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INDÚSTRIA 4.0: UMA ANÁLISE BIBLIOMÉTRICA COMPARATIVA DA PESQUISA NO BRASIL E EM PAÍSES LÍDERES MUNDIAIS

INDUSTRY 4.0: A COMPARATIVE BIBLIOMETRIC ANALYSIS OF RESEARCH IN BRAZIL AND IN GLOBALLY LEADING COUNTRIES

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Resumo - O objetivo deste artigo é mapear e analisar o panorama da pesquisa sobre a Indústria 4.0 no Brasil, comparando-o com o realizado por pesquisadores em países líderes neste campo. O artigo busca identificar as principais tendências de pesquisa, destacar lacunas e oferecer insights sobre oportunidades para que pesquisadores brasileiros contribuam para a base de conhecimento global da Indústria 4.0. Esse artigo oferece uma nova perspectiva comparativa sobre a pesquisa em Indústria 4.0, focando no Brasil e sua relação com as tendências globais, além de fornecer novos insights sobre os pontos fortes e fracos da pesquisa no Brasil, permitindo, assim, uma melhor compreensão da posição do país no cenário global da Indústria 4.0. O artigo emprega uma análise bibliométrica de publicações científicas indexadas na base de dados Scopus. Técnicas de mineração de texto e análise de redes, utilizando o software VOSviewer, foram aplicadas para mapear e revisar os dados científicos, redes de colaboração e clusters temáticos sobre pesquisa em Indústria 4.0 no Brasil e em países líderes nesta área. A análise dos dados mostra um crescimento significativo da pesquisa em Indústria 4.0 globalmente, e um crescimento mais lento no Brasil em comparação aos países líderes no campo. Também evidencia que a pesquisa no Brasil segue as tendências internacionais, com ênfase no uso de Internet das Coisas (IoT), Big Data e Machine Learning, mas também aponta um foco particular no Brasil em soluções para eficiência operacional e sustentabilidade. Os achados deste artigo oferecem novos insights para pesquisadores, formuladores de políticas e profissionais da indústria no Brasil. O estudo destaca áreas potenciais para futuras pesquisas e colaborações, com ênfase na necessidade de aumento no investimento em pesquisa e desenvolvimento, bem como na importância de fomentar parcerias internacionais para fortalecer a posição do Brasil no cenário global da Indústria 4.0.

Palavras-chave: Manufatura; Revolução Industrial, Inteligência Artificial, Tomada de Decisão; Fábrica Inteligente.

Abstract - The aim of this article is to map and analyze the research landscape on Industry 4.0 in Brazil, comparing it with that conducted by researchers in leading countries in this field. The article seeks to identify the main research trends, highlight gaps, and offer insights into opportunities for Brazilian researchers to contribute to the global knowledge base of Industry 4.0. This article offers a new comparative perspective on Industry 4.0 research, focusing on Brazil and its relationship with global trends, as well as providing new insights into the strengths and weaknesses of research in Brazil, thereby allowing

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a better understanding of the country's position in the global Industry 4.0 landscape. The article employs a bibliometric analysis of scientific publications indexed in the Scopus database. Text mining and network analysis techniques, using the VOSviewer software, were applied to map and review scientific data, collaboration networks, and thematic clusters on Industry 4.0 research in Brazil and in leading countries in this area. The data analysis shows significant growth in Industry 4.0 research globally, and slower growth in Brazil compared to leading countries in the field. It also shows that research in Brazil follows international trends, with an emphasis on the use of the Internet of Things (IoT), Big Data, and Machine Learning, but also points to a particular focus in Brazil on solutions for operational efficiency and sustainability. The findings of this article offer new insights for researchers, policymakers, and industry professionals in Brazil. The study highlights potential areas for future research and collaborations, with an emphasis on the need to increase investment in research and development, as well as the importance of fostering international partnerships to strengthen Brazil's position in the global Industry 4.0 landscape.

Keywords: Manufacturing. Industrial Revolution. Artificial Intelligence. Decision Making, Smart Factory.

1 Introduction

The term Industry 4.0 harks back to 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 incorporates emerging and converging technologies that add value to the product life cycle, such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, Cyber-Physical Systems (CPS), Multi-Agent Systems (MAS), and Cloud Computing (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 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 provide insights into the structure and evolution of research in this area (Cobo et al., 2014; Morris; Van Der Veer Martens, 2008).

This article is as follows: Section 1 introduces the topic of Industry 4.0, presents this article's relevant research problem, aims, and justification. Section 2 shows the theoretical grounds for Industry 4.0, the Scopus database, and the VOSviewer software. Section 3 presents the methodology used for this article with details on data collection, processing, and analysis. Section 4 brings a discussion on the results. Section 5 brings the concluding remarks.

2 Background

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 the key technologies for such. 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 Industry 4.0 brings in cause deep 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). Articles published in journals during the period from 2013 to 2023 were considered, since those timeframes 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.

Tabela 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.

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 an average annual growth rate over a specific period from compound growth and as calculated through formula (1):

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

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.

Tabela 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

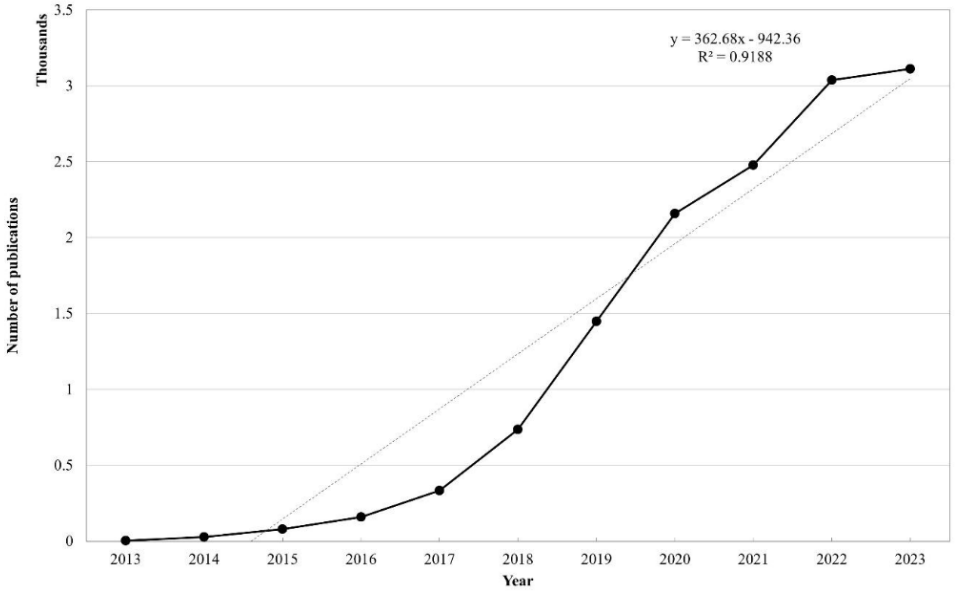
Notes: *Compound Annual Growth Rate. **Use of Thesaurus. ***For Brazil data. Source: The authors.

4 Results and Discussion

4.1 Countries

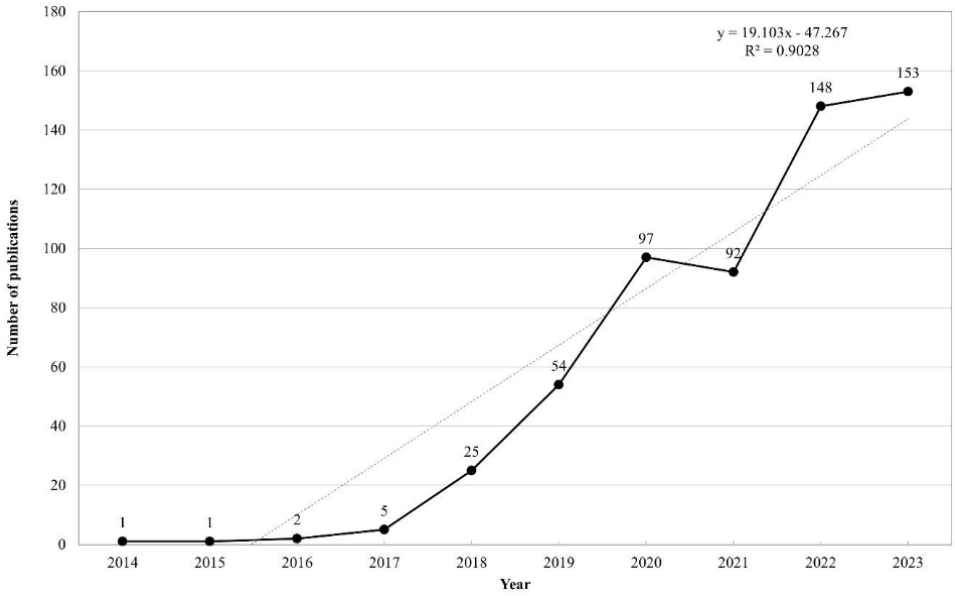
Figure 1 displays the temporal evolution of global publications on Industry 4.0 (CAGR = 100.3%). Figure 2 displays the corresponding trend for publications in Brazil (CAGR = 74.9%). Both figures highlight the linear growth in number of publications with the data fitting a straight line and hence yield a statistically significant result ($p < 0.01$).

Figura 1: Temporal evolution of global publications on Industry 4.0.



Source: The authors

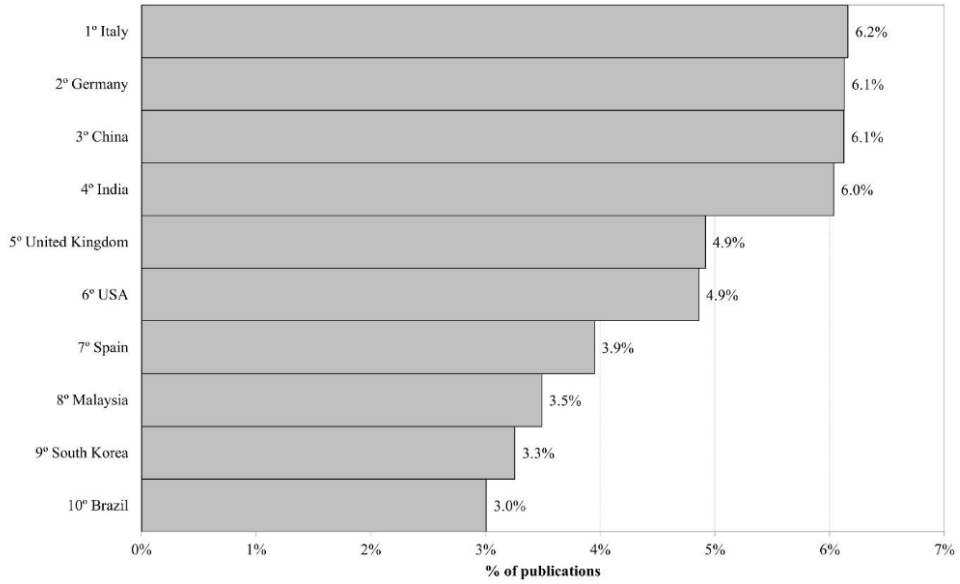
Figura 2: Temporal evolution of publications from Brazil on Industry 4.0.



Source: The authors based on data from Scopus.

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

Figura 3: The top 10 countries in number of publications on Industry 4.0.

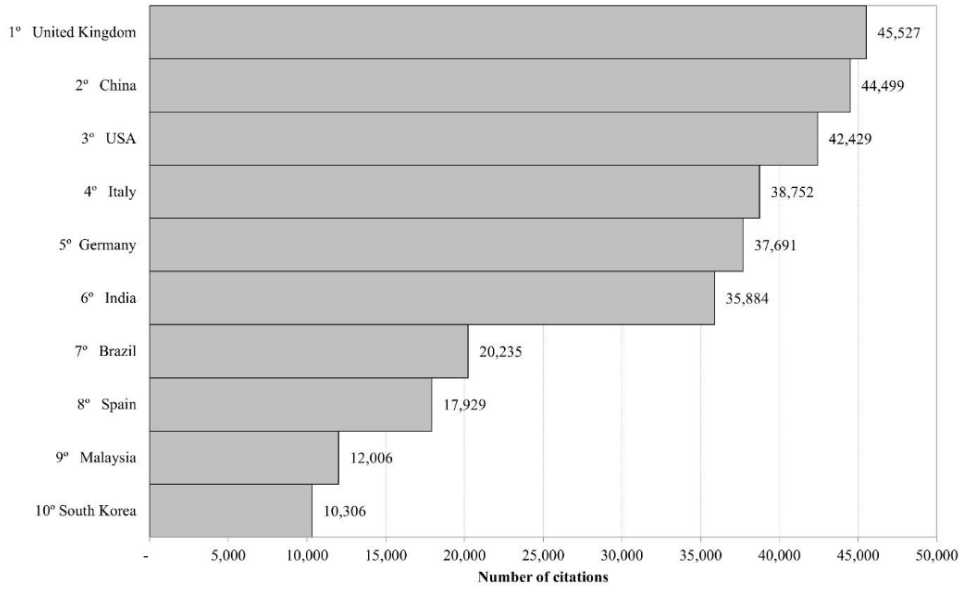


Source: The authors based on data from Scopus.

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, they 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.

Figura 4: The top 10 countries in number of citations for Industry 4.0.

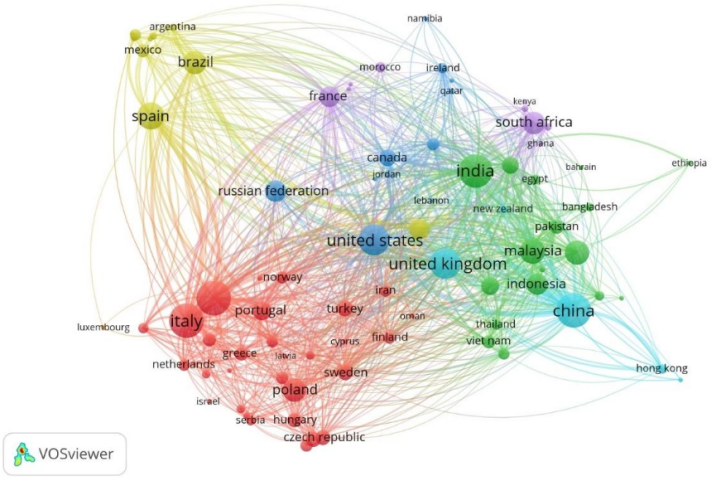


Source: The authors based on data from Scopus and results from VOSviewer.

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.

Figura 5: Co-authorship network with 87 countries in 5 clusters.

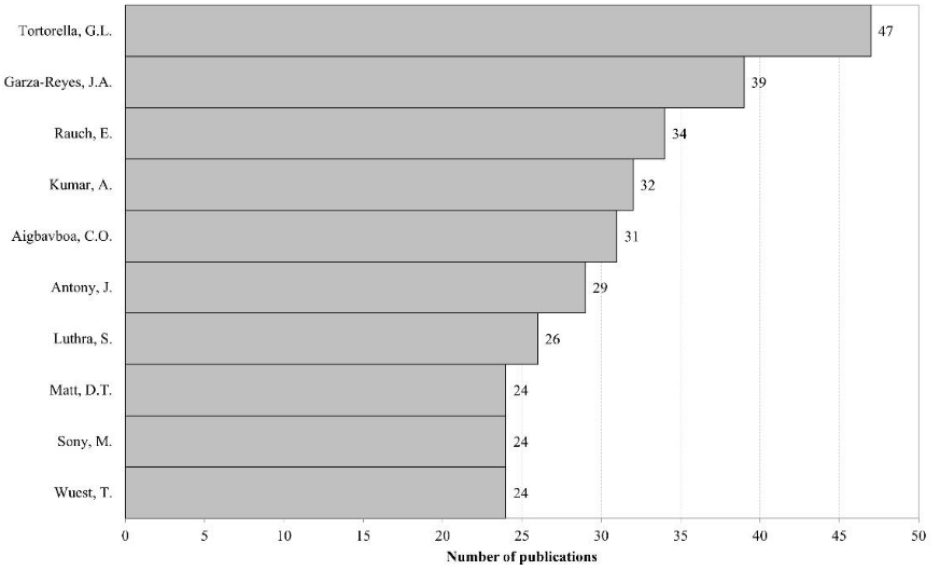


Note: The size of the nodes is proportional to the number of publications. Source: VOSviewer with data from Scopus.

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.

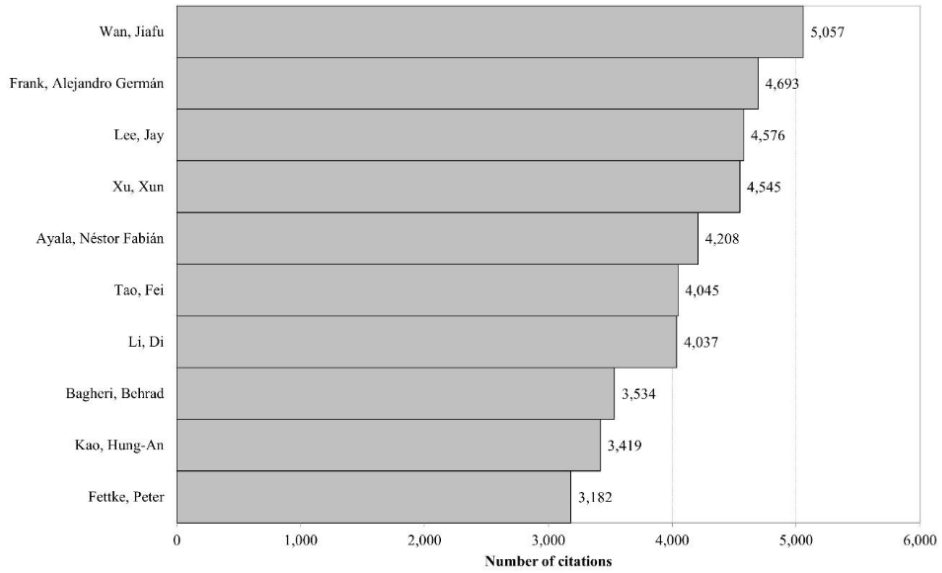
Figura 6: The top 10 authors in number of publications on Industry 4.0.



Source: The authors based on data from Scopus.

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.

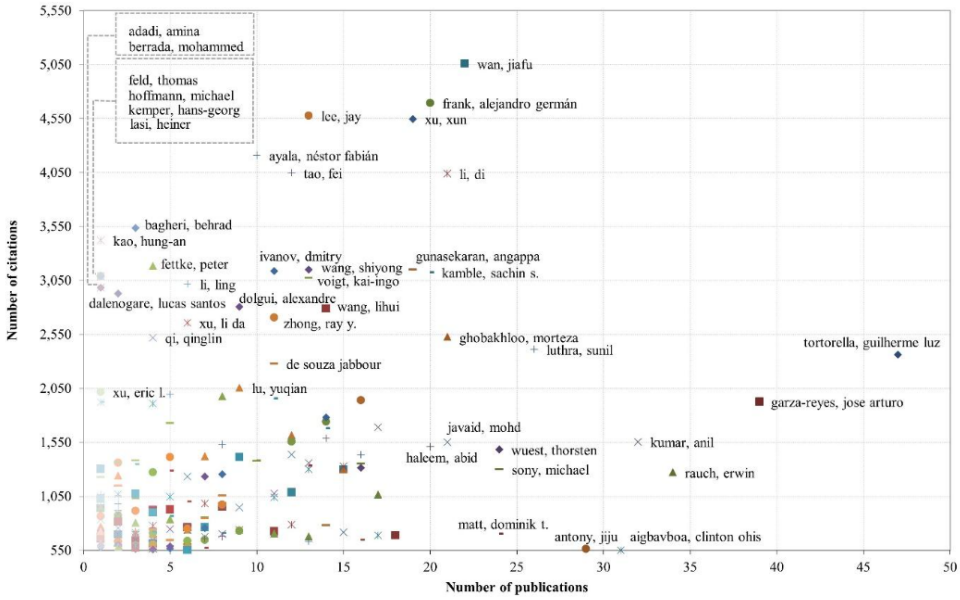
Figura 7: The top 10 authors in number of citations on Industry 4.0.



Source: The authors based on data from Scopus and results from VOSviewer.

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.

Figura 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 based on data from Scopus and results from VOSviewer.

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 publications 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.

Tabela 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 et al., 2015)	Lee, J., Bagheri, B., Kao, H.-A.	Manufacturing Letters, 3, pp. 18–23	2015	3,390	424
Industry 4.0 (Lasi et al., 2014)	Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., 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 & Berrrada, 2018)	Adadi, A., Berrada, M.	IEEE Access, 6, pp. 52138–52160	2018	2,969	594
Industry 4.0: State of the art and future trends (Xu et al., 2018)	Xu, L.D., Xu, E.L., 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 et al., 2017)	Zhong, R.Y., Xu, X., Klotz, E., Newman, S.T.	Engineering, 3(5), pp. 616–630	2017	1,909	318
Industry 4.0 technologies: Implementation patterns in manufacturing companies (Frank et al., 2019)	Frank, A.G.***, Dalenogare, L.S., 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 IoT and industry 4.0 (Wollschlaeger et al., 2017)	Wollschlaeger, M., Sauter, T., Jasperneite, J.	IEEE Industrial Electronics Magazine, 11(1), pp. 17–27	2017	1,298	216

Continued on the next page...

Tabela 3 – Continuação

Title	Authors	Journal	Year	C*	C/A**
The expected contribution of Industry 4.0 technologies for industrial performance (Dalenogare et al., 2018)	Dalenogare L.S.***, Benitez, G.B.***, Ayala, N.F., 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 & Rüsch, 2017)	Hofmann, E., Rüsch, M.	Computers in Industry, 89, pp. 23–34	2017	1,212	202
Towards smart factory for industry 4.0: A multiagent system with big data-based feedback (Wang et al., 2016b)	Wang, S., Wan, J., Zhang, D., Li, D., Zhang, C.	Computer Networks, 101, pp. 158–168	2016	1,062	152

Notes: *Number of citations. **Citations divided by (2023 – year). ***Author from Brazil.

Source: The authors based on data from Scopus.

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".

Tabela 4 – The top 20 most frequent keywords: Global and Brazil.

	Global		Brazil	
Position	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

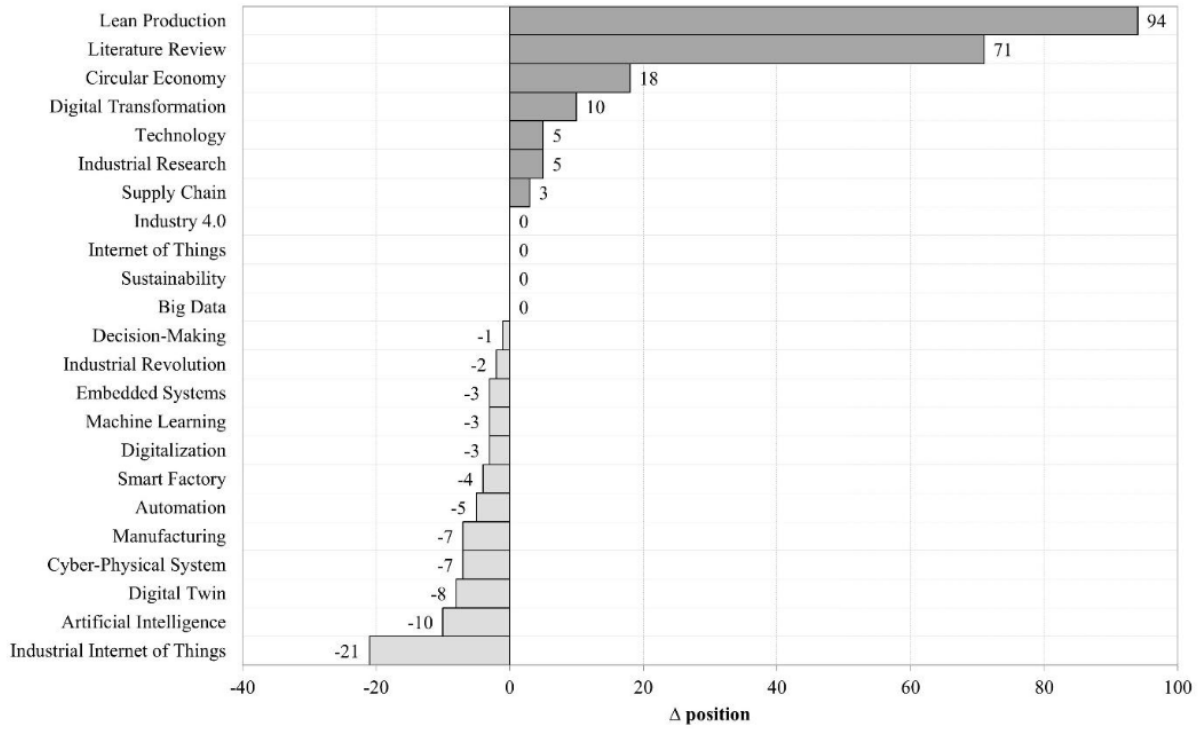
Tabela 4 – Continuação

	Global		Brazil	
-2*Position	Keyword	# Occurrences	Keyword	# Occurrences
19	Industrial Internet of Things	497	Lean Production	22
20	Digital Twin	469	Cyber-Physical System	22

Source: The authors based on data from Scopus and results from VOSviewer.

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

Figura 9: Difference (△) in position of keywords between the Global and Brazil.



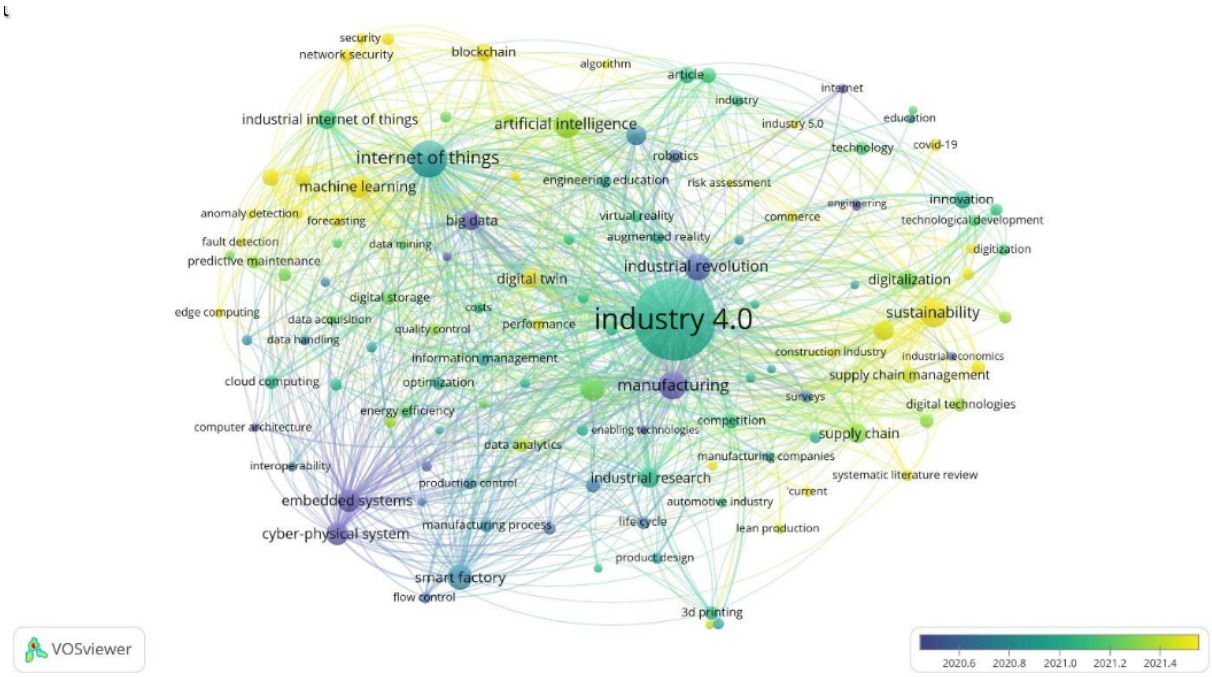
Notes: (1) The keywords "Automation", "Digital Twin" and "Industrial Internet of Things" are in positions 22, 28 and 40 in the Brazilian ranking, respectively, while "Circular Economy", "Literature Review" and "Lean Production" are in positions 35, 74 and 113 in the global ranking, respectively. (2)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

Figure 9 shows that keywords "Lean Production," "Literature Review," and "Circular Economy" stand out in publications from Brazil, which indicates a focus on efficiency and sustainability in Brazil. On the other hand, "Industrial Internet of Things," "Artificial Intelligence," and "Digital Twin" are frequent key words in publications globally, resulting from a focus on advanced emerging technologies. The keyword with the highest rate of co-occurrence with "Industry 4.0" was "Internet of Things," which thus demonstrates alignment of interest between Brazil and other countries. This alignment can be noticed also with keywords "Sustainability" and "Big Data."

Figures 10 and 11 display the keyword co-occurrence networks, with a time scale, for global publications and publications from Brazil, respectively. The keyword "Machine Learning" is noteworthy as it occurs in recent publications in both cases, which indicates a recent convergence of interest in the

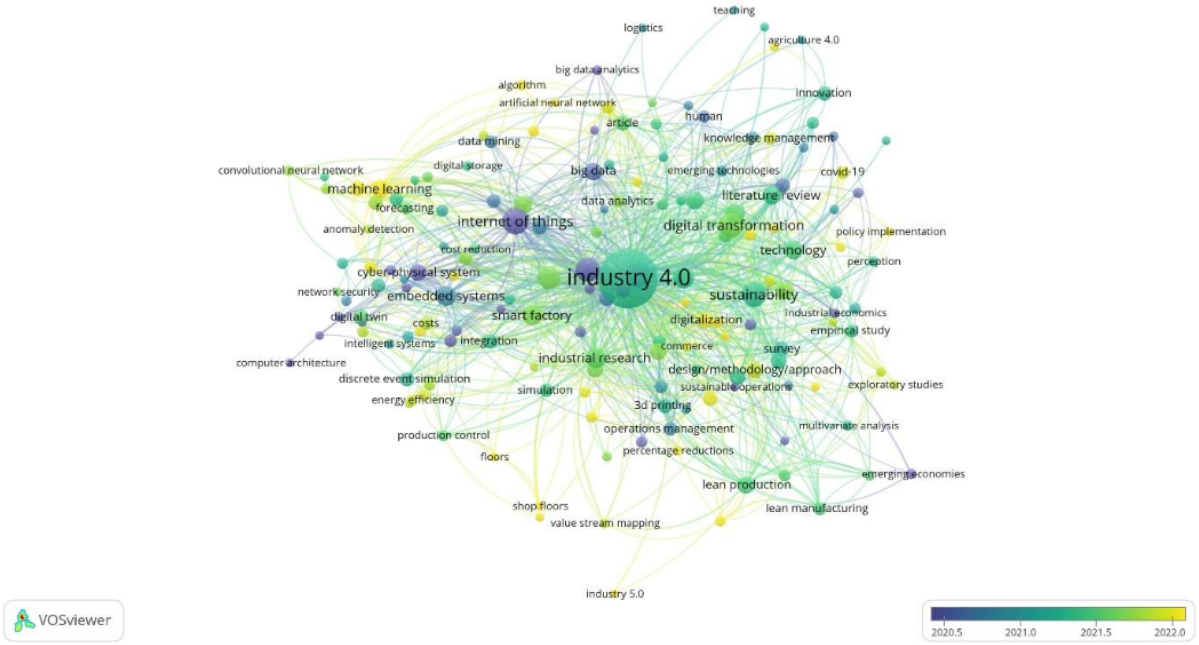
topic.

Figura 10: Keyword co-occurrence network over time: Global.



Source: VOSviewer with data from Scopus.

Figura 11: Keyword co-occurrence network over time: Brazil.



Note: The size of the nodes is proportional to the number of publications. Source: VOSviewer with data from Scopus.

5 Concluding remarks

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 in Brazil have made a significant contribution both in number of publications and their influence. Comparative analysis highlights Brazil's potential to excel in Industry 4.0 if collaborations between academia, industry, and government are fostered, and hence an environment of innovation and technological development is fostered. 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. Other steps that should be recommended for such may 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.

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