



Do Latin American universities engage industry in the scientific publication? A bibliometrics approach through *Scopus*

¿Atraen las universidades latinoamericanas a la industria en la publicación científica? Una aproximación bibliométrica a través de *Scopus*

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RESUMEN:

El principal objetivo de este trabajo es determinar el nivel de colaboración científica entre universidades latinoamericanas y empresas, en términos de co-autoría, así como identificar las principales instituciones involucradas en esas colaboraciones. Para ello, se extrajeron todas las publicaciones entre 2009 y 2018 que dispusieran de un/a autor/a afiliado/a a una universidad de un país latinoamericano (de un total de 20 analizados), y otro co-autor/a afiliado/a a una empresa, utilizando para ello *Scival*, producto de *Elsevier* alimentado con datos de *Scopus*. Se obtuvieron 22,469 registros, de los que se identificaron 1531 empresas y 428 universidades latinoamericanas. Los resultados evidencian unos porcentajes bajos de colaboración Universidad-Industria durante el período analizado. Sin embargo, estas publicaciones se caracterizan por lograr un alto impacto en citas. A pesar del alto número de empresas identificadas, solamente unas pocas (principalmente de las industrias farmacéuticas, tecnológicas y Petróleo) han establecido conexiones robustas con un conjunto pequeño de universidades, principalmente brasileñas, cuyo rendimiento enmascara el resto de colaboraciones de menor intensidad identificadas en otros países. Por otro lado, la presencia de empresas públicas (por ejemplo, Petrobras, Agrosavia, Embrapa, YPF, Petróleos Mexicanos, etc.) es igualmente destacable. Se recomiendan el establecimiento de políticas públicas estables orientadas a fomentar y potenciar las relaciones Universidad-Industria en la región, basadas en la integración y regulación de estas acciones en las actividades del investigador.

PALABRAS CLAVE: Colaboración científica, Empresas, Universidades, Bibliometría, América Latina.

ABSTRACT:

The main objective of this work is to determine the collaboration level of Latin American universities with companies in terms of scientific co-authorship, and to identify the main institutions involved in these collaborations. To do this, all publications from 2009 to 2018 with at least one co-author belonging to each of 20 Latin American countries, and another co-author affiliated to a company, were extracted from Elsevier's Scival (powered by Scopus data), obtaining a set of 22,469 records, from which 1,531 companies (both of public and private nature) and 428 Latin American universities were identified. Despite publications co-authored by universities and companies are highly-cited, results evidence low percentages of academic collaboration between Latin American universities and companies over the period. Just few firms (mainly from Pharmacy, Technology and Petroleum markets) have established strong connections with few universities, mainly from Brazil, whose performance masks the remaining minor linkages established in other countries. Otherwise, the presence of publicly-traded companies (e.g., Petrobras, Agrosavia, Embrapa, YPF or Petróleos Mexicanos) is also remarkable. The establishment of stable public policies aimed at promoting and strengthening University-Industry relations in the region, and based on the integration and regulation of these actions in the researcher's activities, is recommended.

KEYWORDS: Scientific collaboration, Companies, Universities, Bibliometrics, Latin America.

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1. INTRODUCTION

University-industry collaboration (UIC) has an extensive literature background (Bruneel, d'Este & Salter, 2010; Nsanzumuhire & Groot, 2020; Perkmann et al., 2013; Sjöo & Hellström, 2019), primarily aimed to understand the nature of these collaborations (purposes, benefits, types of linkages) on one side of the spectrum, and to analyze their effects as potential economic engines on specific regions, on the other side.

Collaborations between universities and corporations (public, private or not-for-profit organizations) can be connected to each of the main missions traditionally assigned to universities (teaching, research, and transfer).

Universities and companies can establish linkages around teaching activities by means of laboratory practices, visits, customized masterclasses, tutorships, temporal internships, access to facilities, infrastructures or software to be used by students. More formal relations are even possible through part-time instructors (*Privatdozent*, Adjunct Professor or *Profesor Asociado*).

Universities and companies can establish linkages around research activities by means of co-authorship in academic and scientific publications or creating research teams to develop public/private funded research projects.

As regards the third mission (commonly referred to as transfer), we need to distinguish between extension activities and knowledge transference, especially in some regions such as Latin America (Sutz, 2007). Extension activities are those related to cultural and social activities, carried out mainly by students' associations, aimed at bringing the university closer to the Society, especially for disadvantaged groups. Otherwise, transference activities are related to services provided by the university to public/private firms, such as customized courses, advisory or innovation processes regulated by industrial property and patents.

These transference activities link universities directly to the promotion of knowledge into the economic growth, strengthening the innovative nature of the industrial sector. This market-oriented behavior of universities was represented by few North American universities, especially the Massachusetts Institute of Technology (MIT), raising a new concept coined as entrepreneurial university (Etzkowitz, 1990), where companies act as knowledge seekers (market demand), and universities as knowledge providers (market offer).

All these ideas were then formalized (Etzkowitz & Leydesdorff, 1995; 2000; Leydesdorff & Etzkowitz, 1996) to propose the well-known Triple-Helix Model of Innovation, based on a set of interactions between universities (performing basic research and generating new knowledge), industries (producing commercial goods) and Government (regulating markets), which might foster economic and social development under a knowledge economy. This model was subsequently expanded by including 'media-based and culture-based public', 'civil society' and 'natural environments of society' (Carayannis, Barth & Campbell 2012).

While Triple-Helix Model is heavily influenced and modeled by transfer activities, interactions between its core elements can be analyzed in all three university missions (teaching, research, and transfer).

As one specific advantage of this model of process innovation is that it is amenable to measurement (Leydesdorff & Meyer, 2003), quantitative methods can be employed to measure interactions. In the case of universities' research mission, Bibliometrics have been traditionally used to measure University-Industry collaborations, especially through the co-authorship of scientific publications, as this indicator is quantifiable and invariant, while the measurement is not invasive (Abramo, D'Angelo, Di Costa & Solazzi, 2009; Confraria & Vargas, 2019).

A wide body of literature about the reasons and factors affecting University-Industry collaborations exist (D'Este & Perkmann, 2011; Fontana, Geuna & Matt, 2006), regardless the collaboration level (teaching, research, transfer). On the one hand university researchers might envisage opportunities such as obtaining additional research funds, testing theories or methods in real environments, or even business opportunities to commercialize products derived from research activities. On the other hand, industrial researchers might

act strategically in order to build reputations, to influence the process of obtaining results, to establish intellectual or industrial claims, to attain potential partners, or just to be included in places where new knowledge emerge to be early adopters obtaining a market advantage. Moreover, companies could solve complex problems using universities' labs for which they would need a set of technologies that they could not develop/maintain themselves (Arza & Carattoli, 2017; Confraria & Vargas, 2019; Li, Youtie & Shapira, 2015; McKelvey & Rake, 2020; Tijssen, 2012).

Regardless the technique used, UICs subject to different geographical and cultural constrains in order to be properly measured and analyzed. The organization, management, culture and missions of universities differ from one country to other, being under different legislative norms and social contracts. Similarly, companies are subjected to specific local demands, whose needs and complexity can vary enormously according to each different business sector.

In the specific case of Latin America, the diversity of universities across countries is significant, from undergraduate systems mainly shaped by public universities with universal access in Argentina, to systems shaped by private universities with massive access in Chile and Colombia, or elitist systems in Brazil. In the case of postgraduate studies, public universities are majority in all Latin American countries (Sutz, 2007).

Given the specific characteristics of the region, several studies on University-Industry relations in Latin America haven been carried out (Crespi & Dutrénit, 2014; Crespi, Navarro & Zuñiga, 2010; de Mello & Etzkowitz, 2008; Dutrénit & Arza, 2010; Grazzi & Pietrobelli, 2016; Rodríguez Pérez y Rojas, 2014; Sutz, 2000; 2007), as well as focused studies in countries, such as Argentina (Arza & Carattoli, 2017), Brazil (Fernandes, De Souza, da Silva, Suzigan, Chaves, C. V. & Albuquerque, 2010; Fischer, Schaeffer & Vonortas, 2019) or Bolivia (Vega-Jurado, Fernández-de-Lucio & Huanca, 2008).

As Confraria & Vargas (2019) emphasize, policies promoting science-industry connections in the Latin American region are motivated by the potential benefit in innovation and technological capacities in the private sector, covering the specificities of each particular region, such as coffee in Costa Rica, aeronautics and oil in Brazil, oil in Mexico or nuclear technology in Argentina. As Crespi & Zuñiga (2012) summarizes, public policies promoting collaboration between universities and companies increase the level of investments in innovation and labor productivity in these firms.

Most of these publications face Latin American University-Industry collaborations under a structural approach, centering on universities' third mission (transference activities), with a focus on innovation procedures, public science policies and investment, and under an economic perspective. However, studies centered on universities' second mission (research) via co-authorship with Industry under bibliometrics indicators are scarce. In this sense, the contribution by Confraria & Vargas (2019) can be highlighted. This outstanding study relies on Incites data (an elitist bibliographic database), and focus at the country-level and discipline-level on two specific periods of five years each (2004-2008, and 2009-2013). However, results do not reach the institution-level.

Precisely the main objectives of this work is to determine the collaboration level of Latin American universities with companies in terms of scientific publication co-authorship, and to identify the main institutions involved in these collaborations. To do this, the following secondary objectives are set:

- To identify the Latin American countries with the highest University-Industry collaboration, in terms of output (number of publications) and impact (number of citations received).
- To identify and quantify the Latin American universities that most collaborate with companies in the scientific publication of research results.
- To identify and quantify the companies that most collaborate with Latin American universities in the scientific publication of research results.
- To identify and quantify the main poles of Latin American Universities and Industry collaboration, in terms of co-authorships.

2. METHOD

The top 20 Latin American countries by population were selected (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haití, Honduras, México, Nicaragua, Panamá, Paraguay, Perú, Uruguay, and Venezuela). Puerto Rico, as US dependent territory, was excluded from the analysis.

After this, all publications with at least one co-author belonging to each of the 20 countries, and another co-author affiliated to a company, were extracted from Scival, (intelligence software powered with Scopus data). The year range established was 2009 to 2018 (both included). Data was exported by 21 May 2020 (citation data was last updated by 13 May, 2020). After a data cleansing and duplicate removal process, a total of 22,469 records were gathered.

A set of bibliometric indicators (total number of publications, total number of citations, Field Weighted view Impact, Views, Field-Weighted Citation Impact, Publication type, number of authors) were gathered for each record. In addition, specific University-Industry indicators (Academic-Corporate Collaboration Impact, and Field-Weighted Citation Impact) were gathered for each country.

All records were exported to VOSviewer (<https://www.vosviewer.com>) in order to get structured co-authorship data. In this stage, hospitals, clinics, museums and botanic parks were excluded for the sake of simplicity, as their legal nature is not only complex but differs among regions. Data was finally exported to Gephi (<https://gephi.org>) where an undirected network University-Company was created, and network properties and indicators (Degree, Diameter, and Centrality) were finally calculated.

3. RESULTS

The set of publications including a collaboration between Latin American universities and companies is characterized to contain documents co-authored by a great number of authors (mean: 39.25 authors per publication; median: 6 authors), attaining significant impact (in terms of citations received and views), and obtaining an elevated field-weighted impact on average, both for views and citation impact (Table 1).

TABLE 1
 Descriptive statistics on publications with UIC(2008-2018)
 for Latin American universities (n= 22,469).

| Statistic | Number of Authors | Views | Citations | Field-Weighted Citation Impact | Field-Weighted View Impact |
|---------------------|--------------------------|--------------|------------------|---------------------------------------|-----------------------------------|
| Minimum | 2 | 0 | 0 | 0 | 0 |
| Maximum | 3,578 | 10,067 | 7,446 | 616.65 | 588.01 |
| Range | 3,576 | 10,067 | 7,446 | 616.65 | 588.01 |
| 1st Quartile | 4 | 10 | 2 | 0.22 | 0.53 |
| Median | 6 | 21 | 7 | 0.83 | 1.13 |
| 3rd Quartile | 11 | 43 | 22 | 2.02 | 2.24 |
| Sum | - | 951,763 | 773,167 | - | - |
| Mean | 39.25 | 42.36 | 34.41 | 3.11 | 2.46 |
| Variance | 28,968.70 | 20,174.98 | 28,395.19 | 283.27 | 87.25 |
| SD | 170.20 | 142.04 | 168.51 | 16.83 | 9.34 |
| Skewness (P) | 8.08 | 37.07 | 21.60 | 20.38 | 26.54 |
| Kurtosis (P) | 8.08 | 37.07 | 21.61 | 20.38 | 26.54 |

Source: Scopus.

At the country-level, Brazil stands as the region with the greatest number of publications in collaboration with Industry (13,293) in absolute terms, followed by Mexico (3,745), Argentina (2,532), Chile (2,210), and Colombia (2,146). The rest of regions remain far in terms of scientific output (Table 2). If these results are contextualized according to the total scientific output in each region (Academic-Corporate collaboration), the collaboration percentage with Industry is low in all countries (2% on average) but achieving significant impact. Notwithstanding, results for countries with less than 1,000 documents should be taken cautiously, as statistical artifacts appear, which may distort percentages.

TABLE 2
 Scientific output, impact and UICby country.

| Country | Output | Citations | FWCI | ACC (%) | ACCI | Population (million) | Rate |
|--|--------|-----------|-------|---------|-------|----------------------|-------|
|  Brazil | 13293 | 428,287 | 3.24 | 2 | 32.2 | 212.7 | 62.5 |
|  Mexico | 3745 | 237,129 | 5.97 | 1.8 | 63.3 | 129.0 | 29.0 |
|  Argentina | 2532 | 177,884 | 7.08 | 2 | 70.3 | 45.2 | 56.0 |
|  Chile | 2210 | 143,561 | 7.14 | 2.1 | 65 | 19.1 | 115.5 |
|  Colombia | 2146 | 129,275 | 6.38 | 2.6 | 60.2 | 50.9 | 42.1 |
|  Peru | 808 | 85,592 | 11.47 | 4.2 | 105.9 | 33.0 | 24.5 |
|  Cuba | 626 | 28,758 | 3.74 | 2.9 | 45.9 | 11.3 | 55.3 |
|  Venezuela | 372 | 21,290 | 4.22 | 1.9 | 57.2 | 28.4 | 13.1 |
|  Ecuador | 334 | 26,519 | 10.6 | 2.1 | 79.4 | 17.7 | 18.9 |
|  Costa Rica | 317 | 30,837 | 11.65 | 3.9 | 97.3 | 5.1 | 62.2 |
|  Uruguay | 285 | 47,962 | 18.96 | 2.2 | 168.3 | 3.5 | 82.0 |
|  Panama | 227 | 51,045 | 27.28 | 4.7 | 224.9 | 4.3 | 52.6 |
|  Bolivia | 83 | 23,198 | 20.92 | 2.9 | 279.5 | 11.7 | 7.1 |
|  Dominican Republic | 73 | 2,583 | 3.72 | 6.6 | 35.4 | 10.9 | 6.7 |
|  Guatemala | 68 | 6,490 | 10.07 | 3.1 | 95.4 | 17.9 | 3.8 |
|  Honduras | 68 | 1,652 | 3.04 | 7.1 | 24.3 | 9.9 | 6.9 |
|  Nicaragua | 50 | 1,086 | 2.01 | 4.4 | 21.7 | 6.6 | 7.5 |
|  Paraguay | 41 | 4,479 | 8.8 | 2.3 | 109.2 | 7.1 | 5.7 |
|  Haiti | 31 | 1,756 | 5.1 | 3.7 | 56.6 | 11.4 | 2.7 |
|  El Salvador | 26 | 3,034 | 8.89 | 2.5 | 116.7 | 6.5 | 4.0 |

Source: Scopus.

ACC: Academic-Corporate Collaboration (%).

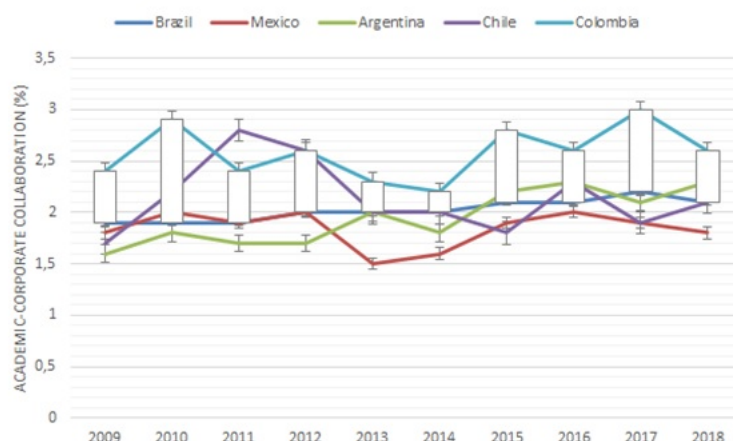
ACCI: Academic-Corporate Collaboration Impact.

FWCI: Field-Weighted Citation Impact.

Rate: Number of documents per 1 million inhabitants.

Despite the existence of significant variations from year to year, the Academic-Corporate collaboration percentage has remained low over the decade 2009-2018 in the main countries analyzed (Figure 1). Among the top 5 countries, Argentina is the region with higher increase in the period (0.7).

FIGURE 1
 Academic-Corporate collaboration (%) over the years by country.

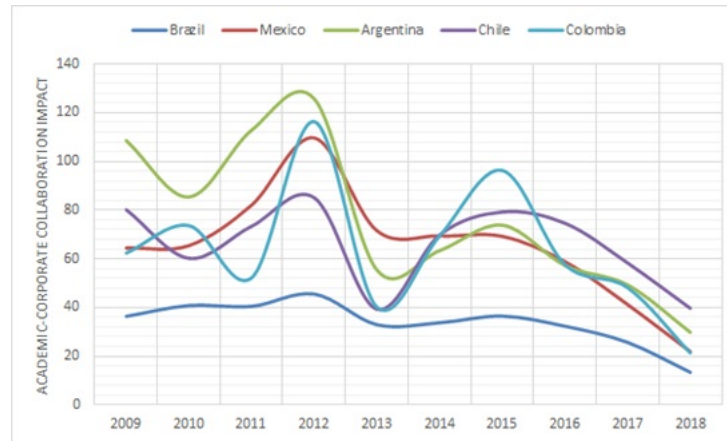


Source: Scopus.

As regards impact, we observe a logical decrease over the years (recent publications did not have time to attain citations yet). However, a general decrease in 2013 is detected, as well as a general increase in the two following years, especially in Colombia (figure 2).

Otherwise, average impact data related to Brazil is lower if compared with Argentina, Chile, Colombia and Mexico. This is due to the great number of publications in the country, which makes ‘harder’ to obtain an elevated average impact performance.

FIGURE 2
Academic-Corporate collaboration impact over the years by country.



Source: Scopus.

A total of 1,531 companies (both of public and private nature) have been identified. Each of these companies published at least one publication in co-authorship with an author affiliated to one Latin American university in the period, according to Scopus coverage. Petrobras (2,714 documents) and IBM (566) stand as the main companies collaborating with Latin American universities in terms of absolute number of publications.

The top 20 companies with the highest number of co-authored publications with Latin American universities are available in Table 3, including the number of citations received. As we can observe, technological companies (IBM, Microsoft, Ericsson, Hewlett-Packard, Yandex), pharmaceuticals (GlaxoSmithKline, Fleury, Merck, Pfizer, Novartis, Bayer, Astrazeneca) and petroleum companies (Petrobras, Petróleos Mexicano, Ecopetrol) shape this ranking of most collaborative companies. It is also noteworthy the appearance of public companies, such as Agrosavia (Colombia) or Embrapa (Brazil).

TABLE 3
Companies with the highest number of co-authored publications with Latin American universities (2009-2018).

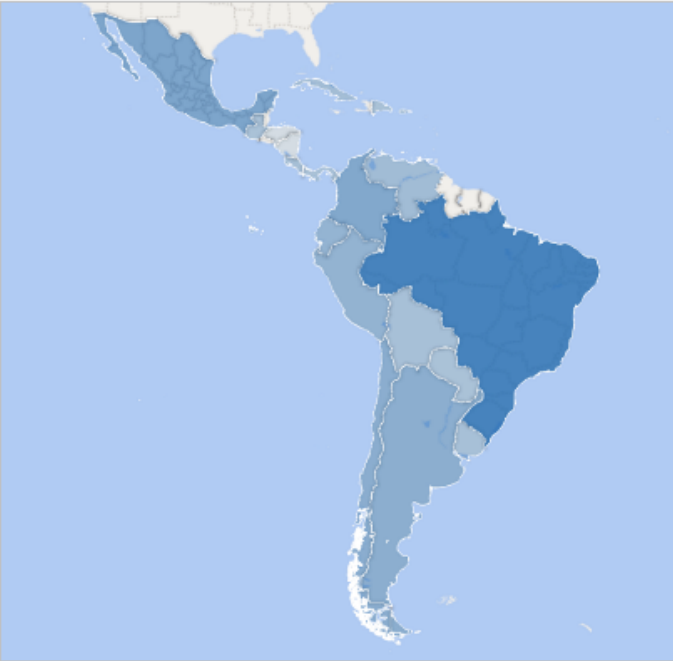
| R | Company | Documents | Citations | Citations/ Documents | Country |
|----|----------------------|-----------|-----------|-------------------------|-------------|
| 1 | Petrobras | 2,714 | 26,582 | 9.79 | Brazil |
| 2 | IBM | 566 | 9,223 | 16.30 | USA |
| 3 | Agrosavia | 385 | 3,796 | 9.86 | Colombia |
| 4 | GlaxoSmithKline | 375 | 23,139 | 61.70 | UK |
| 5 | Fleury | 348 | 3,669 | 10.54 | Brazil |
| 6 | Ecopetrol | 339 | 6,149 | 18.14 | Colombia |
| 7 | Merck | 336 | 29,309 | 87.23 | USA |
| 8 | Pfizer | 336 | 20,046 | 59.66 | USA |
| 9 | Embraer | 317 | 1,876 | 5.92 | Brazil |
| 10 | Novartis | 265 | 21,099 | 79.62 | Switzerland |
| 11 | Microsoft USA | 248 | 8,254 | 33.28 | USA |
| 12 | Ericsson AB | 223 | 2,402 | 10.77 | Sweden |
| 13 | Eli Lilly | 215 | 13,598 | 63.25 | USA |
| 14 | Petróleos Mexicano | 208 | 1,300 | 6.25 | Mexico |
| 15 | Hewlett-Packard | 200 | 2,549 | 12.75 | USA |
| 16 | Bayer AG | 199 | 12,016 | 60.38 | Germany |
| 17 | Bristol-Myers Squibb | 193 | 33,384 | 172.97 | USA |
| 18 | Yandex | 179 | 5,845 | 32.65 | Russia |
| 19 | Embrapa | 173 | 7,101 | 41.05 | Brazil |
| 20 | Astrazeneca | 163 | 12,170 | 74.66 | UK |

Source: Scopus.

As regards Latin American universities, 428 institutions have been identified with at least one publication co-authored with a company in the period (Table 4). Brazilian universities (151) stand out as the most productive country in the region in collaboration with Industry, under the view of scientific co-authorship. Brazil is followed at distance by México (62) and Colombia (53).

TABLE 4
Latin American countries with the highest number of universities publishing co-authored publications with companies (2009-2018).

| COUNTRY | UNIVERSITIES |
|----------------|--------------|
| Brazil | 151 |
| Mexico | 62 |
| Colombia | 53 |
| Chile | 39 |
| Argentina | 38 |
| Peru | 26 |
| Ecuador | 24 |
| Venezuela | 8 |
| Cuba | 5 |
| Bolivia | 3 |
| Costa Rica | 3 |
| Uruguay | 3 |
| Dominican Rep. | 2 |
| Guatemala | 2 |
| Panama | 2 |
| Paraguay | 2 |
| Honduras | 1 |
| Nicaragua | 1 |
| Haiti | 0 |
| El Salvador | 0 |
| Total | 428 |



Source: Scopus.

Universidade São Paulo stands out as the institution with the highest number of co-authored publications with companies, followed by *Universidade Federal do Rio de Janeiro*, and *Universidade Estadual de Campinas*, all from Brazil. Outside Brazil, *UNAM* and *Benemérita Universidad Autónoma de Puebla* (Mexico), *Universidad de Chile* y *Pontificia Universidad Católica de Chile* (Chile), *Universidad Nacional de Colombia* (Colombia), and *Universidad de Buenos Aires* (Argentina), are the most productive institutions in collaboration with companies (Table 5).

TABLE 5
Latin American universities with the highest number of
co-authored publications with companies (2009-2018).

| R | University | Documents | Citations | Citations / Document | Country |
|----|---|-----------|-----------|----------------------|-----------|
| 1 | São Paulo | 2,577 | 113,161 | 43.91 | Brazil |
| 2 | Federal do Rio de Janeiro | 1,725 | 39,367 | 22.82 | Brazil |
| 3 | Estadual de Campinas | 1,262 | 35,419 | 28.07 | Brazil |
| 4 | UNAM | 948 | 48,199 | 50.84 | Mexico |
| 5 | Federal do Rio Grande do Sul | 752 | 52,336 | 69.60 | Brazil |
| 6 | Pontificia Univ. Católica do Rio de Janeiro | 690 | 9,945 | 14.41 | Brazil |
| 7 | Federal de São Paulo | 593 | 34,015 | 57.36 | Brazil |
| 8 | Federal de Minas Gerais | 589 | 25,607 | 43.48 | Brazil |
| 9 | Chile | 515 | 19,266 | 37.41 | Chile |
| 10 | Nacional de Colombia | 504 | 13,222 | 26.23 | Colombia |
| 11 | Buenos Aires | 459 | 20,911 | 45.56 | Argentina |
| 12 | Federal de Santa Catarina | 431 | 8,093 | 18.78 | Brazil |
| 13 | Estadual Paulista Júlio de Mesquita Filho | 415 | 7,597 | 18.31 | Brazil |
| 14 | Pontificia Univ. Cat. de Chile | 404 | 26,050 | 64.48 | Chile |
| 15 | Federal Fluminense | 342 | 3,349 | 9.79 | Brazil |
| 16 | Univ. do Estado do Rio de Janeiro | 333 | 10,979 | 32.97 | Brazil |
| 17 | Federal da Bahia | 322 | 5,008 | 15.55 | Brazil |
| 18 | Federal do Paraná | 309 | 9,347 | 30.25 | Brazil |
| 19 | Benemérita Univ. Autónoma de Puebla | 273 | 16,791 | 61.51 | Mexico |
| 20 | SENAI CIMATEC | 264 | 2,187 | 8.28 | Brazil |

Source: Scopus.

Big numbers achieved by some institutions might be a consequence of specific and productive collaborations with few companies. For example, Petrobras exhibits a great collaboration intensity with *Universidade Federal do Rio de Janeiro* (866 publications), *Universidade São Paulo* (254), *Pontificia Universidade Católica do Rio de Janeiro* and *Universidade Estadual de Campinas* (229). These four connections explain results in tables 3 and 5 and make Petrobras and Brazil the major pole of innovation in Latin America, in terms of scientific co-authorship (Table 6).

TABLE 6
 Collaboration intensity: the most frequently collaborations
 between Latin American universities and companies (2009-2018).

| 1 | Petrobras | Federal do Rio de Janeiro | 866 |
|-----------|---------------|---|-----|
| 2 | Petrobras | São Paulo | 254 |
| 3 | Petrobras | Pontificia Univ. Cat. do Rio de Janeiro | 250 |
| 4 | Petrobras | Estadual de Campinas | 229 |
| 5 | Yandex | Pontificia Univ. Cat. do Rio de Janeiro | 178 |
| 6 | Yandex | Nacional de Colombia | 178 |
| 7 | Yandex | Federal do Rio de Janeiro | 178 |
| 8 | Petrobras | Federal Fluminense | 175 |
| 9 | Fleury | São Paulo | 172 |
| 10 | Fleury | Federal de São Paulo | 172 |
| 11 | Yandex | Federal do Triângulo Mineiro | 153 |
| 12 | Petrobras | Univ. do Estado do Rio de Janeiro | 144 |
| 13 | Ecopetrol | Industrial de Santander | 141 |
| 14 | Muons | Técnica Federico Santa Maria | 137 |
| 15 | Muons | Iberoamericana (UIA) | 136 |
| 16 | Agrosavia | Nacional de Colombia | 111 |
| 17 | Petrobras | Federal do Rio Grande do Sul | 107 |
| 18 | Senai Cimatec | Federal da Bahia | 102 |

Source: Scopus.

Collaboration breadth, measured in terms of number of different institutions with which a university or company has published, constitutes another attribute of interest to describe the collaboration patterns found. This way, we can find that Petrobras has collaborated with 122 different Latin American universities and IBM with 92. As regards universities, *Universidade São Paulo* has collaborated with 472 companies and UNAM with 240. However, most of these collaborations are eventual.

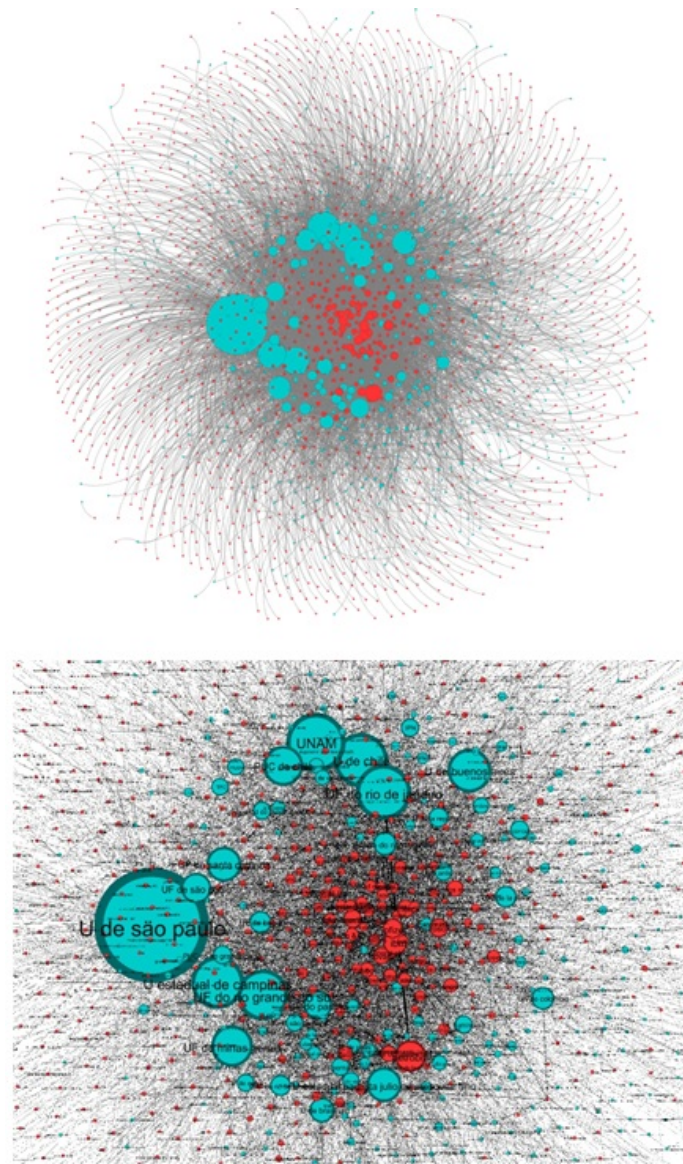
TABLE 7
 Collaboration breadth (Degree) for Latin American universities and companies (2009-2018).

| R | Company | Degree | University | Degree |
|----|--------------------|--------|---|--------|
| 1 | Petrobras | 122 | São Paulo | 472 |
| 2 | IBM | 92 | UNAM | 240 |
| 3 | Embrapa | 91 | Federal do Rio de Janeiro | 222 |
| 4 | Agrosavia | 82 | Chile | 217 |
| 5 | Pfizer | 72 | Estadual de Campinas | 213 |
| 6 | Microsoft USA | 68 | Federal do Rio Grande do Sul | 205 |
| 7 | GlaxoSmithKline | 67 | Buenos Aires | 174 |
| 8 | Merck | 64 | Federal de Minas Gerais | 166 |
| 9 | Novartis | 61 | Pontificia Univ. Cat. de Chile | 158 |
| 10 | Petróleos Mexicano | 58 | Estadual Paulista Júlio de Mesquita Filho | 137 |
| 11 | Fleury | 52 | Federal de Santa Catarina | 137 |
| 12 | Dupont | 49 | Federal de São Paulo | 117 |
| 13 | Syngenta | 49 | Federal do Paraná | 111 |
| 14 | Intel | 46 | Brasília | 96 |
| 15 | Bayer AG | 45 | Univ. do Estado do Rio de Janeiro | 88 |
| 16 | Ecopetrol | 45 | Nacional de Colombia | 87 |
| 17 | Johnson & Johnson | 44 | Federal da Bahia | 83 |
| 18 | General Electric | 43 | Nacional de La Plata | 81 |
| 19 | Sanofi | 42 | Pontificia Univ. Cat. do Rio de Janeiro | 77 |
| 20 | Nestle | 41 | Univ.de la República | 75 |

Source:Scopus.

Despite this elevated Degree values for top performers, the whole University-Industry network shows a discrete average Degree value (7.7), with network properties of long diameter (8), low density (0.004) and long average path length (3.521). These results are expected as only university-to-company relations are exhibited, avoiding university-to-university and company-to-company. However, results evidence that few universities (mainly from Brazil) and few companies have established strong scholarly collaborations (Figure 3).

FIGURE 3
UICnetwork in Latin America (2008-2019).



Source: Scopus; powered by Gephi (Fruchterman-Reingold algorithm).
Note: blue nodes correspond to universities; red nodes correspond to companies; node diameter corresponds to the Degree (number of documents published in collaboration).

UIC might be influenced or masked by the existence of national scientific councils in some regions. These organizations are inherited from a historical scientific structure model installed in some European countries, such as Spain (CSIC), France (CNRS), Italy (CNR) or Germany (Helmholtz-Gemeinschaft and Max-Planck-Gesellschaft). This model has been implanted in some Latin American countries. This is the case of the National Scientific and Technical Research Council (CONICET) in Argentina. Table 8 shows the main companies with which CONICET has co-authored publications. This way, we can observe a strong connection between CONICET and Argentinean companies, especially YPF (58 publications). The connection of YPF with universities is weaker (32 publications with Universidad de Buenos Aires, and 27 with Universidad Nacional de La Plata), for example.

TABLE 8
Companies with the highest number of co-authorship collaborations with CONICET (2009-2018).

| R | Company | Documents | Country |
|-----------|-----------------------------------|------------------|----------------|
| 1 | Yacimientos Petrolíferos Fiscales | 58 | Argentina |
| 2 | General Electric | 20 | USA |
| 3 | Novartis | 18 | Switzerland |
| 4 | Reprobiotec | 14 | Argentina |
| 5 | IBM | 13 | USA |
| 6 | Clariphy Argentina | 12 | Argentina |
| 7 | Repsol YPF | 12 | Spain |
| 8 | Novozimes A/S | 11 | Denmark |
| 9 | Tenaris Group | 11 | Luxembourg |
| 10 | Advanta Semillas | 9 | Argentina |
| 11 | Yahoo Research Labs | 9 | USA |
| 12 | Petrobras | 8 | Brazil |
| 13 | Lockheed Martin | 7 | USA |
| 14 | Royal Dutch Shell PLC | 7 | Netherlands |
| 15 | Saudi Aramco | 7 | Saudi Arabia |
| 16 | Électricité de France | 7 | France |
| 17 | Fera Science | 6 | UK |
| 18 | GlaxoSmithKline | 6 | UK |
| 19 | INVAP | 6 | Argentina |
| 20 | Merck | 6 | USA |

Source:Scopus.

4. DISCUSSION AND CONCLUSIONS

Few limitations on the research design should be acknowledged in order to properly contextualize the results obtained. First, Scopus data was used as a baseline for capturing bibliometric indicators. This bibliographic database has its own coverage strengths and weaknesses, greater in some disciplines than others (Martín-Martín, Orduña-Malea, Thelwall & Delgado López-Cózar, 2018). Other University-Industry academic collaborations in document types others than journal articles written in English are expected to be found, and future works using other wider databases is advisable. Second, Bibliometrics applied to companies exhibit certain added difficulties and methodological challenges. Companies are not as stable as universities or other research organizations. This way, companies may change their names, merge with other companies, or change its legal status or business lines over time. International companies with offices in different countries make geographic analyzes difficult to interpret as well. Despite Scival provides a master list of institutions categorized as companies, this task requires manual inspection, which might be difficult when managing international data. Therefore, there is an inherent human error rate that should be considered, although it does not affect the overall results obtained.

Results evidence a low percentage of academic collaboration between Latin American universities and companies on average over the last decade (2009-2018). In any case, these values are higher than those obtained by Confraria & Vargas (2019, p. 884). However, results seem logical as these authors used data from

Web of Science (Incites), with a lower coverage, and other earlier period. In absolute terms, Brazil, México, Argentina, Chile, and Colombia stand out as the most productive universities when it comes to share results with Industry via scientific publications.

Publications co-authored by Latin American universities and companies are characterized by being highly cited (including citations rates higher than World's average on their specific fields) and co-authored by a large number of authors. Therefore, companies are engaged with large scientific projects involving a great number of participants from different institutions and countries.

Despite the large number of companies identified (1,531), just few firms (mainly from Pharmacy, Technology and Petroleum markets) have established strong connections with few universities, mainly from Brazil, whose performance masks the remaining minor linkages established.

Specifically, the connection between Petrobras and few Brazilian universities (especially *Universidade do Rio de Janeiro*) constitute the core of University-Industry connection in Latin America. The intense scientific collaboration between Petrobras and Brazilian universities was previously highlighted by Gielfi, Furtado, de Campos & Tijssen (2017), who suggest that research collaboration was fostered by the establishment of sector-specific funds policy to support R&D activities. Otherwise, the presence of publicly-traded companies (not only Petrobras but also Agrosavia, Embrapa, YPF, Petr6leos Mexicanos, etc.) is also remarkable.

The local outreach of these public companies can influence the commitment of university scholars to collaborate in the development and publication of research results that will have limited dissemination and attention outside the region, and consequently, difficulties to find manuscript acceptances in international journals, and receiving citations, when the current academic promotion system precisely rewards citations mainly. For this reason, it is feasible to think that university scholars are not interested enough in creating such synergies with industries, taking apart the performance of sporadic consultancy activities, which involves money transactions, a more attractive reward. However, further qualitative studies are necessary to check this hypothesis.

Given the evidence provided by literature on the benefits for university-industry collaborations as an economic engine, public research policies oriented to integrate, regulate and reward such collaborations within the common activities attributed to university scholars should be advisable. Likewise, adequate activities to properly disseminate the knowledge capacities and services offered by universities in companies would be also beneficial, helping to expand the notion of utility of universities to society.

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