

Mapping the conceptual structure of science and technology parks

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Abstract This paper aims to contribute to a better understanding of the literature on science and technology parks. The use of bibliometric analysis techniques is growing rapidly in management and organization research as a way of supplementing the subjective evaluation of literature reviews. Even though studies in some research fields such as innovation, entrepreneurship, and strategy have applied bibliometric methods considerably, other studies on subjects such as science and technology parks are in the process of using them. This paper has two main objectives. The first is to present a descriptive bibliometric analysis (number of authors per work and year, number of papers per author, top authors, author affiliations and top journals). The second objective is to analyze the conceptual structure of the field and the evolution of concepts and topics through a co-word analysis. Our work identifies the main topics explored by science and technology park literature and describes their relationships and evolution over time. Moreover, our results complement findings obtained through previous studies that have used other bibliometric methodologies such as methods of co-citation and bibliographical coupling.

Keywords Science park · Technology park · Innovation · Co-word analysis

JEL Classification M15 · O32 · R12

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1 Introduction

In recent years, themes of innovation and of the localization of firms in science and technology parks have become more relevant. This has generated growing interest from the scientific community that has materialized through the publication of works on science and technology parks in academic journals (Díez-Vial and Montoro-Sánchez 2017; Fukugawa 2006). For instance, Fukugawa (2006) investigate the value-added contributions of science parks to new technology-based firms (NTBFs), and a qualitative review of empirical studies on the value-added contributions of science parks is made. And, Hobbs et al. (2017a) present an annotated and analytical literature review of science and technology parks over the past 30 years (1986–2016) and identify five papers that classify as “literature review” (Albahari et al. 2010, Link and Scott 2007, 2015; Phan et al. 2005; Quintas et al. 1992; Siegel et al. 2003), and just Díez-Vial and Montoro-Sánchez (2017) use bibliometric analysis methods.

Literature reviews must be conducted to determine the current state of a given subject. Such reviews can be carried out using different complementary methods (e.g., qualitative approaches such as structured literature reviews or quantitative approaches such as meta-analyses and science maps that use bibliometric methods) (Zupic and Čater 2015). For example, Lee and Kang (2017) adopt the topic model approach, a quantitative one, to discover topics in technology and innovation management. The use of this quantitative methodologies, specially bibliometrics, to describe, evaluate and monitor published research renders the process more systematic, transparent and reproducible (Zupic and Čater 2015).

Bibliometric analysis methods are expanding rapidly in management and organization research as a way of supplementing the subjective evaluation of literature reviews. In this context, Zupic and Čater (2015) synthesized guidelines from 81 bibliometric studies on management and organization. They found that the median year of publication of bibliometric studies in this field is 2011, meaning that over half of these articles were published in recent years (2011–2013). Even though studies in some research fields such as innovation, entrepreneurship, and strategy have applied bibliometric methods considerably, other studies on subjects such as science and technology parks are in the process of using them.

The first paper to present a bibliometric study of research on science parks is that of Díez-Vial and Montoro-Sánchez (2017), who use bibliometric techniques of co-citation analysis and bibliographic coupling to identify the foundations of science park and incubator research from a longitudinal perspective (i.e., based on intellectual structures) to identify areas for future research and the intellectual structure of recent/emerging literature and of its development through time.

However, there are other ways to analyze a research field. While co-citation is used to describe the intellectual structure of a scientific research field, co-word analysis is focused on conceptual structures. That is, co-word analysis allows us to discover the main concepts explored by a field and to uncover and describe interactions between different fields of scientific research (Cobo et al. 2011).

The co-word analysis technique was first developed during the 1980s (He 1999), and an early study in this field maps the dynamics of aquaculture from 1979 to 1981 (Bauin 1986). However, Zupic and Čater (2015) found that in the management and organization fields, the first bibliometric studies were conducted from the 1990s and only 13.6% of the 81 bibliometric studies published in this area use co-word analysis techniques (e.g.,

Benavides-Velasco et al. 2011; Leone et al. 2012; Wallin 2012), but none of them analyze the research on science and technology parks.

This paper has two main objectives. The first is to develop a descriptive bibliometric analysis. In this sense, we list the number of authors per work and year, the number of papers per author, top authors (considering the Lotka Law), and affiliations for institutions and countries. We also analyze top journals that publish papers in this field.

The second objective is to analyze the conceptual structure of the field and the evolution of related concepts and topics. We apply one bibliometric technique, the co-word analysis method, following Cobo et al. (2011), in a longitudinal framework to identify different themes treated by the field across the studied period to create a science map.

After accomplishing these two objectives, we will be better able to (a) orient the new research about science and technology parks considering the innovative and emerging themes; and (b) propose new research questions. Moreover, we identify the main journals and authors in this research line whose papers are the intellectual basis of recent literature.

2 Data: research protocol and descriptive analysis

In this section, first we explain the search protocol and then we carry out a descriptive analysis of the main results according to the authors and journals information. This process involves the use of the WoS database, which is the most prestigious and widely used database within the sciences and social sciences fields. Table 1 shows the search protocol consisting of a series of processes defined according to different combinations of keywords based on the selection criteria.

Zupic and Čater (2015) found that the 69.1% of the bibliometric studies published in management and organization use the Social Science Citation Index (SSCI) of (WoS). It is necessary to emphasize that the first search was conducted only based on that database. However, a first review of the results highlighted the absence of some works that are relevant according to the researchers. For this reason, we proceeded to check whether these works appeared in WoS and found that they just appeared in the Science Citation Index (SCI) database of WoS. This led us to expand the search, including both databases. The results of the searches performed according to these selection criteria are shown in Table 2. Table 2 presents the results obtained for each of the keywords defined in the search protocol, both individually and combined; the data that combine all terms provide the total population of articles (706) without any duplicates.

Table 1 Search protocol

	Temporal scope	Type of document	Database	Search criteria	Keywords
WoS	Until October 2017	Article	Social Science Citation Index Science Citation Index	Title, Keywords and Abstract	“science park*” OR “techno* park*” OR “research park*” OR technopark

Table 2 Search results

Keywords	WoS (SSCI)	WoS (SSCI + SCI)
“science park*”	335	436
“techno* park*”	98	145
“research* park*”	60	153
technopark	14	26
Combined search	460	706

After a combined search of both databases, a filtering process was performed for each researcher through the analysis of the titles, abstracts, and keywords of each work. As a result of this process, we eliminated works that are not focused on the study of science and technology parks. The most common reason, indeed for the majority, for removing a work from the sample was checking that the reference to a scientific and/or technological park was exclusively related to a company’s or experiment’s localization in a park, without any other consideration of the topic at hand. The result of the filtering process showed a total of 447 works. After filtering the works, a descriptive analysis of the following aspects was conducted: authors and journals. Figure 1 shows the evolution of the selected articles.

A total of 1.34% of the works were published in the 1966–1984 period, 6.94% in the following 10 years (1985–1994), and 16.33% during the 1995–2004 period. The greatest development of this line of research has occurred since 2005, accumulating a total of 337 works, or 75.39% of the work that has been published.

2.1 Authors

The data show that, in this line of research, the number of authors ranges from one to three in 89.5% of all cases. However, it is significant that 67.8% of the works have two or more authors, with the maximum being six (Table 3). These results highlight two remarkable facts. First, in academia, researchers are subject to evaluation processes in which, in some cases, the signing of more than average number of authors for the discipline leads to a reduction in the value given to each work. The results show that the works have four or

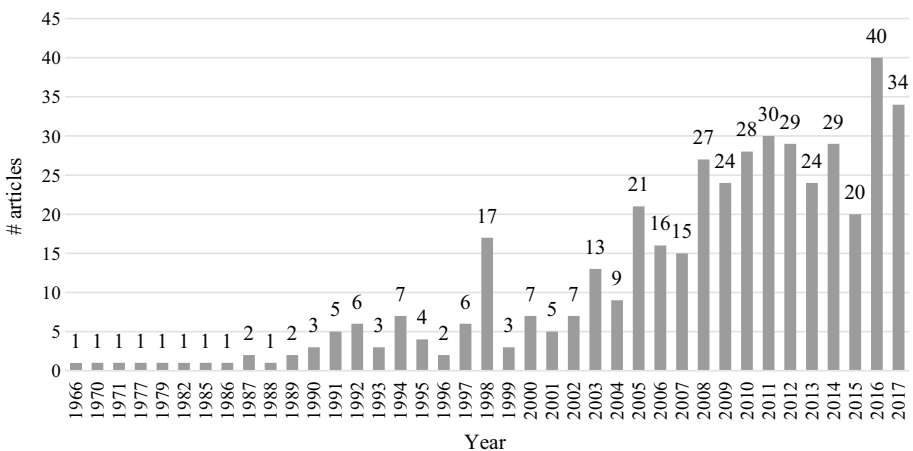
**Fig. 1** Temporal evolution

Table 3 Authors per article

Authors per article	Frequency	Percentage (%)	Cumulated percentage (%)
1	144	32.2	32.2
2	135	30.2	62.4
3	121	27.1	89.5
4	36	8.1	97.5
5	9	2.0	99.6
6	2	0.4	100.0

more authors in only 10.5% of all cases. In this regard, it is increasingly common for journals to include a clause in the instructions for the authors to explain the need for a greater number of signatories. Second, the joint authorship of a work can increase its quality by providing a more multidisciplinary and complementary approach due to the synergies generated between the authors.

A more detailed analysis of the number of authors per work and year shows that the first works that were published were by single researchers who began the study of this topic (1966–1990). After 1991, there was a greater development of this line of research, which led to the formation of research teams and, therefore, joint publication. After 2003, there was the greatest growth in works with three or more authors (Fig. 2). This fact suggests greater collaboration between researchers, which is characteristic of a more mature field of study.

Another interesting fact is the number of works published on this topic by each author. In this work, to count the authors, each co-author was considered a unit, regardless of the number of authors who signed a work. Of the 447 reviewed works, there are a total of 648 authors who have published a single work, 73 who have published two, and 18 who have published three. There are very few who have published four or more works on this topic (Table 4). One possible interpretation of these results can be that

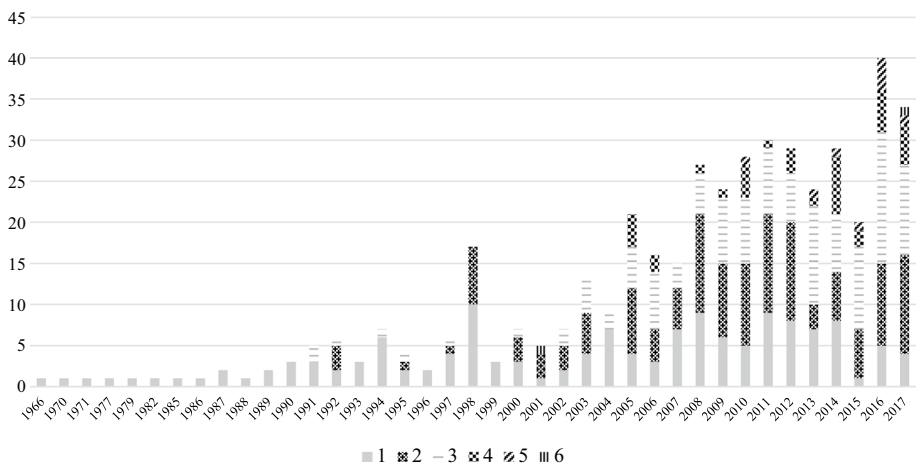


Fig. 2 Number of authors per work and year

Table 4 Number of papers per author

Articles per author	Frequency
1	658
2	73
3	18
4	8
5	7
6	2
7 or more	5

this line of research remains in the process of development compared to other more traditional themes such as the study of cooperation or innovation.

Table 5 shows the authors who have published the most works on science and technology parks. Authors such as Wright, Lindelof, and Lofsten, who have more than 10 published works, stand out. Other authors such as Liu and Link have published between eight and seven works, respectively. Díez-Vial and Schwartz have published six articles and there are seven authors with five papers.

The so-called Lotka's Law (Lotka 1926; Price 1973), one of the laws of bibliometry, implies that the distribution of authors according to their productivity remains a pattern: specifically, the number of authors who have published "n" works on a topic is inversely proportional to the square of "n". In simple terms, this law implies that the most works in an area are typically accumulated by a relatively small number of authors. Figure 3 represents the Lotka distribution for the articles linked to the field analyzed. As shown, the evolution moderately fits the prediction proposed by this bibliometric law. This fact can highlight an initial evolution of this research topic.

To calculate the statistics on affiliation, both for institutions and countries, each article is considered a unit that is divided proportionally between the institutions or countries that the participating authors represent. As shown in Table 6, the universities that have the greatest number of articles published are Chalmers University of Technology

Table 5 Top authors

Author ^a	Articles
Wright M.	14
Lofsten H.	11
Lindelof P.	11
Liu X.H.	8
Link A.N.	7
Díez-Vial I.	6
Schwartz M.	6
Cabral R.	5
Filatotchev I	5
Montoro-Sánchez A.	5
Siegel D.S.	5
Westhead P.	5
Scott J.T.	5
Lin G.T.R.	5

^aThe reference list does not include all the papers published by authors of Table 5 due to space limitations. Full bibliographic references to these papers are available from the authors

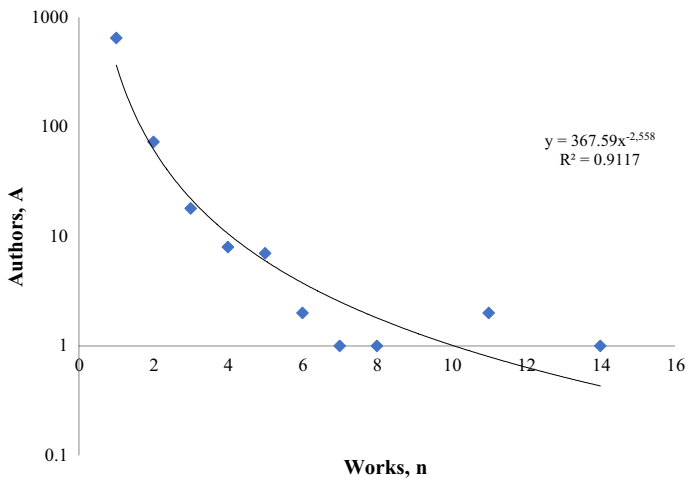


Fig. 3 Lotka distribution

Table 6 Statistics on affiliation for institutions

Institutions	Frequency (articles)
Chalmers Univ Technol	8.75
Univ Complutense Madrid	8.33
Natl Chiao Tung Univ	7.17
Univ Nottingham	5.78
Univ N Carolina	5.00
Natl Cheng Kung Univ	4.78
Univ Sao Paulo	4.25
UCL	4.00
Halle Inst Econ Res	3.83
Carlos III Univ Madrid	3.83
Chang Jung Christian Univ	3.50
Wolverhampton Univ	3.50

(Sweden) and Universidad Complutense of Madrid (Spain), which have published more than eight works. National Chiao Tung University (Taiwan) has published over seven works and the University of Nottingham and the University of North Carolina (USA) more than five articles. The remaining universities have published between three and four works.

Another interesting analysis is the affiliations by country. In this case, Taiwan is the country that has published the most articles on the subject (58.18). The US and England also have a significant presence, with 43.08 and 41.18, respectively. Spain, the People's Republic of China and Sweden have published between 23 and 36 works. Germany, Italy, Japan and Netherlands exceed 11 articles (Table 7).

Table 7 Statistics on affiliation for countries

Countries	Frequency (articles)
Taiwan	58.18
USA	43.08
England	41.18
Spain	35.67
Peoples R China	26.07
Sweden	23.33
Italy	20.81
Germany	16.43
Japan	12.17
Netherlands	11.50

Table 8 Top journals

Journals	Articles
Technovation	48
The Journal of Technology Transfer	28
International Journal of Technology Management	24
Research Policy	18
R&D Management	11
Technology Analysis and Strategic Management	10
European Planning Studies	10
Small Business Economics	9
Technological Forecasting and Social Change	9

2.2 Journals

Table 8 reflects the journals that have published the most work on the subject analyzed. In this regard, it is noted that most journals address issues of technology and innovation in companies. The role of journals such as Technovation, The Journal of Technology Transfer, International Journal of Technology Management and Research Policy is highlighted.

3 Co-word analysis

The co-word analysis method is used to identify relationships between subjects in a research field and thus to trace the development of science (He 1999), and it is also applied using a longitudinal approach to observe the evolution of a research field over consecutive periods of time (Garfield 1994). A general co-word analysis is focused on detecting hierarchies among areas of a research problem and minor but potentially growing areas (He 1999).

Callon et al. (1983) were the first to propose the co-word analysis method as a suitable means of identifying and representing associations between concepts from textual information. This content analysis technique involves the use of models of the

co-occurrence of pairs of items in a set of articles or texts to identify relationships between ideas within the areas of knowledge (He 1999). In this regard, it is understood that items are representative of texts, in turn collecting the essential ideas that they contain. Thus, the emergence of associations involves the presence of relations between topics that items represent (He 1999).

The approach has been used to identify themes of a given research area, relationships between these themes, the extent to which these themes are central to a broader area, and degrees to which these themes are internally structured (He 1999). It is the only method to use the actual content of documents to construct a similarity measure while others relate documents indirectly based on citations or co-authorships (Zupic and Čater 2015).

Zupic and Čater (2015) explain that the output of a co-word analysis is a network of themes and of their relations (a semantic map) that represents the conceptual space of a field- cognitive structure. In addition, maps produced for different time periods can trace changes in this conceptual space (Coulter et al. 1998).

To identify and illustrate major conceptual subdomains developed in the analyzed field and to identify major themes addressed, in this work, a co-word analysis is presented from the approximation proposed by Cobo et al. (2011), who describe a form of analysis carried out over four stages. In the first phase, the phase of theme identification, main themes of the research in the field analyzed (science and technology parks) are identified. The second phase of theme and thematic network visualization involves the graphical representation of themes and thematic networks obtained during the previous stage. The third phase of theme evolution involves analyzing how themes have evolved. Finally, the fourth stage of performance analysis involves the calculation of different quantitative (related to the number of documents, authors, journals and countries), qualitative or impact measures (received citations and bibliometric indices).

3.1 First phase

Following Cobo et al. (2011), the process of theme detection is divided into five steps: (1) collection of raw data (SCI and SSCI of WoS), (2) selection of the type of item to analyze (keywords), (3) extraction of relevant information from the raw data (co-occurrence frequencies of keywords), (4) calculation of similarities between items based on the extracted information and (5) use of a clustering algorithm to detect themes.

To study themes discussed in this line of research, an analysis of keywords related to each article was performed. Following from previous works, keywords were considered representative terms for the themes studied (Choi et al. 2011; Cobo et al. 2011). In addition, the keywords analyzed were those defined by authors and WoS database for each document. Before constructing the co-word analysis, keywords in the previous section were standardized following Choi et al. (2011). The following rules were used in refining the keywords:

- Standardization into a unique form: e.g., park, parks.
- The avoidance of abbreviations: when both the original word and the abbreviated form(s) were in the keyword list, they were consolidated into the original word: e.g., research and development, R&D.
- The addition of hyphens: hyphens were added between the terms: e.g., research-and-development.

- The unification of synonyms: when two or more synonyms existed in the list, they were changed into the most general keyword: e.g., interfirm-cooperation, interfirm-relationship.
- The elimination of terms without a clear meaning or too general: e.g., model, framework.

Thus, these rules were applied to 1714 different keywords. After this refinement, the resulting keyword database consisted of 321 keywords. Table 9 reflects the most frequent keywords (WoS).

To analyze the structure of the keyword network constructed from this database, we used the SciMAT software program (1.1.04 version), a tool that has been used to conduct, among other analyses, a co-word analysis in a rigorous but user-friendly manner (Cobo et al. 2012). In addition, we used Bibexcel (Persson et al. 2009) and Microsoft Excel to perform a descriptive bibliometric analysis of our database and we used Pajek (De Nooy et al. 2011) to carry out a special analysis that could not be performed using SciMAT software. Attending to the statistics published by Zupic and Čater (2015), we used a rare mix of software programs cited in the organization and management literature.

Major themes of research were identified by computing co-occurrences of keywords considered to be representative from each document based on the periods studied (Callon et al. 1991).

To perform the co-word analysis, in light of the results shown in Fig. 1, we decided to consider three different periods: first, one that contains the articles published until 2007; second, one that includes the works published between 2008 and 2012; and third, one that contains articles from 2013 until 2017. Nevertheless, our analysis was focused on the two latter periods.

After calculating the co-occurrence matrix, the association index is calculated. In the literature, there are various approaches to performing this calculation, with one of the most common being called the equivalence index (Callon et al. 1991; Coulter et al. 1998) and calculated as $e_{ij} = c_{ij}^2 / (c_i \cdot c_j)$, where c_{ij} is the number of documents in which terms i and j appear simultaneously and c_i and c_j indicate the number of documents in which term i and term j appear, respectively. From these indexes, a clustering algorithm is applied to identify subgroups of keywords that are strongly associated and are topics on which researchers focus. Among these techniques, the simple centers algorithm stands out (Cobo et al. 2011;

Table 9 Top keywords

Keywords	Frequency
Park	264
Innovation	183
Performance	113
Technology-Based-Firm	92
Incubator	83
Industry	77
Entrepreneurship	75
Network	73
Growth	64
Research-and-Development	62
Technology-Transfer	61

Coulter et al. 1998); its application yields a set of networks that revolve around a key term, which would be the relevant subject of research.

3.2 Second phase

Co-words are used in mapping science to obtain clusters of keywords viewed as themes (Cobo et al. 2011). The second phase involves identifying themes and networks. Based on centrality and density measures, some authors have used strategic diagrams (e.g., Callon et al. 1991; He 1999). According to Callon et al. (1991), a strategic diagram identifies four types of themes. In the upper right quadrant are *motor themes*, which are characterized by a high degree of internal development and by strong ties with other concepts within a given field of research. In the upper left quadrant are *highly developed and isolated themes*, which show a high degree of internal development but which are of marginal importance to the rest of the scientific area. In the lower left quadrant are *emerging or declining themes*, which are either not yet sufficiently relevant to the field studied and will perhaps not be or which have begun to lose importance while their degree of internal development is high for the period studied. Finally, in the lower right quadrant are *basic and transversal themes*, which are those themes that show strong ties with other issues outside of the network and which are thus relevant to the area of knowledge considered but whose internal development levels are lower.

Cobo et al. (2011) propose enriching this diagram based on the size of a circle that represents the topic to incorporate quantitative or qualitative measures in a graph. Examples of these metrics include the number of documents in a network, the number of authors who investigated a given topic, and the number of references to documents in a network.

For each theme, a thematic network can be represented from keywords that are related by tagging from the most significant keyword, which is typically that word with the highest level of centrality within a network. The size of each node or each keyword represents a quantitative or qualitative measure such as the number of documents that include the word or the h-index among other measures, whereas the thickness of arcs often represents the association between keywords (in our case the equivalence index).

Figures 4 and 5 present strategic diagrams for the selected periods. In both cases, the size of the circles represents the number of main documents.

Based on the strategic diagrams presented, *motor themes* are discussed first. In Fig. 4, “innovation” and “absorptive capacity” are motor themes in the 2008–2012 period. “Innovation” was the topic that accumulated the largest number of documents (107). For the 2013–2017 period (Fig. 5), the terms “park” and “interorganizational relationship” are motor themes with a higher number of documents (108 and 30, respectively). In the *basic and transversal themes* quadrant, the 2008–2012 period includes the term “knowledge” with a relatively high number of documents (32). In the 2013–2017 period, this term disappears, and no term is found in this quadrant. In the *emerging or declining themes* quadrant, only for the 2013–2017 period, we find the term “spin-off” with 17. For the *highly developed and isolated themes*, we find the term “size” in the 2008–2012 period, whose performance measures are the lowest in terms of the number of documents (4). In the 2013–2017 period, the term “job” appears in 7 documents.

Finally, we have found several *border themes*. For the 2008–2012 period, among emerging themes and basic and transversal themes, “innovation policy” appears as a theme in 16 documents. Additionally, between emerging themes and highly developed themes is “China”, with values showing limited development and a low number of documents (6). In

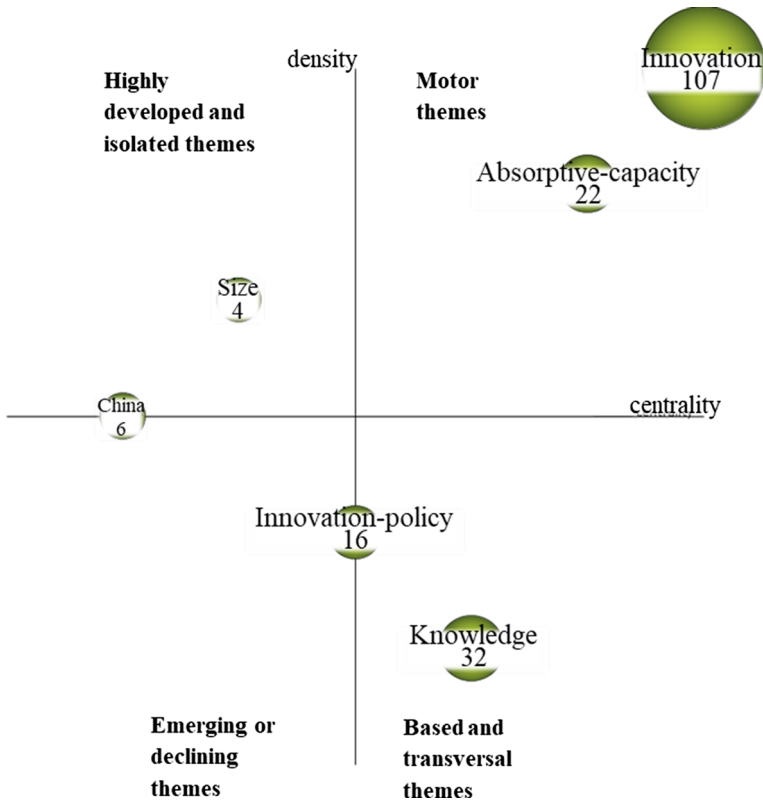


Fig. 4 Strategic diagram for 2008–2012

the 2013–2017 period, between motor themes and basic and transversal themes, the term “spillover” appears in 28 documents. In addition, between basic and transversal themes and emerging themes is “technology” with 23 documents.

3.3 Third phase

The purpose of this stage is to observe the evolution of thematic groups of the field of research analyzed. To analyze the full set of themes, the so-called stability index is used to measure overlap between two periods, i.e., the continuity or discontinuity between terms. Figure 6 illustrates the stability of the area of research and shows that the field is still nascent with a low rate of similarity and with a relatively high increase in different keywords. For the first period considered, there are 313 different keywords (with a relevant frequency) for the purpose of this analysis, of which 123 remain in the following period and 190 leave this category. In contrast, along with the 123 that remain, 289 new words are incorporated. This increase is explained in part by the growth in the number of articles published, as is shown in Fig. 1, and partly by the change in themes, which is characteristic of a new area of knowledge.

The evolution of themes is also analyzed. Cobo et al. (2011) propose using the Sternitzke and Bergmann (2009) inclusion index as a measure to determine the level of similarity between two thematic networks with elements in common over consecutive

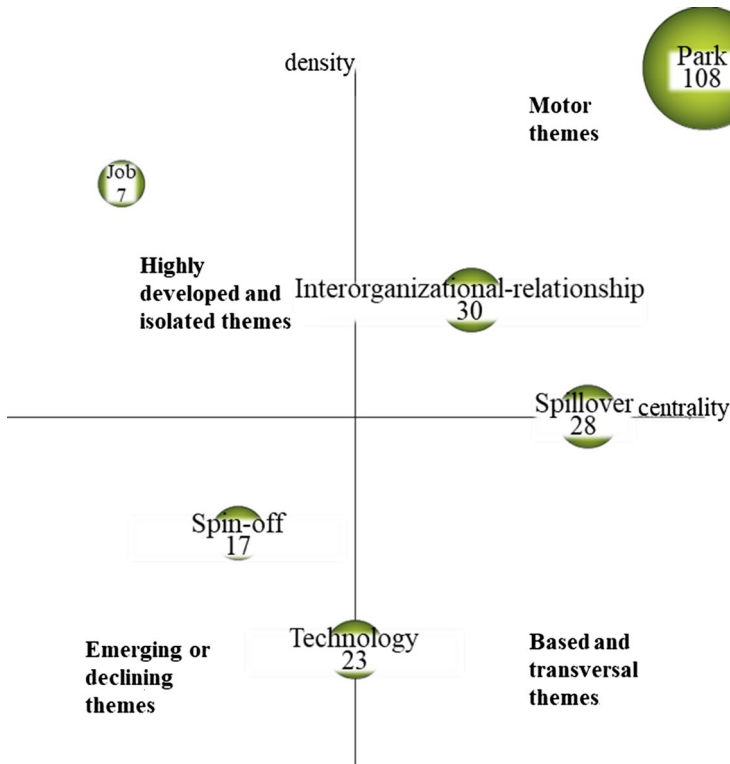


Fig. 5 Strategic diagram for 2013–2017

periods of time. From this index, a chart is produced; in this chart, each theme is represented by a circle and by lines between thematic networks, the thickness of which represents the inclusion index. In addition, the solid (continuous) line appears when the central node of one or both of the networks is included in the other network (as a central or non-central node). The dotted line appears in other cases when the networks share elements that are not central nodes (Fig. 7). The size of a circle represents the number of documents that compose each network. To avoid too much complexity, this graphic simply contains the themes that are in the right part of the strategic matrix in the last period and the themes in 2008–2012 with an inclusion index for these motor themes higher than 2.5.

“Innovation” and “park” are the main terms used in this area of research, showing remarkable growth in the number of documents. In noting the evolution between the three periods considered, the “park” theme evolves to the “innovation” theme in 2008–2012 and returns to “park” in 2013–2017. The other motor theme network in 2008–2012 period, “absorptive-capacity”, maintains an important qualitative and quantitative relationship with “interorganizational-relationship”. It is also interesting to highlight the evolution of “knowledge” towards “technology” based themes in the last period and the important contribution of the “China” network in the 2008–2012 period to the “spillover” theme.

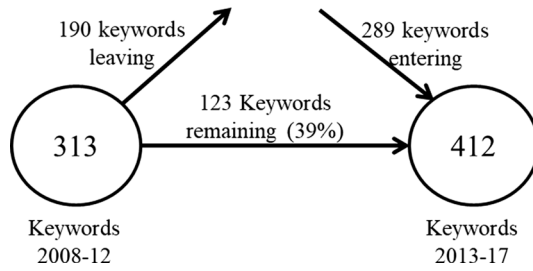


Fig. 6 Overlap fractions

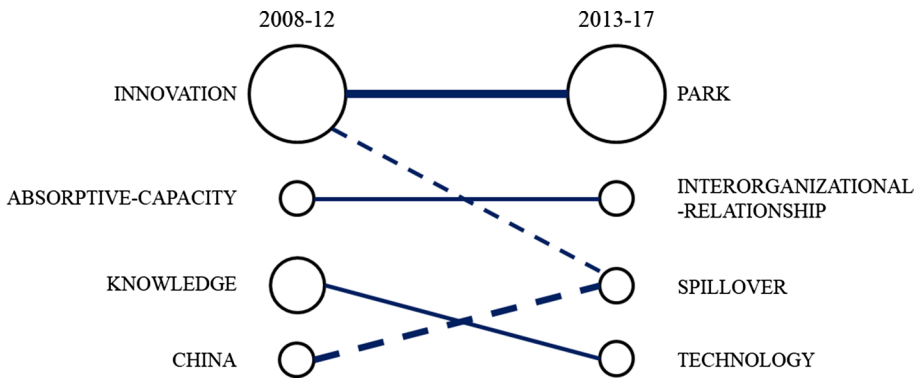


Fig. 7 Thematic evolution of the research field

Figure 8 represents the composition of the thematic network of “innovation”, with the size of the nodes representing the number of documents that reference this thematic network and the thickness of lines between nodes representing the intensity of the link. For the 2008–2012 period, there are two topics with greater weight in terms of the number of works: “innovation” and “park”. However, other topics such as “performance”, “industry”, “research-and-development”, “interorganizational-relationship” or “incubator” play a very important role in this subnetwork and in the complete network of themes. Relations between the different themes are very heterogeneous in terms of intensity levels: “innovation” and “park” form the pair with the most intense relationship in this thematic network. In fact, “park” has five strong relationships with the themes “incubator”, “industry”, “performance” and “research-and-development”. “Network” also shows intense links with “park”, “innovation” and “interorganizational-relationship”. On the other hand, the central element of the network, “innovation”, is also noteworthy, maintaining a relationship with not only all of the members that form the network but also strongly with terms such as “growth”, “industry”, “cluster” and “technology-transfer”. In contrast, “cluster” and “management” are the subjects with the fewest links within this network.

Regarding the evolution of the “innovation”—“park” thematic network, there is stability with a medium level of homogeneity in terms of keywords that are part of the network. In particular, elements such as “incubator”, “network”, “performance” or “growth” continue as a part of Fig. 8, and themes such as “innovation-policy”, “entrepreneurship”, “university”, “China” or “technology-based-firm” are incorporated in Fig. 9. In fact, some of these

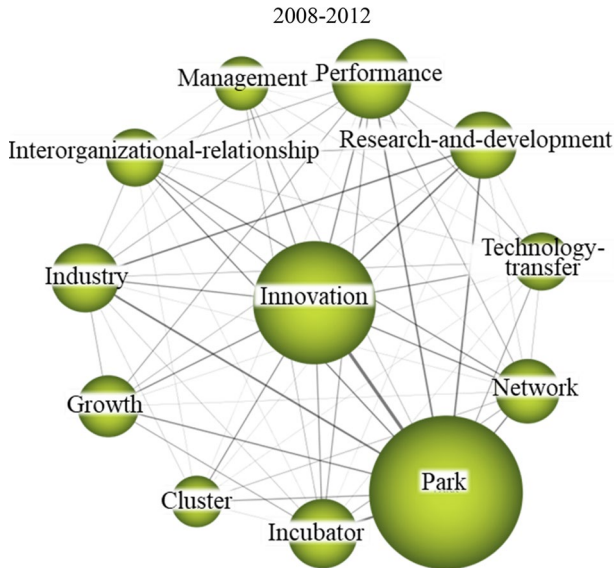


Fig. 8 Network “innovation”

topics had important links in the previous period, as we have noted, although they were not part of this thematic network.

For the 2013–2017 period (Fig. 9), there are very intense relationships between the equivalence index of “park” and topics such as “incubator”, “innovation”, “performance”, and “technology-based-firm”. Within this network, there is also a strong relationship between “incubator” and “technology-based-firm”, in the same way as in the previous period, although in this case in the same subnetwork. Elements as “entrepreneurship” and “start-ups” also play a very important role due to the strong links that they have inside and outside subnetworks, with themes such as “venture-capital”, “spin-off” or “technology-transfer” (all of which are in the “spin-off” subnetwork), as we will show when we analyze these external connections among topics (Fig. 13). In fact, it is possible to detect three groups of themes that maintain closer relations inside the “park” subnetwork. Specifically, there is a group of themes related to entrepreneurship (formed by themes such as “incubator”, “start-ups”, “entrepreneurship” and “technology-based-firm”), another group that contains themes that are close to cooperation (themes such as “university”, “innovation-policy” and “network”) and another group with themes related to “growth” and “China”. In the center of this subnetwork, a triad links all of these themes: “park”, “innovation” and “performance”.

Figure 10 describes the three networks involved in the evolution of the theme “inter-organizational-relationship” for the 2013–2017 period. This network derives from three networks in the 2008–2012 period: “innovation”, “absorptive-capacity” and “knowledge”, although the strongest relationship is with “absorptive-capacity”. Focusing on the 2008–2012 period, the network “absorptive-capacity” shows several terms related to the strategic management research field: “resource-based-view”, “competitive-advantage”, “capability” and “knowledge-management”, four main topics in Resource-based Theory. There are also important relations between topics as “multinational-firm”,

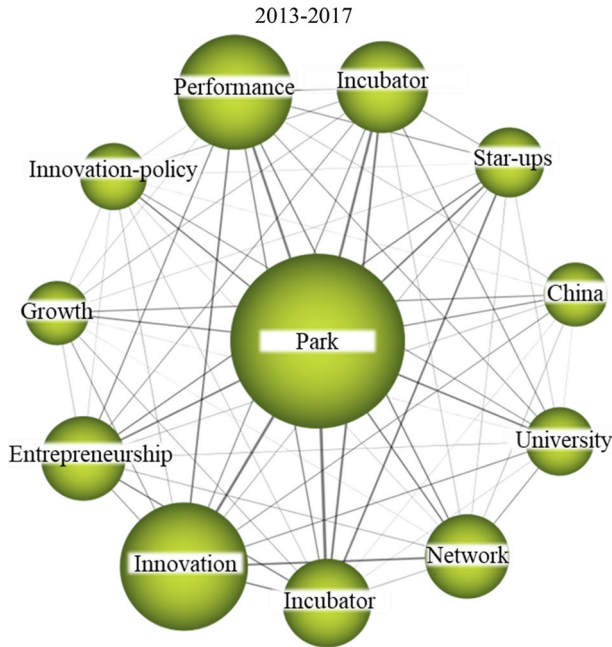


Fig. 9 Network “park”

“manufacturing-firms”, “innovation-performance”, “absorptive-capacity” and “business-research”. The majority of those topics are general and represent general research lines.

In 2013–2017, the network “interorganizational-relationship” received several topics from the latter network and others that complete it. The concentration of themes related to cooperation among firms and other institutions is interesting. Terms such as “knowledge” and “competitive-advantage” also remain, and others, such as “SMEs” and “structural-holes”, enter into the network.

Figure 11 shows networks with a direct relationship between the two periods considered and explains the source of the “spillover” thematic network.

With regard to the “China” network of the first period, only the strong links of the central theme with “foreign-direct-investment” and “diffusion” are noteworthy. Additionally, in this time, the “innovation” network is the origin of several strong themes included in the “spillover” subnetwork in the 2013–2017 period: terms such as “cluster”, “industry” and, above all, “research-and-development” appear with a relatively strong relationship and with a remarkable number of documents. Moreover, the relation between “research-and-development” and “academic-research” is noteworthy.

Regarding the “technology” network of the 2013–2017 period, Fig. 12 shows its components and the main precedent. As can be observed, this subnetwork receives many basic themes, several from the management research area, and several from more economic research topics. Technology is the true link in this subnetwork in which, with the exception of the relation between “resources” and “innovation-actors”, there are no relations without “technology”.

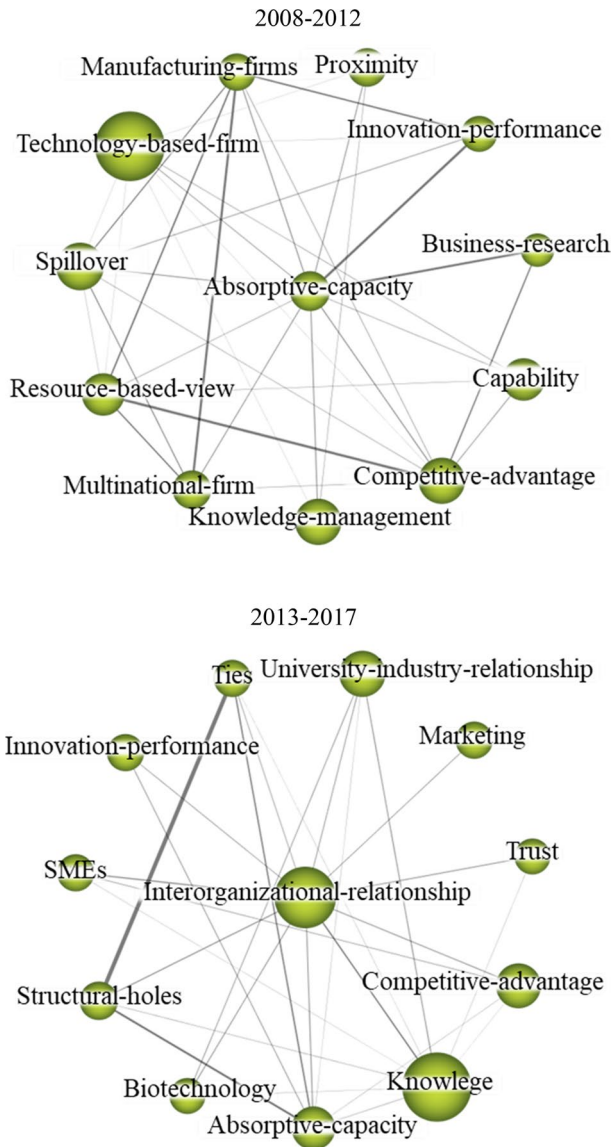


Fig. 10 Network involved in the evolution of “interorganizational-relationship”

All the subnetworks that have been previously described are integrated in a complete network that contains all of the topics of the analyzed research field. In fact, although the simple center algorithm that was used to group themes in subnetworks creates subnetworks, there are relationships among topics that are placed in different subnetworks. These kinds of relations are called “external links”. We analyze these links in the 2013–2017 period (Fig. 13).

The elements of the “park” subnetwork hold intense relationships with the “spillover”, “spin-off”, “technology” and “interorganizational-relationship” networks. These

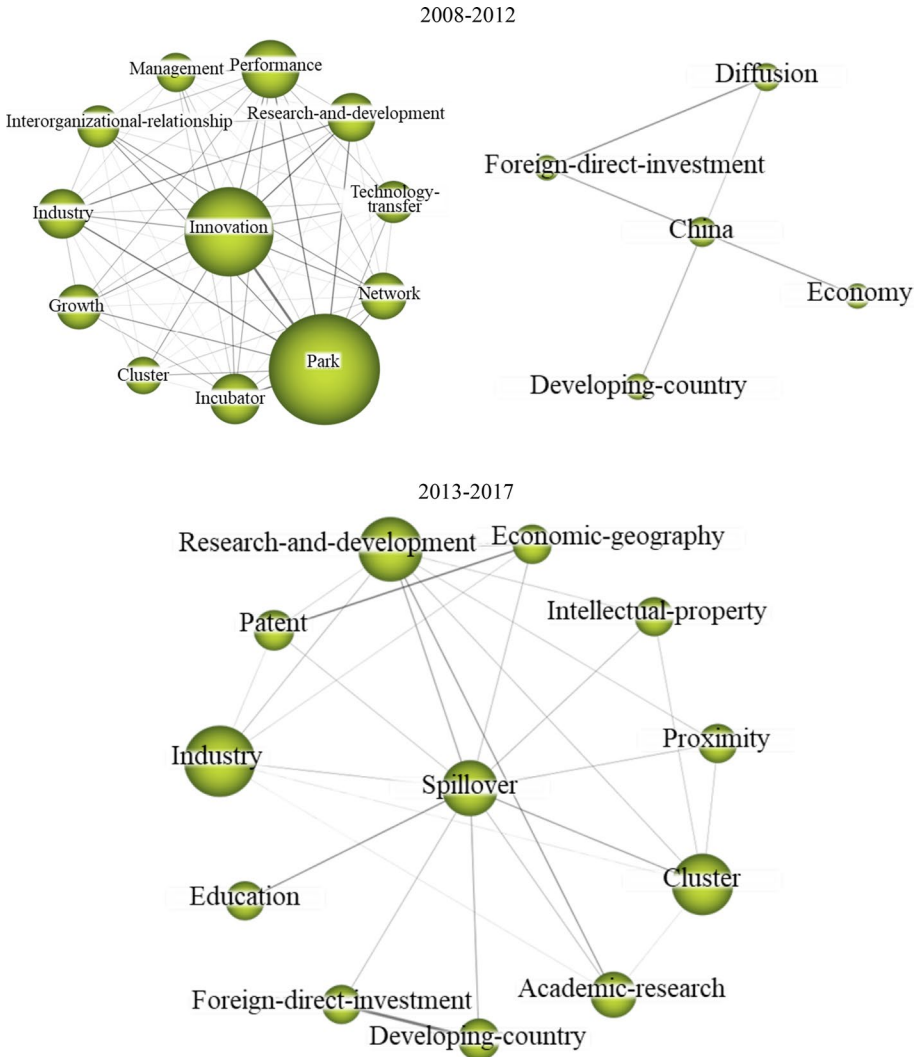


Fig. 11 Thematic network “spillover”

relations are more clearly observed in the network shown in Fig. 13, in which all terms included in the different thematic networks identified for the 2013–2017 period are jointly represented.

In this network (Fig. 13), the color of each node represents the thematic network to which the term belongs according to the simple centers algorithm used in the prior phase. However, when preparing the representation, Kamada–Kawui’s procedure combined with Pajek’s was used (De Nooy et al. 2011). We limited the network to relations with a value superior to 2.5 and nodes with a degree superior to 1.

Furthermore, it is interesting to note several groups that are also directly related to the theme based on their position in the network. Specifically, there is a very important

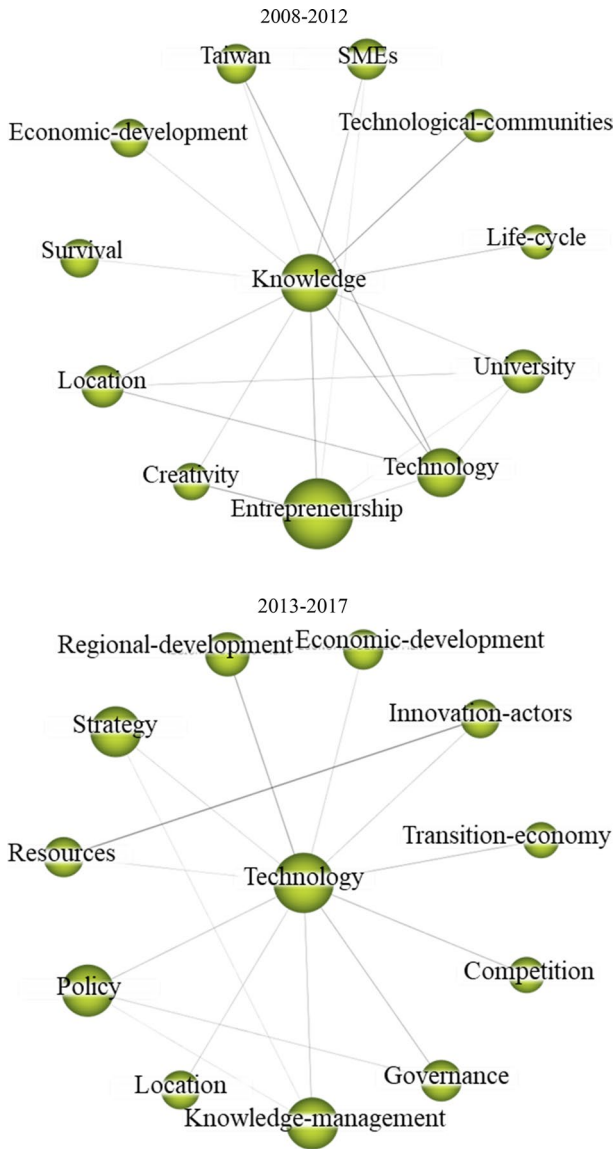


Fig. 12 Thematic network “technology”

thematic core of three terms, “innovation”, “science-park” and “performance”, in addition to “network”. Additionally, in the lower part of the center of the network, three terms belong to the “spin-off” network: this same term, “technology-transfer” and “venture capital”. Along with these, “incubator”, “entrepreneurship” and “start-up” from the “park” network form a set that is strongly related to entrepreneurship. Additionally, with great intensity in the right part of the network, the terms “knowledge”, “ties”, “management” and “interorganizational-relationships” appear linked with “innovation”, “performance” and

The results of this phase show that in the 2008–2012 period, the “innovation” network shows significant distance in the number of documents and the h-index. The average number of citations for “absorptive-capacity” and “knowledge” is remarkable (Table 10). For the 2013–2017 period, the “park” network has the highest number of documents and h-index. Obviously, the last period presents a lower number of citations; “spin-off” and “spillover” are the networks with the highest average number of citations (Table 11).

4 Conclusions

In this paper, we have developed a previous literature review on science and technology parks. For this purpose, first, a descriptive bibliometric analysis has been made. Second, we identify topics analyzed in the literature and their relationships (conceptual structure) through a co-word analysis that complements other previous studies that apply other bibliometric methods (Díez-Vial and Montoro-Sánchez 2017). A co-word analysis is one of the less frequently used bibliometric methods (13.6%) in this field of research (Zupic and Čater 2015).

Our descriptive analysis reveals some interesting conclusions and complements the results obtained in Hobbs et al. (2017a) that analyzed the number of publications by year and country, the impact of publications (Google Scholar citations) and the types of studies (empirical studies, case studies, theoretical and conceptual studies, literature reviews and publications related to park evaluation methods). In addition, we observed that until 1990, there was no co-authorship, and for the period analyzed, few authors have published more than six works on this topic: Wright, Lofsten, Lindelof, Liu and Link. If we consider the journals that published these papers, many are journals that specialize in topics of innovation and technology management, such as *Technovation*, *The Journal of Technology Transfer*, *International Journal of Technology Management*, and *Research Policy*. This phenomenon can partly be explained through our co-word analysis, showing that the works that explore these types of parks often focus on the analysis of innovation and technology-based firms.

The results of our co-word analysis reveal five main thematic networks: innovation, park, interorganizational relationship, spillover and technology. In this sense, co-word analysis allows us to return a set of clusters (networks). The clusters represent groups of textual information that can be understood as semantic or conceptual groups of different topics by the research field (Cobo et al. 2011). These clusters are different from the clusters of the co-citation analysis, which represent groups of references that form the intellectual base of the different subfields. However, both techniques complement one another and are compatible, representing topics analyzed in the literature (keywords) and serving as bases for studying these themes (co-citation).

For the 2008–2012 period, the literature focuses on the study of innovation (e.g., Radosevic and Myrzakhmet 2009; Squicciarini 2008, 2009), interorganizational relationships (e.g., Mukherjee and Ramani 2011; Schwartz and Hornych 2010), technology transfer (e.g., Alshumaimri et al. 2010; Chan et al. 2009), performance and growth (e.g., Caldera and Debande 2010) and other themes such as management (e.g., León Serrano 2011).

For the last analyzed period, some topics are developed, and others arise. Some papers have focuses in innovation (Vásquez-Urriago et al. 2014), concretely in R&D management (e.g., Lamperti et al. 2017), innovation performance (e.g., Albahari et al. 2017; Lai et al. 2014) and innovation policy (e.g., Albahari et al. 2017; Clark 2014). The analysis of the

relationship between innovation policies and science and technology parks can be analyzed in a bidirectional way. In this sense, Link and Link (2003) suggested the importance of studying the effect of science and technology parks on local and regional economic growth. Other papers consider the effects of parks on regional economic development (e.g., Fukugawa 2016; Ramirez et al. 2013). Future research should analyze the impact of the regional and local innovation policies in the creation and development of science and technology parks.

Other papers have analyzed themes related to entrepreneurship. Specifically, the terms incubator (e.g., Barbero et al. 2014; Tang et al. 2014), entrepreneurship (e.g., Tang et al. 2014), and technology-based firm (e.g., Ubeda et al. 2013) show strong relationships with one another and with the term park. This relationship seems logical if we understand that science and technology parks, among other objectives, promote company creation. Additionally, new science and technology parks could be considered as an instrument for employment growth (Link and Yang 2017). Future investigation about the characteristics of entrepreneurs that located their new firms in science and technology parks should be developed. In this way, the differences between the entrepreneurs on and off parks can be analyzed.

In addition to these themes, issues related to the analysis of interorganizational relations have attracted interest in the research community (e.g., Vázquez-Urriago et al. 2016). In that case, the papers analyze the university-industry relationships (Fernández-Esquinas et al. 2016), networks (Koçak and Can 2014) and factors such as trust (Giaretta 2014) and structural holes (Díez-Vial and Montoro-Sánchez 2016). Future evidence should analyze other determinant factors in university-firm relationships such as commitment, communication, level of institutionalization or dependence. Other works analyzed the interorganizational relationships between firms located in science and technology parks and universities (Minguillo and Thelwall 2015). Clusters are analyzed as well (Choi et al. 2013) as the effect of the proximity and the location and parks (Hobbs et al. 2017b). Some papers are focused on the role of universities close to the science and technology parks, creating terms such as university-research park (Link and Link 2003; Link and Scott 2006). These studies reveal the influence of science parks on university productivity (Link and Scott 2003). Future research should analyze the universities' access to financial sources because of their relationships with science and technology parks.

The analysis of performance and growth remains in the last period (e.g., Huang et al. 2016; Stokan et al. 2015; Hobbs et al. 2017b). Aspects related to knowledge management in science and technology parks have been developed in the most recent literature, analyzing themes such as absorptive capacity (Díez-Vial and Montoro-Sánchez 2016), intellectual property (Olcay and Bulu 2016) and patents (Clarysse et al. 2014). Another interesting topic is the effect of spillovers, arising because of the relationship between a university and science park, on the university's performance and other indicators such as employment and regional and local economic growth (Link 2016).

A new and remarkable trend is the development of studies about human resource management in science parks (e.g., Huang 2014; Wang et al. 2013). Future works could study job profiles, motivation, stress management, and other issues in the context of science parks. In that sense, there are some research questions such as the following: what are the main characteristics of the science and technology park managers? What kind of formation is the most suitable for managing a science and technology park? Is there any difference in the performance of science and technology parks that are managed by different managers?

Another new research direction is the analysis of the business models of firms inside the science and technology parks. In that sense, it is interesting to consider the traditional

business models and the modern ones, especially those based on open data (Zimmermann and Pucihar 2015).

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