Article

Industry 4.0 in Latin America: Countries and Institutions with the Greatest Innovation and Global Impact

Víctor Herrero-Solana[1]* and Yelina Piedra-Salomón[2]

[1] Information & Communication Department, Universidad de Granada, 18070 Granada, Spain
[2] Information Science Department, Universidad de La Habana, 10400 La Habana, Cuba; yelinapiedra@fcom.uh.cu
*Corresponding author: victorhs@ugr.es

Featured Application: This article reports the first bibliometric analysis of Industry 4.0 in Latin America and, in general, the first use of the new article level Incites/Clarivate micro citation topic *4.224.1040 Industry 4.0.*

Abstract: Industry 4.0 (i4.0) is one of the fields of knowledge that is most extensively researched recently and whose definition is the most controversial, and Latin America (LatAm) is no exception. Identifying the LatAm countries and institutions with the highest degree of innovation and global impact in the i4.0 field. New citation micro-topics were used to identify the thematic domain: 4.224.1040 Industry 4.0. Difference indicators were extracted from Web of Science, Journal Citation Reports and especially Incites. Broadly speaking, the LatAm effort rate in i4.0 is high, as well as its global impact. The main countries are, in decreasing order, Brazil and Mexico. These countries show a high number of industry collaborations, and Brazil boasts many patent citations. Spain is a key partner of Mexico, Colombia, Argentina, Cuba and Ecuador. The most prominent institutions are the Monterrey Institute of Technology (*Tecnológico de Monterrey*) and the University of Rio Grande do Sul (*Universidade Federal do Rio Grande do Sul* – UFRGS). The former specializes in engineering and smart manufacturing systems and the latter in ICT (cloud computing, IoT, and big data, among others).

Keywords: Industry 4.0; América Latina; LatAm; i4.0; Incites; Bibliometrics

1. Introduction

The Fourth Industrial Revolution, also known as Industry 4.0 (i4.0), is a hot topic and field of research, and not without controversies; it originated in Germany [1] and has recently generated considerable literature output. Although at first i4.0 focused on the relationship with modern manufacturing systems, such as those known as cyber-physical systems [2], over time, the concept evolved more towards information and communication technologies (ICT) content such as the Internet of Things (IoT) [3] and Blockchain [4].

In Latin America (LatAm), the topic has generated significant expectation because a few authors believe that i4.0 can provide developing countries with a "shortcut," [5] even though many barriers to their development persist [6] and the degree of innovation remains low [7]. Among all the countries in the region, Brazil stands out, with citations in many articles on i4.0 and with an industrial system that is more akin to those of more developed countries than of other Latin-American countries [8]. The development of the Brazilian industry is compared to that of Canada [9] and Germany [10], [11], [12].

The leading i4.0 areas in Brazil include the plastic industry, IoT, and cyber-physical systems, [13], all of which emphasize sustainability [14] and small enterprises [15]. However, in some more classic areas, such as the automotive industry, their size and the economic crisis have made it difficult to implement i4.0 [16]. These adverse factors are compounded by other drawbacks, such as insufficient training of engineers at the university level, [17], the need for strengthening the relationship between business and scientific

 doi:10.20944/preprints202208.0403.v1

partners [18] and for improving the field of human resources [19], and even the COVID-19 pandemic [20].

Despite these drawbacks, Brazil is regularly placed among the top-15 countries in global bibliometric studies, ranking at the eleventh [21], fourteenth [22], seventh [23], and third [24] positions, depending on the keywords used in each study.

Only one bibliometric study of i4.0 in Brazil is available in the literature [25]. This study highlights the participation of the University of São Paulo (Universidade de São Paulo—USP) and the Federal University of Santa Catarina (Universidade Federal de Santa Catarina—UFSC) in knowledge creation in this field of research. Below, we will show that, although these universities are important, they are outpaced by a third university whose innovation and impact is even greater: the Federal University of Rio Grande do Sul (Universidade Federal do Rio Grande do Sul—UFRGS).

Few studies have addressed other Latin-American countries except Brazil. Generally, authors highlight the limited degree of i4.0 development that is still found in countries such as Colombia [26], Mexico [27], Chile [28], or Cuba [29].

No bibliometric study of i4.0 in LatAm has been previously conducted; however, a specific study of connectivity technologies, such as 5G and the IoT, has shown the dynamism of these technologies in the region, indicating that Brazil leads research output and citations, albeit closely followed by Chile, Colombia, and Mexico [30]. These results, as discussed below, are not necessarily in line with the findings of this study.

One of the main problems with i4.0 is the lack of a clear consensus on its definition, which makes it difficult to define the thematic domain based on keywords. In this article, we will use a different method from that followed in the aforementioned bibliometric studies; that is, instead of arbitrarily chosen keywords, we will use the new Incites/Clarivate citation topics, so that we can answer, among others, the following research questions: How is the research on i4.0 in LatAm? What is the degree of effort in the region? Does LatAm research on i4.0 have a global impact? Which are the leading countries in this field? Where do they publish and from where do they receive citations? What role do patents play in these citations? Which are the most outstanding institutions and why are they the leaders? What is the global impact and thematic profile of i4.0?

2. Materials and Methods

One of the main problems in researching i4.0 is the method used to define and delimit this thematic domain. Many authors have tried to do so by compiling keywords, but this procedure usually has several drawbacks. The main drawback is that this concept is relatively new and documents with this term are not available prior to 2015. Another major shortcoming is that i4.0 is a mostly German concept and has not yet been widely accepted in the Anglo-Saxon world. Therefore, i4.0 research requires a method for identifying technologies without the need to explicitly mention the "Industry 4.0" concept.

For this purpose, a good alternative consists of using some type of algorithm for detecting thematic fields or research fronts. In January 2021, Clarivate implemented in its Incites product a community detection algorithm in complex network graphs developed by the Centre for Science and Technology Studies (CWTS) [31]. The algorithm performs a massive clustering of bibliographic citations and identifies the different communities grouped into three hierarchical levels: macro- (10), meso- (326) and micro-topics (2444). Unlike the traditional subject categories, these topics do not operate at the journal level but rather at the article level, so that each record receives a single topic. This type of classification is much finer than those previously applied in recent research and frequently used by journal subject categories.

In April 2022, a new clustering was performed, leading to the same number of macro- (96.88% stability) and meso-topics (90% stability), and with only a name change in one of the latter. However, approximately 160 name changes and 13 new topics were identified

 doi:10.20944/preprints202208.0403.v1

at the micro level[1]. The macro- and meso-topics were labeled by humans, whereas the micro-topics labels were automatically generated.

On both occasions, the algorithm detected a micro-topic that automatically identifies the topic at hand: *4.224.1040 Industry 4.0*. The classification code informs that the macro-topic is 4 (Electrical Engineering, Electronics, & Computer Science) and the meso-topic 224 (Design & Manufacturing). The dataset of this micro-topic amounts to 18,424 records for the entire period covered by Incites (1980–2022). Every month new documents are added to this classification scheme, without the need to perform a re-clustering, only by analyzing their references.

Using the code 4.224.1040, the total i4.0 research output of LatAm, each of its countries, and the most important institutions were identified. Incites also generated queries to access the original data in the Web of Science (WOS), including those corresponding to the Emerging Source Citation Index (ESCI). The information of the Journal Impact Factor (JIF) quartiles derives from the Journal Citation Reports (JCR). Among the most important indicators, the following were considered: Web of Science Documents, Times Cited, Category Normalized Citation Impact (CNCI), Documents in Q1, Q2, Q3, & Q4 Journals, Cites in Q1, Q2, Q3, & Q4 Journals, % International Collaborations, % Industry Collaborations, Citations from Patents, etc.

All these values were calculated for both the micro-topic 4.224.1040 and total research output in all disciplines. The data were processed in MS-Excel, using MS-Excel, Tableau, Scimago Graphica [32] and Vosviewer [33] for the graphical representations.

3. Results

The topic i4.0 totals 18,424 documents globally, of which 943 have at least one author from a LatAm institution. These 943 documents account for 5.12% of the total output, which is significantly high because LatAm accounts for only 3.49% (2.5M/74.2M) of all documents in the entire database. Highlighting the significance of this value, Figure 1 shows a series of effort ratios in relation to the total research output of the region.

The number of citations is even more significant because Latin-American i4.0 citations account for 5.40% of the worldwide total, whereas the corresponding value of the region in general science barely reaches 2.71% (32.6M/1200M). In other words, LatAm output is not only significant but also cited globally above average in other disciplinary fields. As expected, this effect is shown by the CNCI indicator because the global impact is lower than one (0.998), but the LatAm impact is 1.05. When performing the same comparison for all disciplines, we find that the difference is greater, but reverse (0.98 vs. 0.77). In i4.0, LatAm again performs above average in relation to other thematic fields.

[1] https://incites.help.clarivate.com/Content/Research-Areas/citation-topics.htm

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 August 2022 doi:10.20944/preprints202208.0403.v1

Figure 1. Effort ratios. Source: Incites.

The temporal evolution of both geographic domains is somewhat similar. As indicated above, the method implemented by Clarivate retrospectively recovers the scientific output even before the coining of the term. In fact, documents can be traced back to the last two decades of the previous century. However, a consistent output can be identified for approximately 20 years.

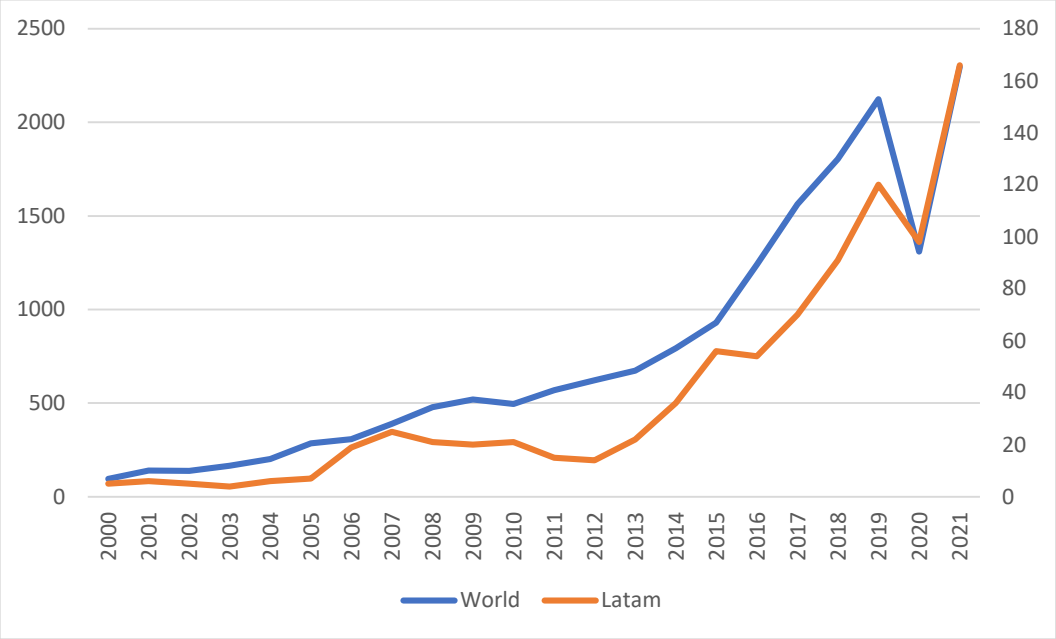

Figure 2. Temporal evolution. Source: Incites.

Figure 2 shows the evolution of the world (main vertical axis) and LatAm (secondary vertical axis) visualizing how the region's growth was slow at first but then accelerated. The sharp decrease in 2020, which occurred both in the World and in LatAm, could be due to some problem in the functioning of the detection algorithm of the cited topic. This matter is outside the scope of this research and its aims, but we will continue investigating.

When examining the countries, we found that Brazil and Mexico lead the research output. By plotting the data by country as in Figure 1, we identified a clear bias of these two countries. On the left-hand side, Figure 3 shows the percentage of i4.0 research output (blue) of each country that accounts for the total output of LatAm in comparison with the same percentage for all disciplines. Brazil accounts for approximately 60% of all the i4.0

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 August 2022 doi:10.20944/preprints202208.0403.v1

documents of LatAm, and for slightly less than half of all scientific documents of the entire region across all fields.

A similar behavior was found in Mexico, but the percentage difference was not as high (slightly more than 5%). The research output of Argentina and Chile are strikingly low because, given their general position (12% and approximately 9%), they should account for more than 3% and 2% of the total research output, respectively. The contribution of the remaining countries is much lower, although Ecuador stands out (with more than 3%). To facilitate the analysis and visualization of the data, we only show the top-eight countries by research output.

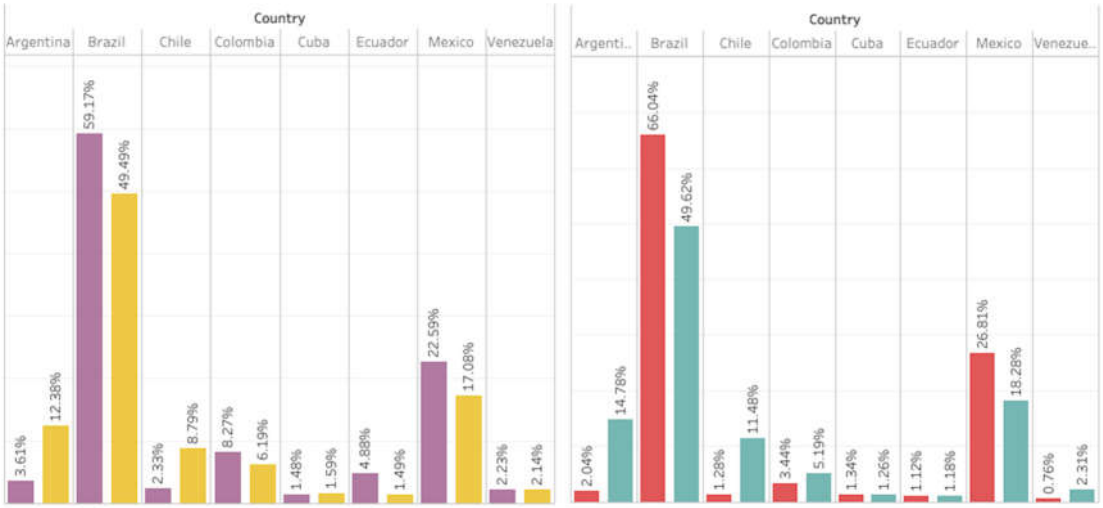

Figure 3. Ratio of documents and citations by country. Source: Incites.

On the right-hand side, Figure 3 shows the percentage of citations on i4.0 in red and on all disciplines in green per country. The results highlight that the gap in Brazil widens to more than 15%. Similarly, in Mexico, the gap is greater in citations than in documents. The differences are also greater (albeit reversely) in Argentina and Chile, with Colombia's imbalance shifting from a higher percentage of documents on i4.0 than on all fields to a higher percentage of citations on all fields than on i4.0. In Ecuador, the imbalance observed in documents vanishes in citations.

Undoubtedly, the positive contribution of citations in the region almost exclusively derives from the contribution of Brazil and Mexico, which, with their singularities, as we discuss below, are sustaining the strength of LatAm in this thematic domain. Figure 4 shows two scatter plots slightly clarifying the causes of the position of these two countries.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 August 2022 doi:10.20944/preprints202208.0403.v1

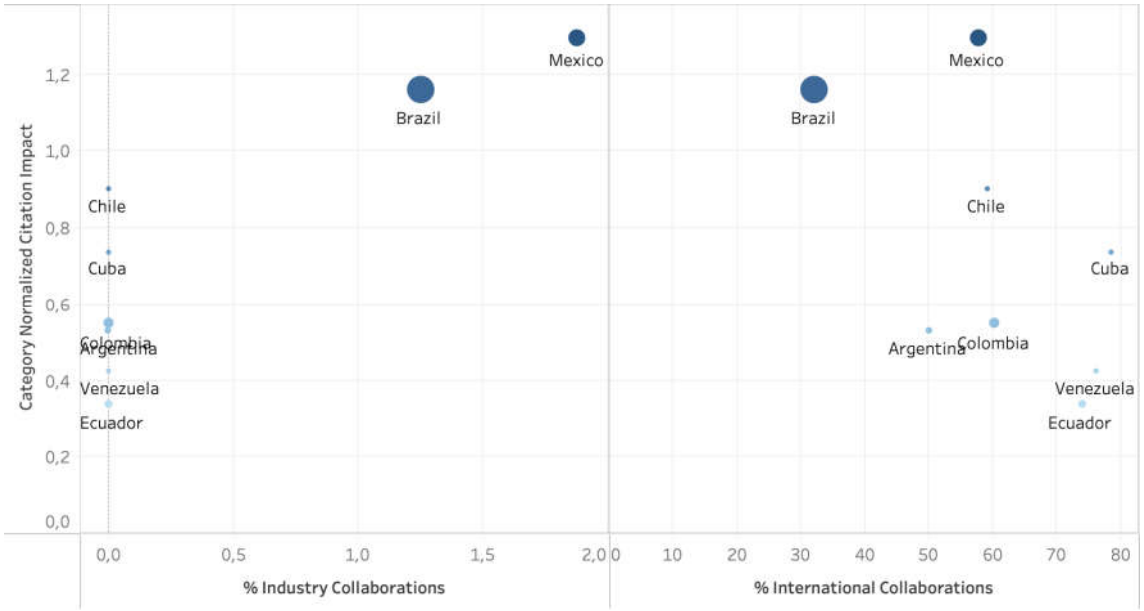

Figure 4. International collaborations and collaborations with the industrial sector. Source: Incites.

In both the graphs, the size of the circles is proportional to the number of studies and the vertical axis is the CNCI. The results show that both Brazil and Mexico lie above 1, that is, the global average. In fact, Mexico has the highest impact at 1.29. The other countries lie below 1. Most noticeably, the graph on the left shows the percentage of international collaborations, highlighting that the higher the number of collaborations, the lower the impact. For example, more than 70% of the research output of Venezuela and Ecuador consists of international collaborations, but their impact is only approximately 0.4. Conversely, the impact of Brazil is higher than 1, that is, above the global average, with only 30% of international collaborations. Brazilian national output seems to be so strong that it requires no external partners. One of the countries outside the region that significantly contributes to international collaboration is Spain, which functions as a prominent partner of Mexico, Colombia, Argentina, Cuba, and Ecuador.

On the right-hand side, Figure 4 shows the percentage of collaborations with industrial sectors. Here, the phenomenon is the opposite: only Brazil and, to a greater extent, Mexico present such collaborations. The other countries fall directly on the vertical axis as they have no industry collaborations. Therefore, for this thematic domain, collaborations with industry/business sectors are more relevant than with foreign institutions.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 August 2022 doi:10.20944/preprints202208.0403.v1

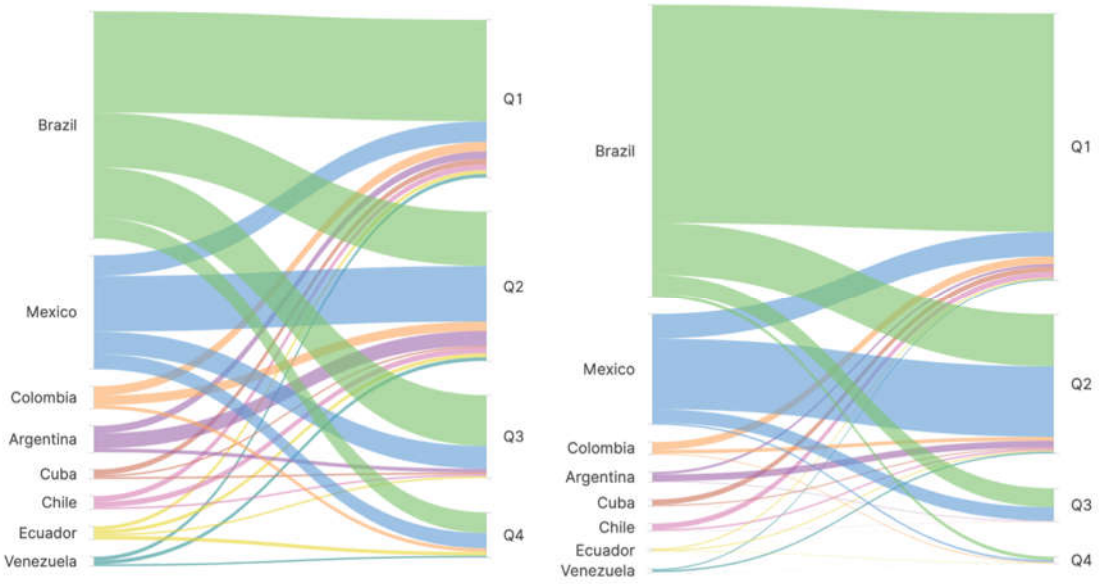

Figure 5. Alluvial diagram of documents and citations. Source: Incites.

These results prompt the following questions: how are research output and citation counts distributed according to the JCR journals? Do all countries display the same behavior? Figure 5 answers these question. The alluvial diagram, on the left, shows the research output of each country and the quartile of each journal. In Brazil, most studies are published in Q1 journals; by contrast, in Mexico, the main volume of studies is found in Q2 journals. The remaining countries are difficult to assess as the flows are much smaller, although Argentina seems to follow a pattern similar to that of Mexico.

On the right-hand side, Figure 5 shows the alluvial diagram of citations. In Brazil, the aforementioned pattern is repeated and even reinforced as Q1 accounts for approximately two-thirds of all citations. In Mexico, similarly, Q2 journals maintain the main flow of citations. Due to the limitations of this study, we are unable to delve into details about each of the journals in these sets, so further research is needed to identify the nature of this set of sources that are not top-tier jounals *stricto sensu*. Lastly, the diagrams were constructed with data on JIF quartiles of the JCR and not on the new Journal Citation Indicator (JCI), thus excluding ESCI articles.

As we continue analyzing the results, the research output and citation profile of the two main countries begin to take shape. An interesting fact to keep in mind about the origin of citations refers to citations from patents. The region received 432 citations from patents for the entire study period, but they were only for two countries, namely Brazil and Mexico. The difference between them is even abysmal, with only seven citations from Mexican studies, whereas Brazilian patents amassed 425 citations, which is a substantial difference. This indicator reinforces the behavior observed in Figure 4, showing the percentage of industry/business collaborations.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 August 2022 doi:10.20944/preprints202208.0403.v1

Table 1. Subject areas of Brazil and Mexico. Source: JCR and WOS.

Brazil		Mexico	
Engineering	26.80%	Engineering	27.24%
Computer Science	20.70%	Computer Science	21.52%
Multidisciplinary	15.00%	Multidisciplinary	15.36%
Economics & Business	10.15%	Materials Science	11.21%
Materials Science	8.46%	Mathematics	8.86%
Mathematics	8.24%	Economics & Business	6.50%
Physics	4.50%	Physics	4.48%
Social Sciences, General	2.58%	Social Sciences, General	2.13%
Environment/Ecology	1.56%	Environment/Ecology	0.67%
Biology & Biochemistry	0.58%	Biology & Biochemistry	0.45%
Visual & Performing Arts	0.49%	Visual & Performing Arts	0.34%
Chemistry	0.40%	Chemistry	0.34%
Literature & Language	0.27%	Literature & Language	0.34%
Clinical Medicine	0.18%	Geosciences	0.22%
Arts & Humanities	0.04%	Psychiatry/Psychology	0.22%
Plant & Animal Science	0.04%	Clinical Medicine	0.11%

Our detailed analysis of the thematic profile of the i4.0 research output of the two main countries showed that they are quite similar. Table 1 outlines the main thematic groups into which the different published documents fall. These thematic groups were formed by clustering the classic thematic categories of the JCR. The approximate reference percentage was included, considering that there is some degree of overlap. The first three clusters are the same and with highly similar percentages. The main clusters are Engineering and Computer Science, as expected. The Multidisciplinary cluster was also expected because this cluster encompasses many miscellaneous thematic categories from different fields.

The main difference between these two countries is that Brazil has a higher percentage in Economics and Business than Mexico, with the latter showing a stronger presence in Materials Science. We can, therefore, affirm that Brazil displays a slightly softer version of i4.0, whereas Mexico has a more heavily industrial i4.0 research, strictly speaking. Nevertheless, the profiles are quite similar and undoubtedly reflect, consequently, the profile of the entire region.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 August 2022 doi:10.20944/preprints202208.0403.v1

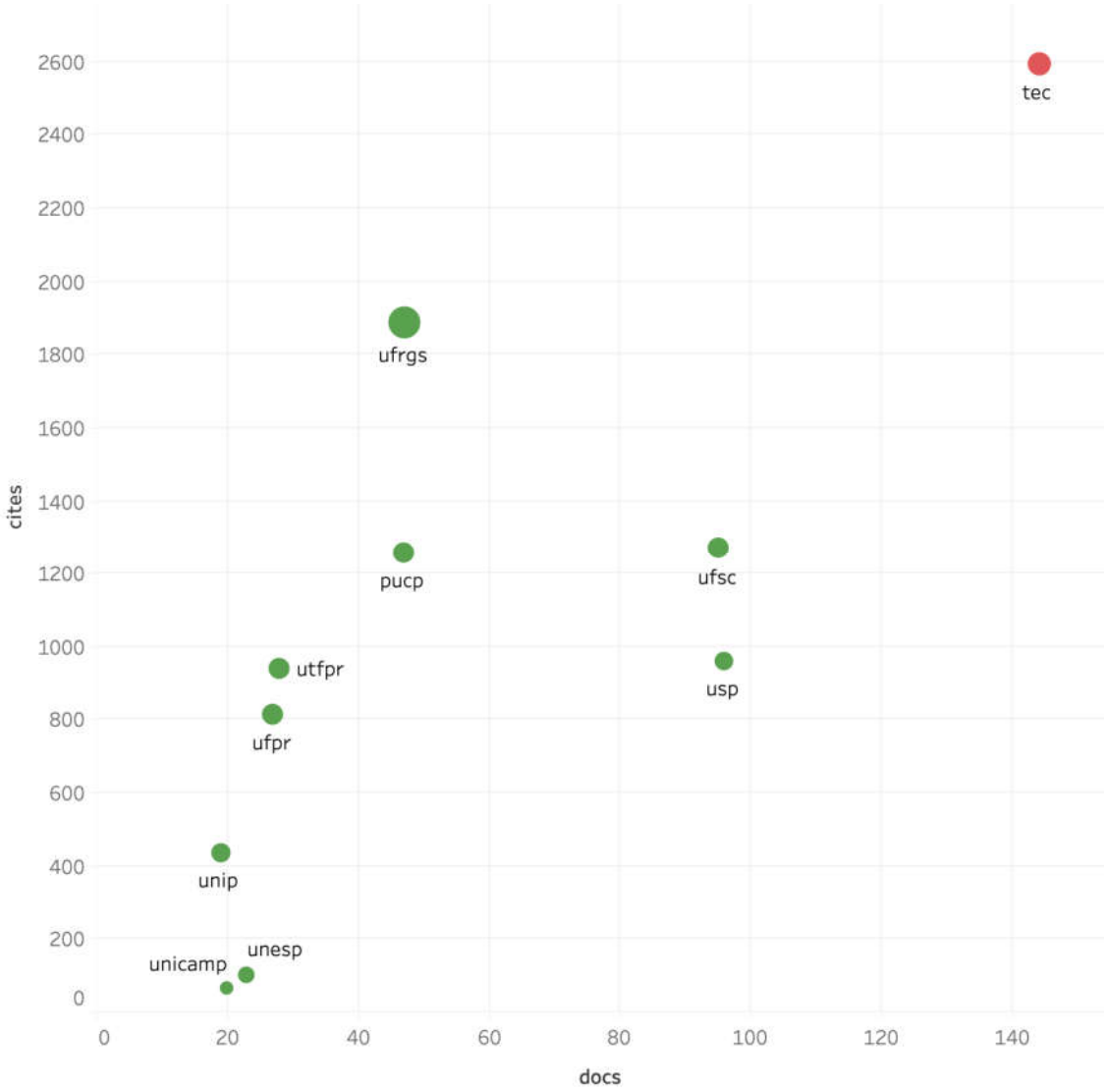

Figure 6. Top-10 institutions: documents vs. citations. Source: Incites.

A more in-depth analysis, at the level of the institutions, shows that approximately 196 in total produce research on i4.0, most of which with few documents. Curiously, among all these institutions, only one belongs to the corporate sector, that is, the Brazilian Petrobras. Figure 6 shows the top-10 institutions with the highest research output in a scatter plot. As expected, the top-10 list includes only Brazilian (green) and Mexican (red) institutions, albeit in an unusual manner. At the top, we find a private academic institution from Mexico: the Monterrey Institute of Technology (Tecnológico de Monterrey-Tec), whereas the remaining nine are mostly Brazilian public universities.

Tec's performance is impressive. This academic institution, with campuses throughout the Mexican territory, is the Latin American institution with the highest number of documents and citations on i4.0. Accordingly, most of the Mexican strength likely rests in this institution, although others, such as the National Polytechnic Institute (Instituto Politécnico Nacional—IPN), National Autonomous University of Mexico (Universidad Nacional Autónoma de México—UNAM), or Center for Research and Advanced Studies of the National Polytechnic Institute (Centro de Investigación y de Estudios Avanzados del IPN—Cinvestav) also contribute to Mexico's research output on i4.0, albeit to a lesser extent. In Brazil, the contribution to the field is more distributed across several universities, such as the University of Sao Paulo (Universidade de São Paulo—USP) and the Federal University of Santa Catarina (Universidade Federal de Santa Catarina—UFSC). How-

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 August 2022 doi:10.20944/preprints202208.0403.v1

ever, as indicated in the Introduction, the Federal University of Rio Grande do Sul (Universidade Federal do Rio Grande do Sul—UFRGS) stands out because, far from being the largest in Brazil, this institution amasses a large number of citations, and therefore, has a tremendous impact, with a CNCI higher than 3. This indicator is directly proportional to the size of the circles in Figure 7, which clearly shows that the other institutions have a considerably lower CNCI. Below, we will analyze in more detail the thematic content of the two most outstanding institutions.

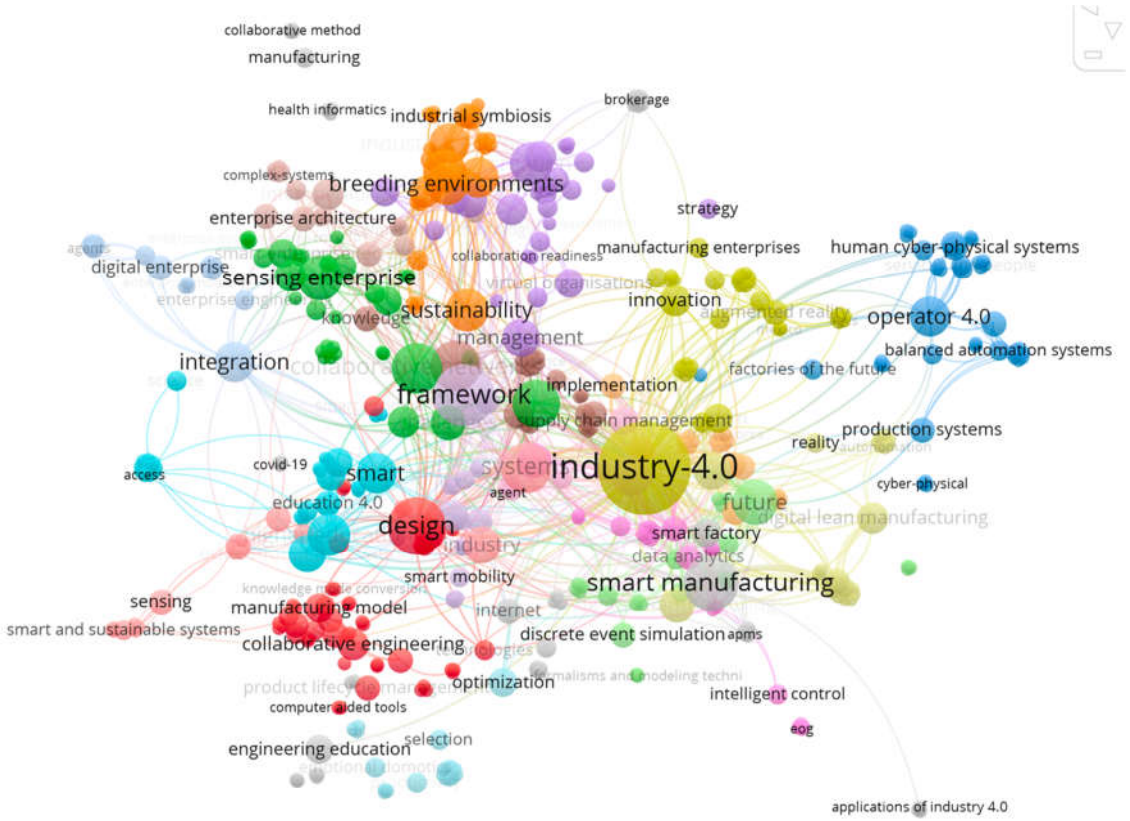

Figure 7. Keyword map of the Monterrey Institute of Technology. Source: WOS.

Figure 7 shows a keyword map of the Tec research output. As expected, the most repeated descriptor is Industry 4.0, albeit surrounded by groups linked to the topic of modern manufacturing techniques. The topics range from smart manufacturing and smart factory through cyber-physical systems, design and manufacturing models, the use of all types of sensors for factory detection and robotization (sensing and sensing enterprise), collaborative engineering, and automatic systems (operator 4.0) to factories of the future in general. This core topic is accompanied by other softer topics such as education 4.0, innovation, and business strategies.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 August 2022 doi:10.20944/preprints202208.0403.v1

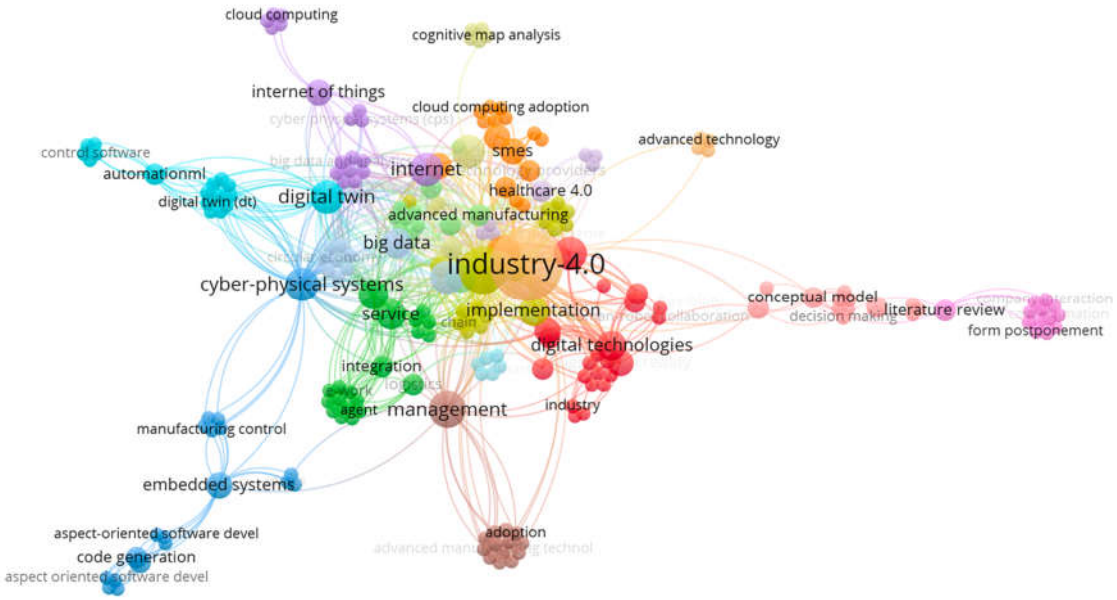

Figure 8. Keyword map of the Federal University of Rio Grande do Sul. Source: WoS.

The comparison of Figures 7 (Tec) and 8 (UFRGS) shows the same center (Industry 4.0) but a different periphery. The UFRGS also publishes content on factory of the future, albeit limited to the blue cluster, on the bottom-left (cyber-physical systems, manufacturing control, embedded systems, etc.) and some on the green cluster (advanced manufacturing). Conversely, some contents are related to management in general (management, implementation, decision making, etc.), but the UFRGS stands out in Computing. The purple cluster best represents this topic; it links the IoT to cloud computing. Added to these are digital technology, in general, and especially, big data. The profile of both institutions is compatible with the thematic profiles of the respective countries. It would be interesting to deepen the thematic profile of all the institutions, but this objective is outside the scope of the present study.

4. Discussion

Considering the above, Latin American scientific output in the field of i4.0 is not only significant in relation to other fields researched in the region, but also has a good international impact. Broadly speaking, the effort rate of LatAm in i4.0 is high, as well as its global impact.

The countries with the best performance are, in decreasing order: Brazil and Mexico. These countries have a high level of industry collaboration, and Brazil receives many patent citations. Spain is an important partner of Mexico, Colombia, Argentina, Cuba, and Ecuador. The research output and citations of Brazilian institutions are mostly based on Q1 journals. By contrast, in Mexico, curiously, Q2 journals are the protagonist. The thematic profile of both countries is strikingly similar, with Brazil focusing more on slightly softer (Management) topics than Mexico, whose institutions primarily address hard (Materials) topics.

The virtual absence of companies and corporations stands out: the entire landscape seems to be dominated by academia. The most outstanding institutions are the Tec and UFRGS. The former amasses the most documents and citations, specializing in engineering and smart manufacturing systems. The latter stands out for the high impact of its research output, specializing in ICT (cloud computing, the IoT, big data, etc.)

In future studies, we will continue analyzing the i4.0 evolution in LatAm. We plan to deepen the thematic profile of the main institutions to identify the specific topics with the greatest innovation and the authors with the greatest global impact.

Author Contributions: Conceptualization, VHS; methodology, VHS & YPS; validation, VHS; formal analysis, VHS & YPS; data curation, VHS & YPS; writing—original draft preparation, VHS; writing—review and editing, VHS & YPS; visualization, VHS supervision, VHS; project administration, VHS; funding acquisition, VHS. All authors have read and agreed to the published version of the manuscript.

Funding: This article was supported by the Ministry of Science, Innovation and Universities (Spain) Grant Nº: RTI2018-098966-B-I00.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Fuchs, C. Industry 4.0: The Digital German Ideology. TripleC **2018**, 16, 280–289, doi:https://doi.org/10.31269/vol16iss1pp280-289.
2. Cobo, M.J.; Jürgens, B.; Herrero-Solana, V.; Martínez, M.A.; Herrera-Viedma, E. Industry 4.0: A Perspective Based on Bibliometric Analysis. Procedia Comput. Sci. **2018**, 139, 364–371, doi:https://doi.org/10.1016/j.procs.2018.10.278.
3. Atzori, L.; Iera, A.; Morabito, G. The Internet of Things: A Survey. Comput. Networks **2010**, 54, 2787–2805, doi:https://doi.org/10.1016/j.comnet.2010.05.010.
4. Clarke, N.S.; Jürgens, B.; Herrero-Solana, V. Blockchain Patent Landscaping: An Expert Based Methodology and Search Query. World Pat. Inf. **2020**, 61, doi:10.1016/j.wpi.2020.101964.
5. Brixner, C.; Isaak, P.; Mochi, S.; Ozono, M.; Suárez, D.; Yoguel, G. Back to the Future. Is Industry 4.0 a New Tecno-Organizational Paradigm? Implications for Latin American Countries. Econ. Innov. New Technol. **2020**, 29, 705–719, doi:https://doi.org/10.1080/10438599.2020.1719642.
6. De Lucas Ancillo, A.; Gavrila Gavrila, S.; Fernández del Castillo Díez, J.R.; Corro Beseler, J. LATAM and Spanish SME Barriers to Industry 4.0. Acad. Rev. Latinoam. Adm. **2021**, doi:https://doi.org/10.1108/ARLA-07-2021-0137.
7. Cortés-Sánchez, J.D. Innovation in Latin America through the Lens of Bibliometrics: Crammed and Fading Away. Scientometrics **2019**, 121, 869–895, doi:https://doi.org/10.1007/s11192-019-03201-0.
8. Tortorella, G.L.; Cawley Vergara, A. Mac; Garza-Reyes, J.A.; Sawhney, R. Organizational Learning Paths Based upon Industry 4.0 Adoption: An Empirical Study with Brazilian Manufacturers. Int. J. Prod. Econ. **2020**, 219, 284–294, doi:https://doi.org/10.1016/j.ijpe.2019.06.023.
9. Ottonicar, S.L.C.; Valentim, M.L.P.; Mosconi, E. Políticas Públicas Aplicadas à Indústria 4.0: Estudo Comparativo Entre o Brasil e o Canadá Com Foco Na Competência Em Informação. Rev. Ibero-Americana Ciência da Informação **2019**, 12, 558–584, doi:https://doi.org/10.26512/rici.v12.n2.2019.19596.
10. Satyro, W.C.; de Mesquita Spinola, M.; Sacomano, J.B.; da Silva, M.T.; Gonçalves, R.F.; de Paula Pessoa, M.S.; Contador, J.C.; Contador, J.L.; Schiavo, L. Implementation of Industry 4.0 in Germany, Brazil and Portugal: Barriers and Benefits. IFIP Adv. Inf. Commun. Technol. **2019**, 567, 323–330, doi:https://doi.org/10.1007/978-3-030-29996-5_37.
11. Mana, R.; César, F.I.G.; Makiya, I.K.; Volpe, W. The Concept of the Industry 4.0 in a German Multinational Instrumentation and Control Company: A Case Study of a Subsidiary in Brazil. Indep. J. Manag. Prod. **2018**, 9, 933, doi:https://doi.org/10.14807/ijmp.v9i3.665.
12. Brunheroto, P.H.; Tomanek, D.P.; Deschamps, F. Implications of Industry 4.0 to Companies' Performance: A Comparison between Brazil and Germany1. Brazilian J. Oper. Prod. Manag. **2021**, 18, 1–10, doi:https://doi.org/10.14488/BJOPM.2021.009.
13. Nara, E.O.B.; da Costa, M.B.; Baierle, I.C.; Schaefer, J.L.; Benitez, G.B.; do Santos, L.M.A.L.; Benitez, L.B. Expected Impact of Industry 4.0 Technologies on Sustainable Development: A Study in the Context of Brazil's Plastic Industry. Sustain. Prod. Consum. **2021**, 25, 102–122, doi:https://doi.org/10.1016/j.spc.2020.07.018.
14. Siltori, P.F.S.; Anholon, R.; Rampasso, I.S.; Quelhas, O.L.G.; Santa-Eulalia, L.A.; Leal Filho, W. Industry 4.0 and Corporate Sustainability: An Exploratory Analysis of Possible Impacts in the Brazilian Context. Technol. Forecast. Soc. Change **2021**, 167, doi:https://doi.org/10.1016/j.techfore.2021.120741.
15. Cruzara, G.; Sandri, E.C.; Cherobim, A.P.M.S.; Frega, J.R. The Value at the Industry 4.0 and the Digital Transformation Process: Evidence from Brazilian Small Enterprises. Rev. Gestão Tecnol. **2021**, 21, 117–141, doi:https://doi.org/10.20397/2177-6652/2021.v21i1.1860.
16. Ruggero, S.M.; dos Santos, N.A.; Sacomano, J.B.; Terra da Silva, M. Investments of the Automotive Sector and the Industry 4.0. Brazilian Case. IFIP Adv. Inf. Commun. Technol. **2019**, 566, 650–657, doi:https://doi.org/10.1007/978-3-030-30000-5_79.

17. Souza, R.G.; Quelhas, O.; Marchisotti, G.; Neto, J.; Anholon, R.; Marinho, C.A. Production Engineering Curriculum in Industry 4.0 in a Brazilian Context. South African J. Ind. Eng. **2020**, 31, 136–150, doi:https://doi.org/10.7166/31-4-2033.
18. Rocha, C.; Quandt, C.; Deschamps, F.; Philbin, S.; Cruzara, G. Collaborations for Digital Transformation: Case Studies of Industry 4.0 in Brazil. IEEE Trans. Eng. Manag. **2021**, 1–15, doi:https://doi.org/10.1109/TEM.2021.3061396.
19. Pio, P.C.; Rampasso, I.S.; Cazeri, G.T.; Santa-Eulalia, L.A.; Pavan Serafim, M.; Anholon, R. Human Resources and Industry 4.0: An Exploratory Study in the Brazilian Business Context. Kybernetes **2021**, doi:https://doi.org/10.1108/K-04-2021-0253.
20. Cazeri, G.T.; Anholon, R.; Santa-Eulalia, L.A.; Rampasso, I.S. Potential COVID-19 Impacts on the Transition to Industry 4.0 in the Brazilian Manufacturing Sector. Kybernetes **2022**, 51, 2233–2239, doi:https://doi.org/10.1108/K-10-2020-0693.
21. Kipper, L.M.; Furstenau, L.B.; Hoppe, D.; Frozza, R.; Iepsen, S. Scopus Scientific Mapping Production in Industry 4.0 (2011–2018): A Bibliometric Analysis. Int. J. Prod. Res. **2020**, 58, 1605–1627, doi:https://doi.org/10.1080/00207543.2019.1671625.
22. Morelli, D.A.; Ignacio, P.S. de A. Assessment of Researches and Case Studies on Cloud Manufacturing: A Bibliometric Analysis. Int. J. Adv. Manuf. Technol. **2021**, 117, 691–705, doi:https://doi.org/10.1007/s00170-021-07782-0.
23. Ejsmont, K.; Gladysz, B.; Kluczek, A. Impact of Industry 4.0 on Sustainability—Bibliometric Literature Review. Sustain. **2020**, 12, 1–29, doi:https://doi.org/10.3390/su12145650.
24. da Silva, I.A.; Barbalho, S.C.M.; Adam, T.; Heine, I.; Schmitt, R. Industry 4.0 Readiness: A New Framework for Maturity Evaluation Based on a Bibliometric Study of Scientific Articles from 2001 to 2020. DYNA **2021**, 88, 101–109, doi:https://doi.org/10.15446/dyna.v88n218.92543.
25. Nascimento, M.R. Ecossistemas de Conhecimento Sobre Indústria 4.0 No Brasil: Uma Análise Bibliométrica. AtoZ novas práticas em informação e conhecimento **2021**, 10, 1, doi:https://doi.org/10.5380/atoz.v10i3.81513.
26. Sinisterra, K.V.B.; Mejía, S.M.; Molano, J.I.R. Industry 4.0 and Its Development in Colombian Industry. Commun. Comput. Inf. Sci. **2017**, 742, 312–323, doi:https://doi.org/10.1007/978-3-319-66963-2_28.
27. Casalet, M.; Stezano, F. Risks and Opportunities for the Progress of Digitalization in Mexico. Econ. Innov. New Technol. **2020**, 29, 689–704, doi:https://doi.org/10.1080/10438599.2020.1719643.
28. de la Fuente-Mella, H.; Rojas Fuentes, J.L.; Leiva, V. Econometric Modeling of Productivity and Technical Efficiency in the Chilean Manufacturing Industry. Comput. Ind. Eng. **2020**, 139, 105793, doi:https://doi.org/10.1016/j.cie.2019.04.006.
29. Llanes-Font, M.; Salvador-Hernández, Y.; Suárez-Benítez, M.Á.; Solórzano-Benítez, R. Cuarta Revolución Industrial y Administración Pública de América Latina y El Caribe. Ciencias Holguín **2020**, 26, 78–92.
30. Corzo, G.D.; Alvarez-Aros, E.L. Technological Competitiveness Strategies in Mobile Connectivity and Industry 4.0 Communications in Latin America. Inf. Tecnol. **2021**, 31, 183–192, doi:https://doi.org/10.4067/S0718-07642020000600183.
31. Traag, V.A.; Waltman, L.; van Eck, N.J. From Louvain to Leiden: Guaranteeing Well-Connected Communities. Sci. Rep. **2019**, 9, 5233, doi:https://doi.org/10.1038/s41598-019-41695-z.
32. Hassan-Montero, Y. Scimago Graphica Available online: https://graphica.app/.
33. Eck, N.J. van; Waltman, L. Software Survey: VOSviewer, a Computer Program for Bibliometric Mapping. Scientometrics **2010**, 84, 523–538, doi:10.1007/s11192-009-0146-3.