

A Bibliometric Overview of University-Business Collaboration between 1980 and 2016

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Abstract. Bibliometrics is a research field that analyses bibliographic material from a quantitative point of view. Aiming at providing a comprehensive overview, this study scrutinises the academic literature in university business collaboration and technology transfer research for the period post the Bayh-Dole Act (1980-2016). The study employs the Web of Science as the main database from where information is collected. Bibliometric indicators such as number of publications, citations, productivity, and the H-index are used to analyse the results. The main findings are displayed in the form of tables and are further discussed. The focus is on the identification of the most relevant journals in this area, the most cited papers, most prolific authors, leading institutions, and countries. The results show that the USA, England, Spain, Italy, and the Netherlands are highly active in this area. Scientific production tends to fall within the research areas of business and economics, engineering or public administration, and is mainly published in journals such as *Research Policy*, *Technovation* and *Journal of Technology Transfer*.

Keywords. University-industry collaborations, science to business, industry-science, technology transfer, bibliometrics.

1 Introduction

Knowledge is widely acknowledged to be one of the main engines for economic and social development of a country [33, 35]. Universities and

research centres, either public or private, play a key role in both generating and disseminating this knowledge [28, 54]. Through the research mission, they generate cutting edge discoveries, expanding the boundaries of science, while the “third mission” implies the dissemination and exploitation of this knowledge, contributing to social growth and economic development [3, 22, 58]. Moreover, knowledge spillovers stimulate other research institutions to commercialize their research findings resulting in acceleration of economic growth. The establishment of university-business collaborations (UBC) is therefore central to this process in order to facilitate this knowledge flow from academia to industry [21].

Reasons for engaging in UBC have been widely documented in the literature. From the standpoint of universities, an important body of the literature has examined the function of the university and their departmental characteristics [52], as well as the technology transfer infrastructures that boost the commercialization of research results [44, 61]. Other studies have shown that scientific productivity of a researcher is positively related to academic engagement in the industrial domain [8, 31, 32]. Going a step further, several works also found a positive connection between the quality of the research conducted and the probability of researchers participating in commercialisation activities [25, 51, 62].

From the industrial side, knowledge sharing between science and industry is a preliminary step for innovation [37]. In order to leverage markets and remain competitive, companies need to be continually alert of new developments. In this respect, universities offer firms a wide access to a variety of experts in various disciplines as well as appropriate infrastructure and state-of-the-art technologies, which can shorten the life cycle for industrial products [57, 66, 68]. Partnering with universities not only provides firms with an adequate cost-benefits extension of the R&D resources (cutting-edge knowledge, equipment, facilities), but also helps firms to take advantage of emerging potential business opportunities, and evaluate the quality of the research into the company and update internal capabilities and skills [30]. Partnering with university scientists is also beneficial for companies, as this form of alliance gives legitimacy to research results [36].

Furthermore, universities can also conduct new research in specific fields that are of interest for firms [15]. Aiming at narrowing the gap between science and industry, many universities have created specific units and designed explicit programs to assist in this endeavour. Technology Transfer Offices (TTOs) and science parks are two clear examples. Acting as knowledge brokers, they are a bridge between academics, companies and venture capitalists, and their main objective is to facilitate the process of knowledge and technology transfer between the university and the company while infusing an entrepreneurial culture of research [17].

Nevertheless, despite the great support given to UBC, there are still significant impediments limiting their potential. Barriers mainly relate to the motivation incentives that drive academics and firms to engage in such a partnership. Science and industry operate differently. Their daily activities are highly tied to a specific organizational culture, mission and organizational practices [59]. Accordingly, goals might signal opposite directions. First, companies cannot evaluate the quality of the invention a priori, and researchers may have difficulties in evaluating the commercial profitability of their inventions [45]. Second, poor communication channels and low interest in academic research are other reasons that prevent universities and business from cooperating [6].

Universities have strong incentives for conducting basic research that leading to new knowledge. On the other hand, industries seek solutions that make their operations and processes more competitive, their products more attractive, and consequently enable them to become more profitable [1, 55]. Third, time-span is another critical factor. University research projects tend to require long periods of time, while industry demands short cycles in order to compete in the market and obtain competitive advantage [16, 26, 12].

Literature on UBC is abundant. The different stakeholders involved in this process (i.e., the universities, firms, and individual researcher) might explain this large corpus of both theoretical and empirical studies, as different approaches, and different points of view have been explored [22].

Another explanation for this diversity relies on the variety of forms in which UBC materialize, ranging from casual interactions in events such as meetings, conferences, recruitment of university graduates, or staff mobility, to more sophisticated agreements such as collaborative joint research, contract research, consulting, consortia, alliances, trade associations, interlocking directorates, equipment or other facilities [22,7].

Although this list is quite exhaustive, scholars converge on the difficulties of categorizing all potential mechanisms for UBC to take place [10]. All these mechanisms had been classified into six categories: (1) personal casual relationships, (2) personal relationships, (3) third party, (4) formal targeted agreements, (5) formal non-targeted agreements and (6) creation of focused structures [13]. Similarly, had been distinguished seven tools through which to strengthen UBC: (1) joint curriculum design and delivery, (2) lifelong learning, (3) student mobility, (4) professional mobility, (5) joint R&D, (6) commercialization of joint R&D, and (7) entrepreneurship [23]. Whatever the mechanism used, the formalization agreement is a very important step, as it monitors and regulates the relationship, avoiding conflict and mistrust between the parties [56].

Today, research in UBC enjoys good health and can be considered a recognised scientific field, with a myriad of researchers studying from different theoretical and practical perspectives.

Many research institutions; associations and international networks have also been created based on UBC at their core.

Some examples include the *Triple Helix Association* (TH) and the *University Industry Interaction Network* (UIIN). These associations organize seminars and conferences that constitute unique vibrant forums where academics and practitioners discuss the newest advances in this field. Similarly, specific journals and conferences have emerged aiming at providing a forum for discussion. Some specific journals that clearly deal with this topic include: *Research Policy*, *Technovation*, *Journal of Technology Transfer*, *Journal of Engineering and Technology Management*, *R&D Management* and the *International Journal of Technology Management*.

Given the amount of research generated around the different mechanisms through which to articulate technology transfer processes between universities and business, there is an urgent need for reviewing the state of the art from its theoretical inception, in the early 1980s, to the present.

We had decided to start this analysis from 1980 due to the fact that in that year the Bayh-Dole Act was enacted in the USA, which allowed universities to appropriate patents derived from public funds. In the same line, researchers working on public funds were stipulated to disclose their inventions to the technology transfer office [9, 50].

This Act fostered the commercialization of university research [38, 42]. It is important to note that since this relevant Act, other countries outside of the USA such as Denmark, Germany, Austria, and Norway have reformed their intellectual property laws by giving universities ownership of publicly funded inventions, similar to the Bayh-Dole Act. [64].

By using an extensive range of bibliometric indicators, in this study, we identify the most influential journals, authors, and papers.

We also analyse which countries and research institutions are taking a leading role in this particular field. The information was obtained from the Web of Science (WoS) database, considered one of the most relevant databases in the academic domain. Some prior studies have adopted a similar approach, but concentrate on specific geographical areas.

Had been presented a study based on joint scientific publications between universities and industry in the UK, covering two decades (1980-2000) [18]. Similarly, there is an analysis that examines public and private research collaboration between universities and industry in Italy for the period 2001-2003 [2]. In the same line, but without using bibliometric indicators, had been analysed academic articles in the field of UBC, starting in 1990 and ending in 2014 [5]. Our study differs from previous ones for considering the most current tools to represent a research area with bibliometric indicators, and for adopting a global geographical perspective [34, 53].

The remainder of the paper is organized as follows. We first describe the methodology. The next section, presents the results, including the most influential journals, the most cited papers, the most productive and influential authors, the main institutions in this area of knowledge and the most relevant countries. Next, we discuss the main implications. The paper ends with some concluding remarks alongside indicators for future works.

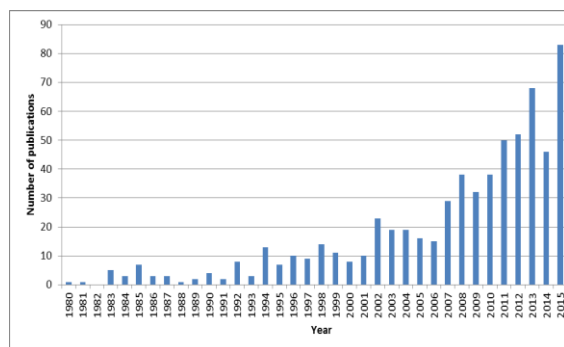
2 Methodology

The search process takes as a basis the Web of Science (WoS) database. Despite the fact that other databases could have been used (e.g. Scopus, EconLit, Google Scholar) we selected this database as it has been acknowledged to be of high quality and one of the main sources of citation information in the world [67, 53]. WoS includes more than 15,000 journals and 50,000,000 articles that encompass all the known sciences [48]. Information is classified into research categories, research areas, articles, authors, journals, institutions, and countries.

Today WoS distinguishes 250 categories that are grouped in 150 areas. For the purpose of this study, the focus is given to the WoS Core Collection, which covers 12,000 of the most recognised journals worldwide as well as Open Access journals in the sciences, social sciences, arts, and humanities, with coverage since 1900. Despite The Social Science Citation Index (SSCI) have received some criticism about ideological bias in journals' inclusion, it could be just a result of chance [40].

Table 1. List of keywords in university business collaboration and technology transfer

Actors involved	Technology transfer agreement
University Business	Collaboration
University-Business	Cooperation
University-Industry or University Industry	Partnership
Industry-Science or Industry Science	Link
Science to Business or Science 2 Business	Technology Transfer

**Fig. 1.** Evolution of papers published by year in university business collaboration and technology transfer from 1980 to 2016

The study was done via the web, and it was consulted less of a quarter of the total journals indexed in SSCI. The first step in the search process was the identification of meaningful keywords that unequivocally return papers that fall within the topic of our interest: technology transfer links between academia and industry. We were therefore interested in papers that contained at least two different ideas: a collaboration or partnership agreement (*mechanism articulating the technology transfer process*), and the actors involved (*industry and university*).

Because literature has referred to these concepts using a variety of terms, we first elaborated a list containing all potential synonyms (see Table 1).

This process was indispensable to determine the inclusion/exclusion criteria to apply in the bibliometric study.

The search was conducted during July and August 2016. The inclusion criteria for accepting papers were: a) document type: article or review, b) language: English, c) timespan: all years, d) indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, and ESCI. This research strategy returned an initial set of 696 records, from which 673 were journal articles and 23 reviews.

It is worth noting that these publications refer to the period comprising 1980 to 2016 (see Figure 1), coinciding with the enactment of the Bayh-Dole Act in 1980. This reform introduced important modifications to how universities could exploit new technologies and research developments created in the university setting, having significant political and management implications for all those involved in the commercialisation of university research results [60, 43]. Aiming at identifying the most influential journals, the most relevant articles, the most productive authors, as well as the leading institutions and countries researching in this particular field, we used several key indicators for measuring the bibliographic material. The purpose is to give a general overview of the bibliographic material [14].

First, we relied on the citations/paper ratio, which permits to identify the most influential articles [48]. Second, we used the h-index a measure that integrates publications and citations in the same formulation, by connecting the number of papers n that has received n citations [34]. This index measures the productivity of a researcher and total impact of the papers.

Thus, researchers with a similar h-index are comparable at the level of scientific impact, although their number of articles and citations differs. (e.g., if a researcher has an h-index of 50, it means that he has a set of 50 articles that have received at least 50 or more citations. The h-index can be utilised in authors, countries, journals, articles, and universities.

Thus, it allows making a holistic analysis of a certain field of research, taking into account several different items [11]. The Impact Factor (IF) for 2015 has been included in Table 3 to present the quality of each journal.

Table 2. Twenty-five main categories according to the web of science core collection report

Rank	Category	Number of records	% Of 696 records
1	Management	334	47.989
2	Planning development	137	19.684
3	Engineering industrial	105	15.086
4	Business	89	12.787
5	Operations research management science	70	10.057
6	Economics	65	9.339
7	Information science library science	63	9.052
8	Engineering multidisciplinary	58	8.333
9	Education educational research	56	8.046
10	Computer science interdisciplinary applications	45	6.466
11	Geography	27	3.879
12	Environmental studies	27	3.879
13	Education scientific disciplines	27	3.879
14	Multidisciplinary sciences	26	3.736
15	Public administration	20	2.874
16	Urban studies	16	2.299
17	Engineering electrical electronic	14	2.011
18	History philosophy of science	10	1.437
19	Social sciences interdisciplinary	9	1.293
20	Computer science information systems	8	1.149
21	Social issues	7	1.006
22	Materials science multidisciplinary	7	1.006
23	Ethics	7	1.006
24	Chemistry multidisciplinary	7	1.006
25	Health care sciences services	6	0.862

Ranking is development according to percentage of University Business Collaboration (UBC) and Technology Transfer papers in the Journals published between 1980-2016 at Web of Science Core Collection. The total records found during this period were 696

The impact factor analyses the influence of a journal over a two-year period, dividing the total citations received in year $n-1$ and $n-2$ by the total number of articles published in year $n-1$ and $n-2$. The impact factor in recent years has received numerous criticisms because it has been argued

the ease of manipulation of results through self-citations or related techniques [19]. Impact Factor considers the two previous years. However; longer time periods of citations and/or sources could be considered, but then the indicator would not be current enough [29].

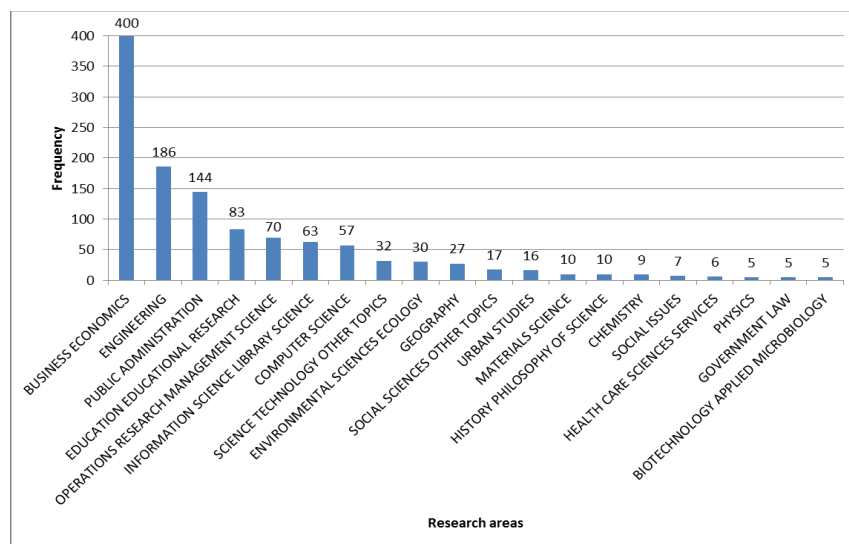


Fig. 2. Top-20 Research areas in university business collaboration and technology transfer from 1980 to 2016

The percentage of papers in UBC of any given journal (TP-UBC/TP) in Table 3 is also included. To evaluate the citation rate of papers in UBC, in Table 7, The countries information is classified according to citation structure with thresholds of, >250, >100, >50 citations.

In order to map the bibliometrical material we employed Science mapping. This science is considered a specific science, in which the different scientific fields are structured in a conceptual, intellectual and social mode [20]. Additionally, the study uses VOS viewer software that provides easy-to-interpret graphical representations of the bibliographic material and has the functionality to construct maps based on citation, co-citation co-authorship, bibliographic coupling and co-occurrence data [65, 47]. Bibliographic coupling takes place when two articles cite the same third article [39].

Co-occurrence identifies the most common keywords used in the articles.

This list of keywords generally can be founded on the first page of the paper [41]. Figure 3 and Figure 4 present the mapping of the most cited authors between 1980-2016 and 1917-1918. The mapping is focused on authors so we look for citation, co-citation, and co-authorship with a threshold of fifty cites and one paper.

Citation analysis counts the number of times that document A cites document B and vice versa [49]. Co-citation results when the study A and study B receive a citation from the same C study [63]. Co-authorship identify the scientific output of researchers as well as their joint publications [46].

The graphical visualization is showed through network where the size of the node increases with the number of publications and the network connection the relationship between them. VOS is available free of charge, and more information about the program can be obtained at the following link: www.vosviewer.com.

Table 2 shows the research categories in which the 696 records fell. Only the top 25 research categories are displayed, however, they cover almost the entire sample (95.97%). The category with the highest number of articles is Management (334 articles), followed by Development Planning (137 articles), Industrial Engineering (105 articles) and Business (89 articles).

Concerning the research areas, Figure 2 reveals that Business and Economics accounts for 57.47% of the total volume, followed by Engineering (26.72%), Public administration (20.69%), and Education & Educational Research (11.92%). Overall, these results mirror the Triple Helix model of university-industry-government relationships [27].

Table 3. Twenty most influential journals in university business collaboration and technology transfer

R	Journal	H-UBC	TC-UBC	TP-UBC	% P-UBC	TP	TC	IF 2015	H
1	Research Policy	39	5,271	91	13.075	3,026	116,959	3.470	155
2	Technovation	15	677	31	4.454	1,933	29,328	2.243	68
3	Journal of Technology Transfer	12	512	50	7.184	433	3,042	2.213	26
4	Scientometrics	12	371	38	5.460	4,587	55,466	2.084	82
5	Higher Education	10	209	21	3.017	3,602	24,583	1.207	59
6	International Journal of Technology Management	8	137	30	4.310	1,982	10,530	0.867	35
7	World Development	6	179	6	0.862	5,844	100,326	2.438	116
8	IEEE Transactions on Engineering Management	6	115	6	0.862	2,024	26,011	1.454	61
9	Technological Forecasting and Social Change	5	62	9	1.293	4,013	33,163	2.678	65
10	R & D Management	5	107	9	1.293	1,972	19,145	1.190	61
11	Industrial and Corporate Change	5	134	6	0.862	723	14,295	1.327	55
12	European Planning Studies	4	45	12	1.724	1,645	10,874	1.056	39
13	Technology Analysis & Strategic Management	4	53	10	1.437	1,105	9,903	0.845	41
14	Papers in Regional Science	4	219	5	0.718	930	7,324	1.144	39
15	Journal of Engineering and Technology Management	4	195	5	0.718	482	6,491	1.474	41
16	International Journal of Engineering Education	3	24	15	2.155	2,453	7,833	0.559	25
17	Science and Public Policy	3	27	12	1.724	532	1,605	1.233	15
18	Industry and Innovation	3	30	11	1.580	296	1,686	0.87	20
19	Research Evaluation	3	53	10	1.437	475	3,661	1.467	26
20	Science Technology and Society	2	13	6	0.862	119	124	0.231	6

Abbreviations: R, rank; H-UBC, H-index only with University Business Collaboration (UBC) and Technology Transfer; TC-UBC, Total Citations of papers in the area of University-Business Collaboration and Technology Transfer; TP-UBC, Total Production of papers on the topic of University-Business Collaboration and Technology Transfer; % P-UBC, percentage of papers published in a given journal in the specific topic of University-Business Collaboration and Technology Transfer; TP, Total number of papers; TC, Total number of citations; H, H-index; IF 2015, impact factor for the year 2015. Journals are ranked according to the H-index and percentage of TC-UBC.

Table 4. Twenty-five most cited papers in in university business collaboration and technology transfer

7	J	TC	Title	Author/s	Year	C/Y
1	RP	379	Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study	Siegel et al.	2003	27.07
2	RP	336	Technology transfer and public policy: a review of research and theory	Bozeman et al.	2000	19.76
3	RP	303	The norms of entrepreneurial science: cognitive effects of the new university-industry linkages	Etzkowitz et al.	1998	15.95
4	RP	240	Searching high and low: what types of firms use universities as a source of innovation?	Laursen et al.	2004	18.46
5	RP	232	University-industry linkages in the UK: What are the factors underlying the variety of interactions with industry?	D'Este et al.	2007	23.2
6	IJMR	200	University-industry relationships and open innovation: Towards a research agenda	Perkmann et al.	2007	20
7	RP	193	Resources, capabilities, risk capital and the creation of university spin-out companies	Lockett et al.	2005	16.08
8	RP	176	University patenting and its effects on academic research: The emerging European evidence	Geuna et al.	2006	16
9	RP	172	Networks of inventors and the role of academia: An exploration of Italian patent data	Balconi et al.	2004	13.23
10	RP	169	The role of academic technology transfer organizations in improving industry science links	Debackere et al.	2005	14.08
11	RP	168	'Technology transfer' and the research university: A search for the boundaries of university-industry collaboration	Lee, Y.S.	1996	8
12	MS	167	A comparison of US and European university-industry relations in the life sciences	Owen-Smith et al.	2002	11.13
13	PRS	160	The geographical and institutional proximity of research Collaboration	Pond et al.	2007	16
14	JETM	160	Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialization of university technologies	Siegel et al.	2004	12.31
15	RP	152	Factors affecting university-industry R&D projects: The importance of searching, screening and signalling	Fontana et al.	2006	13.82
16	RP	150	Knowledge interactions between universities and industry in Austria: sectoral patterns and determinants	Schartinger, et al.	2002	10
17	JBV	148	The effects of business-university alliances on innovative output and financial performance: a study of publicly traded biotechnology companies	George et al.	2002	9.87
18	RP	144	Bottom-up versus top-down policies towards the commercialization of university intellectual property	Goldfarb et al.	2003	10.29
19	IJIO	142	R&D cooperation between firms and universities. Some empirical evidence from Belgian manufacturing	Veugelers et al.	2005	11.83
20	RP	136	How effective are technology incubators? Evidence from Italy	Colombo et al.	2002	9.07
21	RP	121	Investigating the factors that diminish the barriers to university-industry collaboration	Bruneel et al.	2010	17.29
22	MS	117	Equity and the technology transfer strategies of American research universities	Feldman et al.	2002	7.8
23	RP	113	Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter?	Bekkers et al.	2008	12.56
24	RP	96	Academic engagement and commercialisation: A review of the literature on university-industry relations	Perkmann et al.	2013	24
25	JEG	88	Innovation, spillovers and university-industry collaboration: an extended knowledge production function approach	Ponds et al.	2010	12.57

Abbreviations: R, rank; J, Journal; TC, Total Citations; Year, Year of Publication; C/Y, Average of citations per year. Rank according to the results from WoS Core Collection for the period 1980-2016, with 696 records; Sum of Times Cited 11553; Average Citations per item 16.6; H-index 51. RP, Research Policy; IJMR, International Journal of Management Reviews; MS, Management Science; PRS, Papers in Regional Science; JETM, Journal of Engineering and Technology Management; JBV, Journal of Business Venturing; IJIO, International Journal of Industrial Organization; JEG, Journal of Economic Geography.

Indeed, the most recurrent categories are business (industry), education (university) and public administration (government).

3 Results

This Section summarises the main results of this paper. First, we provide a comprehensive analysis of the most influential journals in the domain of technology transfer processes aimed at fostering university-business collaborations. The analysis is limited to the top-20 journals. Second, following a similar strategy, we concentrate on the most cited articles. Next, we focus on the most prolific authors. Lastly, we study which institutions and countries act as drivers in this particular field.

3.1 Most Influential Journals

The most influential journals were selected according to the h-index and the percentage of publications during the period 1980-2016. The impact factor was also included as an indicator of the relative importance of the journal in its area. Information was collected from the Journal Citation Reports.

This indicator is computed by dividing the number of citations received during two previous years by the total number of articles published in the same period.

The 20 most influential journals in this field are shown in Table 3. However, as it can be inferred, the most representative ones are those in the top 10, because their impact factor, h-index and total citations is relatively high compared to the total volume. This list includes: *Research Policy*, *Technovation*, *Journal of Technology Transfer*, *Scientometrics*, *Higher Education*, *International Journal of Technology Management*, *World Development*, *IEEE Transactions on Engineering Management*, *Technological Forecasting and Social Change* and *R&D Management*. As will be discussed later, these journals are also the target journal outlets where the most productive authors publish their research.

3.2 Most Cited Articles

In order to rank journals, we used the number of citations. This indicator serves as proxy for the relevance and impact of an article within the academic community. A total of 25 articles were selected.

The citations/papers ratio was also used to complement the information for relevance [48]. Table 4 displays the list of top articles. Remarkably, the majority of these papers leave published in *Research Policy*. Authors that appear

in top positions are: D.S. Siegel, D. Waldman, A. Link, B. Bozeman, H. Etzkowitz, K. Lausen, A. Salter, P. D'Este, P. Patel, M. Perkmann, and K. Wash, all with more than 200 citations.

The most cited papers were published during the first decade of the beginning of the millennium. As it will be later shown in Tables 5 and 6, most cited articles are authored by those authors listed as the most influential ones, and belong to leading institutions in this area.

For instance, Perkmann and Salter are affiliated to the Imperial College London (UK); Cassiman, Debackere and Veugelers to KU Leuven (Belgium); Frenken and Bekkers to the Eindhoven University of Technology (The Netherlands); D'Angelo, Abramo, and Solazzi to the University of Rome Tor Vergata (Italy) and Freitas and Geuna to University of Turin (Italy).

3.3 Most Productive Authors

Table 5 presents a list of the 25 most productive authors in UBC. As shown, Perkmann leads the ranking with 10 papers; D'Este and Muscio tied with 8 papers each, followed by Salter and Leydesdorff, with 7 publications. Looking at the citations record, Siegel achieves the highest number (687). This figure suggests that despite not being the most productive author in this area, his research is impactful, as his works have been widely cited by other authors.

D'Este obtains second position in terms of citations (641) followed by Perkmann (561), Geuna (523) and Salter (521). With the objective to show a global view, some columns were added displaying information about the total citations and number of papers published beyond UBC production (also recorded in WoS). We also include the number of top papers of each of the authors listed in the table according to the Web of Science Essential Science indicators.

Table 5. Twenty-five most productive authors in university business collaboration and technology transfer.

R	Author/s	Affiliation	Country	TP	TC	H	T25	TP	TC	ESI
1	Perkmann, M.	Imperial College London	England	10	561	7	5	17	567	2
2	D'Este, P.	Universitat Politècnica de València	Spain	8	641	7	4	19	591	4
3	Muscio, A.	University of Foggia	Italy	8	123	4	1	0	0	0
4	Salter, A.	Imperial College London	England	7	521	5	4	62	1,763	4
5	Leydesdorff, L.	University of Amsterdam	The Netherlands	7	222	5	1	163	3,282	13
6	Geuna, A.	University of Turin	Italy	6	523	5	4	17	581	2
7	Brostrom, A.	Royal Institute of Technology	Sweden	6	156	5	1	115	1,867	5
8	Park, H.W.	Yeungnam University	South Korea	6	109	3	1	0	0	0
9	Frenken, K.	Eindhoven University of Technology	The Netherlands	5	265	3	2	41	1,710	11
10	Freitas, I.M.B.	University of Turin	Italy	5	149	4	1	0	0	0
11	D'Angelo, C.A.	University of Rome Tor Vergata	Italy	5	83	5	0	83	873	1
12	Abramo, G.	University of Rome Tor Vergata	Italy	5	83	5	0	77	793	1
13	Fernandez-Esquinas, M.	CSIC	Spain	5	25	3	0	0	0	0
14	Siegel, D.S.	University at Albany	USA	4	687	4	4	103	3,524	10
15	Veugelers, R.	KU Leuven	Belgium	4	381	4	2	30	794	1
16	Walsh, K.	Georgia Institute of Technology	USA	4	339	4	3	0	0	0
17	Debackere, K.	KU Leuven	Belgium	4	277	4	1	29	760	0
18	Cassiman, B.	KU Leuven	Belgium	4	191	4	1	13	618	2
19	Bekkers, R.	Eindhoven University of Technology	The Netherlands	4	132	2	1	42	572	1
20	Tartari, V.	University of Bath	England	4	119	2	1	0	0	0
21	McKelvey, M.	University of Gothenburg	Sweden	4	110	3	1	0	0	0
22	Solazzi, M.	University of Rome Tor Vergata	Italy	4	74	4	0	0	0	0
23	Welsh, R.	Clarkson University	USA	4	59	2	0	45	2,492	4
24	Biscotti, D.	University of California Davis	USA	4	59	2	0	0	0	0
25	Thune, T.	University of Oslo	Norway	4	43	4	0	0	0	0

Abbreviations: R, rank; H-UBC; H-index only with University Business Collaboration (UBC) and Technology Transfer; TC-UBC and TP-UBC, Total Citations (TC) and Total Production (TP) in UBC; T25, number of papers in the top 25 list shown in Table 4; TP and TC, total papers and total citations in all publications indexed in WoS Essential Science Indicators for the past 2 years; ESI, top 1% papers of WoS (past 2 years).

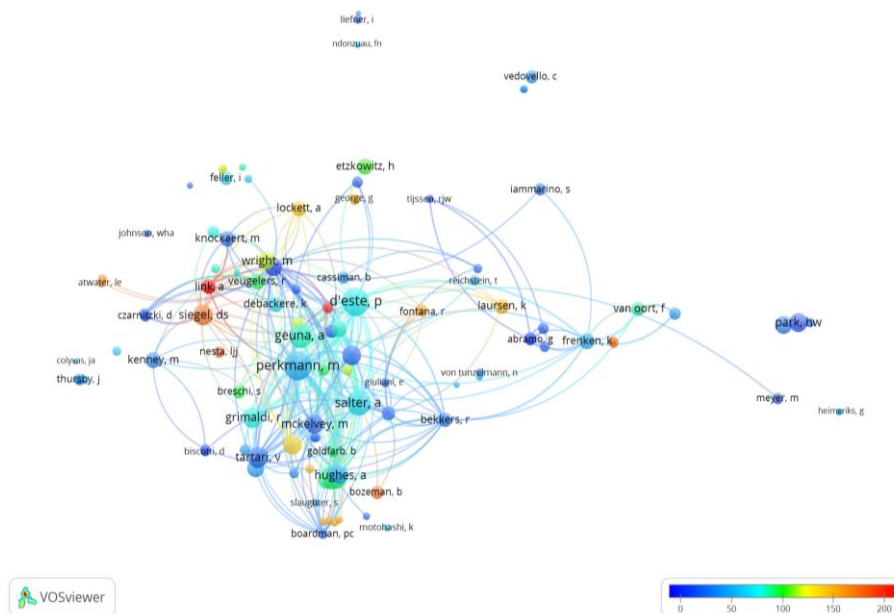


Fig. 3. The Most cited authors from 1980 to 2016. Colours indicate the citation impact of different authors, and the size of the node, the productivity of them. The link width shows the citations frequency between authors

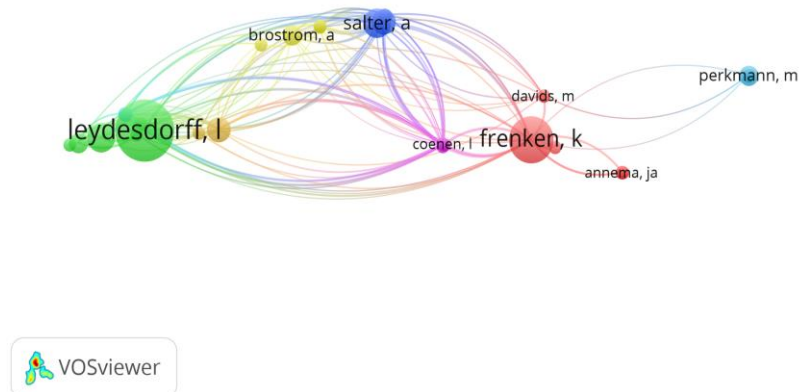


Fig. 4. The most cited authors from 2017-2018. Colours indicate the citation impact of different authors, and the size of the node, the productivity of them. The link width shows the citations frequency between authors

All these columns provide meaningful information on how influential and active an author is.

We believe it is relevant for the reader to know whether the authors concentrate their research efforts on UBC or have made important contributions in other research areas.

This is the case with Leydesdorff (163 papers in WoS and 13 top papers), Brostrom (115 papers in WoS, and 5 top papers), Siegel (103 papers in WoS, 10 top papers), D'Angelo (83 papers in WoS, 1 top paper), Abramo (77 papers in WoS, 1 top paper), Salter (62 papers in WoS, 4 top papers) and Welsh (45 papers in WoS, 4 top papers).

Table 6. Most influential institutions in university business collaboration and technology transfer

R	Institution	Country	TP-UBC	TC-UBC	H-UBC	TP (Y-10)	TC (Y-10)	H	TP (J-10)	TC (J-10)	H
1	CSIC Spain	Spain	20	511	10	20	511	10	11	428	8
2	KU Leuven	Belgium	17	609	10	13	233	6	9	395	7
3	Imperial College London	England	16	912	12	14	646	10	9	743	8
4	University of Sussex	England	13	859	10	11	804	8	8	681	6
5	Universitat Politècnica de València	Spain	13	469	8	13	469	8	9	400	6
6	University of London	England	12	173	5	10	169	5	2	58	2
7	University of Cambridge	England	11	249	7	8	197	5	6	195	5
8	Penn State University	USA	10	209	5	7	65	3	4	66	4
9	University of Tokyo	Japan	9	179	6	5	85	4	4	143	4
10	University of Manchester	England	9	82	4	7	48	3	3	40	2
11	University of California Davis	USA	9	271	6	9	271	6	9	271	6
12	Copenhagen Business School	Denmark	9	473	6	8	231	5	7	418	5
13	University of North Carolina	USA	8	592	5	1	3	1	3	409	3
14	University of Foggia	Italy	8	124	4	8	124	4	2	11	1
15	Loughborough University	England	8	341	4	8	341	4	2	75	2
16	Georgia Institute of Technology	USA	8	432	5	8	432	5	6	421	4
17	Bocconi University	Italy	8	418	8	6	236	6	6	389	6
18	University of Nottingham	England	7	809	5	4	164	2	6	737	4
19	University of Amsterdam	The Netherlands	7	222	5	7	809	5	2	87	2
20	Royal Institute of Technology	Sweden	7	161	5	7	161	5	4	148	4
21	CNRS France	France	7	44	4	6	44	4	2	19	2
22	Yeungnam University	South Korea	6	109	3	6	109	3	2	87	2
23	University of Utrecht	The Netherlands	6	321	6	6	321	6	2	49	2
24	University of California Berkeley	USA	6	106	4	5	103	4	6	106	4
25	Newcastle University	England	6	37	3	6	37	3	0	0	0

Abbreviations: R, rank; H-UBC, H-index only with University Business Collaboration (UBC) and Technology Transfer; TC-UBC and TP-UBC, Total Citations and papers only with UBC; TP-UBC10, TC-UBC10 and H-UBC10; Total Papers and citations, and H-index by institutions in the last 10 years in UBC; TP-UBC (J-10), TC-UBC (J-10) and H-UBC (J-10), Total Papers, citations and H-index in UBC in the first 10 Journal shown in the Table 3. 10 journals include Higher Education, IEEE Transactions on Engineering Management, International Journal of Technology Management, Journal of Technology Transfer, R&D Management, Research Policy, Scientometrics, Technological Forecasting and Social Change, Technovation, and World Development.

Table 7. Most productive countries in university business collaboration and technology transfer.

R	Country	TP- UBC	% Of 696 records	TC- UBC	H- UBC	>250 UBC	>100 UBC	>50 UBC	TP- UBC (Y-10)	TC- UBC (Y-10)	H- UBC (Y-10)
1	USA	190	27.30	4043	31	3	6	7	97	1,369	22
2	England	103	14.80	3442	30	1	8	11	84	2,179	23
3	Italy	63	9.05	1477	16	0	4	5	57	976	15
4	Spain	50	7.18	926	14	0	2	3	45	668	12
5	The Netherlands	44	6.32	980	18	0	2	4	40	871	16
6	Germany	37	5.32	600	12	0	1	2	31	365	10
7	Japan	34	4.89	414	11	0	0	1	23	252	9
8	Canada	30	4.31	253	8	0	0	0	19	154	8
9	South Korea	29	4.17	245	9	0	0	1	25	225	8
10	France	29	4.17	532	11	0	1	2	25	524	11
11	Australia	28	4.02	305	7	0	1	0	21	81	6
12	Belgium	27	3.88	916	15	0	2	4	22	465	10
13	China	26	3.74	104	6	0	0	0	26	103	6
14	Sweden	24	3.45	425	9	0	1	1	19	242	7
15	Denmark	16	2.30	510	7	0	2	1	15	268	6
16	Taiwan	13	1.89	68	4	0	0	0	12	67	4
17	Switzerland	11	1.58	113	5	0	0	0	10	95	4
18	Ireland	11	1.58	56	5	0	0	0	10	55	5
19	Norway	10	1.44	58	4	0	0	0	10	58	4
20	Finland	10	1.44	133	5	0	0	1	9	115	5
21	Singapore	9	1.29	60	3	0	0	0	7	48	3
22	Scotland	8	1.15	117	5	0	0	1	6	43	4
23	Portugal	8	1.15	131	3	0	0	1	7	49	3
24	India	7	1.01	18	2	0	0	0	4	6	1
25	Hungary	7	1.01	99	3	0	0	1	6	48	3

Abbreviations: R, rank; H-UBC, H-index only with University Business Collaboration (UBC) and Technology Transfer; TC-UBC and TP-UBC, Total Citations and Papers only with UBC; >250, >100, >50, number of papers with more than 250, 100 and 50 citations in UBC; TP-10, TC-10, and H-10, Total Papers, Total Citations and H-index in the last 10 years in UBC.

3.4 Evolution of Productive Authors between 2017-2018

To study the evolution of UBC field during the period between 2017-2018 ten authors with the highest presence and influence were chosen to compare their scientific contribution over a period

from the last two years, (from January 2017 to February 2018).

In order to analyse this data set, we have used Web of Science (WoS) and Google Scholar databases. We selected those databases as they have been acknowledged to be of high quality and one of the primary sources of citation information

in the world [67, 53]. For the searching process, we focus on the total number of articles and the total number of citations of each author in both databases.

Table 8 presents the Evolution of 10 Most productive authors between 2017-2018. As we can see, Leydesdorff, is the most productive author with 15 papers; Frenken, 9 papers, Salter 4 and Muscio, 3 followed by Perkmann, Brostrom, Freitas, with 2 publications and D'Este with 1 article. Finally, Geuna and Park have not published papers during this period in spite of those authors had been very active the previous years. Looking at the citations records, we observed that Frenken and Leydesdorff have received more citations in WoS with 9 and 15 new publications each. The leading authors in Google Scholar also are Frenken, with 21 papers and 106 citations and Leydesdorff, with 20 articles and 80 quotes.

To provide a complete picture of the results, we compare the information found in WoS database to that of Google Scholar and both are quite similar. In general, most of the authors present an increase in papers and citations in Google Scholar database due to it includes papers, books and conference proceedings as well. Especially in the case of Leydesdorff and Frenken who have also made contributions in other areas and show significant increments. To compare the 2016 and 2018 rankings of the most productive authors, Table 9 summarises and show the main changes. Note that D'Este with one article and Park and Geuna with not publications are the authors lost positions in the classification. On the other hand, Leydesdorff and Frenken jumped up places due to the number of papers published and citations obtained. Most authors kept their position in the ranking.

It is worth noting that of 9 of the ten leading authors in UBC field are from Europe; this could mirror the interest of European researchers in the market application of their inventions through the engagement with the industry.

In order to complement the information of the most productive authors (Table 5) and their evolution (Table 8), we mapped the bibliographic material using concepts such as citation, co-citation and co-authorship with a threshold of fifty cites and one paper. Figure 3 and Figure 4 show

the social network and identify their professional ties between them.

As we can see, the typology of network showed in Figure 3, and Figure 4 follow a power-law connectivity distribution, *“it implies that most of the nodes have only a few links, held together by a few highly connected hubs”* [4].

Figure 3 shows Perkmann with the most massive network; He keeps links with 120 authors of a sample of 134. Perkmann, as the central hub in this network, takes part in many representative clusters who hold the network connected. i.e. (Perkmann, Grimaldi, Tartari and Boardman), (Perkmann, D'Este, Salter, Geuna, Muscio and Frenken) and (Perkmann, Tartari, Etkowitz). This strong connections confirms why Perkmann is the most recognised author in the UBC field.

Figure 4 shows, Leydesdorff, Frenken, Salter, Brostrom and Perkmann as important names for the period of 2017-2018.

In this period Leydesdorff and Frenken appear as the authors with more connections due to higher productivity in the last two years.

3.5 Leading Institutions

Table 6 presents the list of the leading institutions publishing papers in the field of UBC. They are ranked according to the ten journals with most influence by using the H-index obtained (see Table 3). We have also considered the total volume of publications for the period under analysis (since 1980) as well as the production over the last 10 years. The Consejo Superior de Investigaciones Científicas (CSIC) leads the ranking with 20 papers, all of them published in the last 10 years, and more than half of them (11) were published in the 10 most influential journals in this area.

KU Leuven is in second position with 17 papers, followed by the Imperial College of London (16 papers). It is remarkable the leading role of UK institutions. Adding the citations received by three of them (Imperial College, University of Sussex and University of Nottingham) they account for 2,580 citations.

The relevant role of KU Leuven as a leading centre in this area is based on the results obtained by the study elaborated by Debackere and Veugelers [24]. These authors report that among Belgian universities, KU Leuven was the one

Table 8. Evolution of 10 most productive authors in UBC between 2017-2018 according to Web of Science and

R	Author	Affiliation	C	TP- UBC WoS 2016	TC- UBC WoS 2016	H- UBC WoS 2016	TP- UBC WoS 17-18	TC- UBC WoS 17-18	H- UBC WoS 17-18	TP-G Scholar 17-18	TC-G Scholar 17-18	H-G Scholar 17-18
1	Perkmann, M.	Imperial College London	UK	10	561	7	2	1	1	3	0	0
2	D'Este, P.	Universitat Politècnica de València	ES	8	641	7	1	0	0	5	1	1
3	Muscio, A.	University of Foggia	IT	8	123	4	3	0	0	4	1	1
4	Salter, A.	Imperial College London	UK	7	521	5	4	4	1	6	13	1
5	Leydesdorff, L.	University of Amsterdam	NL	7	222	5	15	13	2	20	80	6
6	Geuna, A.	University of Turin	IT	6	523	5	0	0	0	1	0	0
7	Brostrom, A.	Royal Institute of Technology	SE	6	156	5	2	2	1	3	5	2
8	Park, H.W.	Yeungnam University	KR	6	109	3	0	0	0	0	0	0
9	Frenken, K.	Eindhoven University of Technology	NL	5	265	3	9	17	3	21	106	6
10	Freitas, I.M.B.	University of Turin	IT	5	149	4	2	0	0	3	29	2

Abbreviations: R, rank; C, Country; H-UBC, H-index only with University Business Collaboration (UBC) and Technology Transfer; TC-UBC and TP-UBC, Total Citations (TC) and Total Production (TP) in UBC indexed in Web of Science. Essential Science Indicators: TP and TC, total papers and total citations in all publications indexed in Google Scholar during the period from January 2017 to February 2018. NL, The Netherlands; UK, United Kingdom; IT, Italy; ES, Spain; SE, Sweden; KR, South Korea.

receiving the largest investment for R&D activities. In fact, data corroborate that this university is very active in terms of granted patents and spin-offs, compared to the average level of European universities. This high volume of output line up with the mission statement of the university, which posits that KU Leuven is: “*an academic institution where research and knowledge transfer are both essential and complementary*”, (KU Leuven, Mission Statement, 2002).

Therefore, the inclusion of this university in this list is not by accident. Likewise, three of the most prolific authors are affiliated to KU Leuven,

corroborating that this university is highly productive in terms of technology transfer outputs but also there is a critical mass of researchers investigating UBC practice.

3.6 Analysis by Country

Lastly, in this part, we analyse the geographical distribution of the scientific production on UBC. The centre of attention is on articles published by the Universities or research institutions and signed by the team inside the country without taking into account the researcher nationality. Table 7

Table 9. Evolution of 10 most productive authors in UBC between 1916-2018, according to Web of Science database

R	Author	Affiliation	Country	TP-UBC WoS (16-18)	TC-UBC WoS (16-18)	H-UBC WoS (16-18)
1	Leydesdorff, L.	University of Amsterdam	NL	22	235	5
2	Frenken, K.	Eindhoven University of Technology	NL	14	282	3
3	Perkmann, M.	Imperial College London	UK	12	562	7
4	Muscio, A.	University of Foggia	IT	11	123	4
5	Salter, A.	Imperial College London	UK	11	525	5
6	D'Este, P.	Universitat Politècnica de València	ES	9	641	7
7	Brostrom, A.	Royal Institute of Technology	SE	8	158	5
8	Freitas, I.M.B.	University of Turin	IT	7	149	4
9	Geuna, A.	University of Turin	IT	6	523	5
10	Park, H.W.	Yeungnam University	KR	6	109	3

Abbreviations: R, rank; H-UBC; H-index only with University Business Collaboration (UBC) and Technology Transfer; TC-UBC and TP-UBC, Total Citations (TC) and Total Production (TP) in UBC Indexed in Web of Science Essential Science Indicators, during the period from January 2016 to February 2018. NL, The Netherlands; UK, United Kingdom; IT, Italy; ES, Spain; SE, Sweden; KR, South Korea.

displays the results ranked according to the H-index, total papers and citations.

The USA is the most productive country, with 190 papers. Half of this production corresponds to the last ten years (97 papers). The UK is the next country in the ranking, with 103. The third position is for Italy, with 63, papers followed by Spain, with 50 papers. The Netherlands appears in the fifth position after Germany and Japan.

4 Discussion and Conclusions

By adopting a bibliometric approach, this study contributes to the current literature by giving a global view of the academic research in technology transfer mechanisms through which UBC can be established. We argue that our study overcomes the limitations of previous studies that adopted a similar approach, by not only focusing on a specific country or territory, but also adopting an international perspective. The period of analysis considers publications from 1980 up to 2016 due

the fact that in 1980 the Congress of USA enacted the Bayh-Dole Act, which eased the commercialization of university research and thus university-business collaboration as well [38,50,64]. The results show that the USA, England, Italy Spain and the Netherlands are the leading countries in this area, and all of them have shown a significant increase in their production over the last 10 years. The analysis also reveals that the major categories in which these publications fall have a strong focus on business, public administration and education.

The logic behind this lies in the fact that these areas are the ones more closely related to growth and economic development.

Regarding the study of the leading institutions, the countries hosting them are Spain, the USA, Belgium, and the UK.

Top institutions include the *Consejo Superior de Investigaciones Científicas* (Spain), followed by The Imperial College London (UK) and KU Leuven (Belgium). All these institutions have a similar h-index, thus the productivity and impact factor are

fairly comparable. Concerning the analysis of the most cited researchers, Perkmann, D'Este, Muscio, Salter and Leydesdorff (co-author of triple helix model) stand as important big names in this area, publishing their works in some of the highest standing journals in this field, such as *Research Policy*, *Technovation* and the *Journal of Technology Transfer*.

We believe this study can help not only academics but also practitioners to identify the leading authors, institutions, and most influential publications in this field. This research might be particularly useful for anyone interested in obtaining a global picture of the current literature on UBC, particularly PhD students or researchers that start investigating this topic. Although we have followed a rigorous methodology, the study is not free of limitations. The bibliometric approach of this study is only informative. The analysis is biased to the records displayed in only one database, the Web of Science.

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