impact on the productivity and competitiveness in different countries. Understanding Brazil's position in the global Industry 4.0 landscape enables policymaking and strategies for innovation that foster technological development and competitiveness in each country. In that regard, this article seeks to answer the following research question: What are the scientific publishing trends and patterns regarding Industry 4.0 in Brazil as compared to those in other countries?

In doing so, a bibliometric analysis is employed, which enables the mapping of trends, the identification of key areas as well as gaps in scientific publishing through indicators such as the number of published studies and citations. Those indicators help assess researchers' and institutions' productivity and impact (Muhuri *et al.*, 2019).

For the bibliometric analysis, the Scopus database has been used, for it has tools that provide easier citation tracking and evaluation of search results through criteria such as country, affiliation, and research area (Gavel & Iselid, 2008). Also, Scopus has broader coverage than other databases (such as Web of Science) in the fields of science, technology, and management (Chadegani *et al.*, 2013; Singh *et al.*, 2021; Vieira & Gomes, 2009).

For visualization and analysis of bibliometric data, the VOSviewer tool was used, as it enables the making of network maps through the identification of relationship patterns among relevant items (Cobo

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*et al.*, 2012). Hence, the use of VOSviewer in connection with the Scopus database makes the identification of research networks and knowledge flows easier in the setting of Industry 4.0 and thus provides insights into the structure and evolution of research in this area (Cobo *et al.*, 2014; Morris & Van Der Veer Martens, 2008).

## 2. Literature Review

Industry 4.0 refers to the fourth industrial revolution as characterized by the integration of emerging and converging technologies adding value throughout the whole product life cycle (Dalenogare *et al.*, 2018; Wang *et al.*, 2016b). Unlike previous industrial revolutions, as focused as they were on mechanization (First Industrial Revolution), electrification and mass production (Second Industrial Revolution), or automation and informatization (Third Industrial Revolution), Industry 4.0 is grounded on digitalization and integration of cyber-physical systems (CPS) (Feng *et al.*, 2001; Hermann *et al.*, 2016).

Several interconnected technologies underpin Industry 4.0, thus providing its foundation as a new industrial paradigm. IoT, AI, and Big Data are among its key enabling technologies. IoT connects devices and sensors throughout the production chain, thereby enabling real-time collection and analysis of operational data and optimizing manufacturing processes (Dalenogare *et al.*, 2018). AI enables intelligent automation, since machines thus learn and adapt to new conditions, continuously improving efficiency (Wang *et al.*, 2016b). As it collects and analyzes large volumes of data, Big Data provides insights for helping strategic decision-making (Porter & Heppelmann, 2015).

In addition to those technologies, additive manufacturing (3D printing), advanced robotics, and augmented reality enable the creation of smart products which offer new functionalities and services to the end consumer and are manufactured more efficiently (Ayala *et al.*, 2019; Zhong *et al.*, 2017). Cloud manufacturing and the use of cyber-physical systems enable the coordination and integration of physical and digital systems on an unprecedented scale (Monostori, 2014; Thames & Schaefer, 2016).

The concepts introduced by Industry 4.0 bring about profound changes in production processes, revolutionizing the way products are manufactured and the way supply chains are managed. One of the most significant impacts of Industry 4.0 on manufacturing is the way it enables mass customization, so that the production of personalized goods can be achieved on a large scale without compromising efficiency (Dalenogare *et al.*, 2018). Industry 4.0 also impacts manufacturers through the integration of the supply chain that is known as the smart supply chain, which synchronizes production with suppliers in order to reduce lead times and the amount of distorted information (Ivanov *et al.*, 2016). Moreover, collaborative manufacturing enables companies to pool resources by focusing on their core competencies and by sharing capabilities for product innovation on industrial platforms (Gawer & Cusumano, 2014; Kortmann & Piller, 2016).

Yet, the implementation of Industry 4.0 is not without challenges. Substantial investments in new technology and the need to retrain the workforce for handling more complex and interconnected systems are significant barriers (Antony *et al.*, 2023; Chen & Tsai, 2017). Despite those challenges, Industry 4.0 offers opportunities for innovation and efficiency while requiring a strategic approach to maximize the benefits and to overcome the inherent difficulties in this transformation (Stock *et al.*, 2018; Tortorella & Fettermann, 2017).

## 3. Methodology

For the research presented in this article, a bibliometric methodology was deployed in mapping and analyzing scientific publications on Industry 4.0 and for comparing Brazil with the leading countries in this field. Bibliometrics is a robust tool for quantitative analysis of scientific literature, enabling the identification of trends, gaps, and research opportunities (Zupic & Čater, 2015). The research presented in this article has been carried out in three main stages: data collection, data processing, and data analysis. Data collection was conducted through the Scopus database, which is recognized as one of the largest and most comprehensive scientific databases, covering a wide range of journals, books, and conference proceedings (Baas *et al.*, 2020). The reason for using Scopus is its broad coverage in the areas of Science, Technology, and Management (STM), surpassing other databases, like Web of Science (WoS), in scope (Chadegani *et al.*, 2013; Singh *et al.*, 2021; Vieira & Gomes, 2009).

Search in Scopus took place on June 22, 2024, through descriptors “Fourth Industrial Revolution,” “Industrial Revolution 4.0,” and “Industry 4.0,” according to the IEEE Thesaurus (IEEE, 2024). Publications indexed as journal sources and classified as articles or conference papers during the period from 2013 to 2023 were considered, since this timeframe encompasses the period when “Industry 4.0” became a popular term.

The search string that was used included the relevant descriptors in the title, abstract, and keyword fields as well as Boolean operators for combining search terms. Table 1 displays in detail the search expressions used, and the number of publications found at each stage.

**Table 1.** Scopus database query

| Aim                                      | Query String   | Publications Found |
|--|--|--------------------|
| Publications on Industry 4.0             | (TITLE-ABS-KEY (“Fourth Industrial Revolution” OR “Industrial Revolution 4.0” OR “industry 4.0”)) AND PUBYEAR > 2012 AND PUBYEAR < 2024 AND (LIMIT-TO (SRCTYPE, “j”)) AND (LIMIT-TO (DOCTYPE, “cp”) OR LIMIT-TO (DOCTYPE, “ar”))   | 13,571             |
| Publications from Brazil on Industry 4.0 | (TITLE-ABS-KEY (“Fourth Industrial Revolution” OR “Industrial Revolution 4.0” OR “industry 4.0”)) AND PUBYEAR > 2012 AND PUBYEAR < 2024 AND (LIMIT-TO (SRCTYPE, “j”)) AND (LIMIT-TO (DOCTYPE, “cp”) OR LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (AFFILCOUNTRY, “Brazil”)) | 578                |

Source: The authors themselves.

After data collection, data were processed and analyzed through text mining and network analysis techniques. Thesaurus lists were created to standardize the names of authors and keywords, ensuring data consistency and analysis accuracy.

The VOSviewer tool was used for visualizing and analyzing collaboration networks between countries and authors, as well as identifying the main thematic clusters that ground research on Industry 4.0 (Van Eck & Waltman, 2010). VOSviewer enables the creation of bibliometric maps for visual representation of relationships between different research elements, thus making the identification of patterns and trends easier.

Table 2 displays details about the metrics and data segments as used in the bibliometric analysis. The combination of these indicators and analysis techniques enabled the construction of a comprehensive view of research on Industry 4.0 for comparison between Brazil and leading countries in this field as well as for identifying the main trends, gaps, and opportunities for Brazil in that regard.

The Compound Annual Growth Rate (CAGR) provides the average annual growth rate over a specific period under a compound growth assumption and as calculated through formula (1):

$$CAGR = (V_f / V_i)^{1/n} - 1 \quad (1)$$

Where:  $V_f$  is the final value (number of publications in 2023),  $V_i$  is the initial value (number of publications in the first year) and  $n$  is the number of years.

Additionally, inferential statistical analysis was conducted to compare growth trajectories between Brazil and global datasets. First, ordinary least squares linear regressions were used to test whether publication trends over time were significantly positive in each dataset. Second, a log-linear specification was applied to compare relative growth rates between the two series, and the estimated slope coefficients were compared using a t-test.

**Table 2.** Metrics and data segments

| Item                      | Metric                                       | Segment                  |
|---------------------------|--|--------------------------|
| Evolution of Publications | Number of publications/year                  | [2013, 2023]             |
|                           | CAGR*  | [2013, 2023]             |
| Countries                 | % of publications                            | Top 10                   |
|                           | Number of citations                          | Top 10                   |
|                           | Co-authorship network                        | >= 10 publications       |
| Authors**                 | Number of publications                       | Top 10                   |
|                           | Number of citations                          | Top 10                   |
|                           | Number of publications x number of citations | >= 550 citations         |
| Publications              | Number of citations and citations/year       | Top 10                   |
| Keywords**                | Number of occurrences                        | Top 20                   |
|                           | Co-occurrence network (time)                 | >=100 (5)*** occurrences |
|                           | Brazil vs. World comparison                  | 23                       |

Notes: \*Compound Annual Growth Rate. \*\*Use of Thesaurus. \*\*\*For Brazil data. Source: The authors themselves.

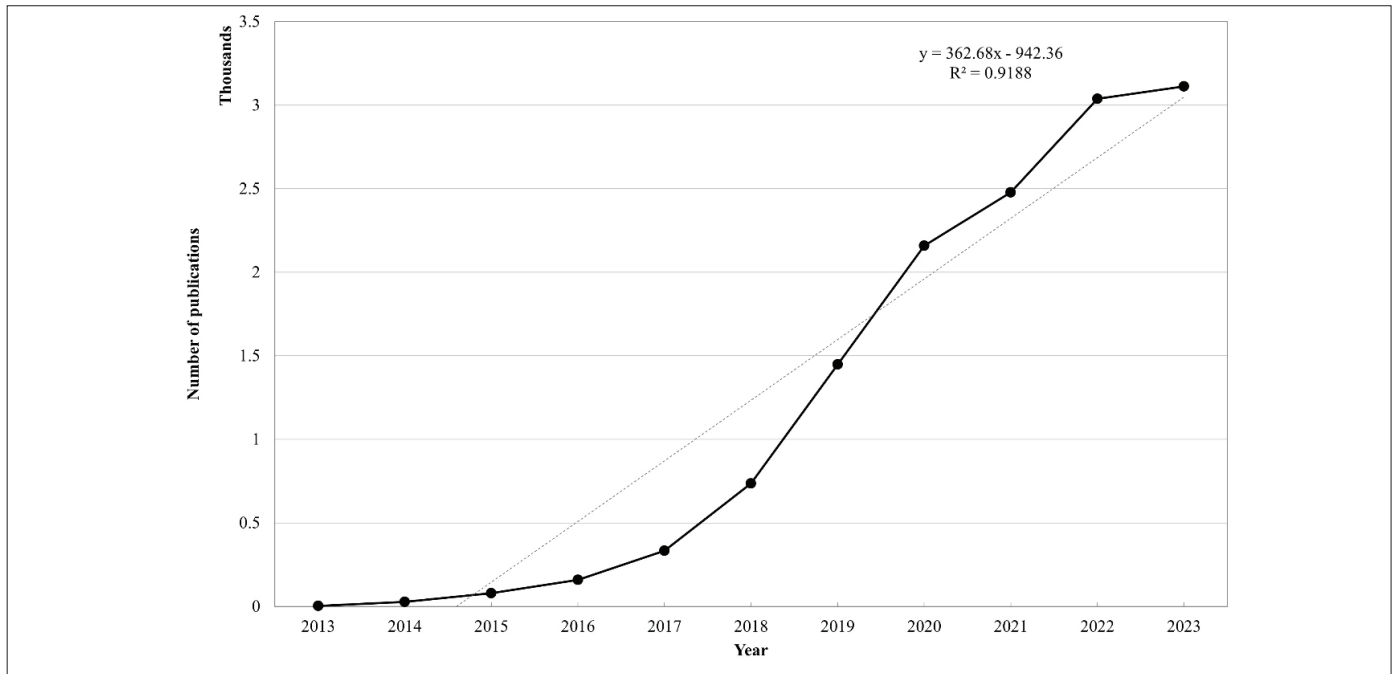
## 4. Results and Discussion

### 4.1 Countries

Figure 1 displays the temporal evolution of global publications on Industry 4.0 (CAGR = 100.3%). Figure 2 displays the corresponding trend for publications in Brazil (CAGR = 74.9%). Both figures indi-

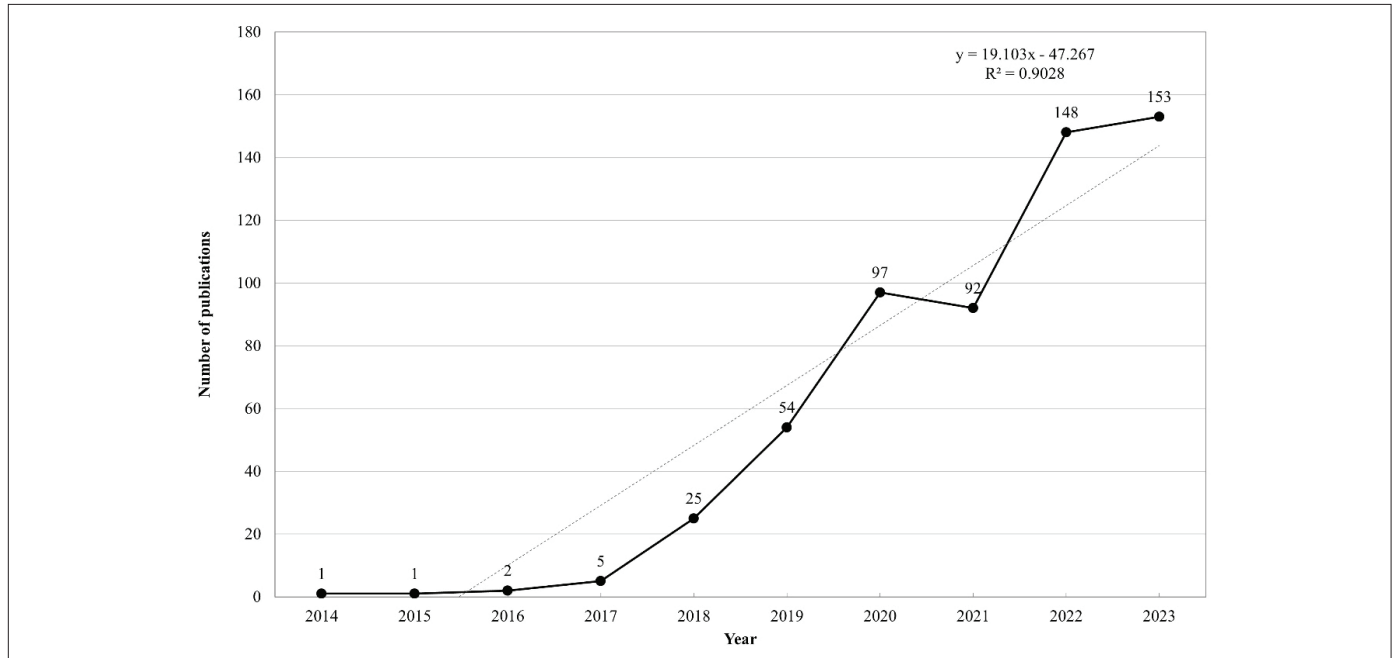
cate a linear growth pattern in the number of publications. Linear regression analysis confirms that slope coefficients are positive and statistically different from zero ( $p < 0.01$ ).

**Figure 1.** Temporal evolution of global publications on Industry 4.0.



Source: The authors themselves.

**Figure 2.** Temporal evolution of publications from Brazil on Industry 4.0.



Source: The authors themselves.

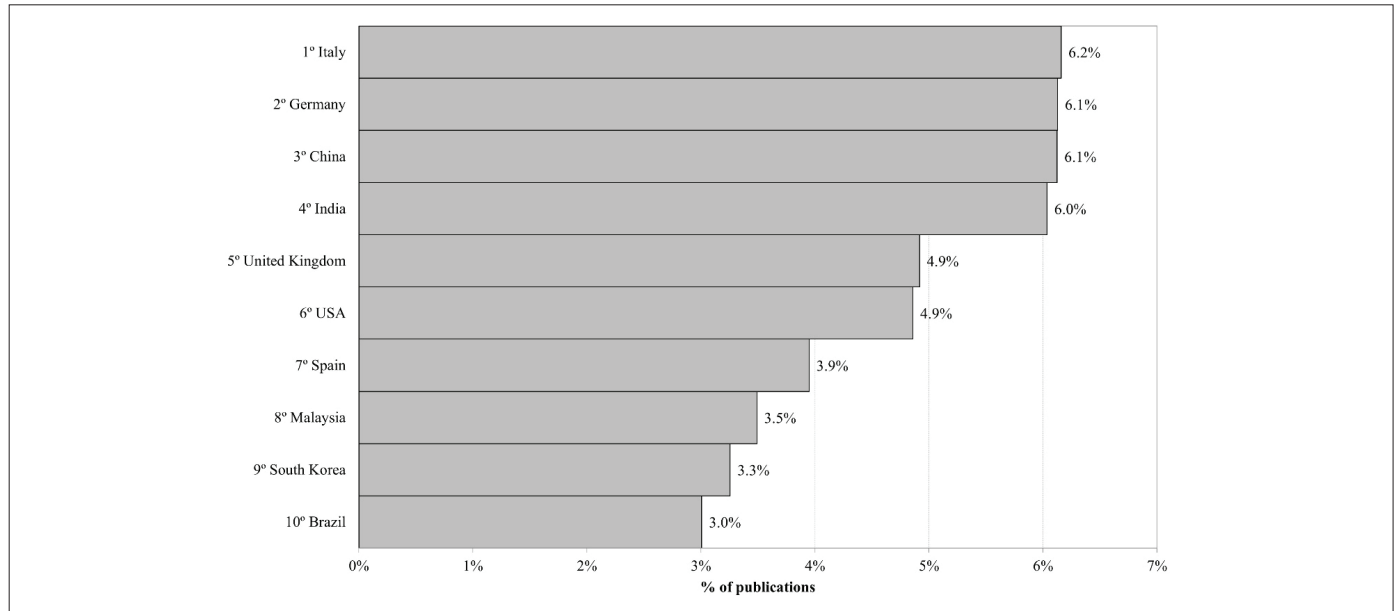
To assess whether the difference in growth trajectories between Brazil and global publications is statistically significant, an inferential comparison was conducted. A log-linear regression model was applied to both time series, and the growth coefficients were compared using a

t-test for differences in slopes. The results indicate that the estimated growth coefficient for the global series is statistically higher than that of the Brazilian series ( $p < 0.05$ ), confirming that the divergence is not only visual but also statistically significant.

While Figures 1 and 2 present linear fits for visualization purposes, inferential comparisons were conducted using a log-linear specification.

The top 10 countries in number of publications on Industry 4.0 are shown in Figure 3.

**Figure 3.** The top 10 countries in number of publications on Industry 4.0.

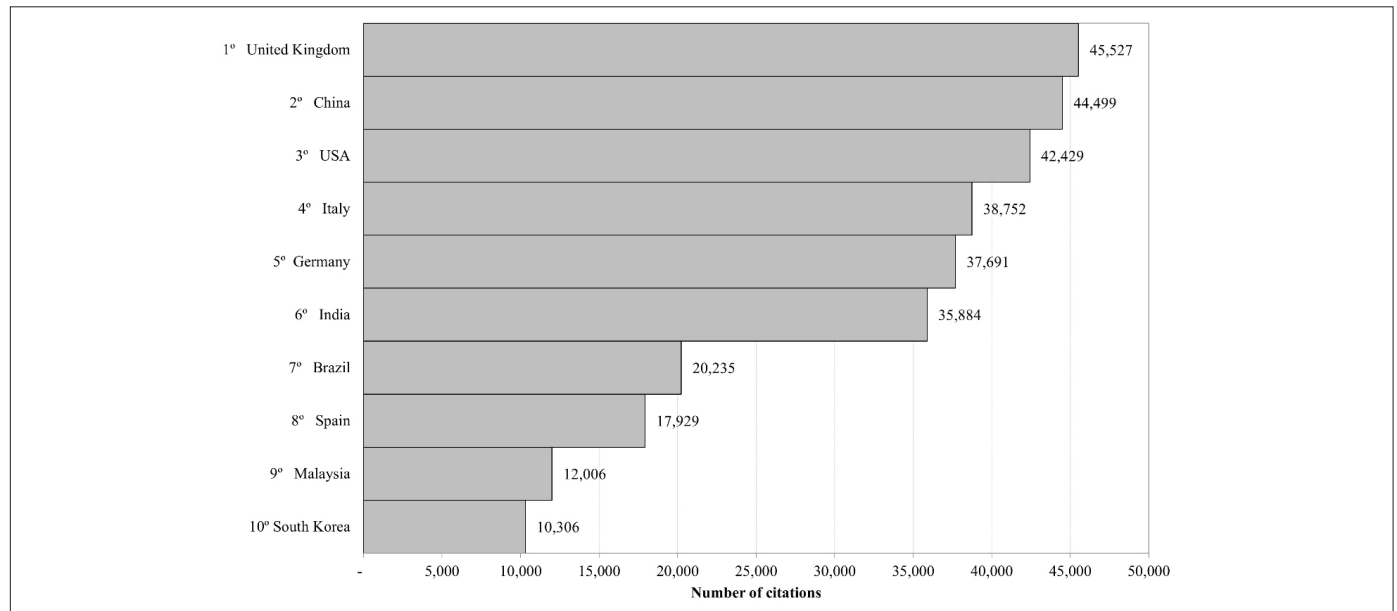


Source: The authors themselves.

Figure 3 shows that Italy (6.2%), Germany (6.1%), China (6.1%), and India (6.0%) are leading countries in publication percentage, all four countries closely matched. Together, these countries account for 24.4% of the publications on the topic. Brazil ranks 10th, with 3.0% of all publications. The 10 countries that published the most on Industry 4.0 have each over 500 publications, together they represent 47.9% of all publications on the topic.

Figure 4 displays the top 10 countries in number of citations for Industry 4.0 as the topic of publication. The United Kingdom, China, and the USA are the three most cited countries. Brazil ranked 7th in number of citations. Regarding the topic of Industry 4.0, Brazil is better ranked both in percentage of publications and in being cited, which shows that Brazil has a significant presence in this field.

**Figure 4.** The top 10 countries in number of citations for Industry 4.0.

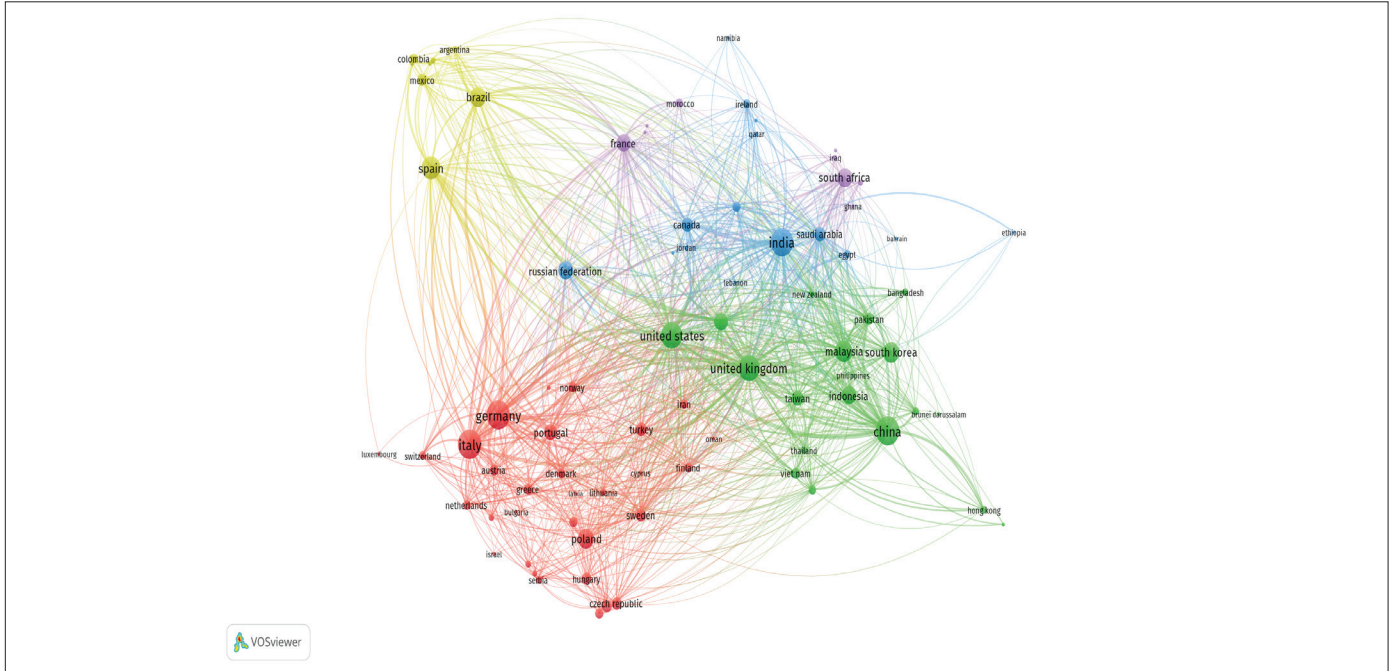


Source: The authors themselves.

Co-authorship network among countries is shown in Figure 5. China, the USA, and the United Kingdom are in the same co-authorship cluster, which indicates alignment of interests among them. Italy and Germany make up a cluster of their own, and so do India and Brazil. Even though it has co-authorship with leading countries in Industry 4.0 publications, Brazil is positioned away from the clusters of

countries that are ranked above it in number of citations, not least China, in relation to which position in the network Brazil is in a diametrically opposite position. This seems to indicate opportunities for Brazil to enhance international cooperation in order to diversify research approaches on Industry 4.0 and increase visibility.

**Figure 5.** Co-authorship network with 87 countries in 5 clusters. Note: The size of the nodes is proportional to the number of publications.



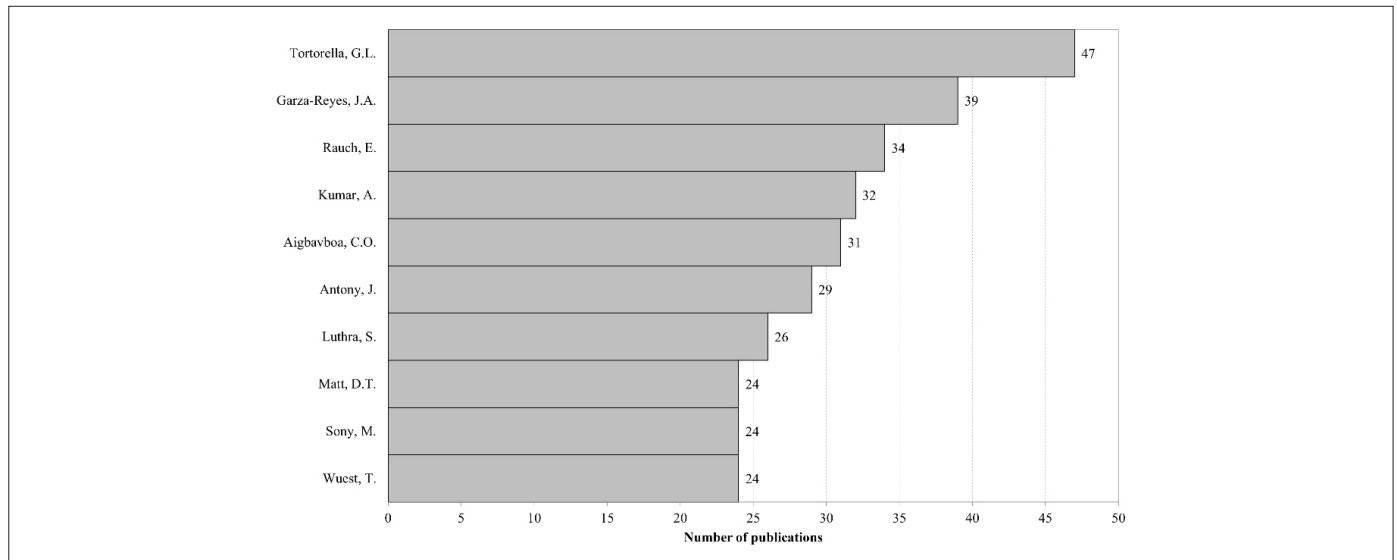
Source: The authors themselves.

**4.2 Authors and publications**

Figure 6 displays the top 10 authors in number of publications on Industry 4.0. Guilherme Luz Tortorella is the author from Brazil with

the highest number of publications (in a total of 47). Jose Arturo Garza-Reyes (with a number of 39 publications) and Erwin Rauch (with 34 publications) are next to him.

**Figure 6.** The top 10 authors in number of publications on Industry 4.0.

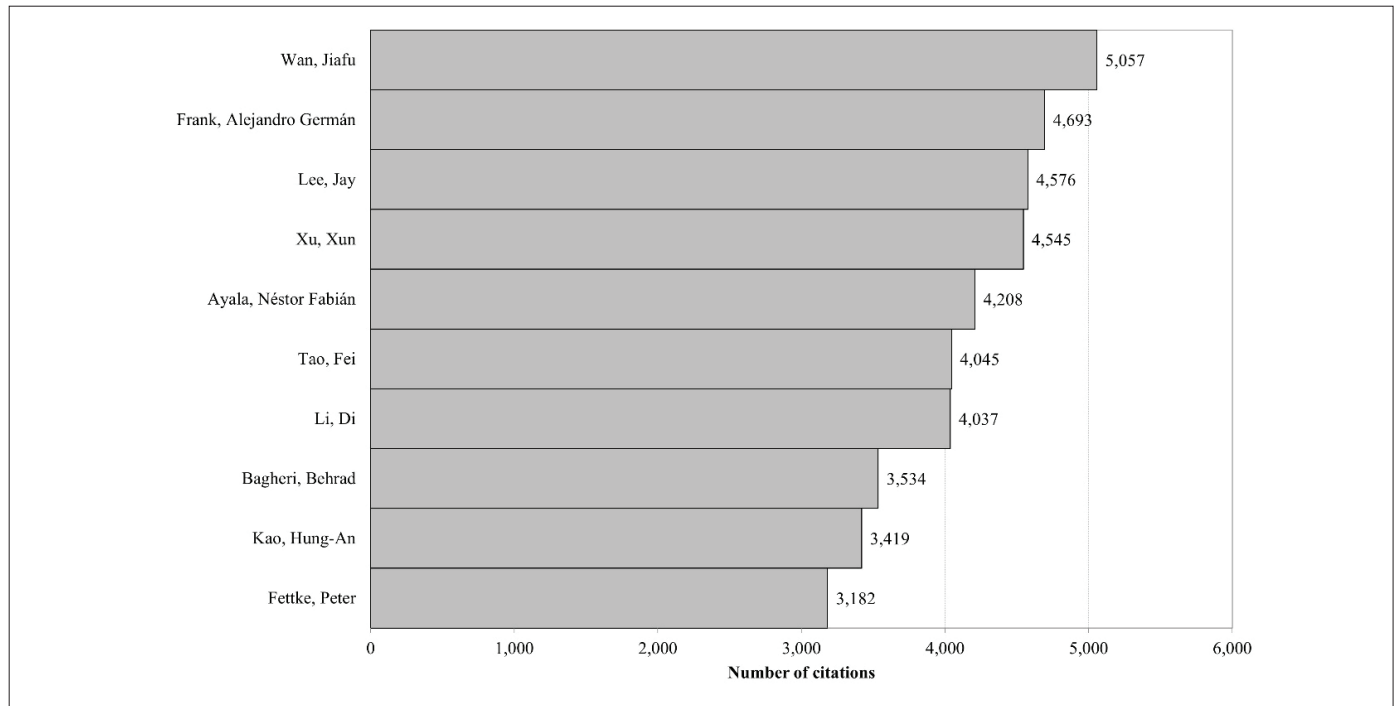


Source: The authors themselves.

Figure 7 displays the top 10 authors in number of citations on Industry 4.0. Jiafu Wan is the most cited author. Alejandro Germán Frank

(2nd) and Néstor Fabián Ayala (5th), two authors who represent Brazil are among the most cited authors.

Figure 7. The top 10 authors in number of citations on Industry 4.0.

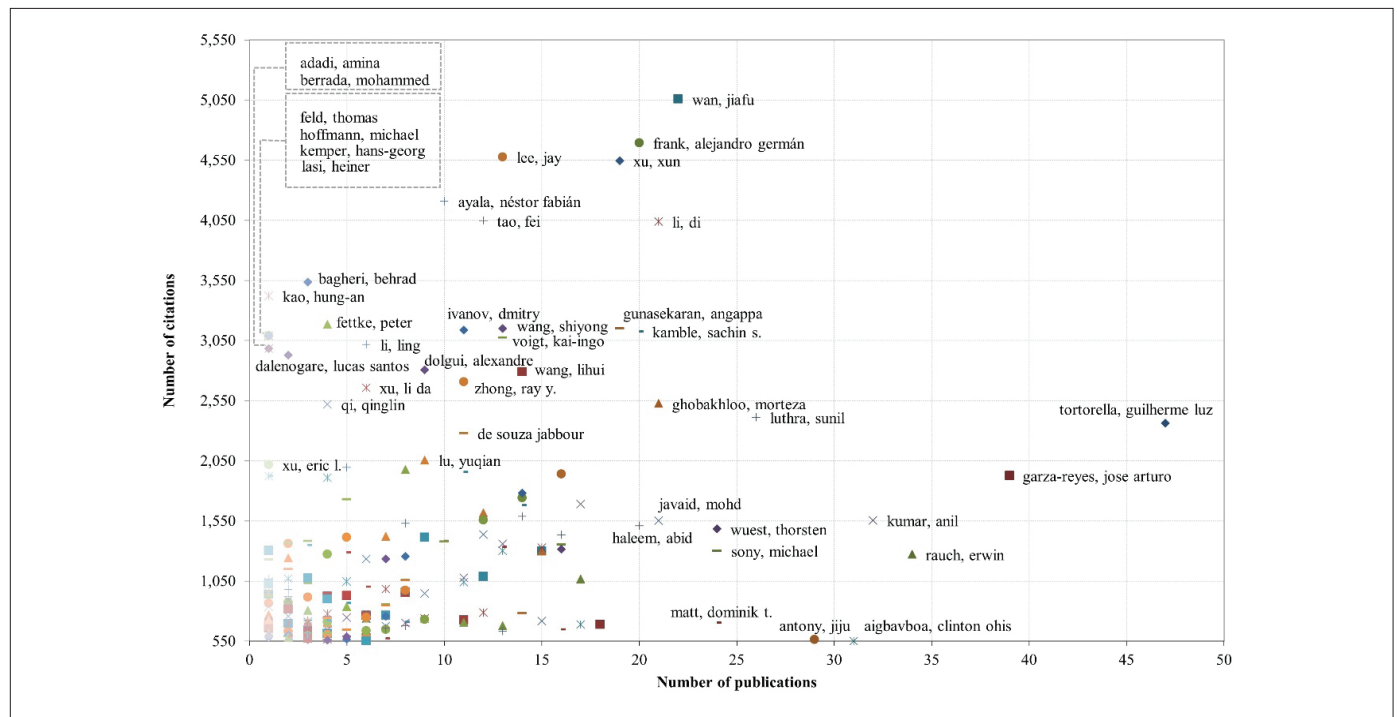


Source: The authors themselves.

Figure 8 displays the relationship between number of publications and number of citations from authors. Noticeably, none of the top

10 authors in number of publications are ranked among the top 10 authors in number of citations.

Figure 8. Relationship between number of publications and number of citations.



Note: The names of authors with fewer than 20 publications and fewer than 2,000 citations have been omitted. Source: The authors themselves.

The top 10 publications in number of citations on Industry 4.0 are shown in descending order of number of citations in Table 3. Publications by authors from Brazil are ranked 6th and 8th. In comparison, a publication by authors Jiafu Wan and Di Li, who are among the top 10 authors in number of citations, is ranked 10. Since older publica-

tions typically have more citations, the number of citations per year should be taken into consideration. The ranking of publications is a different one when the number of citations is considered per year. If this criterion is applied, the number of publications by authors from Brazil would rank 3rd and 6th.

**Table 3.** The top 10 publications in number of citations on Industry 4.0

| Title  | Authors   | Journal  | Year | C*    | C/A** |
|--|---|--|------|-------|-------|
| A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems (Lee <i>et al.</i> , 2015)  | Lee, J.,<br>Bagheri, B.,<br>Kao, H.-A.                                      | Manufacturing Letters, 3, pp. 18–23                                | 2015 | 3,390 | 424   |
| Industry 4.0 (Lasi <i>et al.</i> , 2014)   | Lasi, H.,<br>Fettke, P.,<br>Kemper, H.-G.,<br>Feld, T.,<br>Hoffmann, M.     | Business and Information Systems Engineering, 6(4), pp. 239–242    | 2014 | 3,078 | 342   |
| Peeking Inside the Black-Box: A Survey on Explainable Artificial Intelligence (XAI) (Adadi & Berrada, 2018)  | Adadi, A.,<br>Berrada, M.   | IEEE Access, 6, pp. 52138–52160, 8466590                           | 2018 | 2,969 | 594   |
| Industry 4.0: State of the art and future trends (Xu <i>et al.</i> , 2018)   | Xu, L.D.,<br>Xu, E.L.,<br>Li, L.  | International Journal of Production Research, 56(8), pp. 2941–2962 | 2018 | 2,014 | 403   |
| Intelligent Manufacturing in the Context of Industry 4.0: A Review (Zhong <i>et al.</i> , 2017)  | Zhong, R.Y.,<br>Xu, X.,<br>Klotz, E.,<br>Newman, S.T.                       | Engineering, 3(5), pp. 616–630                                     | 2017 | 1,909 | 318   |
| Industry 4.0 technologies: Implementation patterns in manufacturing companies (Frank <i>et al.</i> , 2019)   | Frank, A.G.***,<br>Dalenogare, L.S.,<br>Ayala, N.F.***                      | International Journal of Production Economics, 210, pp. 15–26      | 2019 | 1,631 | 408   |
| The future of industrial communication: Automation networks in the era of the internet of things and industry 4.0 (Wollschlaeger <i>et al.</i> , 2017) | Wollschlaeger, M.,<br>Sauter, T.,<br>Jasperneite, J.                        | IEEE Industrial Electronics Magazine, 11(1), pp. 17–27, 7883994    | 2017 | 1,298 | 216   |
| The expected contribution of Industry 4.0 technologies for industrial performance (Dalenogare <i>et al.</i> , 2018)                                    | Dalenogare, L.S.***,<br>Benitez, G.B.***,<br>Ayala, N.F.,<br>Frank, A.G.*** | International Journal of Production Economics, 204, pp. 383–394    | 2018 | 1,283 | 257   |
| Industry 4.0 and the current status as well as future prospects on logistics (Hofmann & Rüsçh, 2017)   | Hofmann, E.,<br>Rüsçh, M.   | Computers in Industry, 89, pp. 23–34                               | 2017 | 1,212 | 202   |
| Towards smart factory for industry 4.0: A self-organized multiagent system with big data-based feedback and coordination (Wang <i>et al.</i> , 2016b)  | Wang, S.,<br>Wan, J.,<br>Zhang, D.,<br>Li, D.,<br>Zhang, C.                 | Computer Networks, 101, pp. 158–168                                | 2016 | 1,062 | 152   |

Notes: \*Number of citations. \*\*Number of citations divided by the difference 2023 – year of publication. \*\*\*Author from Brazil. Source: The authors themselves.

### 4.3 Keywords

Table 4 displays the top 20 most frequent keywords in global publications and publications from Brazil. After the keyword “Industry 4.0”, the most frequent one is “Internet of Things”.

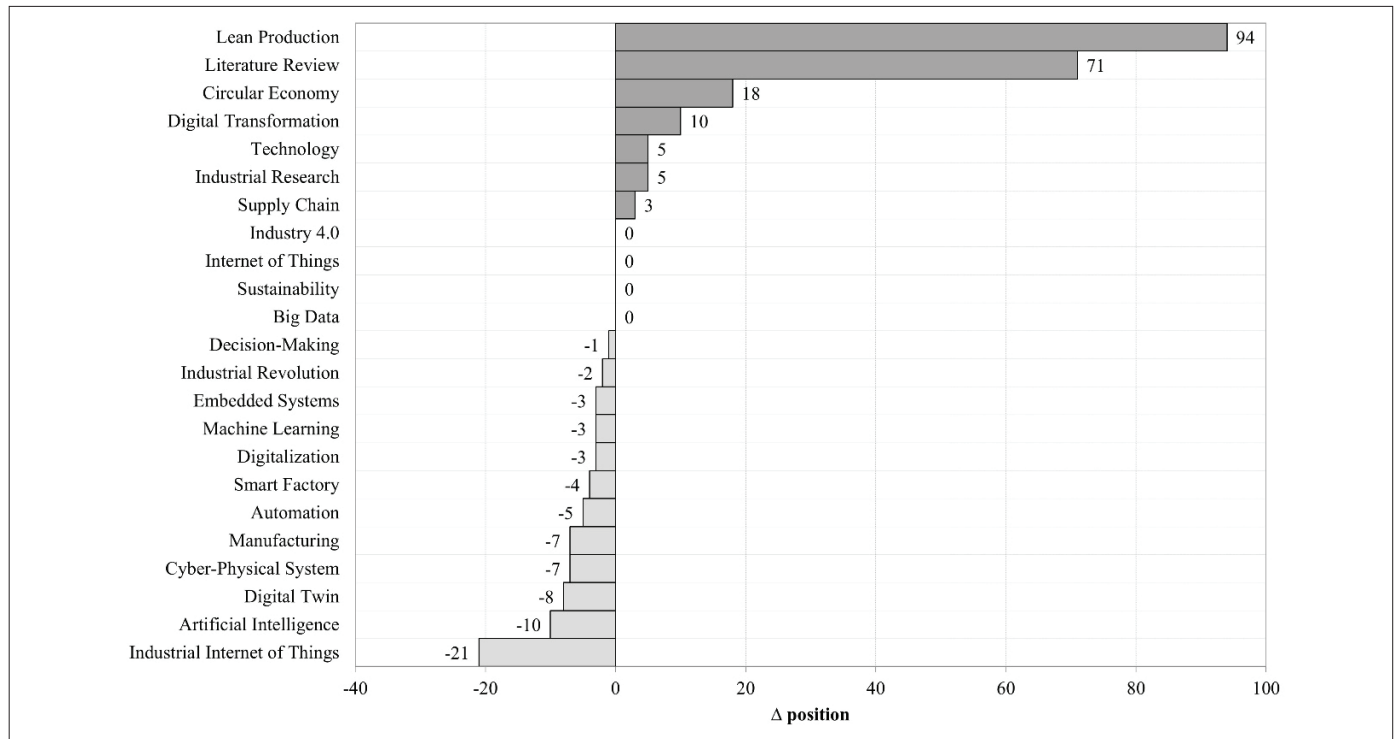
**Table 4.** The top 20 most frequent keywords: Global and Brazil

| Position | Global                        |               | Brazil                  |               |
|----------|-------------------------------|---------------|-------------------------|---------------|
|          | Keyword                       | # Occurrences | Keyword                 | # Occurrences |
| 1        | Industry 4.0                  | 7790          | Industry 4.0            | 405           |
| 2        | Internet of Things            | 1682          | Internet of Things      | 63            |
| 3        | Manufacturing                 | 1022          | Literature Review       | 56            |
| 4        | Sustainability                | 1004          | Sustainability          | 53            |
| 5        | Industrial Revolution         | 915           | Digital Transformation  | 51            |
| 6        | Artificial Intelligence       | 895           | Supply Chain            | 48            |
| 7        | Decision-Making               | 825           | Industrial Revolution   | 47            |
| 8        | Smart Factory                 | 799           | Decision-Making         | 43            |
| 9        | Supply Chain                  | 773           | Technology              | 39            |
| 10       | Embedded Systems              | 678           | Manufacturing           | 33            |
| 11       | Machine Learning              | 674           | Industrial Research     | 33            |
| 12       | Digitalization                | 671           | Smart Factory           | 31            |
| 13       | Cyber-Physical System         | 669           | Embedded Systems        | 31            |
| 14       | Technology                    | 574           | Machine Learning        | 27            |
| 15       | Digital Transformation        | 553           | Digitalization          | 27            |
| 16       | Industrial Research           | 533           | Artificial Intelligence | 26            |
| 17       | Automation                    | 524           | Circular Economy        | 24            |
| 18       | Big Data                      | 501           | Big Data                | 23            |
| 19       | Industrial Internet of Things | 497           | Lean Production         | 22            |
| 20       | Digital Twin                  | 469           | Cyber-Physical System   | 22            |

Source: The authors themselves.

Figure 9 displays a keyword ranking alignment in comparison, in which  $\Delta$  is the difference in position of a keyword in the global ranking versus the Brazilian ranking.

**Figure 9.** Difference ( $\Delta$ ) in position of keywords between the Global and Brazil.



Notes: (1) The keywords “Automation”, “Digital Twin” and “Industrial Internet of Things” are in positions 22, 28 and 40 in the Brazilian ranking, respectively, while “Circular Economy”, “Literature Review” and “Lean Production” are in positions 35, 74 and 113 in the global ranking, respectively. (2) Positive values reflect preferences in publications from Brazil; negative values reflect global preferences; and null values indicate alignment of interests. Source: The authors themselves.



## 5. Conclusions

The annual volume of publications from Brazil still lags behind that by the leading countries in publications globally, which shows a need for increased investment in research and development so that Brazil can keep pace with technological advancements globally. Bibliometric analysis of Industry 4.0 in Brazil has shown significant trends and publication patterns that highlight Brazil's standing in the ranking as compared to other leading countries in the field. The main thematic areas covered in publications from Brazil include application of the Internet of Things (IoT), Big Data, and Machine Learning. While these tally with the relevant international trends, there is emphasis in Brazil in particular on solutions for optimizing operational efficiency and sustainability.

Authors affiliated with Brazilian institutions have made a relevant contribution in terms of both publication volume and citation impact. Comparative analysis highlights Brazil's potential to excel in Industry 4.0 if collaborations between academia, industry, and government are strengthened, thereby promoting an environment of innovation and technological development. The global landscape as it stands indicates a growing movement for decentralization, intelligent automation, and advanced cyber-physical systems.

Proposals for strengthening research on Industry 4.0 in Brazil include fostering international collaborations with leading countries, encouraging research in emerging areas such as IoT and AI, supporting interdisciplinary research, investment in researcher training, and increasing scientific dissemination. Additional recommended actions include fostering technological innovation, developing public policies that encourage research and development, creating research networks, and focusing on practical results which could be directly applied to the industry, thereby improving the competitiveness and productivity of Brazilian companies.

To sum up, this article enables a better understanding of the existing gaps and opportunities for Brazil in that field by providing insights for strategies that can help position Brazil more competitively in the global Industry 4.0 landscape, thereby fostering academic advancement and sustainable economic as well as social development.

## 6. Limitations

This study presents methodological limitations associated with its research design and data source selection. First, data collection was conducted exclusively through the Scopus database. Although Scopus provides extensive international coverage, it predominantly indexes journals published in English and may underrepresent regionally relevant scientific production.

In the context of Brazil, this introduces an epistemological bias, as important contributions indexed in regional databases such as SciELO and Redalyc are not captured. Consequently, the results may underestimate the volume and thematic diversity of domestic research output.

Additionally, the bibliometric approach focuses on quantitative indicators (e.g., publication counts, citations, co-occurrence networks), which may not fully capture the qualitative impact or contextual relevance of research contributions.

Finally, the analysis is constrained by the selected time frame (2013–2023), which may not reflect emerging trends beyond this period.

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