UNIVERSITY INDUSTRY COOPERATION: A RESEARCH PROFILING

GERARDO ANGULO-CUENTAS
Universidad del Magdalena / Santa Marta, Colombia
gerardoangulo@unimagdalena.edu.co

MARYURIS CHARRIS-POLO
Universidad del Magdalena / Santa Marta, Colombia
mcharris@unimagdalena.edu.co

CLAUDIA MARCELA GARCIA-PERTUZ
Universidad del Magdalena / Santa Marta, Colombia
cgarciap@unimagdalena.edu.co

ABSTRACT

This article presents a profiling research on 'University – industry cooperation' based on bibliographic data collected on ISI Web of Science database during period 1997 – 2016. The methodology of analysis explores behavior of publications over time, scientific production by institutions, journals and authors, and subject fields worked in collected documents. This quantitative study provides an overview on knowledge generation process about university-industry cooperation. Our results reveal a growing up in the last years, focused mainly to strategy and management field. Publications predominantly come from Europe and America, and there is lack of contribution from Africa and Latin America. The publications have had a high collaborative development between authors from different countries and institutions. The investigation hopes to be useful in research agendas, science and technology activities, management strategies according to the particular interest of readers.

Key words: University-industry cooperation, transfer of knowledge, publications analysis, research profiling, bibliometric analysis

INTRODUCTION

The exchange of knowledge between industry and academy is a crucial mechanism to apply science in the market and promote economic growth (OECD, 1998; OECD, 2002; Scandura, 2016). University-industry collaboration (UIC) is currently considered a significant economic driver (Rajalo and Vadi, 2017), which helps in researching the problems and stimulates competitiveness (Ivascu t al., 2016). Governments have intervened to strengthen these relations and promote the development of different sectors (Park, and Leydesdorff, 2010; Perkmann et al, 2013, Vaivode, 2015).

In academic field, UIC is a topic of research that has kept in continuous growth (Ankrah and Al- Tabbaa, 2015) in the last 20 years (Vera, Alvarez, and Angulo, 2013), and is becoming more important, because this can create benefits for all parties involved and for society (Muscio, 2010). UIC supports enterprise's innovation activities and improves performance of researches (Gulbrandsen and Smeby, 2005).

The publication is a key element in knowledge exchange within the scientific community (Van Raan, 2004), and the increasing knowledge pool drives scientific progress (Sriwannawit and Sandström, 2015). The using bibliometrics is a relevant action in research process (Bertocchi et al., 2015; Escorcia, 2008) to evaluate the quality of process of knowledge generation and its impact on scientific field (Rueda et al., 2010), and identify emerging and novel research topics (González et al. 2016).

Bibliometric field analyses the bibliographic information of papers (Takahashi and Kajikawa, 2017) using mathematics and statistics (Hawkins 1977), and is a useful tool to evaluate the scientific production (Aguado and Becerril, 2016). The results obtained allow to make decisions and manage knowledge, because they could identify topics poorly studied, evaluate scientific production of researchers, institutions and countries (Romaní, Huamaní and González, 2011) to obtain trends and information about their performance, among others.

A bibliometric approchement to UIC could have as referent to Teixeira and Mota (2012), they made a quantitative overview of the existing literature through the use of bibliometric techniques, in the area of the Social and Human Sciences on the database SciVerse Scopus between 1986 and 2011. They analyzed the evolution of the literature by themes/topics, identified its origins/roots and assessed the extent of its influence on this field of research. Feng et al. (2015) took university- industry cooperation studies 1966–2013 as an example to show the performance of a visual document analysis software CiteSpace, which displays trends of certain discipline. Seguí et al. (2016) presented a bibliometric analysis of the literature 1990-2014 on spin-offs. Cheng et al. (2016) examined research collaboration between universities and industry in the field of computer science using bibliometric methods during the period 2002-2011. This study calculated indicators as density, degree centrality, betweenness centrality, and closeness centrality of UI collaborative networks.

The scientific production on UIC has grown in recent years and has not been evaluated in the current reviews of topic. Hence, the present study intends to contribute an updated quantitative overview of the existing literature. To analyze data, this study employs the research profiling method proposed by Porter et al. (2002), a broad scan of contextual literature to improve the understanding of a research field, and discover topical relationships, research trends and complementary capabilities.

The objective of this study is to profile using bibliometric techniques and statistical analysis the ‘University-industry cooperation’ research based on publications and citation data obtained from bibliographic fields, to identify trends, leaderships, cooperation networks and subject categories in the global scientific production during period 1997 – 2016.

The paper is organized as follows: the section “Data searching” shows the process used to obtain data and the section “Methodology of data analysis” explains briefly the profiling scheme which consists of three approaches and defines its element. Then, section “Results” presents the analysis of each

approach with records obtained in database. Finally, section "Conclusions" summarizes research findings and proposes the orientation of future works.

DATA SEARCHING.

The first defined element was the source where scientific documents were consulted. Web of Science database by Thomson Reuters was chosen, a powerful database which provide different searching and browsing options (Lopez-Illescas et al., 2008).

The second element was the definition of search equation to find relevant publications which will be processed in this study. Equation is built with expressions and boolean operators, through an iterative process. A basic expression is defined and the results are evaluated. The search expression is modified with synonymous and keywords identified in found registers in each iteration of search, as many times as needed. The final expression is validated with an academic expert in research.

The search was made between 1997 and 2016, and was collected 821 records. Some registers were rejected because they had incomplete information. Therefore, 806 documents were listed to develop this review.

METHODOLOGY OF DATA ANALYSIS.

The profiling schema of this study is similar to the used by Choi et al. (2011) and Martínez et al. (2012). It consists in various quantitative evaluation approaches. The methodology of analysis is summarized in Figure 1.

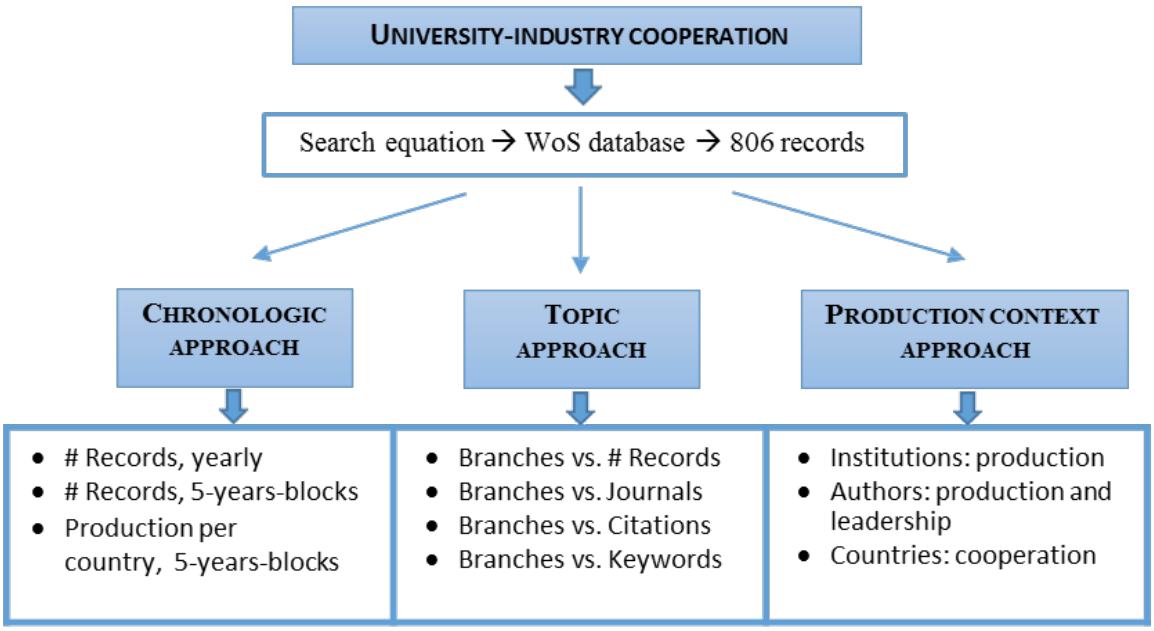

Figure. 1 Methodology of analysis for research profiling.

The chronologic approach analyses scientific production over time. The topic approach evaluates quantitative aspects of publications that are grouped by 'branches'. Finally, the production context approach analyses productivity and leadership of authors and institutions, and cooperation networks between countries, where scientific knowledge has been generated.

University-enterprise cooperation is a research topic very wide, that authors have worked from different thematic areas; for example, some researchers focus it in business scopus, and other ones in an ethic field. The collected registers from Web of Science have a data column "WoS categories" which assign one or more domains to each publication according to their information.

This study makes a quantitative analysis of publications that share the same thematic in a similar way of Choi et al. (2011). Therefore, the authors propose to classify publications into 'branches' in the topic approach. A branch is defined as a group of documents which WoS categories are similar.

The names of branches are established taking by reference Vera et al. (2013)'s work, making analogy to global context of literature, to express the content of each branch in terms of investigated subject. Table 1 shows defined branches and categories included into each one.

Table 1. WoS Categories included in branches.

Branches	Categories WoS
Strategy & Management	Management, Planning & development, Operations research & management science, Industrial engineering, Business, Public administration, Economic, Finance
Culture	Sociology, History & philosophy of science, Social sciences, Psychology, Social issues, Ethics, Cultural studies, International relations
Interaction structures	Computer science, Information science & library science, Software engineering, Cybernetics, Hardware & architecture
Systems	Materials science, Automation & Control Systems, Transportation science & technology, Civil engineering, Electrical & electronic engineering, Multidisciplinary Engineering, Metallurgy & metallurgical engineering, Biotechnology & applied microbiology, Nanoscience & nanotechnology, Construction & building technology, Applied physics, Mechanic
Others	Enviromental studies, Green & sustainable science, Ocean, Ecology, Forestry, Chemical, Medicine, Biology pharmacology & pharmacy, Health care sciences & service, Surgery, Education & educational research, Art, Language & linguistics, , Acoustics, Sport sciences, Law, Urban studies, Energy & fuels, among others

Some registers contain multi-categories as “Information Science & Library Science, Social Sciences” (case 1) or “Psychology, Business, Applied management” (case 2). These terms belong to different branches. In the first case, the first category focuses to Interaction structures and the second one refers to Culture. In the second case, the first category focuses to Culture and the other ones refer to Strategy & Management.

In this situation, the publication is classified according to hierarchy of branch, that is established in the order where are placed them in Table 1. Upper branch has priority to define a document on the lower branches. Then, in the first case, Culture is chosen because it reveals studied field, and in the second case, Strategy & Management is chosen because the psychology is applied to direction strategy.

Three measure variables are proposed for analysing scheme: leadership, production and cooperation. The leadership refers to scientific performance of author in the topic University-industry cooperation, and is measured by H-index based on download records in this review. Arencibia and Carvajal (2008) confirmed in their study that this indicator is related to scientific production quantity of authors and citations received in their works. It is a more effective and integrate tool than citation average by article. “An index H=x means that there are x articles with x or more citations” (Arencibia and Carvajal, 2008). The production refers to accumulated scientific production in period 1997 – 2016 by country and institution, and it is calculated counting number of documents which have at least one author with this nationality or university’s affiliation. Finally, the cooperation refers to working networks that are established between authors from different countries; research authorism evidences it.

CHRONOLOGIC APPROACH.

To analyze scientific production behavior during period 1997-2016, the registers are organized by publication year. This information is presented in Figure 2.

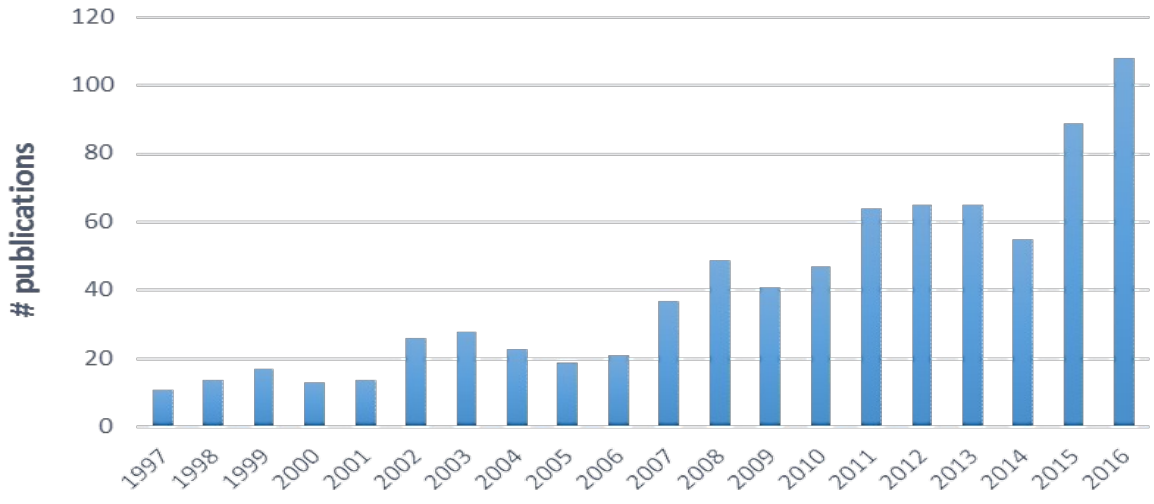

Figure. 2 Scientific production yearly.

It is clear to observe that research has maintained a continuous growth in the last 20 years with small slopes in some periods. In 2016, the most quantity of published document in literature is registered. This behavior reveals the validity of the topic in research field. In addition, Figure 3 organizes scientific production in 5-years blocks.

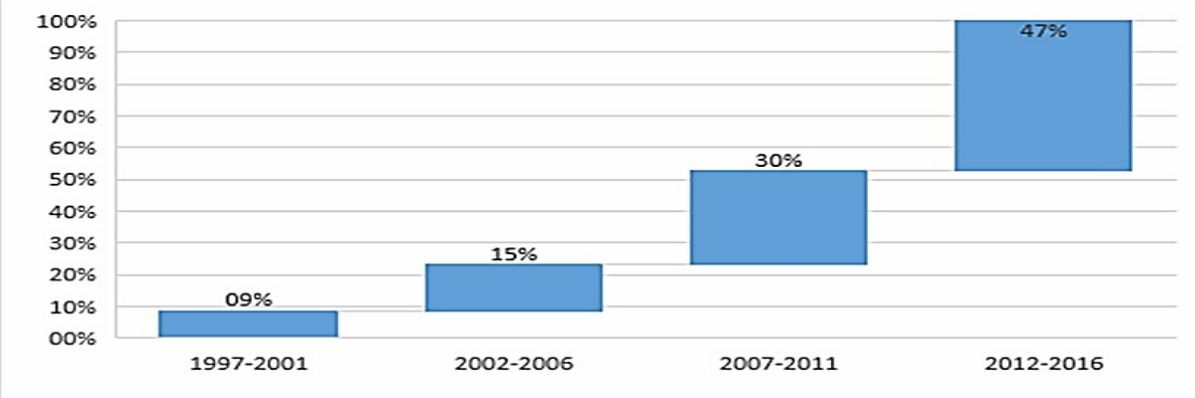

Figure. 3 Scientific production in 5-years-blocks.

The most notorious increase of publications is detected in the last 5 years, from 2012 to 2016, when almost 50% of total research was produced. This reflects nowadays exists more interest in scientific community to evaluate and propose new ideas for cooperation between universities and enterprises.

The, geographic origin of works is analyzed according to authors nationality to detect places with the most scientific productivity in the topic. Figure 4 shows the number of publications by country in each 5-years blocks. The twenty-three countries with the most quantity of registers are enlisted ordered from minimum to maximum. (See Table 2).

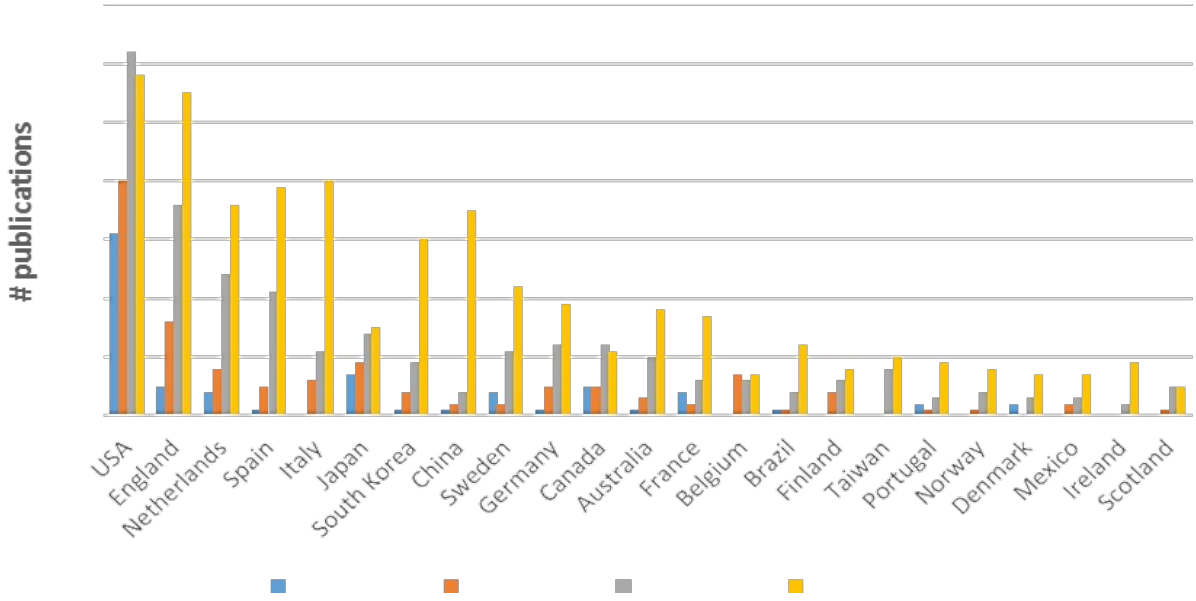

Figure. 4 Scientific production by country in 5-years-blocks.

Table 2. Number of publications by country.

Country	Total
USA	191
England	112
Netherlands	72
Spain	66
Italy	57
Japan	45
South Korea	44
China	42
Sweden	39
Germany	37
Canada	33
Australia	32

Country	Total
France	29
Belgium	20
Brazil	18
Finland	18
Taiwan	18
Portugal	15
Norway	13
Denmark	12
Mexico	12
Ireland	11
Scotland	11

The results show United States leads scientific production in all time blocks, obtaining the most quantity between 2007 and 2011. The majority of countries have the greatest number of publications in period 2012-2016, this information is congruent with Figure 3.

The most predominant idiom in papers is English with 96.2% of total documents. Spanish is present in 1.9%, Portuguese in 1.5% and less than 1% are Japanese, Turkish and Catalan.

TOPIC APPROACH.

All documents were grouped by 5 branches according to topic content, as was explained in previous section Methodology of data analysis. Figure 5 presents total records and number of publications by document type in each branch, to know research level respectively.

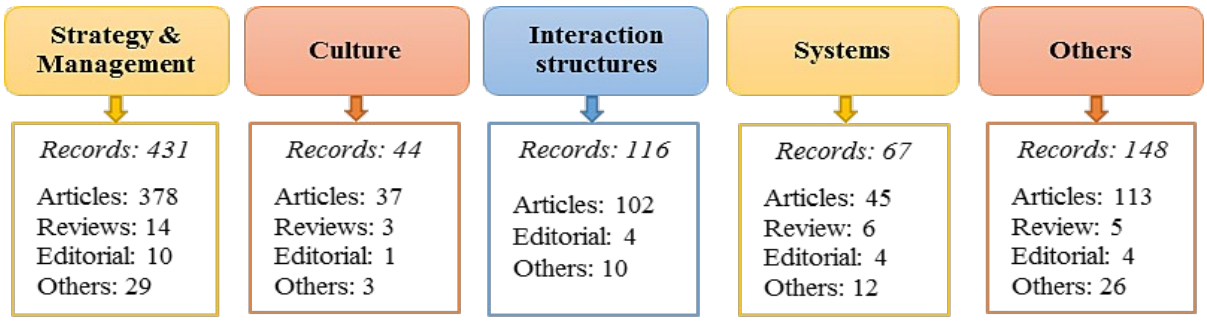

Figure. 5 Records of branches.

The 53% of documents belong to Strategy & Management branch, the most worked subject in literature about University-industry cooperation. The other ones correspond to 47%: Culture (5,5%), Interaction structures (14,4%), Systems (8,3%) and Others (18,4%). Scientific articles predominate in all branches, reviews were in a greater quantity in Strategy & Management, a proportional size to total production of group.

First, the journals with the most quantity of documents are presented for each branch, to identify main publication places. The top four most productive journals and quantity of registers published in each one is shown in Table 3.

Table 3. Top four most productive journals by branch

Branch	Journals	
Strategy & Management	Research Policy	93
	Journal of technology transfer	44
	International Journal of Technology Management	27
	Technovation	25
Culture	Minerva	6
	Science and Enginering ethics	5
	Social studies of science	4
	Quality and quantity / Science technology & human values / Rural sociology	3
Interaction structures	Scientometrics	56
	Research Evaluation	14
	Journal of the Ameican Society for Information Science and Technology	6
	Journal of informetrics	5
Systems	International journal of engineering education	11
	Current Science / IEEE transactions on education	3
	Mr Bulletinal, Ingeniería e investigación (and 2 more)	2

The journals Research Policy, Minerva, Scientometrics and International journal of engineering education leads the membership of publications of each area. Documents of Strategy & Management and Interaction structures have the greatest number of publications in the same journal.

“Citation impact indicators nowadays play a prominent role in the evaluation of scientific research” (Waltman, 2016). The citation times of a paper is an acceptable measure of its impact, where impact is defined as “actual influence on surrounding research activity at a given time” (King, 1987). Then,

documents with the most number of citations reported in all database from publication date until 2016 are identified by branch. This information is presented in Table 4.

Table 4. Most citated documents by branch.

		Type	# Citations
Strategy & Management	The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations (2000)	Article	1305
Culture	The triple helix and new production of knowledge: Prepackaged thinking on science and technology (2002)		131
Interaction structures	Innovation in innovation: the Triple Helix of university-industry-government relations (2003)		234
Systems	Functionally graded hardmetals (2002)		74

Strategy & Management contains the most quantity of publications and the article with the most number of citations. The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations wrote by H. Etzkowitz and L. Leydesdorff, published in 2000 and citated 1.305 times until May 2017.

Finally, a study about keywords assigned by authors in their publications is made in order to analyze frequent directions in the works. Table 5 presents the most common words in collected documents. The expressions ‘University industry collaboration’ and similar words are omitted, because they defined search process and indisputably are in all publications.

Table 5. Principal keywords by branch.

Branch	Keywords	
Strategic & Management	Innovation	42
	Triple helix	24
	Academic entrepreneurship	13
	R&D	13
	Open innovation	11
	Patents	10
	Science Parks	10
Interaction structures	Triple helix	28
	University-industry-government relation (synonymous)	11
	Innovation	7
	Patent	6
	Indicator	4
	Social network analysis	3
	Mutual information	3
Culture	Innovation	6
	Triple helix	6
	Conflict of interest	4
	Institutional/organizational theory	3
Systems	Engineering education	4
	Triple helix	3
	Profesional skills	3
	Biotechnology	2
	Development	2
	Employers students links	2
	Innovation	2
	Intellectual property	2
	Scientometrics	2

Keywords describe the research focus moderately in each branch about university-industry cooperation. The words Innovation and Triple Helix were common in four groups, they were used in 7.1% and 7.6% of documents. Finding studies from different perspectives that involve government in this investigation field highlights the interest of researchers to analyze these relations. It is important the role that government plays as a promoter in the transfer of knowledge and technologies. Expressions as Entrepreneurship, Patent, R&D, Science parks, intellectual property were found in many papers.

PRODUCTION CONTEXT APPROACH.

Universities with the most number of publication about the topic are identified, to know institutions whose affiliated researchers have led knowledge generation. Table 6 presents eight main universities. Branches where are classified documents are specified.

Table 6. Top eight institution with more publications.

Institutions	Country	# publications	Branches
University of Amsterdam	Netherlands	30	Strategy & Management, Culture, Interaction structures, Systems
University of California	USA	20	Strategy & Management, Culture, Others
Polytechnic University of Valencia	Spain	19	Strategy & Management, Interaction structures, Systems, Others
University of Sussex	England	16	Strategy & Management, Culture, Interaction structures, Others
Yeungnam University	South Korea	14	Strategy & Management, Interaction structures, Culture, Systems
University of Leuven	Belgium	13	Strategy & Management, Interaction structures, Others
Imperial College London	England	12	Strategy & Management, Systems
University of Tokyo	Japan	11	Strategy & Management, Systems, Others

Universities with the greatest production are placed in Europe mainly, and all have works focused to Strategy & Management. If a bigger set of institutions is analyzed, with 5 or more publications, a similar context is observed. More of 50% are placed in Europe, mainly England and Netherlands, the others ones are in North America (USA 26%) and Asia (South Korea and Japan, 15%).

Respect to authors productivity (See Figure 6), following researchers stand out: Loet Leydesdorff with 29 documents, Han Woo Park with 13 and Henry Etzkowitz with 11. It is important to exposure that only 1% of authors published more than 5 documents, 95% have 1 or 2 publications. This indicates there is a small proportion of specialized authors in the research topic.

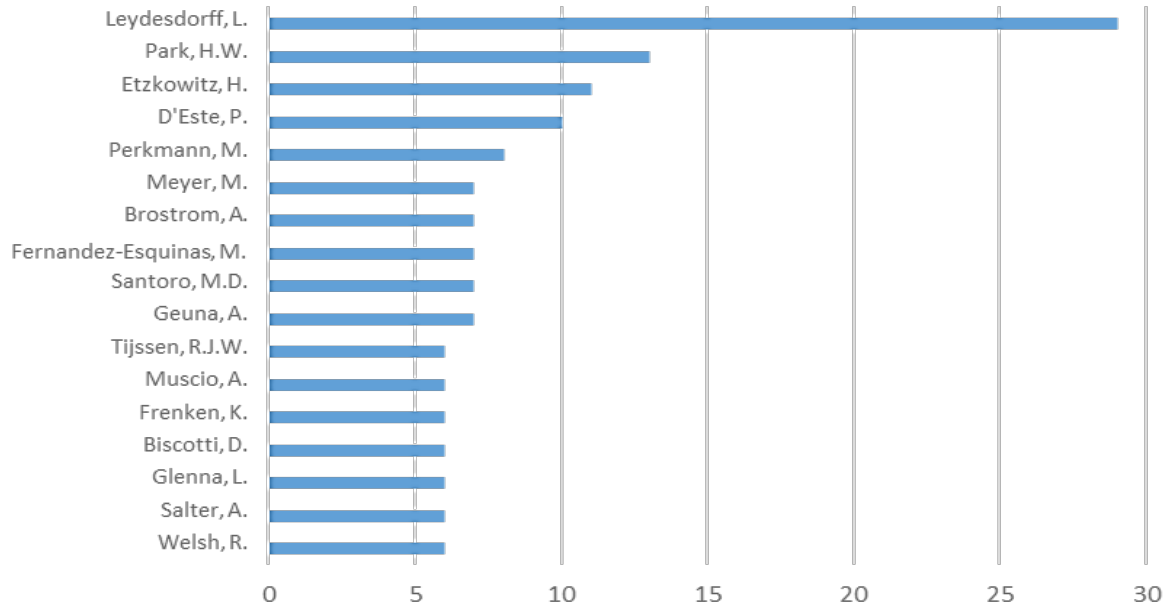

Figure. 6 Scientific production of most productive authors.

Authors' H-index is calculated to evaluate and compare their performance in topic 'University- industry cooperation' between 1997 and 2016. Figure 7 displays leading researchers and academics based on their works in literature and reported citations in all database.

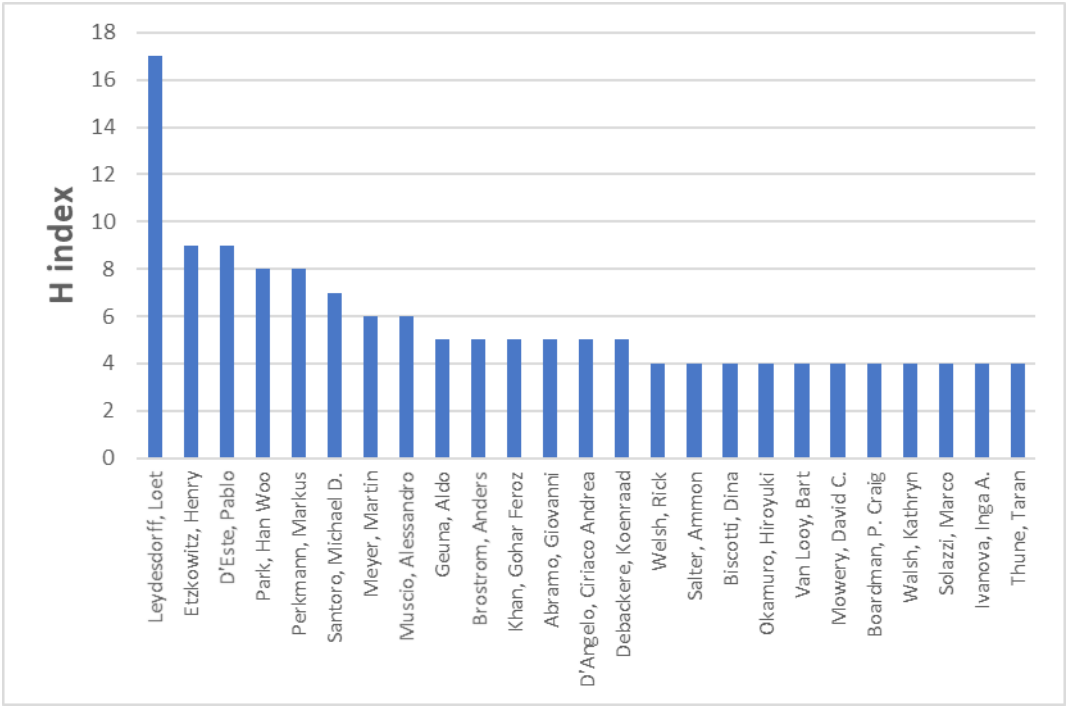

Figure. 7 Highest H-index of authors.

The results show that Loet Leydesdorff with the greatest scientific production in the topic, is also leadership in his outputs. Etzkowitz and D'Este excelled in their

works. The 98% of researchers have an H-index less than 4, hence only a small group highlights in its scientific activity.

The 26.6% of documents are made by one author, the 31.9% by two authors and 41.6% includes the participation of more authors. It evidences a high level of collaborative development.

The graphic representation of cooperation networks between countries (See Figure 8) illustrates that

scientific production in ‘University-industry cooperation’ has established several international connexions. England is the country with the greatest collaborative working networks with others nations. USA, Netherlands, Germany Italy, France and Spain also highlight in the analysis.

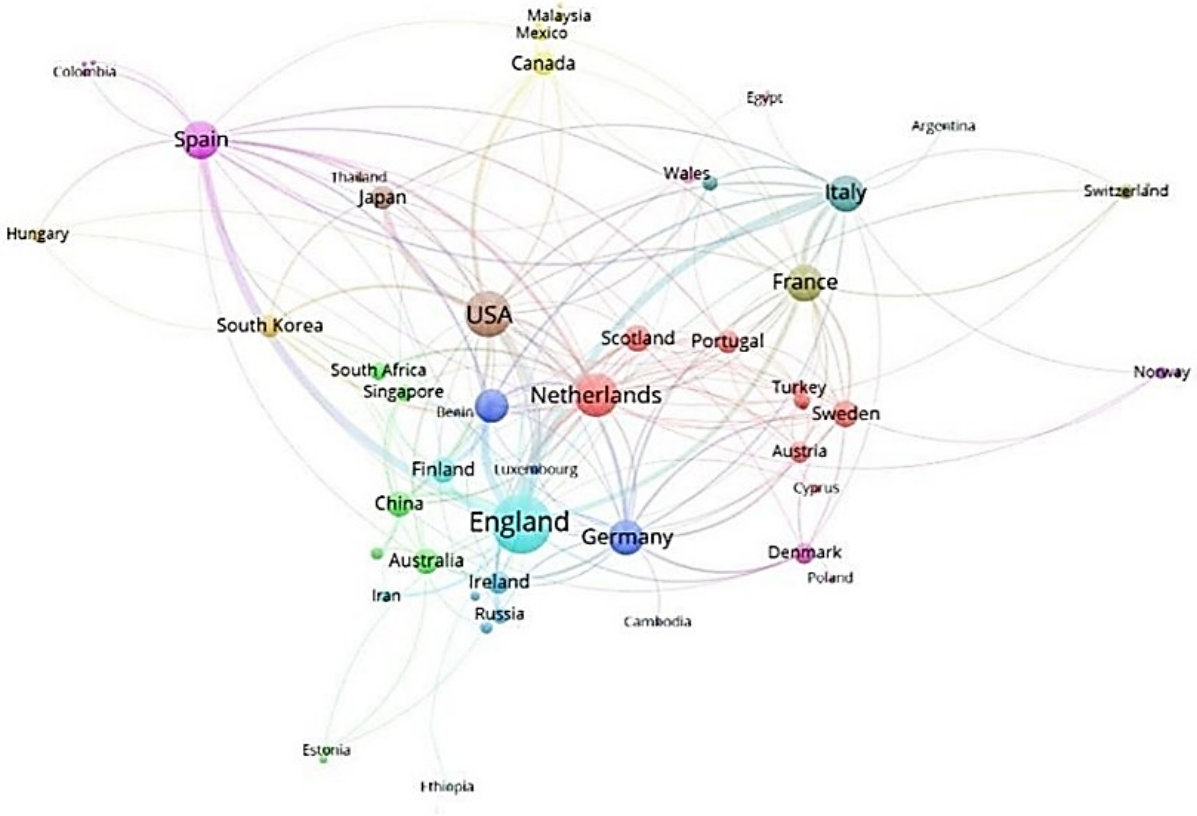

Figure. 8 Cooperation networks between countries

It is not coincidence that these countries have at the same time, the higher scientific production mass. Perhaps, working networks between authors from different nations, and possibly of different institutions, create more productive research places.

CONCLUSIONS.

This study made a profiling research about ‘University – industry cooperation’ between 1997 and 2016, by searching for documents in ISI WoS database, compilation of bibliographic fields, and a subsequent quantitative analysis of

publications. The analysis scheme is composed of three approaches: Chronological, topic and production context approach. In each one, bibliometric indicators and statistical calculations were used in order to identify trends, production level by subject, leaders and working networks.

The results showed that the topic is booming yet in academic field, and the interest of community scientific has had a notorious growing up in the last 5 years. This situation evidences, without distinction of the quality of works, that many contributions must be reflected in some degree of improvement of cooperation activities and conditions at worldwide. The competitiveness requires innovation; therefore companies are encouraged to consult and apply scientific knowledge in improvement of their processes.

According to classification of papers by topic based on WoS categories, this study identified that the greater number of works belong to Strategy & Management branch. Culture and Systems had been the least studied. Therefore, increasing investigations of less worked branches would be profitable.

The most citated article *The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations*, wrote by Henry Etzkowitz and Loet Leydesdorff and published in 2000, reveals that collaboration have extended to make reciprocal connections with government, who acts as an economic and legislative enabler.

Keywords analysis evidences the frequency of studies about government-university-enterprise relations. 64 documents were identified under concept “Triple Helix”, and 28 under “Government- industry-university relations” and synonymous. This is the 11% of collected registers.

The production of documents has had a high collaborative development. Loet Leydesdorff was the most prolific author and with the greatest research performance in the topic according to H-index. The research is mainly concentrated in Europe and North America, and there is a lack of works from Latin America and Africa. There last regions could participate more actively and contribute with their experiences and needs, besides the results of investigations could at the same time have a positive impact in their economies.

The countries whose researchers have the greatest production are USA, England and Netherlands, and at the same time, these have greater collaboration networks with foreign nations. Perhaps, the economic and social situation of these development countries and connections with international authors and institutions stimulate the investigation and generation of new proposals.

The study can be limited by search scope in database, which could omit documents published in the literature. However, this profiling research hope to be useful for academic and researchers interested in the topic, as a guide tool to make decisions in the academic and industry field. The paper describes under a global approach –what, who, where- the scientific production in the topic university-industry cooperation.

REFERENCES

- Aguado López, E., & Becerril García, A. (2016). Revista Investigación Económica: análisis bibliométrico a partir de redalyc. org, 2005-2014. Investigación económica, 75(295), 3-30.
- Ankrah, S., & Al-Tabbaa, O. (2015). Universities–industry collaboration: A systematic review. Scandinavian Journal of Management, 31(3), 387-408.
- Arencibia Jorge, R., & Carvajal Espino, R. (2008). Los índices H, G y R: su uso para
- identificar autores líderes en el área de la comunicación durante el período 2001-2006. Acimed, 17(4), 0-0.
- Bertocchi, G., Gambardella, A., Jappelli, T., Nappi, C. A., & Peracchi, F. (2015). Bibliometric evaluation vs. informed peer review: Evidence from Italy. Research Policy, 44(2), 451-466.
- Cheng, H., Chen, C. T., Wei, L. F., Yen, C. L., & Huang, M. H. (2016). Exploring University–Industry Collaboration Trends in Computer Science: A Study on Hardware and Architecture and Software Engineering. IETE Technical Review, 1-11.
- Choi, D. G., Lee, H., & Sung, T. (2011). Research profiling for ‘‘standardization and innovation’’. Scientometrics, 88(1), 259–278.
- Escorcia Otálora, T. A. (2008). Análisis bibliométrico como herramienta para el seguimiento de publicaciones científicas, tesis y trabajos de grado (Bachelor's thesis).
- Feng, F., Zhang, L., Du, Y., & Wang, W. (2015). Visualization and quantitative study in bibliographic databases: A case in the field of university–industry cooperation. Journal of Informetrics, 9(1), 118-134.
- Gulbrandsen, M., & Smeby, J. C. (2005). Industry funding and university professors’ research performance. Research policy, 34(6), 932-950.
- Hawkins, D. T. (1977). Unconventional uses of on-line information retrieval systems: on- line bibliometric studies. Journal of the American Society for Information Science, 28, 13–18.
- Ivascu, L., Cirjaliu, B., & Draghici, A. (2016). Business Model for the University-industry Collaboration in Open Innovation. Procedia Economics and Finance, 39, 674-678.
- King, J. (1987). A review of bibliometric and other science indicators and their role in research evaluation. Journal of information science, 13(5), 261-276.
- López-Illescas, C., de Moya-Anegón, F., & Moed, H. F. (2008). Coverage and citation impact of oncological journals in the Web of Science and Scopus. Journal of Informetrics, 2(4), 304-316.
- Martinez, H., Jaime, A., & Camacho, J. (2012). Relative absorptive capacity: A research profiling. Scientometrics, 92(3), 657-674.

- Muscio, A. (2010). What drives the university use of technology transfer offices? Evidence from Italy. The Journal of Technology Transfer, 35(2), 181-202.
- OECD, 1998. STI Policy Review No. 23 Special Issue on Public/Private Partnerships in Science and Technology, Paris.
- OECD, 2002. Benchmarking Industry–Science Relationships, Paris.
- Park, H. W., & Leydesdorff, L. (2010). Longitudinal trends in networks of university–
- industry–government relations in South Korea: The role of programmatic incentives. Research policy, 39(5), 640-649.
- Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., ... & Krabel,
- S. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. Research policy, 42(2), 423-442
- Porter, A., Kongthon, A., & Lu, J. C. (2002). Research profiling: Improving the literature review. Scientometrics, 53(3), 351-370.
- Rajalo, S., & Vadi, M. (2017). University-industry innovation collaboration: Reconceptualization. Technovation.