# A BIBLIOMETRIC REVIEW OF THE TECHNOLOGY TRANSFER LITERATURE

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**Funding:**

Funding for this research was provided by the Spanish Ministry of Science, Innovation & Universities (MCIU/AEI/FEDER-UE) under the grant number RTI2018-097579-B-100, by UPV/EHU under the grant number GIU16/46, and by FESIDE.

**Acknowledgements:**

The authors gratefully acknowledge comments and suggestions from Dr. Donald Siegel and anonymous referees on earlier versions of this paper. Any errors and misjudgements remain the responsibility of the authors.

**Conflict of Interest:**

The authors declare that they have not conflict of interest.

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**Abstract**

This study explores academic research on technology transfer (TT) and the related themes. The TT field has attracted considerable scholarly attention in recent years and has grown rapidly, resulting in a large body of knowledge. Using a bibliometric approach, this study reviews related research issues as well as their influence and connections and provides directions for future research. It uses Clarivate Analytics' Web of Science database that includes 3,218 bibliographic references. Several bibliometric analysis techniques and a subsequent review of the content of the most relevant documents are adopted. The performance analysis provided an updated overview of the evolution of the TT literature from 1969 to 2018 and quantitatively identified the most active and influential journals, articles, authors, and organizations. The co-authorship network analysis allowed us to identify and visualize the structure of relations between authors as well as determine the collaboration patterns among them. On the basis of the information supplied by the co-authorship network, the main literature was reviewed to identify the current status and research trends related to TT, identifying five main research streams and related topics. The implications of the study's findings and directions for future TT research are finally discussed to enhance our understanding of TT agents and issues and support further research in this field.

**Keywords**

Technology transfer, Bibliometrics, Performance analysis, Co-authorship analysis

**JEL Classification**

M15, O3

# 1 INTRODUCTION

The creation and application of new knowledge is the primary factor that drives sustainable economic growth, and science, technology, and innovation are the main drivers of future success, playing a leading role in the so-called knowledge economy (Heinzl et al. 2013). Indeed, the United Nations asserts that the creation, development, and diffusion of new innovations and technology-associated knowledge, including the transfer of technology under mutually agreed upon terms, are powerful drivers of economic growth and sustainable development. Efficient technology transfer (TT) from the agents that generate new knowledge (e.g., universities and research institutes) to other agents in the value chain can thus be fundamental (Kogut and Zander 1992; Tsai 2001). For this reason and because of its economic importance, practitioners and researchers have recently placed considerable attention on TT, despite several aspects of TT having been addressed for many years. In fact, TT began its scientific development in the early 1970s and since then has become a research field of its own (Bozeman 2000; Hsieh et al. 2014; Noh and Lee 2017; Wahab et al. 2012). Some indicators of its relevance include the existence of several specialized journals and a job position entitled *technology transfer agent* (Bozeman 2000).

Although TT is a highly debated topic, no definition has reached consensus as it is a complex, difficult process that also needs time to evolve. Indeed, many of the studies do not draw a clear line between knowledge and technology transfer (Wahad et al. 2012a). According to Autio and Laamanen (1995), TT is considered and intentional and goal-oriented process of interaction between two or more social entities during which the technology and the knowledge related to it is transferred. However, as Gopalakrishan and Santoro (2004) point out, they serve different purposes and are distinct constructs embodying different kind of activities which are facilitated by different organizational factors. Technology is usually more explicit and codified including production processes and computer hardware. However, knowledge captures the underlying cause and effect relationships on which a technology is constructed and embedded (Gopalakrishan and Santoro, 2004).

Several literature reviews of TT research have been conducted to understand how the field has evolved and summarize the body of knowledge (e.g. Battistella et al. 2015; Noh and Lee 2017; Wahab et al. 2012a). Some of these structured literature reviews have been general (e.g., Geisler 1993; Hsieh et al. 2014), while others have focused on specific aspects of TT. For example, Wahab et al. (2009) focus on different models of TT, while Geuna and Muscio's (2009) work concentrates on TT channels from universities. Absorptive capacity also seems to be a relevant aspect of TT literature reviews, as several papers have a high number of citations (e.g., Zahra and George 2002; Lane et al. 2006). Other reviews focus on the critical factors of TT (Oliver et al. 2014) or leadership in organizations (Elkins and Keller 2003).

Despite the important contributions of these literature reviews, however, the picture of the topic they paint may be incomplete. As Zupic and Čater (2015) point out, traditional literature review methods are time-consuming and thus the number of works that can be analyzed is limited and prone to the researcher's biases. Hence, scholars have called for quantitative bibliometric methods to complement traditional qualitative reviews since bibliometrics can automate the document selection process for large databases and thus minimize any omissions or errors (Van Oorschot et al. 2018). Moreover, bibliometrics can be used to evaluate research performance using quantitative indicators based on data from selected bibliographic references (Cobo et al. 2015). Furthermore, combining these quantitative indicators with graphical visualization tools allows the researcher to identify how knowledge is shared by studies and authors, thereby helping address different orientations and the scope of a research field.

In the case of the TT literature and given its rapid growth in recent years, synthesizing the wide range of academic publications using a traditional literature review has become increasingly difficult. The academic production of TT research has resulted in a vast body of the literature, with more than 3,200 articles published to date. Hence, bibliometric analysis has often been chosen as the best method to review the TT field. This approach introduces a systematic and reproducible review process that permits the creation of a general overview of the research field (Baier-Fuentes et al. 2018) and improves the subsequent content review of papers (De Bellis 2009). As Schraven et al. (2015) indicate, bibliometrics complements extensive reading and a fine-grained narrative review rather than replaces it.

Previous bibliometric studies of TT center on either specific areas of research interest or a small number of publications or short periods of time. For example, the studies by Abramo et al. (2009), Teixeira and Mota (2012), Feng et al. (2015), Giunta et al. (2016), and Skute et al. (2017) focus only on university–industry collaborations. The studies by Volberda et al. (2010) and Apriliyanti and Alon (2017) emphasize the concept of absorptive capacity, while Schmitz et al. (2017) focus on academic entrepreneurship. The most complete bibliometric review of TT is Noh and Lee’s (2017) study, which analyzes academic production in this field from 1980 to 2015. They use the correlated topic modeling technique to analyze the titles and abstracts of all 120 articles in the Scopus database to identify research themes in TT and subsequently employ a co-authorship analysis to explore collaboration patterns among researchers.

The present study builds upon previous reviews of TT to show the main characteristics of this field, discuss the structure of collaborations among authors and its body of knowledge, and recommend avenues for future research. In this regard, the purpose of this study is threefold. The first objective is to perform a descriptive analysis of the TT literature, showing the growth of the field over time and offering useful information for measuring different aspects at both the micro (authors and journals) and the macro (institutions and countries) levels. The results include a general perspective of TT research to identify the number of publications per year, articles, journals, and scholars that have made relevant contributions to the development of the field as well as the institutions (and countries) with the highest productivity. The second objective is to identify the TT research community through a co-authorship analysis, assuming that the main outcome of scientific collaborations is the creation of new knowledge in the form of publications (Abbasi et al. 2011). On the basis of the results obtained from the co-authorship analysis, the third objective is to identify areas of interest and potential directions for future research by categorizing the research topics of papers according to the similarities of their themes (Braun and Clarke 2006). This results in the establishment of five main research streams and related topics, allowing us to speculate on future TT research. TT scientific production is analyzed from 1969 to the end of 2018 using the Web of Science (WoS) Core Collection as the bibliographic database.

The rest of this paper is organized as follows. The research methodology, source document selection, and software tools are explained in Section 2. The results of the performance analysis are detailed in Section 3. Section 4 presents the co-authorship network analysis of the TT field, while Section 5 presents and examines the thematic clusters deduced from the co-authorship analysis. Finally, Section 6 discusses the study's main considerations, limitations, and future research suggestions.

## 2 METHODOLOGY

### 2.1 Bibliometric research design

Bibliometrics, a part of scientometrics, uses mathematical and statistical methods to study and analyze bibliographical data from a quantitative perspective (Naseer and Mahmood 2009). It provides objective criteria for selecting, evaluating, and monitoring published research and therefore is increasingly valued as a tool for assessing scholarly quality, productivity, and influence in a subject (Moed et al. 1995). Bibliometric methods are not new but have become popular, with an increase in online databases containing bibliographic information with citations to the scientific literature, such as Clarivate Analytics' WoS database and Elsevier's Scopus database. The existence of freely available software tools developed by the academic community has also expanded the use of bibliometrics. These software tools allow us to handle and manipulate vast amounts of information to provide a broad view of a research field (Zupic and Čater 2015). Moreover, those analyses are complemented by the development of science mapping analysis, which is a graphical visualization combined with bibliometric analysis, using various techniques and units of analysis such as co-occurrence of keyword analysis, co-citation analysis, and co-authorship analysis (Gaviria-Marin et al. 2018).

There are two main methods of bibliometric analysis: performance analysis and science mapping (Cobo et al. 2011). Recent studies such as Baier-Fuentes et al. (2018) and Gaviria-Marin et al. (2018) recommend using both methods since they complement each other and offer a general overview of a research field. Performance analysis provides bibliometric indicators to measure the activity and impact of authors, journals, and institutions' contributions to research fields, among other elements. Science mapping through co-authorship analysis measures the degree of collaboration among the most productive authors, providing us with useful data for understanding the structure and dynamics of research fields (Murgado-Armenteros et al. 2015). Figure 1 shows our bibliometric research design, which combines these two methods based on Schmitz et al. (2017) and Cobo et al. (2012). Our aim is to give readers the possibility to replicate the execution process and apply it in other bibliometric reviews.

**Figure 1.**

**Research methodology**

### 2.2 Information retrieval

The protocol used to locate and retrieve bibliographic information was as follows:

A. <u>Choose the information source</u>. The first step in conducting a review study is to establish the database, which ensures that the sample of documents will be sufficiently extensive. In our study, information was collected from the WoS Core Collection database, the oldest and most widely known citation database, which indexes only the most relevant peer-reviewed academic journals. For example, its publication and citation data are used for the Academic Ranking of World Universities, also known as the Shanghai ranking, and the Times Higher Education World University Rankings. According to Clarivate Analytics, the WoS contains more than 20,300 journals, books, and conference proceedings.

B. Select the search terms. To identify bibliographic records in the WoS, the words that best describe the TT field were used as search terms. The specific queries enclosed in quotation marks used in the search were "technology transfer."

C. Define the search fields. Searches can be performed using 15 search fields in the WoS database. The *Topic* tab was chosen among these 15 search fields because it includes the sub-fields *Title*, *Summary*, *Keywords* of the author, and *Keywords Plus*®[1]. This means that published documents included in the WoS can be explicitly positioned for the *Topic* tab using "technology transfer" in the title, abstract, or keywords search fields.

D. Determine the restrictions and filters to be used. Restrictions must be used to ensure that the search results are as precise as possible by considering the following three filters:

(1) *Time span*. The search was finalized on April 14, 2019 and only documents published to December 31, 2018 indexed in the WoS Core Collection were included.

(2) *Type of document*. This study only considered articles and reviews.

(3) *Research domain*. The WoS has a well-specified set of research domains, which ensures the retrieved documents belong to disciplines related to the research topic: *Management*, *Business*, *Economics*, *Operations Research/Management Science*, *Development Studies*, and *Public Administration*.

E. Perform the search. The search process resulted in a dataset of 3,218 bibliographic references for articles and reviews.

F. Store the results. The search results were stored using SciMAT software to allow a complete analysis of the retrieved references' essential information (e.g., title, authors' names and affiliations, keywords, summary, and citations) to be performed.

G. Refine the search results. A filtering process is used to ensure accurate results (e.g., when references contain multiple versions of the same publication because of the use of several databases). This

[1] *Keywords Plus* is the result of Clarivate Analytics' editorial expertise. Its editors review the titles of all bibliographic references and highlight additional relevant keywords not listed by the authors or publishers, which results in more precise searches.

refinement was not necessary in this study because we used only one database (i.e., the WoS) to identify TT-based documents.

### 2.3 Data processing software

The Bibexcel (Persson et al. 2009), SciMAT (Cobo et al. 2012), and VOSviewer (Van Eck and Waltman 2010) software tools were used to perform the bibliometric analysis of the TT literature. Bibexcel is a versatile bibliometric tool that allows easy interaction with other software (e.g., Excel, SPSS, and Pajek), offering the user a high degree of flexibility for working with large datasets in both data management and analysis. The frequency of a variable's occurrence in the different fields of the dataset was determined and analyzed using Bibexcel. SciMAT can store all the information obtained in the dataset in an organized way. In this study, the relevant information included title, to correctly identify each article; authors, to perform the co-authorship analysis; authors' affiliations, to identify their organizations and countries; keywords and summary, to identify the research theme of each article; and citations, to evaluate the influence of the articles. Finally, VOSviewer is a powerful tool for science mapping, including co-authorship, co-citations, keyword co-occurrence, and bibliographic coupling. Based on the bibliographic dataset, VOSviewer software can define restrictions and automatically generate the desired science map, or the graphical representation of the concurrences among bibliographical elements.

## 3 BIBLIOMETRIC PERFORMANCE ANALYSIS

The bibliometric performance analysis presented in this section, based on these various bibliometric indicators, allowed us to identify patterns in authors, journals, articles, and institutional production. This then helped us understand the most relevant research in the field of TT based on different units of analysis and determine the research orientation.

### 3.1 Evolution of scientific production

The number of publications on a given topic can be considered to be a measure of scientific activity. The distribution of the 3,218 articles over time in Figure 2 reflects a clear trend in the development of published papers. The first article was published in 1969, and TT research has been growing steadily since. While the field is still in an early growth stage, it has been rapidly evolving with exponential growth in the number of academic publications in the field in recent years.

**Figure 2.**

**Yearly evolution of scientific production**

The chronological distribution of the 3,218 publications by year shows three stages of publications: an *initial period* from 1969 to 1990, with fewer than 20 publications per year; a *pre-expansion stage* from 1990 to 2005, during which the number of publications increased from 20 to 80 documents per year; and an *expansion stage* from 2005 to 2018, when TT research experienced exponential growth. These results indicate that TT is a contemporary discipline with great dynamism and continuous growth.

### 3.2 The most relevant journals

The relevance of journals, or how influential they are in the development of the TT field, was measured as a function of their productivity (the number of articles published in that journal) and number of citations. Table 1 includes the 25 most relevant journals in TT, detailing the number of articles, number of citations, average citations per article, and their Journal Citations Report (JCR) impact in 2018.

**Table 1.**

**Top 25 productive and influential journals**

The journals that have published the greatest number of TT papers were *Journal of Technology Transfer* (226), *Research Policy* (192), *International Journal of Technology Management* (147), and *Technovation* (145). Three of these journals have a strong technological innovation and transfer orientation as their names denote. Moreover, these journals emerged in the first period of TT development, when TT was not considered to be a research field, thereby contributing strongly to its development[2]. Later, while TT research was also being considered by the management and economics disciplines, the number of journals that published articles in this field proliferated. According to Table 1, a wide variety of journals from the business and management areas publish TT-based articles, indicating the importance of this subject and its ability to explain economic and business phenomena, behaviors, and relationships.

Another aspect used to identify the influence of journals is the number of citations published by each journal. According to Table 1, the most relevant journal, with 18,156 citations, is *Research Policy*, followed by *Organization Science* with 6,666 citations. Four journals have over 4,000 citations: *Technovation, Journal of Technology Transfer, Academy of Management Review*, and *Strategic Management Journal*. Most of these journals do not focus specifically on TT; therefore, the high frequency of citations could be the consequence of strong interest in this theme in the areas of business and management and the high cross- and interdisciplinary aspect that TT offers to other research fields.

### 3.3 The most relevant articles

Analyzing the most cited articles in a given discipline provides information about the academic literature that the research community considers to be the most relevant. Table 2 shows the 25 most influential articles on TT, including the number of citations and percentage of citations per year. Keep in mind that the articles retrieved from the bibliographic database are those published until December 31, 2018, whereas the number of citations depends on when the search of the database was performed. In this study, the information was retrieved on April 14, 2019; if a researcher repeats the same search, the articles retrieved would be the same but the number of citations would have increased.

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[2]The first issue of *Journal of Technology Transfer* was published in 1977. *Technovation* began in 1981 and *International Journal of Technology Management* in 1986.

Table 2 includes a group of five articles that each has more than 1,000 citations, most of which also have a higher number of citations per year, confirming their relevance and contribution to the development of TT research. The articles by Kogut and Zander (1992) with 5,057 citations, followed by Zahra and George (2002) and Hansen (1999), with 3,394 and 2,420 citations, respectively, are clearly the most influential papers.

**Table 2.**

**Top 25 cited articles**

It is also interesting to analyze which journals published these 25 most cited articles. As shown in Table 1, all of these are well-recognized journals, with high research impact, which is indicative of their quality. Nine of the 25 most cited articles were published in *Research Policy* (5.425 JCR), four in *Strategic Management Journal* (5.572 JCR), two in *Academy of Management Review* (8.855 JCR), and one each in *American Economic Review* (4.097 JCR), *Economic Journal* (2.926 JCR), *Industrial and Corporate Change* (1.824 JCR), *Journal of International Business Studies* (7.724 JCR), *Management Science* (4.219 JCR), *Organization Science* (3.257 JCR), *Review of Economics and Statistics* (3.636 JCR), and *World Bank Research Observer* (1.833 JCR). Thus, it can be assumed that the number of citations generated by these publications may be significantly related to the rankings of the journals in which they were published.

### 3.4 The most relevant authors

An author's number of publications in a given period is considered to indicate his/her scientific activity in a research field. In total, 5,106 distinct TT-related authors were identified, reflecting the dispersion of authorship. More than 81% of these authors published only one article on TT, which is common in relatively new research fields that have not yet reached maturity (Casillas and Acedo 2007). Of course, these authors have likely published other papers that were not included in the current study, as this dataset includes only TT-based articles.

Table 3 presents the complete picture of the most productive authors. Mike Wright, a well-known author with 35 TT-related published articles dominates the list; therefore, he may be considered to be one of the most influential in the field, strongly contributing to the growth of the academic literature on TT. The second most productive author is Donald Siegel, with 20 articles, followed by Clarysse and Saggy with 19.

**Table 3.**

**Top 25 prominent authors**

Table 3 also presents the most influential authors based on the number of citations of their TT-based articles, since citations imply the influence of research efforts in a field. Most of them have received more than 1,000 citations. If we consider an author's relevance to be a function of his/her number of citations, the most relevant authors are Udo Zander and Bruce Kogut with 5,124 and 5,099 citations, respectively.

One interesting fact is that Kogut and Zander (1992) stand out from the rest of the authors in the number of citations (5,057) with just one article titled "*Knowledge of the firm, combinative capabilities, and the replication of technology*." Without doubt, this is one of the most relevant articles in the field of TT and the authors can be considered to be two of its most relevant (although they are not the most productive ones). The relevance of Shaker Zahra and Gerard George in the TT literature should also be stressed, as their article "*Absorptive capacity: A review, reconceptualization, and extension*" (Zahra and George 2002) has 3,394 citations.

### 3.5 The most popular keywords

Keywords are fundamental in any literature review since they are used to catalogue and index documents, and consequently to find documents and related issues. In addition, the identification of keywords indicates the descriptors used by authors that work in a field, a clue for exploring potential research interests and directions. Hence, keywords serve as a first approximation to reveal the knowledge structure of a research area (Chen and Xiao 2016).

The keyword analysis in this study included searching the title, summary, list of the keywords of authors, and keywords plus® in all bibliographic references in our dataset. Since there is no standardized glossary of keywords, the authors of an article select a set of keywords using their best knowledge; this is the likely reason there were 6,837 keywords in the dataset. To streamline this large amount of data, only those keywords that appeared in more than 10 articles were considered, reducing the number of keywords to 374 terms[3]. Table 4 lists the 25 most popular keywords by number of appearances.

**Table 4.**

**Top 25 popular keywords**

The most relevant keywords are related to the themes of *knowledge and technology development* (technology, knowledge, science, innovation, research and development, TT, knowledge transfer, absorptive capacity, policy, model, university, intellectual property, academic entrepreneurship), *economic development* (performance, growth, productivity, spillovers, commercialization), *firms* (firms, industry, entrepreneurship), and *international trade* (foreign direct investment, trade, China, developing countries). This may be because TT falls within the scope of business and management areas and is closely related to the economic impact of TT in organizations.

### 3.6 The most relevant contributing organizations

The affiliations of all authors were extracted from the bibliographic references in our dataset to analyze the production of universities and institutions in the TT research field. Table 5 shows the top performing organizations as well as their number of articles and citations.

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[3] This list is available to readers upon request.

**Table 5.**

**Top 25 contributing organizations**

The results reveal that the most productive organization in TT-related research (based on the number of papers) is the University of Nottingham with 65 articles. This university ranks second on the list of universities with the most citations. The citation count reveals that universities whose TT papers have more than 3,000 citations include the Stockholm School of Economics (6,589 citations), the University of Nottingham (5,241 citations), the University of Wisconsin (4,098 citations), Harvard University (3,767 citations), and Georgia State University (3,485 citations). It is obvious that these results depend on which organization employs the authors and to what extent they are involved in interorganizational co-authorships. The top 25 organizations all come from developed countries. As Frame (1979) asserts, it is logical to expect research outcomes for developed countries to be higher than those from developing ones because of the latter's limited access to physical, monetary, and human capital resources. As shown in Table 5, all the most prolific contributors to the development of the TT research field come from European and US universities.

## 4 CO-AUTHORSHIP NETWORK STRUCTURE

Performance indicators provide a general overview of the various dimensions of the TT research field and offer an up-to-date synthesis of the TT literature. However, they do not allow us to display the structure of the field. For this purpose, bibliometrics uses science maps to describe how specific disciplines or research fields are conceptually, intellectually, and socially structured (Cobo et al. 2011), providing a spatial representation of how different units of analysis (e.g., authors, documents, journals, and words) are related to one another (Small 1999).

In this study, co-authorship network analysis was chosen to organize the documents of the dataset in concordance with the similarities and relationships between bibliographical elements. Co-authorship analysis connects documents and authors when authors jointly publish documents. For example, when author A publishes jointly with author B and author B publishes with author C, authors A, B, and C are involved in a network. The greater the number of articles they publish together, the stronger their relationship is. Thus, a co-authorship network provides information on how fragmented or cohesive a knowledge community is, who are the best connected authors in that network, and who are the prestigious authors (Kumar 2015). Furthermore, the analysis of co-authorship clusters can identify the research topics in which groups of authors are involved (Abbasi et al. 2011; Murgado-Armenteros et al. 2015). Indeed, co-authorship analysis is used to determine thematic similarities among those colleagues (Melin and Persson 1996).

Given the large amount of data in our dataset of 3,218 documents, 5,106 authors, and 6,837 keywords, an exhaustive analysis of all possible co-authorship clusters was practically impossible. To enable a practical and accurate analysis given the time limitations, the criteria used to consider a co-authorship network were hardened without altering the essence of its main elements. To do this, VOSviewer software can choose a minimum number of citations per author to filter the elements to be considered in the analysis[4]. In the present study, to ensure the presence of a real co-authorship network, we set the following criteria: each author involved in a network should have at least 100 citations related to TT articles and each cluster should have a minimum of four authors. As a result of these criteria, 30 co-authorship clusters were identified. In particular, applying this high relationship threshold meant that only stable and consolidated collaborations were obtained. Table 6 lists the main authors in each co-authorship cluster[5].

**Table 6.**

**Authors in co-authorship clusters**

Visualization forms an important component of network analysis. Distinct research elements can be analyzed by visualizing networks through graphic mapping, where the size of the sphere varies according to the importance of the elements, the network connections represent the closeness of the link between elements, and the circle colors and their location in the graphic allows elements to be clustered (Baier-Fuentes et al. 2018). Figure 3 shows a visual representation of the 30 co-authorship networks, where the nodes represent the authors connected when they share the authorship of articles. Many of the most productive and influential authors occupy a prominent position in the networks in which they participate, as they maintain a higher degree of interconnectedness.

**Figure 3.**

**Co-authorship network in the TT research field**

## 5 RESEARCH STREAMS RESULTING FROM CO-AUTHORSHIP NETWORKS

The content of the literature included in each of the 30 co-authorship networks was analyzed to identify thematic similarities among these TT researchers and thus categorize information into themes according to those similarities (Braun and Clarke 2006; Melin and Persson 1996). The process of identifying and grouping similar themes in which each cluster of authors researched was based on Braun and Clarke's (2006) work. Thus, the primary task was to review each co-authorship network's main documents, where articles were examined to determine similar research topics. In many cases, they were easily identified by simply analyzing the title, abstract, and keywords. In other cases, an in-depth analysis of the articles was required to identify their scope. The first iteration resulted in a pool of topics that were subsequently

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[4] As the number of citations increase over an established threshold of citations, the network decreases and thereby the number of clusters and related articles in each cluster also fall. Notwithstanding this reduction, the main clusters remain but with fewer authors and articles in each of them.

[5] A complete list of authors can be made available upon request.

refined and synthesized. The iterations continued to sort and group topics with a similar research scope, thereby eliminating thematic redundancy and ensuring internal consistency[6]. Bear in mind that a co-authorship cluster can research several topics and a topic can be studied in several co-authorship clusters. Thus, once the grouping and categorizing of themes was completed, the names of the resulting groups were revised by assigning a name to each group of topics based on the most used keywords previously identified in the TT field.

Finally, this iterative process of grouping and categorizing research topics based on the information in the articles in the 30 co-authorship networks allowed us to identify the main TT research streams. In a thematic group several research themes were assigned as secondary topics. Hence, owing to the relevance and large number of research topics addressed, it was convenient to subdivide certain research themes. The results of this process allowed us to identify five main research streams and related topics: (1) *university TT* (*academic entrepreneurship, intellectual property, new ventures, technology transfer offices, university–industry relationship*), (2) *international TT*, (3) *intra-firm TT*, (4) *absorptive capacity*, and (5) *public innovation policies.*

Table 7 presents the number of articles and authors in the co-authorship networks falling under each research stream. This allows us to display the degree of specialization of each group of authors in relation to the research streams.

**Table 7.**

**TT research streams resulting from co-authorship networks**

To confirm the coherence of the thematic groups and consequently of the research streams and related topics, the main documents were read comprehensively. This reading also provided a more complete understanding of those topics and allowed us to identify research interests and potential directions for future research. The following is an interpretation and discussion of the thematic streams from the co-authorship network clusters based on reading and interpreting the bibliographic information on each of the five main research streams and topics.

### 5.1 University TT

The engagement of universities with their socioeconomic context, referred to as the "third mission" (where teaching and research are the first two missions), has generated significant relevance, specifically in the context of the knowledge society. As Etzkowitz and Leydesdorff (2000) assert, the university is not only a source of new knowledge and human capital, but also a source of many innovations and new firms. Hence, besides generating and transmitting knowledge, universities also need to put it to use and interact

[6] For instance, in the thematic group identified as *international TT*, two close topics were identified: *international joint venture* and *mergers and acquisitions.* These subjects were finally renamed under a single sub-topic called *international joint venture*.

closely with industry to maintain socioeconomic development (Rothaermel et al. 2007; Schmitz et al. 2017). Given the changing role of universities in recent years, the research topic of university TT has become one of the most studied in the TT literature; indeed, 18 of the 30 co-authorship clusters have dealt with this subject from different perspectives. This stream of the research focuses on university entrepreneurship, university policies on TT, the various channels through which technology and knowledge are transferred from university to industry or society in general, how different transfer mechanisms can be improved, and the specialized structures established by universities to support TT. As indicated above, five specific research topics were identified: *academic entrepreneurship*, *new ventures*, *intellectual property*, *technology transfer offices (TTOs)*, and *university–industry relationship*.

### 5.1.1 Academic entrepreneurship

Based on the view that universities should have an entrepreneurial mission beyond teaching and basic research, academic entrepreneurship can be understood as the efforts undertaken by academics to link their work more closely to economic needs and set up business ventures (Grimaldi et al. 2011; Martin 2012; Schmitz et al. 2017). Specifically, this topic of research determines which actors are involved in academic entrepreneurship. Among these are faculty members, postdoctoral fellows, students, and alumni, along with other agents acting as technology managers or supporters and those necessary to promote academic entrepreneurship (Siegel and Wright 2015). Studies that analyze the roles of academics in the establishment of entrepreneurial activities at universities fall into this research topic.

This strand of the literature also focuses on analyzing the characteristics, motivations, and entrepreneurial capabilities of academic entrepreneurs (D'Este and Perkmann 2011) as well as the incentives to carry out a new venture since they are critical components of entrepreneurial success (Bercovitz and Feldman 2008). Studies show that academic entrepreneurs are motivated by a plurality of factors including financial incentives, peer recognition, the provision of funding for research groups and their universities, and problem solving or acting in the public interest. In this regard, we highlight the contributions of Etzkowitz (1998, 2000, 2004), Etzkowitz and Leydesdorff (2000), Hayter (2015), Lam (2011), Perkmann et al. (2013), and Rizzo (2015), among others. Some authors have also focused on examining academic entrepreneurship collectively, investigating how in some universities a series of research groups operates as "quasi-firms," their entrepreneurial motivations and behaviors, and their influence on the university's entrepreneurial culture (e.g., Etzkowitz 2003; Ranga et al. 2003).

This research topic has been studied by authors belonging to co-authorship clusters 1, 2, 3, 4, 5, 7, 8, 10, 12, 14, 16, 19, and 24.

### 5.1.2 New ventures

The increased significance of start-ups by current or former university academics, students, and alumni is one indicator of an emerging perspective on university entrepreneurship. The articles included in this topic focus on the determinants, motivations, and incentives of both universities and academics to create new firms as well as on the critical factors for their success (e.g., O'Shea et al. 2005). Among the various channels available for facilitating TT, the commercialization of academic knowledge through the establishment of spin-offs has attracted major attention within the literature. University spin-offs are, according to Pirnay et al. (2003), new firms created to exploit commercially some of the knowledge, technology, or research results developed within a university, which may or may not have to be formalized. Spin-offs enable the tacit knowledge of academics, which is otherwise difficult to transfer, to be transferred straight into a new firm. In this regard, academic entrepreneurs play an important role in founding and developing university spin-offs. As indicated previously, the analysis of their characteristics, motivations, and commercial skills to create viable ventures has been a recurring theme in the TT literature (e.g., Hayter 2016; Mustar et al. 2006).

The spin-off phenomenon, with a few exceptions such as MIT and Stanford University, is relatively new for the majority of universities, especially in Europe (Djokovic and Souitaris 2008). Indeed, research on their formation, knowledge inheritance, and performance is scant (Agarwal et al. 2004). Moreover, it is a complex phenomenon because of the number and diversity of parties involved and conflicts of interest that arise as a result of their interdependence (Birley 2002). For example, Roberts and Malonet (1996) developed five alternative structural 'models' for formal efforts aimed at spinning off new companies from universities, government laboratories, and other research and development organizations combining the roles of the technology originator, the entrepreneur, the R&D organization itself, and the venture investor. Likewise, Clarysse et al. (2005) identify three types of spin-out models which differ not only in terms of the amount of resources, but also in the kind of resources required. Mustar et al. (2006) point out that the development of strategies to aid spin-offs should be tailored to the specific needs of the spin-off and the institution from which they emerge. Therefore, the increase in the number of studies that analyze this issue from different points of view and units of analysis (e.g., firm level, university level, and academic entrepreneur level) is no surprise (e.g., Lockett and Wright 2005; Rothaermel et al. 2007).

Capturing and measuring the outcomes, outputs, and impacts of academic spin-offs has been another area of study. Scholars have used several measures to proxy spin-off success, from the most traditional variables (e.g., financial performance, sales growth, sales per employee, formal intellectual property) to the most contemporary ones (e.g., employment, technology commercialization). As Siegel and Wright (2015) assert, the traditional vision of new ventures has recently evolved toward new modes of academic entrepreneurship such as social ventures and commercial start-ups launched by students and alumni as well as the transfer of knowledge to existing businesses. In particular, see the work carried out by Agarwal et al. (2004) and Hayter (2015) among others. Other works have analyzed what is more influential: the specific characteristics of regional innovation systems in which start-up/spin-off ventures emerge and compete, the importance of the space and place in which the research activity is developed, or public programs and university policies to support university spin-offs and promote entrepreneurial ventures, among other factors. Highlighted here are the works of Di Gregorio and Shane (2003), Lockett et al. (2005), Rothaermel et al. (2007), Perkmann and Walsh (2007), Walter et al. (2006), and Wright et al. (2006).

In particular, new business ventures from universities have been studied in clusters 1, 2, 3, 4, 7, 11, 26, 28, and 29.

### 5.1.3 Intellectual property

Among the indicators that can be used to assess the contributions of universities to local and regional development, patenting and licensing have been particularly interesting to scholars. Several articles included in this topic explore the degree to which patents are representative of TT (e.g., Agrawal and Henderson 2002). Others identify the forces that drive university engagement in the commercialization of technology as well as the factors affecting TT and its commercialization at universities, with a focus on the commercialization programs and practices used by universities (e.g., Siegel et al. 2004; Siegel et al. 2007).

Numerous studies have also examined the potential benefits and effects of different incentives to patent as well as the best mechanisms used to license them (e.g., Geuna and Nesta 2006). The attitudes and motivations toward the patenting and licensing of academic inventors are also analyzed by the TT literature (e.g., Balconi et al. 2004). The term "Bayh-Dole Act of 1980" appears several times in articles related to intellectual property policies in the United States. This law changed the ownership of the inventions created through research financed by federal funds from the government to universities, permitting US institutions to patent federally funded research results. Various studies have also tried to establish a relationship between government policies and patent creation (e.g., Grimaldi et al. 2011; Mowery et al. 2001; Mowery et al. 2002; Sampat 2006).

This topic is mainly found in co-authorship clusters 1, 3, 8, 10, 11, 14, 16, 20, 21, and 26.

### 5.1.4 University–industry relationships

The current debate on university entrepreneurship has extended the focus of its activities, adding more to economic growth than present TT indicators traditionally focused on the transfer of intellectual property. Besides the mechanisms already mentioned, there are other alternatives to consider for university–industry TT such as collaborative research, sponsored and contract research, consulting, testing, training, and formal/informal relationships (e.g., D'Este and Patel, 2007; Perkmann et al. 2013; Siegel and Wright 2015). For example, Klofsten and Jones-Evans (2000) find considerable entrepreneurial experience among academics, which translates into a high degree of involvement in informal intellectual property such as consultancy and contract research, but not into organizational creation via technology spin-offs. Likewise, D'Este and Patel (2007) identify consultancy and contract research, joint research, and training as the main channels through which academics interact with industry compared with patenting and spin-off activities. All these activities are outside the normal university duties of basic research and teaching that function as social pathways through which information, knowledge, and other resources are exchanged or co-produced across universities and industry (Perkmann and Walsh 2007; Wright et al. 2008), which brings about financial and non-financial rewards for the individual and/or his/her organization (Abreu and Grinevich 2013).

The TT literature acknowledges that these rewards are more difficult to measure than, for example, publications, patents, licenses, and start-ups/spin-offs (e.g., Nilsson et al. 2010). As Abreu and Grivenich (2013) point out, they can occur directly or indirectly through an increase in reputation, prestige, influence, or societal benefits. Hence, there has been some attempt to show outputs that do not come through the formal route of TTOs, which is where data on transfers are usually recorded. Indeed, Agrawal and Henderson's (2002) work shows that patenting is a minority activity, even at MIT.

The identification of the main barriers to collaborations between universities and industry and the ways to reduce those barriers has been another research topic (Bruneel et al. 2010). In general, most of the articles included in this topic focus on the critical factors of university–industry collaborations from the perspective of universities and research institutions as opposed to those that analyze the relationship from the industry perspective.

This topic has been studied in co-authorship clusters 1, 4, 6, 10, 11, 16, 20, 21, and 26 to find the critical factors that can increase engagement and improve the efficiency of this relationship.

#### 5.1.5 TTOs

The growing attention paid by universities to patenting and licensing activities has been paired with different actions to promote and implement TT, where TTOs are crucial since they facilitate technological diffusion through the licensing to industry of the inventions or intellectual property resulting from university research (Siegel et al. 2003; Siegel et al. 2004).

The articles classified under this topic deal mostly with the creation, organization, and characteristics of TTs and their effect on the transfer of knowledge and technology from universities (e.g., Mowery et al. 2001; Siegel et al. 2007; Lockett et al. 2005). Indeed, most studies analyze the productivity impact and critical factors that influence the effectiveness of TTOs (e.g., Chappel et al. 2005). As Markman et al. (2005) point out, the need to organize the process of accelerating technology spillover and innovation in universities is often a principal driver behind the establishment of TTOs and other transfer structures (e.g., science parks and incubators).

In general, the literature shows significant differences in the performances of TTOs depending on whether they use activity-based or income-based metrics (Lockett et al. 2014; Siegel et al. 2003). Further, the experience and size of TTOs are two of the most important success factors (Chapple et al. 2005; Lockett and Wright 2005; Siegel and Wright 2015). Having a supportive environment in which these structures operate is important for the success of TT; however, their performance also depends on organizational aspects and the proactive role of universities in TT (Siegel et al. 2003). Other critical factors for the success of TTOs are universities' incentive systems, the compensation practices for those who work in TTOs, and the cultural barriers between universities and firms (Siegel et al. 2004; Siegel et al. 2007).

This research topic has been studied by the authors in clusters 1, 2, 6, 12, 14, and 16.

### 5.2 International TT

This research topic is the second most relevant one in the TT research area in terms of the number of co-authorship clusters involved. Indeed, how technology flows across borders has a great economic impact in firms and countries (Aitken and Harrison 1999), and it has attracted considerable interest from the research community. This research stream focuses on different issues related to foreign direct investment and how technology is transferred across borders between headquarters and subsidiaries. In the 1990s, foreign direct investment became the largest source of external funding for developing countries (Aitken and Harrison 1999). Hence, it is interesting to note that most relevant articles on this topic were published around 2000 in the context of economic globalization.

Notable studies include Rugman and Verbeke’s (2001) work that presents a framework for synthesizing several types of multinational enterprise–subsidiary linkages leading to capability development as well as the article of Madhock (1997), which compares and contrasts the mode of foreign market entry decision from the cost and value perspectives in the management of know-how. There is also some evidence in the TT literature of spillover benefits to domestic firms (e.g., Görg and Greenaway 2004; Moran 2001) and how some countries offer incentives to foreign enterprises in the belief that foreign investment generates externalities in the form of TT (Aitken and Harrison 1999). Blomström and Sjöholm's (1999) work shows that foreign enterprises maintain high levels of labor productivity and that domestic enterprises benefit from spillovers. Likewise, Bresman et al. (1999) conclude that the immediate post-acquisition period is characterized by imposed one-way transfers of knowledge from the acquirer to the acquired; however, this gives way to high-quality reciprocal knowledge transfer over time. Mowery et al. (1996) analyze the effects of alliance activity on inter-firm knowledge and TT, finding that equity joint ventures are more effective conduits for the transfer of complex capabilities than contract-based alliances.

Other works included in this research area examine the role played by trade in international TT, if the technologies introduced by multinational firms are diffused to local firms, and successful policies for encouraging the absorption of technology from abroad (Saggi 2002). In this regard, Archibugi and Pietrobelli (2003) argue that TT has to be assessed jointly with a country's capability to make use of technology, absorb it and adapt it to local conditions since the access to and acquisition of foreign technology, by itself, is not sufficient to ensure local technological and industrial development.

This research stream has been developed by authors belonging to co-authorship clusters 6, 9, 13, 15, 17, and 28.

### 5.3 Intra-firm TT

All firms, but especially large ones, try to transfer the critical technology, knowledge and best practices generated in one division of the firm to other divisions to improve their efficiency and competitiveness (Mowery et al. 1996), leading to interest from the TT literature in studying this research topic. Papers focused on this research stream have tried to analyze how TT can be transferred either among units of a firm or between partners of joint ventures and alliances, which leads a range of complex issues that managers must deal with (Malik 2002; Szulanski, 1996). However, when studying these relationships, it is also important to distinguish between simple techniques and higher-level technological capabilities (Kobate et al. 2003).

Papers included in this research stream have also focused on the difficulties in providing adequate intra-firm TT. Following Szulanski (1996), issues that hamper transfer efforts may include the lack of the absorptive capacity of knowledge recipients, lack of formalized structures and systems, and distant relationships between transfer partners. The transfer process not only involves cooperation, communication, and learning among firms (Teece 1977), but also requires the support of other intangible factors such as infrastructure, organizational culture, and absorptive capacity (Lin et al. 2002). Therefore, some papers have analyzed the influence of cultural and language barriers in TT process (e.g., Cui et al. 2006). Since TT is a collaborative process in which all involved parties have a decisive influence on the result, it is not surprising that social capital and absorptive capacity are closely linked to intra-firm TT, according to the works of Battistella et al. (2015), and Mowery et al. (1996), among others.

This research topic has been studied by authors belonging to co-authorship clusters 21, 23, and 25.

### 5.4 Absorptive capacity

This research stream is also of great interest from the academic community. The concept of absorptive capacity was introduced by Cohen and Levinthal (1990), who define it as a firm’s ability to recognize, assimilate, and apply external knowledge and learning processes (see also Lane et al. 2006). Absorptive capacity does not only depend on the firm’s direct interface with the external environment; it also depends on transfers of knowledge across and within firms. As mentioned before, this topic is strongly linked to inter- and intra-firm TT research.

According to Zahra and George (2002), absorptive capacity involves not only the transmission of knowledge, but also the learning process of technological knowledge that is continually assimilated into the human capital of firms. Thus, a firm may successfully assimilate external knowledge, but may face problems in exploiting that assimilated knowledge. Therefore, articles on this topic have focused on understanding the different factors that influence firms’ absorptive capacity, when and how it can be considered to be a source of competitive advantage (Zahra and George 2002), and the importance of absorptive capacity for improving performance (e.g., Cohen and Levinthal 1990; Mowery et al. 1996; Murovec and Prodan 2009).

Following Kogut and Zander (1992), absorptive capacity can be used to explain organizational phenomena and how the culture and internal knowledge of organizations can enable or hamper their capacity to assimilate new knowledge. In this regard, Bierley III et al.’s (2009) work suggests the need to examine organizational conditions that facilitate the application of technology and knowledge transferred. Hence the concept of absorptive capacity can also be seen at an inter-firm level (Tsai 2001). There is also an important link between TT and open innovation, where the results show that the openness of the innovation process forces firms lacking absorptive capacity to search for different ways to engage in open innovation (Spithoven et al. 2010) The concept of the internal stickiness of knowledge transfers is also a relevant issue developed together with absorptive capacity in the TT literature (e.g., Blackman and Benson 2012; Szulanski 1996, 2000; Szulanski et al. 2016).

This topic has been studied in co-authorship clusters 12 and 16.

### 5.5 Public innovation policies

Innovation systems and the role they play in generating new knowledge are the focus of papers included in this research area. Papers also consider the relationship between regional/national systems of innovation and institutional frameworks as well as how those innovation systems support knowledge generation agents with the aim of being more competitive (Freeman 1989). The contributions should be noted of Rothwell and Dodgson (1992), who map trends in public policies in Europe to stimulate industrial technological change from the largely uncoordinated "science policies" and "industrial policies" of the 1960s to the more integrated "innovation policies" of the 1970, and to the collaborative pre-competitive research-based "technology policies" of the 1980s. In the same vein, Bozeman (1994) describes the history of US technology policy focusing on the cooperative technology development paradigm in the 1990s. Grimaldi et al.'s (2011) work is also notable. They discuss and appraise the effects of legislative reform in several OECD countries relating to academic entrepreneurship.

Similarly, the papers included in this research streams present different ways of evaluating innovation systems, identifying good practices, and recommending their adaptation to specific environments (e.g., Bozeman 2000; Siegel et al. 2007; Griffith et al. 2004; Colyvas and Powell, 2006). The effectiveness and impact of public policies have been assessed by distinct channels, including market impacts, political impacts, impacts on personnel, and impacts on available resources (Balzat and Hanusch 2004). The literature has also reported different programs coordinated by regional/national bodies to promote and stimulate innovation and TT as well as supporting the utilization of scientific and technological research results (Lundvall et al. 2002).

This is not an extensive research topic, but it includes relevant articles and authors. In particular, this topic has been studied in co-authorship clusters 3, 7, 8, 10, 11, 18, and 30.

To conclude this section, Table 8 summarizes the five top-ranked articles in each research stream and related topics[7].

**Table 8**

**Top five cited articles included in each research stream**

## 6 CONCLUDING REMARKS

Given the substantial increase in the number of studies published on TT, periodic literature reviews are necessary to recompile and synthesize the topics studied within this research field. In this regard, this bibliometric study provides evidence of how TT has developed since 1969—when the first article was published—and posits some research trends on the future development of TT. To achieve this aim, performance and co-authorship analyses were conducted on a dataset of 3,218 bibliographic references and the main TT literature was reviewed, from which several conclusions can be drawn, allowing us to speculate on future TT research.

[7] A complete list of the articles included in each research stream and topic can be made available upon request.

The performance analysis identified the most relevant elements of the TT research field in terms of influential and prolific papers, journals, authors, and organizations. TT is constantly growing with specialized journals as well as relevant articles in peer-reviewed journals across several disciplines. The distribution of TT production is scattered among many authors, too. Similarly, there is a need for the unification of concepts and integration of terminology on TT, indicating that academic and public interest in TT is growing at a fast pace and has not yet reached maturity. This is certainly a welcome development, since not long ago research on TT was scarce.

Using a co-authorship analysis, a proxy of research collaboration, we identified 30 groups of four or more authors whose TT papers have at least 100 citations to identify academic communities and their leaders. Moreover, given that co-authors cannot write a paper together unless a degree of acquaintance exists between them, co-authorship network analysis was the starting point for a further content analysis. Finally, five research streams and important topics were identified: (1) *university TT* (*academic entrepreneurship*, *intellectual property*, *new ventures*, *TTOs*, and *university–industry relationship*), (2) *international TT*, (3) *intra-firm TT*, (4) *absorptive capacity*, and (5) *public innovation policies*.

Taking a wider perspective of the TT field, we found that the literature covers an array of topics and has been studied from diverse angles, particularly from an economics perspective. Most research efforts have focused on the analysis of and search for new and more efficient ways of transferring knowledge and technology in different links of the knowledge chain. The human and organizational aspects of TT, critical factors (facilitators and barriers) that promote or inhibit efficient TT, and absorptive capacity have also been widely studied. Considering the different agents involved in TT (transferors and transferees), most papers have concentrated on studying how knowledge and technology are transferred within large enterprises, mostly multinationals, or from university to industry.

If we assume that we are immersed in a knowledge-based economy which is rooted in production, distribution and use of knowledge, technology and information, new TT mechanisms that support and facilitate new scientific and technological knowledge, innovation activities and entrepreneurship require a more thorough analysis. As several scholars point out (e.g. Feldman et al. 2002; Leyden et al. 2008; Siegel and Wessner, 2012), in response to the rapid changes occurring in the world, the focus of TT literature has also evolved in recent years so that there is a greater focus on new ventures and TT mechanisms through property-based institutions designed to promote technological entrepreneurship, such as incubators, accelerators and science/technology parks, among others. We recommend extending research to other aspects of collaborative TT with different units of analysis and perspectives to enhance our understanding of the TT phenomenon.

Although ~~this~~ TT is a bidirectional process, limited attention has been paid to detecting the difficulties and efforts in an effective university–industry relationship from the perspective of firms. It would be interesting to explore what technology and knowledge are required by firms from universities and research institutions and how these institutions meet or could meet these needs without losing their independence.

Overall, we know little about the effect of TT from industry's side and even less from the perspective of small and medium-sized enterprises (SMEs). As an example, if we analyze all the keywords related to SMEs, only 46 articles (1.4%) mention them. However, the vast majority of active firms are SMEs, which play an important role in the economy in terms of production, employment generation, and contribution to and distribution of wealth. From our perspective, there is a need for further studies that examine the role and behaviors of SMEs in the TT process. As Feldman et al. (2002) assert, despite many small firms do not conduct R&D, they can be very innovative and relatively more adept at absorbing knowledge from external sources, such us universities comparing to large firms. It would also be interesting to explore whether the results of TT research can be supported in the context of SMEs or if they exhibit differences in the TT process compared with large firms. In many cases the impediments to effective TT can be due to cultural and informational barriers between universities and firms, especially for small firms.

Related to TTOs, more research is needed to fully understand other mechanisms of TT. It would also be interesting to analyze the impact of academic entrepreneurship beyond patenting and licensing activities or the creation of new ventures. These more informal activities and initiatives may require new structures or management systems to implement them. Further research should aim to advance the study of other mechanisms to monitor TT apart from TTOs. The role of incubators, science/technology parks as a place for facilitating university–industry interaction and hence stimulating TT, should be analyzed more in depth. Thus, for example, Leyden et al. (2008) highlight the need for more theoretical and empirical evidence of the firm-level decision to locate on a science/technology park. Siegel and Wessner (2012) also point out that there is a need for more empirical research on the contribution that incubators play in enhancing the success of entrepreneurial ventures (e.g. university-based spin-outs and start-up firms). Science/technology parks and incubator are platforms facilitating university-industry collaborations which contribute towards the creation of a supportive environment for the processes of innovation, technology/knowledge transfer and entrepreneurship.

In addition to the quantitative rewards used by TTOs for monitoring TT activities, mixed-methods analysis (i.e., qualitative and quantitative evaluations) are recommended, since context is important for understanding TT. Researchers should also consider developing longitudinal datasets to compare and analyze the evolution of the identified indicators. Moving forward, research should take a perspective that acknowledges the complexities associated with the TT process to capture and measure its impact with a clear identification of the outcomes and outputs.

Moreover, the challenges associated with the digital transformation of society should be studied, since digitalization and connectedness have implications for technological and knowledge transfer. The literature often focuses on the characteristics and capabilities of entrepreneurs; however, in the near future, the connection between Industry 4.0 and Internet technology is likely to require the analysis of new skills and characteristics. These features are especially important now, where globalization and digital transformation require identifying the sources of differentiation to maintain a sustainable position in the global market.

Our review tried to clarify and provide a framework that summarizes the extant TT knowledge. The current topics and suggestions for future research show that TT continues to be a hot topic in academic research. We hope our review offers new opportunities to advance the understanding of TT, and we look forward to having a deeper understanding of the issue in the future.

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**FIGURES**

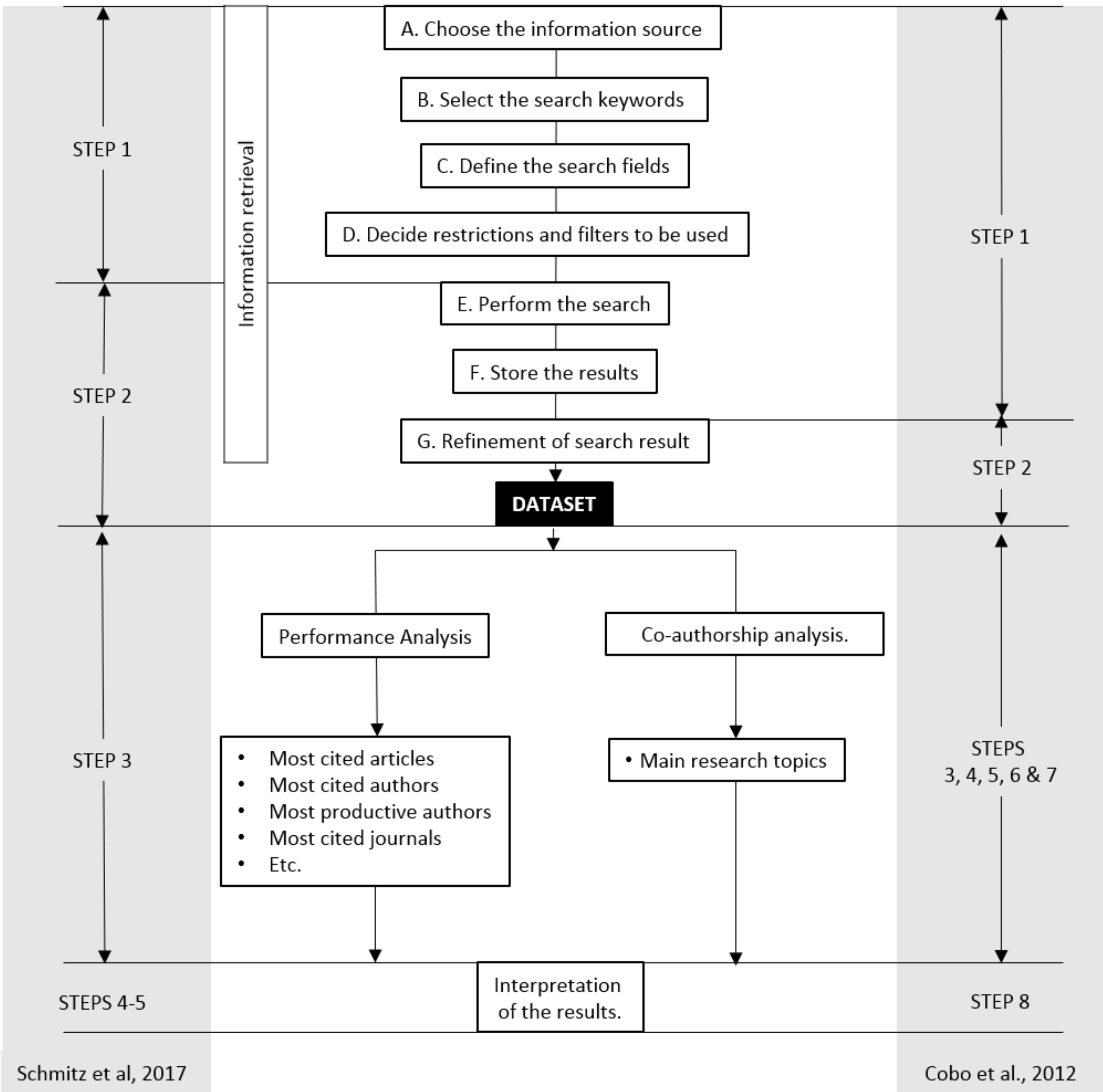



**Figure 1. Research methodology**

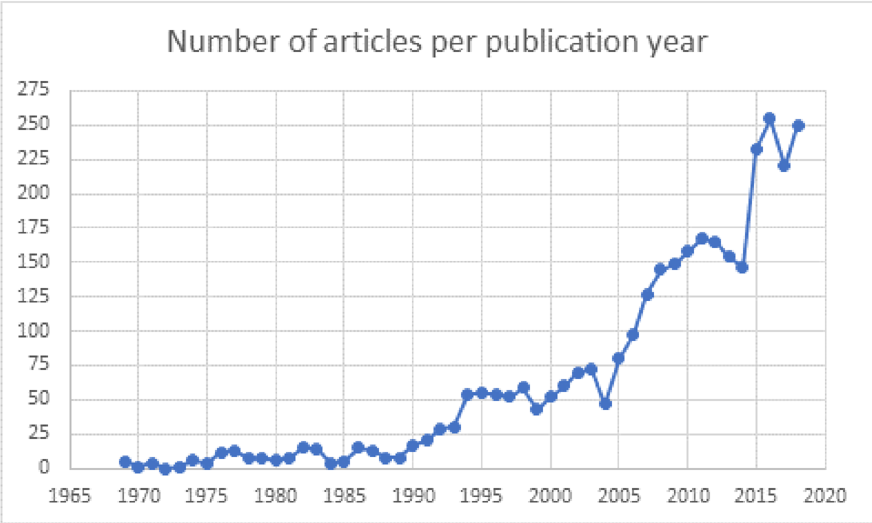
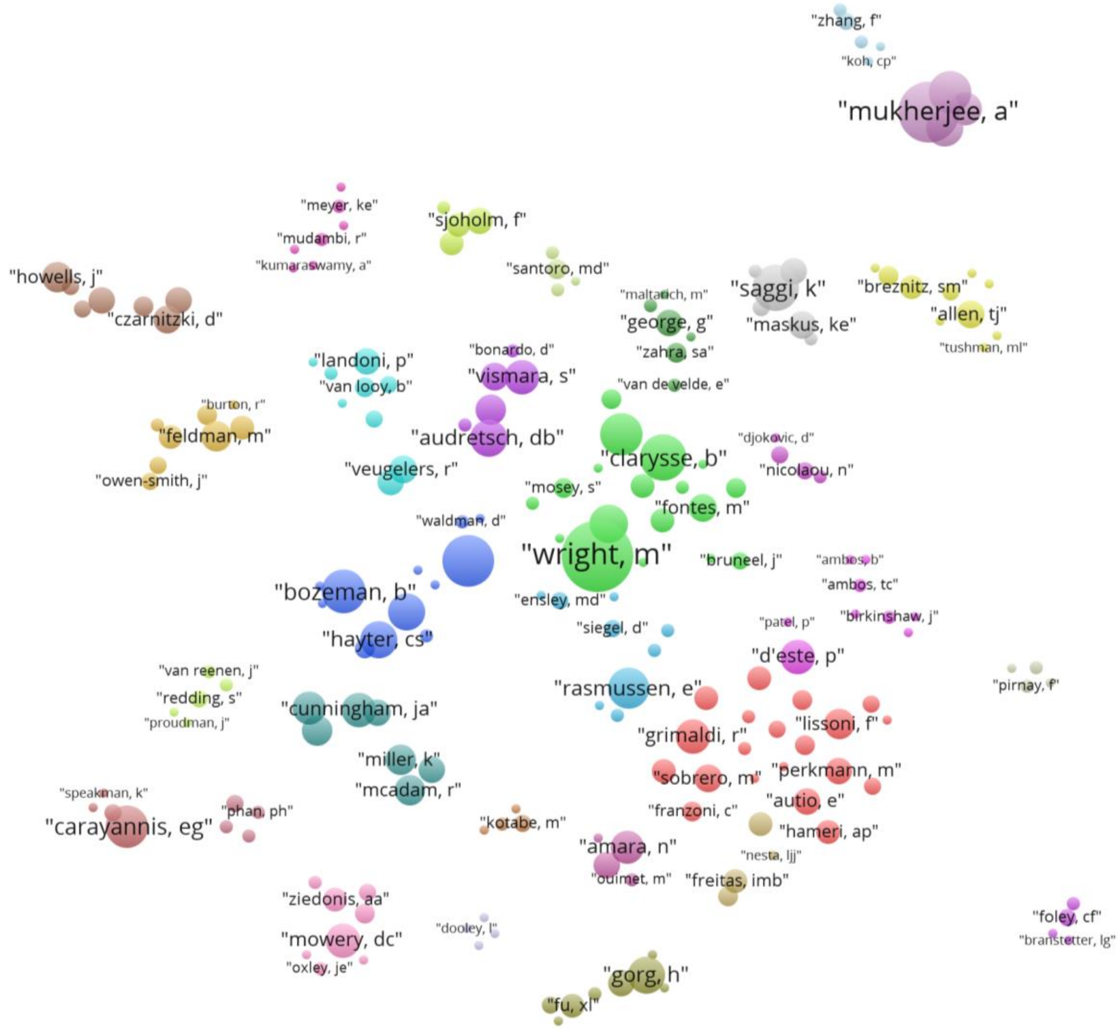



**Figure 2. Yearly evolution of scientific production**




The size of the spheres is proportional to the total number of citations of authors in the clusters

**Figure 3. Co-authorship network in the TT research field**

**TABLES**

| Journal | TP | TC | TCA | IP |
|---|---|---|---|---|
| Journal of technology transfer | 226 | 4455 | 19,7 | 4.037 |
| Research policy | 192 | 18156 | 94,6 | 5.425 |
| International journal of technology management | 147 | 1226 | 8,3 | 1.16 |
| Technovation | 145 | 4852 | 33,5 | 5.25 |
| Technological forecasting and social change | 85 | 1247 | 14,7 | 3.815 |
| Energy policy | 78 | 2731 | 35,0 | 4.88 |
| R & D management | 54 | 1082 | 20,0 | 2.354 |
| World development | 52 | 1806 | 34,7 | 3.905 |
| IEEE transactions on engineering management | 48 | 1361 | 28,4 | 1.867 |
| Journal of international business studies | 31 | 2667 | 86,0 | 7.724 |
| Small business economics | 29 | 1189 | 41,0 | 3.555 |
| Journal of development economics | 28 | 2011 | 71,8 | 2.855 |
| Journal of international economics | 25 | 963 | 38,5 | 2.216 |
| Industrial and corporate change | 24 | 1453 | 60,5 | 1.824 |
| International journal of industrial organization | 24 | 1048 | 43,7 | 0.96 |
| Strategic management journal | 14 | 4121 | 294,4 | 5.572 |
| European economic review | 14 | 1077 | 76,9 | 1.711 |
| Journal of business venturing | 13 | 1975 | 151,9 | 6.333 |
| Management science | 13 | 1752 | 134,8 | 4.219 |
| Organization science | 12 | 6666 | 555,5 | 3.257 |
| American economic review | 10 | 1636 | 163,6 | 4.097 |
| Review of economics and statistics | 9 | 1276 | 141,8 | 3.636 |
| World bank research observer | 7 | 1075 | 153,6 | 1.833 |
| Academy of management review | 6 | 4315 | 719,2 | 10.632 |
| Economic journal | 5 | 1090 | 218,0 | 2.926 |

TP: total papers; TC: total cites; TCA: cites per article; IP: Impact in JCR

**Table 1. Top 25 productive and influential journals**

| Authors | Article | Journal | Citations | Citations/ year |
|---|---|---|---|---|
| (Kogut and Zander, 1992) | Knowledge of the firm, combinative capabilities, and the replication of technology | Organization Science | 5057 | 187,3 |
| (Zahra and George, 2002) | Absorptive capacity: A review, reconceptualization, and extension | Academy of Management Review | 3394 | 199,6 |
| (Hansen, 1999) | The search-transfer problem: The role of weak ties in sharing knowledge across organization subunits | Administrative Science Quarterly | 2420 | 121,0 |
| (Mowery, Oxley and Silverman, 1996) | Strategic alliances and interfirm knowledge transfer | Strategic Management Journal | 1426 | 62,0 |
| (Aitken, Harrison, 1999) | Do domestic firms benefit from direct foreign investment? Evidence from Venezuela | American Economic Review | 1166 | 58,3 |
| (Howells, 2006) | Intermediation and the role of intermediaries in innovation | Research Policy | 670 | 51,5 |
| (Teece, 1977) | Technology-transfer by multinational firms - resource cost of transferring technological know-how | Economic Journal | 647 | 15,4 |
| (Siegel, Waldman and Link, 2003) | Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study | Research Policy | 621 | 38,8 |
| (Mowery et al., 2001) | The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh-Dole act of 1980 | Research Policy | 579 | 32,2 |
| (Bozeman, 2000) | Technology transfer and public policy: a review of research and theory | Research Policy | 574 | 30,2 |
| (Rothaermel, Agung, and Jiang, 2007) | University entrepreneurship: a taxonomy of the literature | Industrial and Corporate Change | 569 | 47,4 |
| (Shrivastava, 1995) | The role of corporations in achieving ecological sustainability | Academy of Management Review | 561 | 23,4 |
| (Etzkowitz, 2003) | Research groups as 'quasi-firms': the invention of the entrepreneurial university | Research Policy | 559 | 34,9 |
| (Görg and Greenaway, 2004) | Much ado about nothing? Do domestic firms really benefit from foreign direct investment? | World Bank Research Observer | 548 | 36,5 |
| (Di Gregorio and Shane, 2003) | Why do some universities generate more start-ups than others? | Research Policy | 524 | 32,8 |
| (D'Esteand Patel, 2007) | University-industry linkages in the UK: What are the factors underlying the variety of interactions with industry? | Research Policy | 505 | 42,1 |
| (Etzkowitz, 1998) | The norms of entrepreneurial science: cognitive effects of the new university-industry linkages | Research Policy | 488 | 23,2 |
| (Rugman and Verbeke, 2001) | Subsidiary-specific advantages in multinational enterprises | Strategic Management Journal | 482 | 26,8 |
| (Perkmann et al., 2013) | Academic engagement and commercialisation: A review of the literature on university-industry relations | Research Policy | 460 | 76,7 |
| (Agrawal and Henderson, 2002) | Putting patents in context: Exploring knowledge transfer from MIT | Management Science | 454 | 26,7 |
| (Madhok, 1997) | Cost, value and foreign market entry mode: The transaction and the firm | Strategic Management Journal | 441 | 20,0 |
| (Kotabe, Martin, and Domoto, 2003) | Gaining from vertical partnerships: Knowledge transfer, relationship duration, and supplier performance improvement in the US and Japanese automotive industries | Strategic Management Journal | 440 | 27,5 |
| (Griffith, Redding, and Reenen, 2004) | Mapping the two faces of R&D: Productivity growth in a panel of OECD industries | Review of Economics and Statistics | 435 | 29,0 |
| (Perkmann and Walsh, 2007) | University-industry relationships and open innovation: Towards a research agenda | International Journal of Management Reviews | 434 | 36,2 |
| (Bresman, Birkinshaw, and Nobel, 1999) | Knowledge transfer in international acquisitions | Journal of International Business Studies | 429 | 21,5 |

**Table 2. Top 25 cited articles in TT research field**

| Author | Citations | Article | Citations / articles | Citations of the most cited article |
|---|---|---|---|---|
| Zander, U | 5124 | 3 | 1708,0 | 5057 |
| Kogut, B | 5099 | 2 | 2549,5 | 5057 |
| George, G | 3936 | 6 | 656,0 | 3394 |
| Wright, M | 3863 | 35 | 110,4 | 408 |
| Zahra, SA | 3745 | 4 | 936,3 | 3394 |
| Mowery, DC | 2561 | 10 | 256,1 | 1426 |
| Hansen, MT | 2420 | 1 | 2420,0 | 2420 |
| Lockett, A | 2251 | 12 | 187,6 | 408 |
| Siegel, DS | 2188 | 20 | 109,4 | 621 |
| D'Este, P | 1710 | 10 | 171,0 | 505 |
| Oxley, JE | 1647 | 2 | 823,5 | 1426 |
| Clarysse, B | 1442 | 16 | 90,1 | 219 |
| Silverman, BS | 1426 | 1 | 1426,0 | 1426 |
| Perkmann, M | 1346 | 6 | 224,3 | 460 |
| Aitken, BJ | 1166 | 1 | 1166,0 | 1166 |
| Harrison, AE | 1166 | 1 | 1166,0 | 1166 |
| Bozeman, B | 1164 | 15 | 77,6 | 574 |
| Saggi, K | 1056 | 16 | 66,0 | 241 |
| Etzkowitz, H | 1050 | 3 | 350,0 | 559 |
| Grimaldi, R | 1045 | 10 | 104,5 | 460 |
| Howells, J | 994 | 8 | 124.3 | 670 |
| Salter, A | 924 | 5 | 184.8 | 460 |
| Teece, DJ | 865 | 4 | 216.3 | 191 |
| Sampat, BN | 859 | 4 | 214.8 | 579 |
| Ziedonis, AA | 858 | 5 | 171.6 | 579 |

**Table 3. Top 25 prominent authors[1]**

[1] *The dataset contains 19 articles with a total of 901 citations written by Ulrisch Lichtentahaler as a result of which he would be the 23th of the ranking. However, given that several of his works have been retracted for data irregularities, this author disappears from the list of top 25 prominent authors.*

| Keyword | Times |
|---|---|
| Technology Transfer | 1792 |
| Innovation | 770 |
| Research and Development | 422 |
| Performance | 404 |
| Knowledge | 366 |
| Foreign Direct Investment | 330 |
| Industry | 313 |
| Firms | 273 |
| Growth | 247 |
| Productivity | 231 |
| Spillovers | 213 |
| Knowledge Transfer | 203 |
| Absorptive Capacity | 203 |
| Entrepreneurship | 198 |
| Science | 190 |
| Trade | 186 |
| Commercialization | 169 |
| China | 165 |
| Developing Countries | 160 |
| Policy | 159 |
| Technology | 154 |
| Model | 148 |
| Academic Entrepreneurship | 145 |
| University | 139 |
| Intellectual Property | 138 |

**Table 4. Top 25 popular keywords**

| Organisation | Citations | Articles |
| --- | --- | --- |
| Stockholm School of Economics | 15 | 6589 |
| University of Nottingham | 65 | 5241 |
| University of Wisconsin | 20 | 4098 |
| Harvard University | 25 | 3767 |
| Georgia State University | 7 | 3485 |
| University of London Imperial College Science, Technology & Medicine | 29 | 2825 |
| MIT | 21 | 2649 |
| Columbia University | 15 | 2386 |
| University California Berkeley | 38 | 2338 |
| University of Michigan | 12 | 2277 |
| Georgia Institute of Technology | 33 | 2156 |
| University of Ghent | 36 | 2139 |
| University of Toronto | 19 | 2000 |
| Indiana University | 25 | 1865 |
| National Bureau of Economic Research | 20 | 1794 |
| University of Carolina | 28 | 1752 |
| Rensselaer Polytechnic Institute | 10 | 1654 |
| natl bur econ res | 21 | 1539 |
| University of Sussex | 34 | 1525 |
| stanford University | 16 | 1506 |
| Katholieke University Leuven | 29 | 1417 |
| Universidad Politécnica de Valencia | 27 | 1319 |
| University Georgia | 14 | 1318 |
| University Cambridge | 20 | 1281 |
| Erasmus University | 18 | 1276 |

**Table 5. Top 25 contributing organizations**

| Cluster | Authors |
|---|---|
| 1 | Autio, E; Balconi, M; Baldini, N; Breschi, S; Brostrom, A; Fini, R; Franzoni, C; Grimaldi, R; Hameri, AP; Hughes, A; Kitson, M; Krabel, S; Lissoni, F; Llerena, P; Mckelvey, M; Perkmann, M; Salter, A; Sobrero, M; Tartari, V; Walsh, K; |
| 2 | Binks, M; Bruneel, J; Clarysse, B; Colombo, MG; Fontes, M; Franklin, S; Knockaert, M; Lockett, A; Mahajan, A; Moray, N; Mosey, S; Mustar, P; Piva, E; Renault, M; Spithoven, A; Vohora, A; Westhead, P; Wright, M; |
| 3 | Atwater, LE; Bozeman, B; Fay, D; Hayter, CS; Link, A; Link, AN; Nelson, AJ; Scott, JT; Siegel, DS; Slade, CP; Waldman, D; Waldman, DA; |
| 4 | Allen, TJ; Bercovitz, JEL; Breznitz, SM; Chevalier, A; Chugh, H; Feldman, MP; Lee, DMS; O'shea, RP; Roche, F; Tushman, ML; |
| 5 | Ambos, B; Ambos, TC; Birkinshaw, J; Bresman, H; D'Este, P; Makela, K; Nobel, R; Patel, P; Schlegelmilch, BB; |
| 6 | Belderbos, R; Callaert, J; Debackere, K; Landoni, P; Lichtenberg, FR; Sapsalis, E; Van Looy, B; Van Pottelsberghe, B; Veugelers, R |
| 7 | Chapple, W; Ensley, MD; Gulbrandsen, M; Hmieleski, KA; Moen, O; Rasmussen, E; Siegel, D; Wennberg, K; Wiklund, J |
| 8 | Bercovitz, J; Burton, R; Colyvas, JA; Feldman, M; Feller, I; Haeussler, C; Owen-Smith, J; Powell, WW |
| 9 | Fu, XL; Girma, S; Gong, YD; Gorg, H; Greenaway, D; Pietrobelli, C; Soete, L; Strobl, E. |
| 10 | Hatch, NW; Lowe, RA; Mowery, DC; Nelson, RR; Oxley, JE; Sampat, BN; Silverman, BS; Ziedonis, AA. |
| 11 | Czarnitzki, D; Edler, J; Fier, H; Grimpe, C; Howells, J; Hussinger, K; Toole, AA. |
| 12 | Cunningham, JA; Guerrero, M; Mcadam, M; Mcadam, R; Miller, K; O'Kane, C; Urbano, D. |
| 13 | Kumaraswamy, A; Meyer, KE; Mudambi, R; Saranga, H; Sinani, E; Tripathy, A; Yang, Q. |
| 14 | Acs, ZJ; Audretsch, DB; Bonardo, D; Lehmann, EE; Paleari, S; Vismara, S. |
| 15 | Glass, AJ; Lin, P; Maskus, KE; Pack, H; Saggi, K; Yang, GF. |
| 16 | George, G; Jain, S; Maltarich, M; Van de Velde, E; Wood, DR; Zahra, SA |
| 17 | Gallagher, KS; Koh, CP; Tong, TW; Wang, P; Zhang, F. |
| 18 | Cameron, G; Griffith, R; Proudman, J; Redding, S; Van Reenen, J. |
| 19 | Balkin, DB; Gianiodis, PT; Markman, GD; Phan, PH. |
| 20 | Bekkers, R; Freitas, IMB; Geuna, A; Nesta, LJJ. |
| 21 | Bierly, PE; Chakrabarti, AK; Damanpour, F; Santoro, MD. |
| 22 | Branstetter, LG; Fisman, R; Foley, CF; Kerr, WR. |
| 23 | Domoto, H; Kotabe, M; Martin, X; Salomon, R |
| 24 | Dooley, L; Lupton, G; O'Reilly, C; Philpott, K |
| 25 | Blomstrom, M; Kokko, A; Sjoholm, F; Wang, JY. |
| 26 | Amara, N; Landry, R; Ouimet, M; Rherrad, I |
| 27 | Kabiraj, T; Marjit, S; Mukherjee, A; Sinha, UB. |
| 28 | Ndonzuau, FN; Nlemvo, F; Pirnay, F; Surlemont, B. |
| 29 | Birley, S; Djokovic, D; Nicolaou, N; Souitaris, V. |
| 30 | Carayannis, EG; Rogers, EM; Speakman, K; Steffensen, M |

**Table 6. Authors in co-authorship clusters**

| Co-authorship clusters | | | | Research streams | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cluster | TP | TC | Num. Author | University TT | | | | | International TT | Intra-firm TT | Absorptive Capacity | Public Innovation Policies |
| | | | | AE | IP | NV | TTO | UIR | | | | |
| 1 | 52 | 1829 | 20 | ✔ | ✔ | ✔ | ✔ | ✔ | | | | |
| 2 | 53 | 4083 | 18 | ✔ | | ✔ | ✔ | | | | | |
| 3 | 43 | 1125 | 12 | ✔ | ✔ | ✔ | | | | | | ✔ |
| 4 | 13 | 2035 | 10 | ✔ | | ✔ | | ✔ | | | | |
| 5 | 6 | 2541 | 9 | ✔ | | | | ✔ | ✔ | | | |
| 6 | 19 | 5153 | 9 | ✔ | | | ✔ | ✔ | ✔ | | | |
| 7 | 11 | 6577 | 9 | ✔ | | ✔ | | | | | | ✔ |
| 8 | 19 | 2476 | 8 | ✔ | ✔ | | | | | | | ✔ |
| 9 | 21 | 1401 | 8 | | | | | | ✓ | | | |
| 10 | 15 | 1063 | 8 | ✔ | ✔ | | | ✔ | | | | ✔ |
| 11 | 25 | 1488 | 7 | | ✔ | ✔ | | ✔ | | | | ✔ |
| 12 | 30 | 1793 | 7 | ✔ | | | ✔ | | | | ✔ | |
| 13 | 4 | 3864 | 7 | | | | | | ✔ | | | |
| 14 | 23 | 2360 | 6 | ✔ | ✔ | | ✔ | | ✔ | | | |
| 15 | 26 | 1792 | 6 | | | | | | ✔ | | | |
| 16 | 8 | 2413 | 6 | ✔ | ✔ | | ✔ | ✔ | | | ✔ | |
| 17 | 5 | 1173 | 5 | | | | | | ✔ | | | |
| 18 | 3 | 483 | 5 | | | | | | | | | ✔ |
| 19 | 3 | 1431 | 4 | ✔ | | | | | | | | |
| 20 | 9 | 1798 | 4 | | ✔ | | | ✔ | | | | |
| 21 | 5 | 1365 | 4 | | | | | | | ✔ | | |
| 22 | 4 | 540 | 4 | | | | | | ✔ | | | |
| 23 | 4 | 480 | 4 | | | | | | | ✔ | | |
| 24 | 1 | 164 | 4 | ✔ | | | | | | | | |
| 25 | 13 | 1247 | 4 | | | | | | ✔ | | | |
| 26 | 8 | 1138 | 4 | | ✔ | ✔ | | ✔ | | | | |
| 27 | 50 | 990 | 4 | | | | | | ✔ | | | |
| 28 | 2 | 606 | 4 | | | ✔ | | | | | | |
| 29 | 4 | 576 | 4 | | | ✔ | | | | | | |
| 30 | 16 | 338 | 4 | | | | | | | | | ✔ |

TP: total papers; TC: total cites; AE. Academic entrepreneurship; IP: Intellectual property; NV: New ventures; TTO: Technology transfer offices; UIR: University-industry relationship;

**Table 7. TT research streams resulting from co-authorship network**

| Research Streams | | Top articles |
|---|---|---|
| University TT | Academic entrepreneurship | - Research groups as 'quasi-firms': the invention of the entrepreneurial university (Etzkowitz 2003). 559 citations<br>- The norms of entrepreneurial science: cognitive effects of the new university-industry linkages (Etzkowitz, 1998). 488 citations<br>- Academic entrepreneurs: Organizational change at the individual level (Bercovitz & Feldman 2008). 298 citations.<br>- Why do academics engage with industry? The entrepreneurial university and individual motivations (D'Este & Perkmann 2011). 229 citations<br>- 30 years after Bayh-Dole: Reassessing academic entrepreneurship (Grimaldi, Kenney, Siegel, & Wright, 2011). 235 citations |
| | New ventures | - Entrepreneurial orientation, technology transfer and spinoff performance of US universities (O'Shea, Allen, Chevalier, &Roche, 2005). 375 citations<br>- Resources, capabilities, risk capital and the creation of university spin-out companies (Lockett & Wright 2005). 326 citations<br>- The creation of spin-off firms at public research institutions: Managerial and policy implications (Lockett, Siegel, Wright, & Ensley 2005). 223 citations<br>- University spin-out companies and venture capital (Wright, Lockett, Clarysse, & Binks 2006). 219 citations<br>- Technology transfer and universities' spin-out strategies (Lockett, Wright, & Franklin, 2003). 204 citations |
| | Intellectual property | - The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh-Dole act of 1980 (Mowery, Nelson, Sampat & Ziedonis 2001). 570 citations<br>- University patenting and its effects on academic research: The emerging European evidence (Geuna & Nesta 2006). 279 citations<br>- Networks of inventors and the role of academia: an exploration of Italian patent data (Balconi, Breschi,& Lissoni 2004). 253 citations<br>- Patenting and US academic research in the 20th century: The world before and after Bayh-Dole (Sampat 2006). 143 citations<br>- Learning to patent: Institutional experience, learning, and the characteristics of US University patents after the Bayh-Dole Act, 1981-1992 (Mowery, Sampat, & Ziedonis 2002). 128 citations |
| | University-Industry relationship | - University-industry linkages in the UK: What are the factors underlying the variety of interactions with industry? (D'Este & Patel 2007). 505 citations<br>- University-industry relationships and open innovation: Towards a research agenda (Perkmann & Walsh 2007). 434 citations<br>- Academic engagement and commercialization: A review of the literature on university-industry relations (Perkmann, Tartari, McKelvey, Autio, Broström, D'Este, & Krabel 2013). 460 citations<br>- Investigating the factors that diminish the barriers to university-industry collaboration (Bruneel, D'Este, & Salter 2010). 327 citations<br>- Mid-range universities' linkages with industry: Knowledge types and the role of intermediaries (Wright, Clarysse, Lockett, & Knockaert 2008). 180 citations |
| | TTOs | - Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study (Siegel, Waldman, & Link 2003) 621 citations<br>- Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: Qualitative evidence from the commercialization of university technologies (Siegel, Waldman, Atwater, & Link 2004) 297 citations<br>- Entrepreneurship and university-based technology transfer. (Markman, Phan, Balkin, & Gianiodis 2005). 234 citations<br>- Technology transfer offices and commercialization of university intellectual property: performance and policy implications (Siegel, Veugelers, & Wright 2007). 200 citations |

| | | |
|---|---|---|
| | | - Assessing the relative performance of UK university technology transfer offices: parametric and non-parametric evidence (Chapple, Lockett, Siegel, & Wright, 2005). 184 citations |
| International TT | | - Do domestic firms benefit from direct foreign investment? Evidence from Venezuela (Aitken & Harrison 1999). 1166 citations<br>- Much ado about nothing? Do domestic firms really benefit from foreign direct investment? (Görg & Greenaway 2004) 548 citations<br>- Knowledge transfer in international acquisitions (Bresman, Birkinshaw, & Nobel 1999). 429 citations<br>- Foreign-investment and technology transfer - a simple-model (Wang & Blomström 1992). 278 citations<br>- Technology transfer and spillovers: does local participation with multinationals matter? (Blomström & Sjöholm 1999). 257 citations |
| Intra-firm TT | | - Strategic alliances and interfirm knowledge transfer (Mowery, Oxley, & Silverman, 1996). 1426 citations<br>- Technology transfer by multinational firms: The resource cost of transferring technological knowledge (Teece 1977). 647 citations<br>- Subsidiary-specific advantages in multinational enterprises (Rugman & Verbeke 2001). 482 citations<br>- Gaining from vertical partnerships: Knowledge transfer, relationship duration, and supplier performance improvement in the US and Japanese automotive industries (Kotabe, Martin, & Domoto 2003). 440 citations<br>- Conventional and reverse knowledge flows in multinational corporations (Yang, Mudambi, & Meyer 2008). 153 citations |
| Absorptive capacity | | - Absorptive capacity: A review, reconceptualization, and extension (Zahra & George 2002). 3394 citations<br>- Absorbing the Concept of Absorptive Capacity: How to Realize Its Potential in the Organization Field (Volberda, Foss, & Lyles 2010). 390 citations<br>- The application of external knowledge: organizational conditions for exploration and exploitation (Bierly III, Damanpour, & Santoro 2009). 148 citations<br>- Building absorptive capacity to organise inbound open innovation in traditional industries (Spithoven, Clarysse, & Knockaert 2011). 147 citations<br>- Absorptive capacity, its determinants, and influence on innovation output: Cross-cultural validation of the structural model (Murovec & Prodan 2009). 144 citations |
| Public innovation policies | | - Intermediation and the role of intermediaries in innovation (Howells 2006). 670 citations<br>- Technology transfer and public policy: a review of research and theory (Bozeman 2000). 476 citations<br>- Mapping the two faces of R&D: Productivity growth in a panel of OECD industries (Griffith, Redding, & Van Reenen 2004). 435 citations<br>- Inward technology-transfer and competitiveness - the role of national innovation systems (Mowery & Oxley 1995). 221 citations<br>- Roads to institutionalization: The remaking of boundaries between public and private science (Colyvas & Powell 2006). 140 citations |

**Table 8. Top five cited articles included in each research stream**