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Science and technology park: Future challenges☆

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ABSTRACT

Science and Technology Parks (STPs) originated in the 1950s in the US. Since then, a number of countries have implemented these types of parks to develop and revitalize regions, boost high-tech industry sectors, foster greater industry-academia interaction, support new technology-based firms (NTBFs), and encourage academic spin-offs. Although these parks have operated for many years, there is no universally accepted definition in the literature or consensus regarding the contributions of STPs to the region and tenant companies. Using the method proposed by Lage Junior and Godinho Filho (2010), this study analyses 56 articles, indicating their objectives and results and providing guidance on controversial topics, and identifies existing gaps, opportunities, and challenges for future studies. The results suggest that the multiple definitions of STPs make expectations about these parks very high. Much of the literature identifies positive contributions for both the region and tenant companies and the main impact is fostering greater interaction with universities.

1. Introduction

Science and Technology Parks (STPs) are an important tool for uniting industry and academia. According to Dierdonck et al. [1]; p. 109), the gap between academic science and industrial technology stems from the belief that academia and industry represent two different worlds that are frequently inconsistent with each other. It is precisely in this context that STPs stand out by providing an environment in which the interaction between research institutes and companies is encouraged. Díez-Vial and Montoro-Sánchez [2]; p. 41) note that STPs create an atmosphere that favours the exchange of knowledge between companies located in the park, universities, and the market.

Using a metaphor [3], points to two main objectives of STPs: to be a seedbed of innovation, which consists of fostering the development and growth of New Technology-Based Firms (NTBFs), to promote the transfer of university know-how to tenant companies and to encourage the development of faculty-based spin-offs. According to this author, the second objective is to be a catalyst for regional development by stimulating economic growth and revitalizing urban areas.

After their emergence in the 1950s in the US, STPs quickly spread around the world. Success stories in the US, such as Silicon Valley and Route 128, encouraged a number of public officials to implement STPs in other countries. However, despite several successful cases, many STPs did not achieve their goals, raising several questions in the literature regarding the true effectiveness of these parks. An important argument by Yang et al. [4]; p. 85) provides guidance on these questions, asserting that the success of an STP cannot simply be replicated from one region to another. In other words, the policy of boosting technological development through parks cannot be implemented without limits and adaptation to different realities.

Despite many years in operation, the contribution of STPs is still not completely clear [5]; p. 137) [6]. analyses 52 Chinese STPs in the period from 1992 to 2000 and finds no evidence that companies benefit when they are located in STPs [7]. evaluate three STPs in Greece, where formal links with universities are identified in only one STP. These authors state that, in general, STPs do not meet expectations. On the other hand [8], identifies that NTBFs located in STPs have a higher propensity to engage in joint research with research institutes by studying six parks in Japan from 1998 to 2003. Similarly, when comparing on-park NTBFs with off-park NTBFs [9], find that the NTBFs in the STPs have more connections with universities whereas the sample of off-park NTBFs has lower performance.

A major difficulty in assessing STPs is clearly defining what their

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purpose is [10]. states that the idea of STPs is to provide infrastructure for technical, logistical, administrative, and financial support to help new companies survive and gain market share. In contrast [2], claim that STPs are created with the goal of transferring technology from universities to tenant companies. In addition [11], suggest that there is no systematic framework for understanding STPs. In certain situations, an STP may fulfil one expected role but not meet another. Thus, many authors believe STPs are not contributing in the expected manner because the expectations are very high, given that the hope is that such parks will satisfy all of the different existing needs and demands. What is clear is that, despite controversial results, STPs generally contribute to tenant firms in some manner.

Given this context, this study analyses 56 articles published in different journals from the 1980s to September 2016 that are identified using keywords such as "technology park", "science park", "technopark", and "techpark". This work fills a gap identified in the STP literature through the analysis of the researched articles and studies that review the literature, as demonstrated in Section 5. Thus, in more detail, the objectives of this work are as follows:

1. To classify and code the studies, integrating results and relating them to emerging issues in the researched topic;
2. To briefly analyse and present the state of the art for the central topics of science and technology park, mainly in terms of their impacts, whether on the region or on the companies; and
3. To provide a research agenda, highlighting the major gaps and challenges in the subject for future researchers.

To fulfil these objectives, this article is structured as follows: the research method is presented in Section 2; the classification and coding criteria for the analysed articles are described in Section 3; a brief contextualization of STPs is performed in Section 4; the results of the coding are discussed in Section 5; and finally, the conclusions are provided in Section 6.

2. Methods

A literature review is an important tool for gathering the results of previous studies on a particular topic [12]; p. 7), by presenting an in-depth analysis of the main studies. In addition, Jabbour [13]; p. 145) notes that this technique identifies challenges for the development of future studies; that is, after identifying the characteristics of how the literature has been discussing a theme, it is possible to discover possible gaps and opportunities for topics that are not being discussed in the same proportion as others. Therefore, such a review makes it possible to indicate a direction for future studies.

Given the relevance that the literature review adds to the academic debate on a given topic, Lage Junior and Godinho Filho [14]; p. 14) present five steps to be followed in conducting this process, as demonstrated in Refs. [15] and [13]:

1 Conduct a search for articles published on the subject in large academic databases using keywords;
2 Filter the articles by ascertaining their relationship with the research topic;
3 Develop criteria for classifying and coding the analysed articles;
4 Through the application of the coding, present the main topics studied and the results found in the analysed articles and provide a complete view of the existing knowledge on the subject; and
5 Analyse existing gaps and opportunities, indicating suggestions for future studies.

Although several researchers use literature reviews in studies in diverse areas [12–17], a gap in the topic of STPs has been observed, shown in Sec. 5. Given this context, this study provides an important contribution by presenting the state of the art and offering guidance for future studies.

Considering step 1, this study used the following keywords to identify articles in the *ScienceDirect* search engine: "science park", "technology park", "technopark", and "techpark". According to Löfsten and Lindelöf [70]; p. 1016), there is no universally accepted term for defining STPs, so the choice of several synonymous keywords aimed to provide a more complete search of the topic and to find the relevant material available. We did not analyse other databases such as *Web of Science* or *Scopus* due to our restricted access to them, which allowed for only the query in the abstract at the time of the collection of the data. Although the method can limit the scope of results, the significant number of papers investigated in our study, published in highly influential journals in the field, allowed us to map how the scientific literature is discussing central topics regarding the impacts of STPs on tenant firms and in the surrounding region. The reason for not considering more keywords related to technological parks is that the inclusion of the search engine was only marginally relevant. As new keywords were added, fewer new articles were identified because they had already been found through other searches.

Once the articles are identified, the next step is to verify their relationship with the research topic. Although many articles had a keyword in their title, their focus was often very distinct and might not have even concerned STPs. To perform such an inquiry, the abstracts of the studies were analysed. In Table 1, the total number of articles found using keywords and how many of these were selected are displayed. First, we searched for the word "science park". A total of 297 articles were found for this search. After checking their relationship with the research theme, we selected 34 articles. Subsequently, we searched for "technology park", finding 226 articles. After careful analysis, only 20 articles were included in this study. The next term searched was "techpark" which resulted in 10 selected articles. The last keyword searched was "technopark", in which three articles that were all related to the theme were identified. Although the total number of articles selected from each keyword is 67, it must be noted that the same article can be identified by different keywords. Bearing this fact in mind, 11 articles were repeated, and therefore, the final analysis considered 56 articles.

3. Classification and coding

After the articles were collected, an analytical framework was elaborated with eight classifications relating to relevant topics in the literature on STPs. Consequently, each article was classified and coded based on its characteristics and the results found. The classifications are composed of numbers and letters (A, B, C, D, E, and so on). Therefore, the code consists of a combination of letters and numbers. This step is important to identify the topics that are being studied the most and possible gaps in studies in the area.

Classification 1 identifies the economic context of the country of the study in question, with a range of coding possibilities from A to

Table 1
Number of articles identified per keyword.

Keyword	Total of Identified Articles	Total of Selected Articles
Science Park.	297	34
Technology Park.	226	20
TechnoPark.	3	3
Tech Park.	14	10
Papers considered.	**-**	**56**

D. The code of D is restricted only to literature reviews, which do not have a country as the focus of study. According to Bakouros et al. [7]; p. 124), most studies are conducted in developed countries, often neglecting the least developed countries. This classification will make it possible to identify whether there continues to be a lack of studies in less developed countries or if, over the years, this gap has been filled.

Classification 2 refers to the continent of the data analysed by the article in focus. The coding scale is composed of the letters A-G. The results of this classification will be important for identifying possible continents with little research on technological parks, thus pointing to a gap in geographical perspective. In addition, studies in less-researched regions would be an important contribution to discussions on this topic because it would be possible to identify whether regions with infrastructure that is admittedly inferior to that of European countries, for example, are able to achieve the expected results in their parks. In other words, when observing studies in different contexts, it will be possible to analyse STPs in different contexts, including different cultures.

Classification 3 analyses the articles based on research objectives. The coding scale is composed of the letters A-H. The results in this classification will allow us to identify whether the focus of the studies is related to the operations of the STPs, the tenant companies, or other relevant subjects, such as innovation.

Classification 4 identifies the specifications of the works analysed, with a coding scale from A to E. Through this category, it will be possible to understand whether the literature on STPs is more associated with empirical or theoretical works. Classification 5, in turn, refers to the research method of the studies and is coded on an A-I scale.

The following classifications will not point to gaps but will instead present a direction of how the literature has been debating essential topics regarding STPs. In this sense, classifications 6 and 7 identify the position defended and the results found by the articles analysed in topics such as the effect of STPs on the region, also called regional development, and the impact of STPs on tenant companies. Both classifications are coded on an A-D scale. Finally, classification 8 adds to the discussion on STPs by identifying the main contributions of STPs to tenant companies, with an A-I coding scale.

It is important to note that, with the exception of classifications 3, 6, and 7, whose coding options are mutually exclusive, the articles could be coded using more than one code. Therefore, the sum of the codes in such categories may exceed 56, that is, the total number of articles analysed. Table 2 shows the classifications and coding possibilities.

4. Brief summary of the literature on STPs

Technological parks, also called science parks, techparks, technopark research centres, and other definitions, originated in 1951 with the creation of the Stanford Research Park [7]; p. 123). The following year, the Cornell Business and Technology Park emerged, and a few years later, in 1959, the Research Triangle Park was established [18]. In the late 1960s, there were already STPs in the UK, more precisely, in Cambridge, and Sophia Antipolis in France. The development of parks in other countries has attempted to replicate US success stories, such as Silicon Valley in California and Route 128 [19,20]. The Hsinchu Science Park, located in Taiwan, is an example. Established in 1980 and inspired by California's Silicon Valley, Hsinchu Science Park encourages the origination of small and medium private companies [21], and is now one of the world's most important STP.

Despite the many years that these environments for innovation have operated, there is no universal definition of STPs [22]; p. 1324). The definition varies considerably, but the concept of STPs generally involves three characteristics [23]; p. 1216):

1. A concentration of high-tech industries and specialized service centres;
2. The existence of at least one university or technology institute with which tenant companies may maintain some form of formal link; and
3. The promotion of knowledge transfer, such as tacit knowledge, and technology to tenant organizations.

To provide a definition of STPs, the International Association of Science Parks and Areas of Innovation defines science parks as follows:

> *A science park is an organisation managed by specialised professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions. To enable these goals to be met, a Science Park stimulates and manages the flow of knowledge and technology amongst universities, R&D institutions, companies and markets; it facilitates the creation and growth of innovation-based companies through incubation and spin- off processes; and provides other value-added services together with high quality space and facilities* [24].

Westhead and Batstone [25]; p. 132) presents a list of 10 objectives of STPs, including: encouraging academic spin-offs and the formation of NTBFs, boosting the growth of tenant companies, promoting interaction and knowledge transfer with universities or research institutes, creating synergy between enterprises, and promoting development in the region and the local economy.

Regarding their objectives, technological parks differ based on their locality and peculiarities. In general, they act by creating a favourable environment for interaction between academia and industry [26–28]. Bigliardi et al. [29]; pp. 489–490) distinguish the role of such parks in countries based on the degree of development. In emerging countries, STPs are expected to act as a catalyst for development, assisting in the growth and consolidation of newly created hi-tech companies, i.e., helping new firms survive and gain market share and, with regard to already established companies, providing direction for them to innovate their products and processes. In developed countries, it is expected that such parks contribute to the development of an area or help eliminate so-called “shadow areas” [29].

One of the main elements that make STPs attractive to companies is the geographic proximity to other companies. To better understand this subject, the ideas proposed by Ref. [30] must be considered. This author shows that small firms in the same region can achieve economies of scale via economy clustering. In addition, a strong concentration of companies from the same industry in one geographical space would create an environment that favours interaction and cooperation between them. According to Díez-Vial and Montoro-Sánchez [2]; p. 42), geographical proximity favours the exchange of knowledge, particularly tacit knowledge, which is more difficult to be shared among companies and between companies and other institutions. This concentration of companies has become known as a cluster.

One of the factors that differentiate STPs from traditional industrial clusters is the link with universities and research institutes. As noted by Löfsten and Lindelöf [70]; p. 1025), the relationship between the tenant companies in parks and universities is a key feature of STPs. These authors also claim that universities and small businesses play an important role in economic progress. In this sense [31], stresses that incubation programmes are one of the

Table 2
Codes used.

Classification	Meaning	Cryptography
1	Economic context.	1A - Mature economy. 1B - Economy considered mature or non mature/emerging. 1C - Non-mature economy. 1D - Not applicable.
2	Geographic region.	2A - North America. 2B - South America. 2C - Europe. 2D - Asia. 2E - Other regions. 2F - Not Applicable.
3	Focus.	3A - Examine/Evaluate the level of innovation. 3B - Presentation of tools/method to evaluate STPs. 3C - Describe/Evaluate experiment/experience in the field of STP. 3D - Presentation of techniques/tools to include companies in the STP. 3E - Presentation/Application of tools/method to evaluate/analyse the companies/industries in the STP. 3F - Examine the performance/operation/impact of the STPs. 3G - Others.
4	Specification of the study.	4A - Empirical. 4B - Conceptual (Theoretical). 4C - Literature review. 4D - Experiment.
5	Method.	5A - Qualitative. 5B - Quantitative. 5C - Conceptual. 5D - Questionnaire/Interview. 5E - Qualitative/Quantitative. 5F - One case study. 5G - Multiple case studies. 5H - Literature review. 5I - Experiment.
6	Contribution in the region.	6A - Positively impacts society/region. 6B - Lower than expected impact on society/region. 6C - Does not have a significant impact on the society/region. 6D - Not applicable/It was not possible to identify.
7	Impact of STPs on tenant companies.	7A - There was a positive impact of the parks on the tenant companies. 7B - Lower than expected impact. 7C - There was no significant impact on companies. 7D - Not Applicable/It was not possible to identify.
8	Main impact of STPs on tenant companies.	8A - Knowledge transfer. 8B - Resources offered by STPs (Subsidies, infrastructure, etc.). 8C - Proximity and interaction with other companies (Clusterization). 8D - Positive image for the company due to being located in an STP. 8E - Provides greater interaction with universities/research institutes. 8F - Networking. 8G - Others. 8H - Positive impacts were not identified. 8I - Not applicable/It was not possible to identify.

methods by which universities seek direct involvement with regional economic development. Finally [32], emphasize that STPs play a role in assisting the transfer of technology and administrative knowledge between universities and tenant industries.

Ideally, the presence of a university close to knowledge-based firms in an STP would create an atmosphere that is conducive to innovation, with knowledge and technology flowing in that environment [2]. Tenant companies could incorporate in their operations what is done in successful companies elsewhere in the world through universities. In other words, the university represents a bridge between nearby companies and the rest of the world because it is possible to learn administrative techniques from distant companies through universities [2]; p. 42). This environment would generate a steady improvement in operations, driving innovation. With the increase in innovation, there would be positive impacts on the region. This view of knowledge spill-over and innovation as positively impacting the region is part of the linear model of STPs, which, according to Hansson et al. [33]; pp. 1039–1040), is based on the expectation that technological innovation derives from (pure) scientific research. Central to these expectations is the belief that STPs act as a catalyst for economic growth through their contribution to innovation and, consequently, development in high-tech companies. Westhead [34]; p. 46) states that the linear model presupposes a chain of successive interrelated activities, beginning with pure scientific research, applied research activities, new product development, prototype evolution and testing, commercial production, and, finally, commercialization and diffusion. As a result, the local technological environment attracts and nurture the creation and development of NTBF in the region.

[35] argues that this model does not reflect reality and consists of an outdated view. Many of the criticisms received by STPs stem from expectations that parks will receive scientific knowledge from universities without difficulty. In fact, many STPs are evaluated as poor because researchers implicitly use a linear framework that focuses on the direct transfer of knowledge to perform such an evaluation. By looking beyond the traditional approach [35], finds that there are more interactions in the Western Australian Technology Park than could be estimated by the linear model, suggesting that, to correctly analyse the parks, it is necessary to go beyond linear optics. This author notes that a considerable error of

the linear model is that it does not consider the complex non-linear process of innovation.

Table A1 presents a brief description of the papers analysed by this work, their objectives and results, and the number of citations. Papers were ordered by year of publication, making it possible to verify trends of the studies in the field. It should be noted that it was not possible to find the number of citations in some articles because the information was not available or because they were very recent. Analysing Table A1 is a good method of understanding how the literature has been discussing the central issues of STPs, such as their contributions to regions and companies, and of identifying the main impacts on tenant companies.

5. Results of the literature analysis

To present the results in the most detailed manner, we performed a bibliometric analysis and codification (Table 2). Bearing this procedure in mind, this section is divided into two subsections: bibliometric analysis and coding results. We hope to thereby briefly evaluate and present the state of the literature on STPs.

5.1. Bibliometric analysis

The first dimension presented consists of the bibliometric analysis. In Table 3, the number and percentage of published articles are listed, decomposed by year and journal.

As shown in Table 3, publications on STPs are highly concentrated in the journal *Technovation*, with 21 publications or 37.5%. The journal *Research Policy* ranks second, with five publications or 8.93%. A total of 22 journals have publications related to STPs. The "Other" category in Table 3 is composed of 15 journals with only one article in the period analysed. Many of these journals do not include technology and innovation in their research scope and, for this reason, have had few published studies on STPs. Examples of this situation are the following journals: *Omega*, *Analytica Chimica Acta*, and the *Journal of Environmental Management*.

With regard to the year of publication, 2005 is the year with the highest number of studies, with 10, followed by 2006 and 2016, with six and five, respectively. The first study on STPs in the sample analysed is [36]; published in *Technovation*, which discusses the beginning of operation of STPs in Israel. From 1986 to 2000, only seven articles were published. On the other hand, in the last 10 years, there have been 29 publications, consisting of 51.79%. This finding shows that, although STPs have been in operation for more than 50 years, to date, the topic has not been extensively explored and carefully discussed, though there are many possibilities for debates and discussions in the literature.

To identify the most relevant articles on the topic, we used Google Scholar to verify the number of citations per study. According to Mariano et al. [15]; p. 38), the number of citations is a valid parameter to classify relevance of papers. In our study, the article by Ref. [11] is ranked first, with 542 citations. This article and the article by Ref. [46] are the only manuscripts among those analysed that reviewed the literature, which highlights the importance of this type of review for the academic debate. Additionally, the results suggest the need for an updated literature review, taking into account a more recent analysis. The study by Ref. [37] is ranked second, cited 462 times [37]. compared firms in STPs and outside of STPs in Sweden. Other most cited papers include those by Refs. [23,38,39]; and [3]; with 369, 322, 316 and 248 citations, respectively [23]. discussed an alternative tool to analyse the performance of business incubators [39], studied the impact of Surrey Technology Park in the interaction among tenant companies and Surrey University [38], studied how STPs in the United Kingdom affected the output of R& D of tenant firms and [3] focused on three STPs in Israel, aiming to investigate whether they promoted innovation. It is important to highlight that, taking into account the citation criterion, for more recent papers, the elapsed time is not enough to make them prominent. The citations by article are detailed in Table A1, in the appendix.

Table 3
Number of papers per year and per journal.

Analysed Criteria	Classification	Amount	Percentage (%)
Journal.	Technovation.	21	37.50
	Research Policy.	5	8.93
	Procedia - Social and Behavioral Sciences.	4	7.14
	Expert Systems with Applications.	3	5.36
	International Journal of Industrial Organization.	3	5.36
	Journal of Business Venturing.	3	5.36
	Technological Forecasting and Social Change.	2	3.57
	Others.	15	26.79
Year.	1986	1	1.79
	1994	1	1.79
	1996	1	1.79
	1997	1	1.79
	1999	3	5.36
	2000	1	1.79
	2002	3	5.36
	2003	4	7.14
	2004	2	3.57
	2005	10	17.86
	2006	6	10.71
	2007	4	7.14
	2008	2	3.57
	2009	4	7.14
	2010	2	3.57
	2011	2	3.57
	2014	1	1.79
	2015	3	5.36
	2016	5	8.93

5.2. Coding results

Table 4 shows the coding for all articles reviewed in this study.

For a better visualization of the results, Table A2 presents the number of articles and the percentage referring to the codes in each classification. This table served as a reference for the preparation of all of the following figures.

5.2.1. National context

The first classification refers to the economic context of the country in which the analysed STPs are located. It is important to include such a classification in this literature review because STPs present considerable differences from one locality to another, particularly in different national contexts. In addition, according to [7]; the vast majority of the literature on STPs focuses on more developed countries, such as the member states of the Organization for Economic Co-operation and Development (OECD). Finally, it is often argued that the success of STPs is related to factors that are more characteristic of developed countries than developing countries, such as the demand for high-tech products, government support, and investments.

The coding possibilities are as follows: A - a mature economy; B - an economy that could be considered mature or non-mature; C - a non-mature economy/emerging economy; and D - not applicable. Code B includes countries such Taiwan and Israel, which are considered mature economies by some and emerging economies

Table 4
Results of codifications.

Article\Categories	1	2	3	4	5	6	7	8
1	1B	2D	3F	4A	5F	6D	7A	8G
2	1B	2D	3F	4A	5A/5D	6B	7B	8D
3	1A	2C	3F	4A	5F	6A	7D	8B
4	1A	2C	3F	4A	5F	6D	7B	8E
5	1A	2C	3G	4B	5C/5F	6D	7D	8I
6	1A	2E	3F	4A	5A/5D/5F	6D	7A	8C/8E/8F
7	1B	2D	3E	4A	5B/5F	6D	7D	8I
8	1B	2D	3F	4A	5F	6A	7D	8I
9	1B	2C	3F	4A	5A/5D/5G	6D	7B	8D
10	1A	2C	3F	4A	5D	6A	7A	8E
11	1A	2C	3F	4A	5D	6B	7B	8G
12	1C	2C	3F	4A	5A/5G	6B	7B	8B
13	1A	2C	3F	4A	5D	6D	7A	8E/8G
14	1A	2A	3F	4A	5D/5E	6D	7D	8I
15	1A	2C	3F	4A	5E	6B	7A	8A
16	1B	2D	3D	4A	5D	6A	7D	8I
17	1C	2C	3F	4A	5A/5F	6D	7D	8I
18	1A	2D	3F	4A	5G/5D	6D	7B	8B
19	1B	2D	3C	4D	5I	6D	7D	8I
20	1A	2C	3F	4A	5F	6D	7A	8A/8B
21	1A	2D	3G	4B	5C	6B	7B	8I
22	1A	2C	3F	4A	5A/5G	6B	7B	8C/8G
23	1A	2A/2C/2D	3B	4A/4B	5C/5F	6A	7A	8A/8B
24	1B/1C	2D	3A	4A	5D/5E/5G	6D	7D	8I
25	1A	2C	3F	4A	5D	6D	7A	8B/8E
26	1D	2F	3G	4C	5H	6D	7D	8I
27	1A	2C	3F	4A	5A/5G	6A	7A	8A/8F
28	1A	2C	3B	4A/4B	5A/5C/5G	6D	7D	8I
29	1B	2D	3E	4A	5B	6D	7D	8I
30	1A	2C	3F	4A	5D	6D	7A	8B/8F
31	1A	2D	3F	4A	5E	6D	7A	8E
32	1C	2D	3F	4A	5A/5F	6A	7A	8A/8C
33	1B	2D	3C	4D	5I	6D	7D	8I
34	1B	2D	3C	4D	5I	6D	7D	8I
35	1C	2D	3F	4A	5B	6B	7C	8H
36	1B	2D	3E	4A	5D/5E/5F	6B	7A	8F
37	1B	2D	3G	4A	5F	6B	7D	8I
38	1A	2C	3E	4A	5G	6D	7A	8B/8C/8D/8E/8F
39	1B	2D	3C	4D	5I	6D	7D	8I
40	1B	2D	3B	4A	5E	6D	7A	8C/8G
41	1C	2D	3F	4A	5D/5G	6C	7B	8B/8D
42	1B	2D	3E	4A	5B/5F	6A	7A	8C/8G
43	1B	2D	3F	4A	5B	6A	7A	8C/8F/8G
44	1A	2C	3F	4A	5A/5F	6A	7A	8E
45	1A	2C	3F	4A	5A/5G/5D	6C	7D	8I
46	1C	2D	3A	4A	5F	6D	7D	8I
47	1B	2D	3E	4A	5B	6A	7A	8C
48	1B	2D	3C	4D	5I	6D	7D	8I
49	1C	2C	3A	4A	5D/5E	6D	7D	8I
50	1A	2C	3G	4A/4B	5C/5F	6D	7A	8G
51	1C	2C	3F	4A	5D	6D	7A	8C
52	1A	2C	3A	4A	5A/5D	6D	7A	8E
53	1A	2C	3F	4A	5A	6D	7D	8I
54	1C	2D	3F	4B	5C	6A	7A	8G
55	1C	2B	3B	4C	5E/5H	6B	7D	8I
56	1A	2C	3F	4A	5B	6D	7A	8E

by others. Because it is not the objective of this work to discuss these questions, a differentiated category for these countries will avoid biased results because STPs in Taiwan are the focus of 15 studies. Bearing this issue in mind, considering these countries as mature or non-mature may lead to a predominance of a code that would not represent reality. In addition, Taiwan and Israel are recognized as having good infrastructure and strong investment in high-tech industries, playing a leading role on the world stage. Thus, these countries have very different characteristics from developing countries, which are often marked by deficient infrastructure and technological backwardness in relation to the major powers.

Thus, it is possible to verify whether successful cases of STPs have concentrated only in mature economies or whether emerging economies have also been successful. The results are presented in Fig. 1. Most of the studies analyse STPs in mature economies, confirming the point made by Ref. [7]. Non-mature or emerging economies are the focus of only 10 studies, indicating a need for more publications in these countries. In this context, we highlight that, although there are still just a few studies of STPs in non-mature or emerging economies, this situation was even worse when considering the literature previous to 2000 and in the period from 2000 to 2005. Of the 7 studies previous to 2000, none focused on STPs of an emerging economy. From 2000 to 2005, 20 manuscripts were analysed, but only [40,41]; and [42] studied non-mature or emerging economies. Taking into account the 10 most recent publications, 4 papers focused on emerging countries [43–46], suggesting that researchers are trying to fill the gap of lack of studies in these economic contexts. Despite this recent trend, since the majority of studies analyse mature economies, the gap identified by Ref. [7] still exists.

With regard to studies in different economic contexts [42], analyse a park in China and Taiwan [33]. and [47] also study STPs in more than one country, but in both cases, the two countries are mature economies. In theoretical terms [19], discuss successful cases of STPs, such as Silicon Valley, Hsinchu, and Cambridge, aiming to develop an analytical framework to apply in an STP development strategy in Singapore.

Only the articles cited above study STPs in different economic contexts, thus indicating an important gap in the literature, particularly regarding the empirical comparison between STPs in mature and emerging economies. It is interesting to note that there are situations in which the first author was associated with a developed country but conducted the study in emerging economies, such as [6,20,40,48]; and [49]. Finally, code D is restricted to the study by Ref. [11]; who review the literature without discussing specific STPs. Based on this context, the following gaps are identified:

*Gap*1 – The gap noted by Ref. [7] remains, indicating the need for more studies in non-mature/emerging economies.
*Gap*2 – There is an absence of studies in different contexts that empirically compare STPs in mature economies and non-mature/emerging economies.

5.2.2. Geographic region

In the second classification, the geographical region of the researched countries is identified. This classification adds information to the first classification, with the following coding options: A - North America; B - Latin America; C - Europe; D - Asia; E – other regions; and F - not applicable. The results found here, presented in Fig. 2, will be relevant to the debate on STPs because each geographic region has its peculiarities. Thus, identifying the performance of STPs in each region will allow a better understanding of the operations of these parks in different cultures.

The largest number of gaps occurs in this classification because the studies are strongly concentrated in Europe and Asia. These two continents together represent 92.85%. Although frequently cited in contextualizations as the precursor of STPs and also with successful cases such as Silicon Valley, the US is only the focus in Refs. [22] and [19]. There are no studies in other North American countries. Similarly, only [45] study South America, and the discussion is restricted to tools for evaluating STPs in this region. Therefore, there is a need for studies that analyse the contributions and operations of STPs in this region. With regard to other regions [35], analyses the Western Australian Technology Park, going beyond the traditional linear approach to innovation by examining interactions and networking in this STP. Due to the long period of time since the work by Ref. [35] and because it represents only 1.78% of the studies analysed, it is vital for other studies to be conducted in these regions. Finally, only [19] seek to analyse STPs in more than one continent. However, the authors restrict themselves to theoretical aspects without empirically comparing STPs. Contrary to what was verified in the previous classification, few changes occurred in the literature regarding the geographic regions of the STPs studied over the years. Although the concentration of research in the European and Asian continents persists throughout the analysed time period,

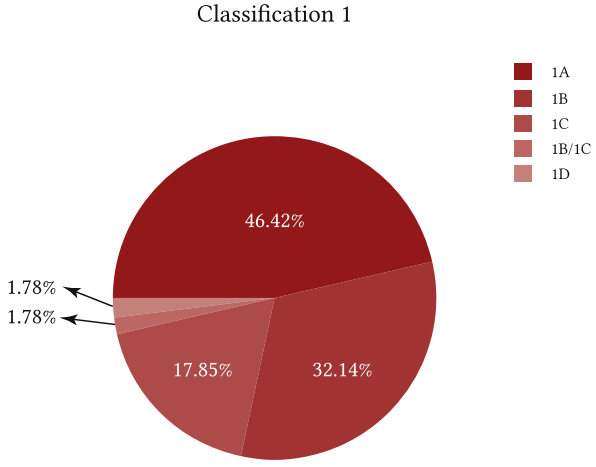

Fig. 1. Frequency distribution for the Classification 1: Economic context.

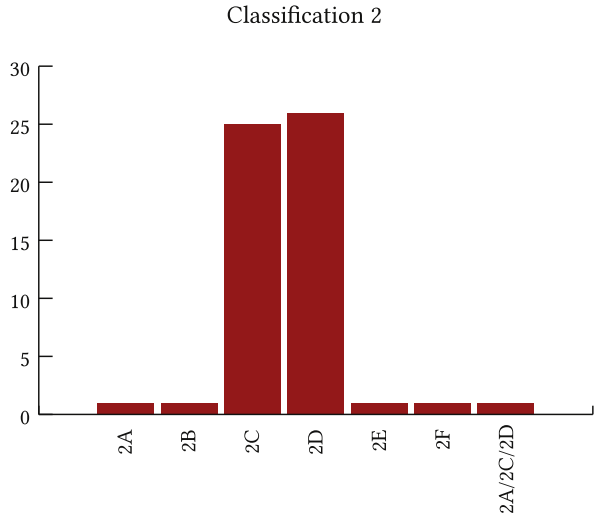

Fig. 2. Frequency distribution for the Classification 2: Geographic region.

a slight predominance is observed in the European continent considering the most recent studies. Based on these aspects, the following gaps are proposed:

*Gap*3 – Why is there a lack of studies in regions outside Europe and Asia?
*Gap*4 – There is a lack of studies that empirically analyse and compare STPs in different continents.

5.2.3. Focus

The third classification presents the scope of the articles. The articles were coded from A to G, where A - examines or evaluates the level of innovation within an STP; B - presents new tools or methods to evaluate STPs; C - describes or evaluates an experiment in the field of STPs; it should be noted that articles belonging to this coding do not address discussions that are commonly pertinent to STPs but instead are related to other areas of knowledge such as chemistry; D - present techniques or tools for the selection of new companies in STPs; E–offers a presentation or application of techniques to evaluate or analyse companies or industries located in a STP; this coding includes the analysis of high-tech clusters located in parks; F - examines or evaluates the impact, operation, and performance of STPs; included in this coding are studies that compare companies located in parks with companies outside these innovation environments to assess the added value of STPs; additionally included in this coding are articles that analysed an STP and its history and operations, as was done by Ref. [50]; and, finally, category G - other includes other focuses, such as a literature review or themes that are not associated with any other category previously discussed.

The design of these codes sought to align with the objectives often found in the articles and with the need to identify the state of the art in topics that are relevant to the literature. In addition, the points made by Ref. [11] that the literature on STPs can be divided into studies that focus on firms located in these parks, those that aim to provide an assessment of STPs, those that discuss the systemic level of university, region, or country, and those that analyze entrepreneurs in these innovation habitats.

The results are shown in Fig. 3. Code F had the largest number of studies. This finding shows that researchers' main focus is to identify the impact or added value of the STPs, as done by Refs. [3,51]; and [52]; or to analyse the operations and characteristics of the STPs themselves [10,36]. In relation to the companies located in these facilities, the focus is much lower. In spite of the high prevalence of the F code, in recent years, this result has been reducing. In the first ten articles of the sample, only [53] had another focus. In the 10 most recent publications, six surveys had another goal [45]. developed a new tool for evaluating STPs [2]; investigated how knowledge generated in universities could boost innovation [54]; applied Everett Roger's theory to analyse the diffusion of innovation in Sardegna Richerce STP in Italy [43]; analysed whether innovation is affected by employees relationships with their superiors and with the organization in an STP [55]; described an experiment performed in an STP; and finally [56], analysed the efficiency and productivity of six industries located in Hsinchu Science Park. An alarming result is the number of studies that discuss how to select companies in STPs, which includes only [57]. In this sense, the following question arises:

*Gap*5 – Are the failures of STPs to positively influence tenant firms due to their own operations or due to companies that cannot absorb the knowledge? For example, parks with more stringent selection criteria, such as Hsinchu STP, a successful case in Taiwan, present more satisfactory results.

5.2.4. Specification of the studies

The fourth classification discusses the specifications of the studies, coded by the following letters: A - empirical; B - conceptual; C - literature review; and D - experiment. The results, shown in Fig. 4, point to a predominance of empirical studies, with 76.78%. Ranked second are studies that perform experiments in an STP, representing 8.9%. All of these have Hsinchu STP as a site, where the experiments aimed to measure the presence of volatile organic compounds in the air and water and to study the impact of adverse climatic conditions, such as typhoons, on air quality [58]. Studies that are considered both conceptual and empirical represent 5.35% of the total, presenting the same percentage as exclusively conceptual works, which is also 5.35%. Finally, only 3.5% of the studies are literature reviews, suggesting the existence of a gap. It should be emphasized that the most cited article of all those analysed is [11]; one of the studies to review the literature, providing evidence of the importance of this method for academic debate. In contrast to what was verified in the previous categories regarding the changes over time in the way literature has been discussing a certain topic, in this classification and in the following, with the

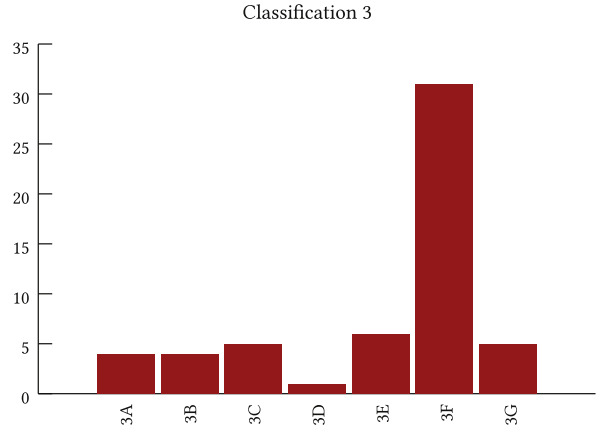

Fig. 3. Frequency distribution for the Classification 3: Focus.

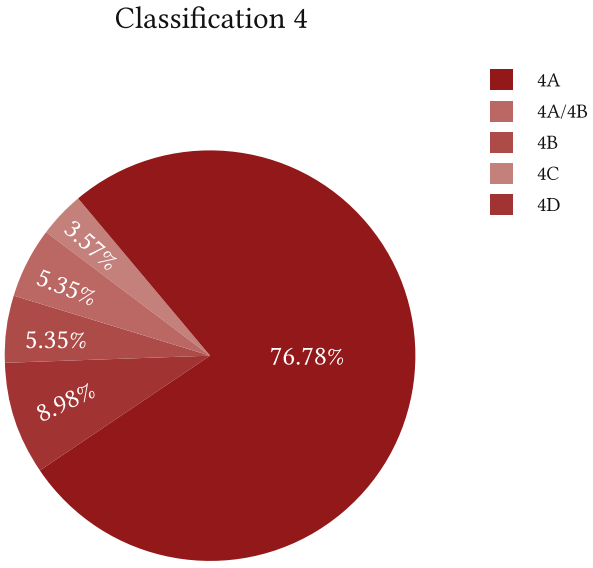

Fig. 4. Frequency distribution for the Classification 4: Specification of the study.

exception of Classification 5: Method, we did not identify expressive change that deserves attention.

This study provides an important contribution to filling this gap by presenting a survey of the state of the art on essential STP topics, identifying the main methods and techniques used, the economic context with the most studies, and the most studied geographic regions, providing guidance for future studies, and noting gaps, opportunities, and challenges.

5.2.5. Method

The fifth classification refers to the method used by the analysed articles, based on the following codings: A - qualitative; B - quantitative; C - conceptual; D - questionnaire and/or interview; E – qualitative and quantitative; F - one case study; G - multiple case studies; H - literature review; and I - experiment. Because many studies used more than one method, the results are presented in two ways: first, we discuss the combinations used by the researchers, and second, we analyse each code individually. In Fig. 5, the results are shown considering the combinations of methods.

This classification is related to the fourth classification and extends the scope of the previous classification. The code 4D, for example, has the same value as 5I, because they refer to the same type of study. This also occurs with the code 4B-5C and 4C-5H. Because there are studies that apply more than one method, the results are decomposed. The predominant code is F, referring to one case study, with eight articles, followed by questionnaires and interviews, with seven articles. It is worth noting that the single case study method was more prevalent in the early surveys, such as in Refs. [10,35,36,39,53,59]; and [60]; where the study locus was a specific STP.

The second way, in which the number of articles is separated by method, shows that 18 articles used a questionnaire and/or interview and 17 present a single case study and 10 multiple case studies. Therefore, 27 of the 56 articles address a case study in some manner. It is worth noting that the sum of the codes exceeds 56 due to the multiple methods used by several articles. The gap identified is the small number of literature reviews, a topic discussed above.

5.2.6. STPs and regional development

The sixth classification addresses the impact of STPs on regional development. This is one of the most controversial topics in the literature on STPs. When parks were idealized, they were expected to lead to regional development by revitalizing urban areas or bringing growth to less favoured regions [3,34].

The coding possibilities were A - positive impact on the region; B - lower than expected impact on the region; C - no significant impact on the region; and D - not applicable. It is important to include option B in this category because, in many situations, the STP impacts the region but not with the intensity that stakeholders would expect. Vedovello [39]; p. 493) highlights that positive regional effects can range from the generation of new jobs and the creation of NTBFs to the revitalization of the local economy. The results are shown in Fig. 6.

Disregarding the 32 articles that do not seek to verify an impact, represented by code D, practically all researchers find some positive regional impact, except for [20] and [61]. In other words, of the 24 studies that somehow address this topic, whether in contextualization or in the results, 22 identify some positive effect. However, 10 studies find that STPs contributed less than expected.

Although this finding indicates a possible failure of STPs, it may also suggest that the expectations placed on STPs are very high [6]. identifies that STPs helped reduce the growing trend of regional disparity in China, although this reduction does not appear to be related to the transfer of knowledge [40]. finds that the impact of the STP in St. Petersburg on the region was restricted to generating new jobs; however, these new jobs came at a bad time in the local economy. Similarly, [60] also identify the positive impact of parks on the creation of several new jobs, in addition to stimulating investments in R&D, improving labour, and improving the country's international ranking in several high-tech industries [50]. presents a very successful case in Dortmund, where the presence of the STP helped recover and leverage the regional economy, which was greatly affected after the decline of the coal and steel industry. On the other hand [61], note that the impacts on the region were modest at best. The generation of new jobs and economic growth were practically imperceptible. When also considering that the STPs of Portugal were in urban areas, this effect would be further diluted. An important issue identified by Ref. [61] is that, with the exception of Tanguspark, a case of excellence, the other STPs were not properly planned.

There are many aspects that can make the STP fail to achieve the expected goals, beginning with unrealistic expectations. The study by Ref. [35]; published several years ago, stresses the need to

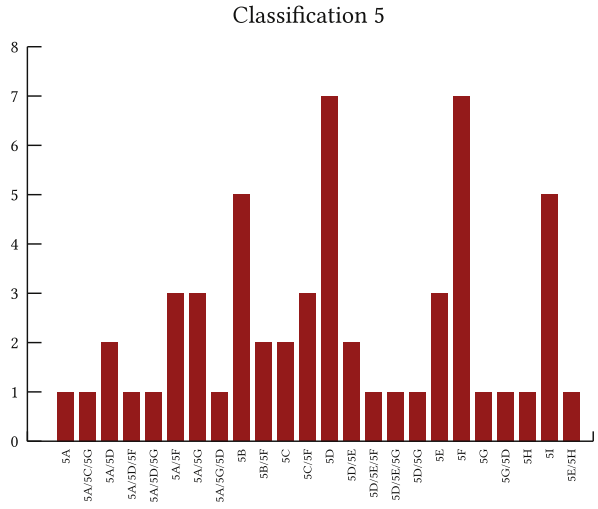

Fig. 5. Frequency distribution for the Classification 5: Method.

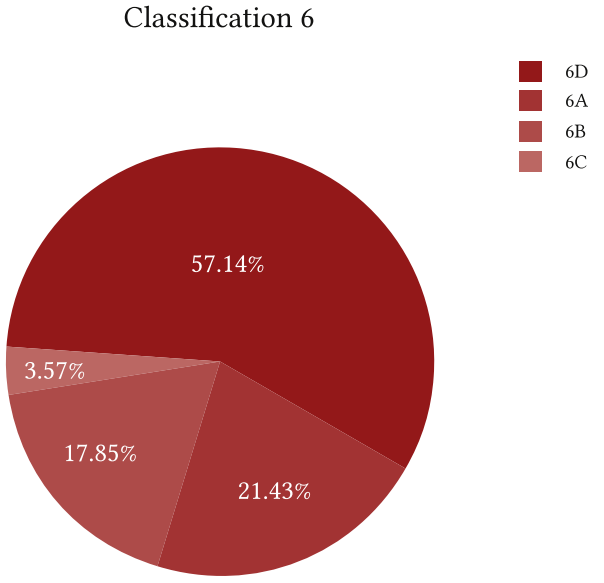

Fig. 6. Frequency distribution for the Classification 6: Contribution in the region.

analyse parks from a different perspective because the traditional linear model in which STPs cause knowledge to spill over from universities to tenant companies and thereby generate regional development may not represent reality. Finally [62], notes that STPs have not been very successful partly because of the inadequate and contradictory policies of the Japanese government.

5.2.7. Contribution of STPs to tenant companies

The seventh classification refers to the impact of STPs on tenant companies. Similar to the sixth classification, this is one of the topics that most arouses curiosity and the divergence of opinions, not only in the literature but also among stakeholders involved with STPs. The studies are coded as follows: A - a positive impact on companies; B - a smaller than expected impact on companies; C - no significant impact on companies; and D - not applicable. The impacts considered here are highly varied and may be associated with the basic assumptions of STPs, which include transferring university knowledge, offering support in the riskiest phases of companies, subsidies, and others. These results are summarized in Fig. 7.

The results indicate that the predominant code was positive effects on companies, with 42.86%, or 24 articles. Disregarding studies that do not address this topic, denoted by code D, this percentage would be 70.58%. Only eight studies find smaller than expected impacts, and only one finds no significant impact. Studies such as [35,47,49,50,52,63]; and [4] find that STPs provided several positive contributions to tenant companies. On the other hand, [6]; the only work to not find evidence of positive contributions, suggests that firms do not benefit from being located in an STP or from being close to a large metropolis. However, the author issues a caveat, stating that it may be too early to assess the performance of Chinese STPs because they are still growing.

The high number of studies that found positive impacts is explained by the fact that many studies worked with successful cases, such as the Hsinchu STP. In relation to the low number of studies that did not find any contribution, this is justifiable because, in the studies, the STPs positively contributed to the companies in some manner [39]. examines the relationship between a university and nearby companies in Surrey Research Park, UK, finding that there was no driving force for the establishment of formal connections. This finding could be an indicator that the STP is not contributing to companies. However, informal links and human resources were boosted. If only a formal connection was considered as a criterion for evaluating the STP, Surrey Research Park could be considered an inefficient park, even though it was contributing in other aspects.

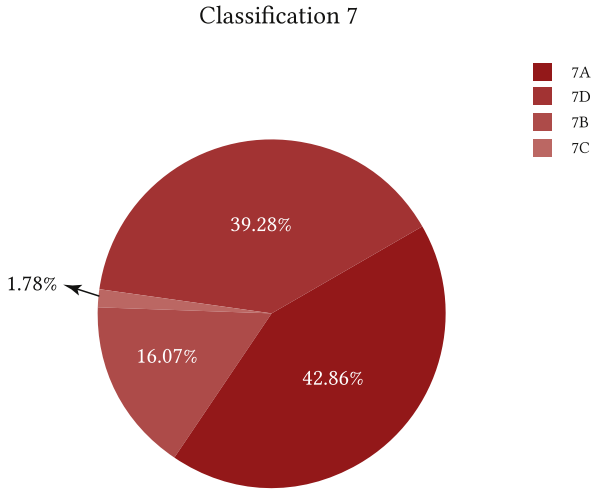

Fig. 7. Frequency distribution for the Classification 7: Impact of STPs on tenant companies.

In this context, this study contributes to the discussion of the impact of STPs on tenant companies by highlighting the need to analyse parks, advancing a traditional, linear method, as suggested by Ref. [35]; by considering the heterogeneity of these habitats of innovation [64]. The review, therefore, provides guidance for future academic research and for policymakers and science park managers, aiming to emphasize the importance of understanding exactly what is expected of the STP in each specific context. More specifically, by defining very high and unreachable expectations built on cases of success in other countries, which can have distinct technological infrastructures, economic environments and policies for fostering innovation, one could underestimate or undermine the relevance of the STPs in a local context. Although the need to consider the peculiarities of each park seems obvious [64], highlight that most of the previous studies focus on homogeneous effects of on-park location. Under this perspective, studies implicitly assume that parks have similar effects on tenant firms, which can benefit from the location in parks in a similar way [64]. These assumptions have recently been questioned by a new line of research, such as by Vásquez-Urriago et al. [65], p.1), which points out to the need to analyse the heterogeneity of parks [64]. suggest that a potential explanation for the existence of conflicting results of the impact of science parks in the scientific literature may reflect the fact that not all companies benefit from STPs in the same way. Similarly [66], state that although STPs constitute a platform that drives innovation in tenant companies, specific aspects of each firm, such as employees' satisfaction and work conditions, resistance to knowledge that originates from external sources to the organization, administrative and financial constraints, and complexity of intellectual property rights, among others, can jeopardize innovation. Therefore, internal factors can negatively affect innovation, even if the firm is located in an environment favourable to innovation, such as an STP. Therefore, the lack of innovation found in some studies is not necessarily due to failures in STPs, but rather to the lack of absorptive capacity of some companies.

Similar situations have been observed in several other studies [20]. find that the companies located in STPs were not more innovative than other companies. They find that STPs were not proving “added value” to companies in terms of improving their operations but they were making them more cost competitive compared to companies outside the STP. In this sense, [20]; p. 653) conclude: *“However, this is also partly a reflection of a low technological level and traditional orientation of tenant firms rather than only the failure of STPs to compensate for missing services and innovation links”*. It should be noted that the STPs analysed by these authors did not have appropriate selection criteria for companies. Therefore, it is not surprising that the companies located within these STPs are not very different from the other companies in terms of innovation. Nevertheless, the STPs were helping reduce costs.

[40] analyses five STPs in St. Petersburg and finds that these parks were successful in financially assisting tenant companies but deficient in providing managerial assistance. The studies by Refs. [6,20]; and [40] are in emerging countries, suggesting that it is more difficult for an STP to reach its goals in these economies. However, cases of STPs that were below expectations are not restricted to these economies. Evaluating the Hong Kong Science Park [23], find that the main benefit of STPs were subsidies and that there was no evidence of positive contributions from clustering, networking, and the image of being in an STP. Given the diversity of the results in the literature, two points are relevant:

- As stated by Ref. [11]; there is not an analytical framework that is capable of understanding and evaluating all STPs.
- [67] emphasize that STPs are heterogeneous.

The discussion proposed when addressing the above studies is the need to analyse STPs from a perspective that considers the frequently exaggerated expectations and other external factors that influence the performance of STPs. Again, using the study by Ref. [20] as an example, the authors note that the greatest difference between the situation in Kazakhstan and the majority of successful cases is the absence of domestic demand in research and development (R&D) and technology-based activities. In short, factors external to the STP are determinant in the performance of STPs.

5.3. Main impact of STPs on tenant companies

The eighth and final classification identifies the main impacts of STPs on tenant companies, thus detailing the focus of the seventh classification. The articles are coded from A to I, where A - transfer of knowledge from the STP to the company/start-up; B - resources offered by STPs, such as infrastructure and subsidies, among others; C - proximity and interaction with other companies, with the possibility of establishing clusters; D - a positive image for the company because it is located in an STP; E – greater interaction with universities and research institutes, whether formal or informal; F - networking; G - others; H - no positive impacts identified; and I - not applicable.

Similar to the fifth classification, the results are analysed in two stages because several studies identify more than one impact. First, we show the results found by the analysed articles, considering the various coding combinations found. The total sum in this phase is equal to 56. Subsequently, each code is analysed individually so that it is easier to identify the most common impact of STPs on companies, as found in the literature. The results are presented in Fig. 8 and Fig. 9, respectively.

When considering the combinations and observing Fig. 8, the results are very fragmented. The number of studies that did not aim to verify the effect of STPs on companies, represented by the code I, is 22, the same value as 7D because they address the same studies. The study by Ref. [47] finds the highest number of positive impacts from being located in an STP, denoted by the following letters: B, C, D, E, and F. A total of 20 different combinations of codes are identified in the literature, showing that the contributions of STPs to companies vary considerably from study to study.

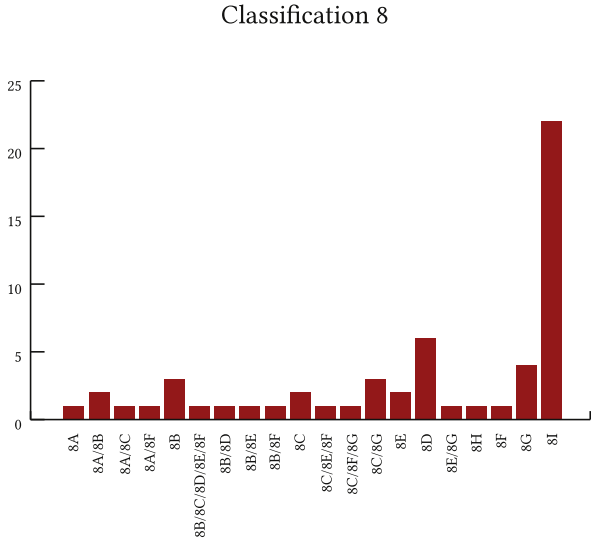

Fig. 8. Frequency distribution for the Classification 8: Main impact on tenant companies.

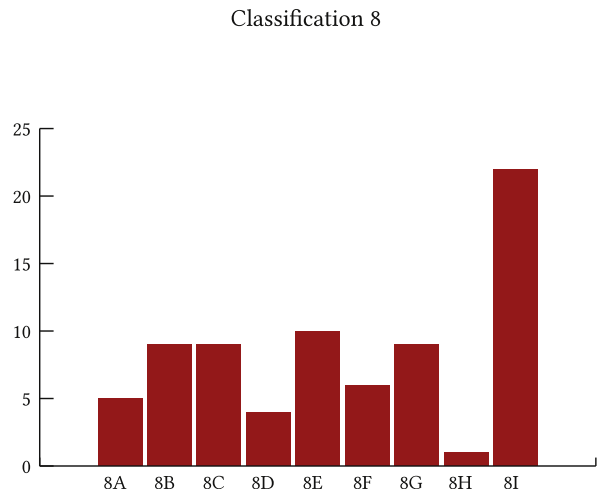

Fig. 9. Frequency distribution for the Classification 8: Main impact on tenant companies by codes.

Analysing the codes individually, as shown in Fig. 9, the main impact identified is the possibility of greater interaction with universities, followed by the resources offered by STPs and the proximity to other companies, which are tied for second place. An important point is that this greater link with universities can be formal or informal or also be related to human resources, such as the hiring of recent graduates. An interesting aspect is that the benefits of the relationship between universities and companies are generally studied from the perspective of companies, but [22] provide an important contribution by examining the effects of being in an STP from a university's perspective. The results found by these authors suggest several positive aspects for these institutions, such as more publications and patents, possibilities to obtain funds, and the perspective of hiring new graduates.

Code A, which is associated with the linear view of STPs, is only ahead of code H, in the penultimate place tied with code D. This finding shows, as discussed above and addressed by studies such as [35]; the incompatibility of this view with reality. In other words, the linear model of innovation does not find empirical support. For the 8G-coded studies, the positive impacts include gains of scale [56], support from governmental policies [4], skilled human capital [68], a greater market inside and outside the country [52], support in the riskiest phase [33,36], and others.

6. Conclusion

This study analysed 56 articles relating to STPs published from the 1980s to September 2016. All of these studies were found using Elsevier's *ScienceDirect* search engine, and the survey considered several keywords to identify the maximum material available on the site referring to science and technology park. This study followed the steps proposed by Ref. [14] to review the literature. In this sense, eight classifications were created, ranging from the geographic region and the economic context to the contributions of the STPs, with several possibilities of codification for each classification. It is believed that, with this study, the state of the art for this subject can be properly mapped. This mapping considers different dimensions of analysis, first bibliographical and with the articles subsequently being coded according to their characteristics.

The review of the literature indicated that, for the most part, the

studies found a positive contribution of STPs, both for the region and for tenant companies. However, in several studies, this impact was less than expected, leading to important questions to explain this fact:

- Are the expectations of STPs too high?
- Is the below-expected performance observed in several situations due to failures in the operations of the STPs or the low absorptive capacity of the companies?

Considering the first question, the results, a priori, suggest that answer is yes. The idea that STPs will revitalize an entire region by generating economic growth appears to be an unrealistic assumption. Moreover, the traditional view of university knowledge spill-over to tenant companies does not find support in the literature because few studies have empirically found this situation. However, there are successful cases in which this effect has occurred. These points are only the beginning of a discussion of what should actually be expected of STPs and how to evaluate them.

In view of the last question, a large gap has been identified in the literature regarding appropriate methods of selecting companies for inclusion in STPs. Only one study discusses this topic, whereas in several others, STPs do not even have criteria for selecting firms. Therefore, it is not surprising that the contribution of STPs in many situations was limited to factors such as subsidies and the structure offered, without a boost in innovation. Nevertheless, the main impact of STPs on tenant companies is providing greater interaction with universities, whether through formal or informal interaction or human resources, followed by the resources offered by STPs and the proximity to other companies, which were tied for second place.

The major contributions of this study were the indication of five gaps in the literature, presented and discussed in the corresponding classifications, and the state of the art of issues of great relevance and controversy regarding STPs. Each of these gaps can be considered an indicator for future research on the topic. In addition, this study contributes to the literature on central issues such as the impacts of STPs on tenant companies and on the region, indicating that there is not yet a single answer for the relationship between these agents of innovation, and showing the need to analyse the heterogeneity of parks and tenant companies. More specifically, studies should acknowledge that external factors (e.g. infrastructure, technology policies and incentives, demand for high-tech products of a given region, etc.) and internal factors of firms (e.g. work condition, management style, etc.) may imply different impacts of STPs in firms and society. One limitation of this study is that it only considered articles found by the *ScienceDirect* search engine. In addition, the lack of studies in certain regions, for example, may not reflect a gap per se but rather the smaller number of parks or innovation environments [64,65].

Acknowledgement

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Appendix

Details of the objectives and results of each study can be obtained in Table A1, which presents the objectives and results of each study. In Table A2, we list the number of papers per code.

Table A1
Brief description of the objectives and results of each analysed study.

N.	Study	Brief Summary	Number of Citations
1	[36].	Describes how the STP operation in Israel began. The Weizmann Institute, the first Israeli research institute to idealize an STP, is a successful example of partnership between academia and industry, serving as an example for other universities in the country.	7
2	[3].	Examines the impact of STPs, verifying whether they actually promote innovation, by comparing on-park companies with off- park companies. The results suggest that STPs do not promote innovation as expected but incorporate innovation. In the author's own words, instead of a “seedbed”, STPs function as “enclaves” of innovation. Tenant companies feature more links with universities.	248
3	[10].	Presents information pertaining to the Aston Science Park, located near the University of Aston and the centre of Birmingham. It is expected that this park will create wealth and jobs in Birmingham through services offered for the establishment and the growth of knowledge-based businesses.	–
4	[39].	Explores the relationship between companies located in the Surrey Technology Park and Surrey University to verify the impact of geographical proximity in this interaction. The results suggest that the STP facilitated the creation of informal links and human resources between companies and universities but geographical proximity did not encourage the creation of formal links between the organizations.	322
5	[53].	Examines the “Extranets”, introducing a multi -Extranet, a special network found in an STP located in Grimstad, Norway, Sørlandets Teknologisente. Network management and security issues are defined as crucial to the success of e-commerce. Existing experiences with Intranets apply to Extranets.	20
6	[35].	Analyses the Western Australian Technology Park, while going beyond the traditional linear view of the knowledge flow between universities and STPs, which has practically only considered formal links. Geographical proximity favours the creation of links between companies and universities and between companies and companies, whether these are formal or informal, which contributes to innovation. The results indicate that it is necessary to analyse the parks beyond the traditional view.	180
7	[59].	Understands in more detail companies' demand, interest, evaluation criteria, and intention to purchase regarding knowledge and administrative information in an STP in Taiwan. Many companies still hesitate to adopt services that would generate more information. The authors list a series of recommendations on how these services could be promoted.	10
8	[60].	Discusses the first Taiwan STP, the Hsinchu Science Park. This park, internationally recognized as a success story, had important impacts on Taiwan, such as stimulating R&D investments, improving the core of national competence, serving as a reference for the next STPs in the country, improving the country's position in the ranking of various high-tech industries, and others.	94
9	[7].	Fills the existing gap in the literature with regard to studies on technology parks in less developed countries by studying three technological parks in Greece, analysing the industry-university interaction. The types of interactions in the three STPs diverged. Only in one park were there formal links between companies and universities, whereas in the others, the links were informal.	226
10	[37].	Compares on-park and off-park companies to verify the possible impacts of the parks on NTBFs. The results indicate that companies located in the STPs were more likely to maintain contact with universities and generated more jobs but that the profitability of such companies and the R&D outputs were not different from the off-park companies.	462
11	[9].		77

(*continued on next page*)

Table A1 (*continued*)

N.	Study	Brief Summary	Number of Citations
		Analyses on-park and off-park NTBFs to identify any possible element of value added that the STPs provide to the NTBFs. One of the biggest problems facing NTBFs is obtaining funding. For the most part, such financing is done through personal reserves or through short-term loans. Companies in STPs have more post-graduate employees.	
12	[40].	Analyses five STPs from St. Petersburg, verifying how effective their contributions to tenant companies are. The STPs have been successful in assisting companies financially but deficient in providing managerial assistance.	66
13	[52].	Identifies the “added value” of the STP for tenant companies by comparing on-park NTBFs and off-park NTBFs. On-park NTBFs showed more connections with universities, whereas off-park NTBFs showed lower performance.	130
14	[22].	Analyses the emergence, growth, and consolidation of STPs in the United States and verifies the impact of such STPs on nearby universities with respect to their mission. Formal links with STPs bring benefits to the university, such as a greater number of publications and patents, funds, the perspective of hiring graduates, and others. Academic curricula tend to change, assuming a more applied nature.	233
15	[38].	Fills the existing gap regarding the lack of empirical evidence of the impact of STPs on firms' research productivity. The authors identify that STPs positively contribute to R&D outputs, such as the development of new products/services and patents.	316
16	[57].	Applies the analytic hierarchy process (AHP) decision -making technique to classify and select new firms for inclusion in the new technology park in Taiwan. In this sense, seven evaluation criteria were proposed, with “marketing potential” being the most important, followed by “technology level” and “government policies”.	145
17	[41].	Studies an STP in Budapest throughout its 15 years of operation, identifying its history, characteristics, challenges, and opportunities. The INNOTECH of Budapest concentrates its activities mainly in the virtual environment, with a focus on professors from the Budapest University of Technology and Economics.	32
18	[23].	Presents and explains an alternative tool whose purpose is to evaluate the performance of an incubation programme from the perspective of companies. Advantages such as subsidies appear to be the main benefit of STPs. There was no impact for companies from clustering, networking, and image because they were in an STP.	369
19	[69].	Evaluates two different processes used for wastewater recovery in a high-tech industrial park in Taiwan. The results of the experiments indicated that the two processes presented excellent performance in the removal of inorganic and organic components.	15
20	[32].	Discusses a virtual tool, developed by the Taguspark STP, for helping entrepreneurs interactively create their own business plans. Virtual initiatives are an important tool for strengthening technological parks, increasing their area of activity.	60
21	[62].	Analyses the feasibility of and obstacles to the Japanese government's policies that aim to promote STPs. The gap between business and science was considered the main obstacle, causing contradictions in Japanese public policies.	26
22	[33].	Proposes a discussion regarding the need for a new way for STPs to operate, in contrast to the usual definitions. Traditional STPs fail to have an impact on development in the region. The authors propose a new STP concept based on a case study.	201
23	[19].	Proposes a tool for analysing the development of STPs. To that end, the success stories of Silicon Valley, Hsinchu, and Cambridge were used to understand the main factors that influenced the success of STPs and, subsequently, to be applied in a Singapore government initiative. Three factors were identified: mechanisms of growth, technological capacity, and integration with the region and with the world.	170
24	[42].	Compares the innovation capacity of two parks located in different countries, one in Taiwan and one in China. The innovation capacity of STPs is different because aspects such as government policies, laws, market, human capital, infrastructure, and other factors impact the innovation capacity of STPs.	167
25	[70].	Compares NTBFs from university spin-offs (USOs) with NTBFs from corporate spin-offs (CSOs) for R&D networks and product innovation patterns. There were no significant differences in growth (sales) and profitability (profit margin) between the two groups. USOs had more interactions with universities.	225
26	[11].	Analyses the literature on STPs and incubators, considering four aspects: the STPs and incubators themselves, the companies located in these institutions, entrepreneurs and the team of entrepreneurs involved with these companies, and a systemic analysis. The results suggest that there is no systematic framework for understanding STPs, incubators, and the other points examined, mainly due to the diversity of existing parks.	542
27	[71].	Describes three success stories of STPs in Sweden. This country has one of the most advanced health systems in the world, and it has a reputation as a leader in biotechnology and pharmaceutical R&D. One of the factors influencing this success is the role played by STPs. Many innovations were performed in these environments, with impacts not only on the country's hospitals but also throughout the world.	–
28	[29].	Proposes a method of designing and implementing a more appropriate method of evaluating the performance of technology parks. Factors such as the legal structure of the STP and the available scientific knowledge are important when evaluating performance, in addition to other items already highlighted in the literature.	156
29	[72].	Applies DEA and the Malmquist Index to evaluate the performance of six high-tech industries operating in the Hsinchu Technology Park in Taiwan. The computer industry was the most efficient, followed by the semiconductor industry, whereas the other four operated with a certain degree of inefficiency.	127
30	[51].	Compares the performance of high-tech companies that are on-park and off-park. The results indicate that the NTBFs located in the STPs performed better, mainly due to formal and informal networks and the structure offered and managed by the parks.	91
31	[8].	Researches the value-added of STPs to NTBFs, verifying whether these companies located in the STPs are more susceptible to establishing relations with research institutes. The results suggest that NTBFs located in STPs are more likely to be involved in joint research with research institutes.	169
32	[49].	Researches the evolution of industrial clusters in the Beijing STP, the region with China's first and largest semiconductor, computer, and telecommunications cluster. The Beijing STP has played a crucial role in facilitating the transfer of technology and innovation since its inception, but this scenario has been changing. Without adequate measures being taken, this scientific park may lose its effectiveness.	219
33	[73].	Monitors volatile organic compounds present in the air, rain, and water of the Hsinchu Technology Park and nearby residential areas. The analysis of the samples identified pollutants from numerous sources other than the STP. It is suggested that an on-line monitoring and alert system be constructed, with regular information on the variation in pollutants over time.	64
34	[74].	Analyses the nanoparticles present in the recycled waters from Hsinchu Technological Park in Taiwan. Hsinchu wastewater contains numerous silicate nanoparticles, which are not effectively removed by existing works.	42
35	[6].	Researches whether there are advantages for companies in focussing on STPs and whether such parks can reverse the trend of regional inequality. No evidence that companies benefit from concentration was found, though productivity increases where there is greater foreign investment. STPs helped reduce the trend of increasing regional inequality.	124
36	[75].	Presents a methodology for analysing the factors that influence the market share of third-party logistics companies in high- tech industries in an STP. The main factors that influenced the choice of industries were the performance of the logistics service, the cost of services, and the value added.	44
37	[76].	Proposes the implementation of a system to prevent accidents and losses in the Southern Taiwan Science Park, called the Emergency Response Centre (ERC). This system must operate in conjunction with a monitoring centre. The analyses suggest that such measures could make the environment safer for STP employees.	10
38	[47].		218

Table A1 (*continued*)

N.	Study	Brief Summary	Number of Citations
		Analyses the resource use of resources in the STPs' incubation programmes by high technology companies in different life cycle stages over time. The results indicate that the propensity of a High Technology-Based Firm (HTBF) to make effective use of the resources and support incubation programmes increases as the company's life cycle phase progresses.	
39	[58].	Analyses the impact of adverse weather conditions, such as typhoons, on the characteristics of volatile organic compounds in the air of the Hsinchu Technological Park in Taiwan. A typhoon influences the quality of the surrounding air, but its effect is short-lived. The concentration of pollutants returns to normal soon after the typhoon.	8
40	[68].	Compares two STPs in Taiwan through the value-created system, dividing the system into four aspects: human resources, technological resources, investment environment, and market development. In the Hsinchu Science Park, human capital was the key aspect of performance, whereas in the Neihu Science Park, it was market-related factors.	176
41	[20].	Analyses the role of STPs as tools for promoting innovation in Kazakhstan. The results show that on-park companies are no more innovative than off-park companies but have managed to achieve better results in terms of income. The main factors that motivated companies to settle in the parks were the cheaper rents, a positive image due to being in a STP, and the possibility of receiving financing.	58
42	[63].	Studies industrial clusters located in the Hsinchu (Taiwan) STP, identifying the forces driving their growth and the main policies adopted by them. The results indicate that the factor conditions, company structure, strategy, and competition are the main driving forces for the growth of industrial clusters whereas local demand and culture occupy the last positions in priorities.	28
43	[4].	Compares the R&D productivity of NTBFs located on- park and off-park. The results indicate that NTBFs in STPs invest more efficiently and have a slight advantage in R&D, mainly because STPs can offer the benefits of clustering and more interaction with research institutes.	143
44	[50].	Analyses the successful case of the Dortmund STP. The creation of the University of Dortmund in the 1960s, which subsequently influenced the emergence of a technology centre and park, was important for regional development. This has generated many positive externalities for the city, such as jobs and a positive financial impact.	–
45	[61].	Analyses the population of an STP and Business Incubator (BI) in Portugal, verifying whether these institutions impact economic growth. The results suggest that the contribution to economic growth was modest.	170
46	[48].	Examines the importance of "returnee entrepreneurs" in an STP in China with regard to knowledge transfer. The authors identify that this human mobility positively affects innovation, not only in the companies in which the "returnee entrepreneurs" are but also in nearby companies.	82
47	[56].	Analyses the efficiency and productivity of six industries located in Hsinchu, Taiwan, from 2000 to 2006. The semiconductor industry was the most efficient, followed by the computer industry and bio- tech. The latter will continue to grow in the coming years. The managers of these industries should improve not only their administrative skills but also their innovation performance.	29
48	[55].	Identifies sources of volatile organic compounds and measures the presence of each in an STP in Taiwan through a three-step approach. Four emission sources were identified: vehicle traffic, industrial solvents, a sewage plant, and cleaning and degreasing products.	7
49	[43].	Examines whether the level of innovation is affected by the leader-employee and organization-employee relationships in a technology park. A greater relationship between the leader and employees drives innovation. In addition, organizational support, when perceived by the employee, positively impacts innovation.	1
50	[54].	Analyses the diffusion of innovations theory proposed by Everett Rogers, applying data from the Sardegna Ricerche technological park. The theory proposed by Rogers implies that certain companies are more adaptable with new technologies and are more likely to innovate than others. Incubators increase the chance that start-ups remain in the market, positioning these companies in the most profitable segment of Rogers' curve.	4
51	[46].	Researches the relationship between clustering and innovation in companies located in a technopark in Turkey. The authors identified that the clusters have a positive impact on the performance of companies and the companies located in the park are more likely to innovate. Cooperation with other companies was one of the main aspects identified, enabling a reduction in operational risks and increased growth capacity.	1
52	[2].	Analyses how the knowledge generated in universities can positively impact the innovation of companies located in technology parks. Companies that receive knowledge from universities tend to increase their capacity for innovation.	2
53	[67].	Analyses the importance of the main variables highlighted in the literature that influence the success of STPs, grouping them according to their operational characteristics. The authors present three strategies for parks to improve.	1
54	[44].	Discusses the importance of implementing STPs in Indonesia. STPs connect important factors for innovation, such as human capital, resources, and public policies.	–
55	[45].	Presents a tool for evaluating the strategic capacity of STPs in Latin America. In this sense, four indicators are proposed: infrastructure, corporate governance, scenarios, and strategic performance. Regarding the model, if an STP in Latin America scores above 80 points, then the result indicates that it has the strategic capacity to be economically, socially, and environmentally sustainable.	–
56	[5]	Analyses the effect of the location of the company in an STP with respect to the results of cooperation for innovation and of facilitating mechanisms to innovate. The results indicate that being in an STP increases the likelihood of cooperation for innovation and the intangible benefits of this cooperation, mainly due to a more diversified relationship.	9

Table A2
Codifications statistics.

Classification	Codification	Number of Articles	Percentage (%)
1	1A	26	46.42
	1B	18	32.14
	1C	10	17.85
	1B/1C	1	1.78
	1D	1	1.78
	2A	1	1.78
	2B	1	1.78
	2C	25	44.64
	2D	26	46.43
	2E	1	1.78
	2F	1	1.78
2	2A/2C/2D	1	1.78
	3A	4	7.14
	3B	4	7.14
	3C	5	8.93

(*continued on next page*)

Table A2 (*continued*)

Classification	Codification	Number of Articles	Percentage (%)
	3D	1	1.78
	3E	6	10.71
	3F	31	55.35
3	3G	5	8.93
	4A	43	76.78
	4A/4B	3	5.35
	4B	3	5.35
	4C	2	3.57
4	4D	5	8.93
	5A	1	1.78
	5A/5C/5G	1	1.78
	5A/5D	2	3.57
	5A/5D/5F	1	1.78
	5A/5D/5G	1	1.78
	5A/5F	3	5.35
	5A/5G	3	5.35
	5A/5G/5D	1	1.78
	5B	5	8.93
	5B/5F	2	3.57
	5C	2	3.57
	5C/5F	3	5.35
	5D	7	12.50
	5D/5E	2	3.57
	5D/5E/5F	1	1.78
	5D/5E/5G	1	1.78
	5D/5G	1	1.78
	5E	3	5.35
	5F	7	12.50
	5G	1	1.78
	5G/5D	1	1.78
	5H	1	1.78
	5I	5	8.93
5	5E/5H	1	1.78
	6A	12	21.43
	6B	10	17.85
	6C	2	3.57
6	6D	32	57.14
	7A	24	42.86
	7B	9	16.07
	7C	1	1.78
7	7D	22	39.28
	8A	1	1.79
	8A/8B	2	3.57
	8A/8C	1	1.79
	8A/8F	1	1.79
	8B	3	5.36
	8B/8C/8D/8E/8F	1	1.79
	8B/8D	1	1.79
	8B/8E	1	1.79
	8B/8F	1	1.79
	8C	2	3.57
	8C/8E/8F	1	1.79
	8C/8F/8G	1	1.79
	8C/8G	3	5.36
	8D	2	3.57
	8E	6	10.71
	8E/8G	1	1.79
	8H	1	1.79
	8F	1	1.79
	8G	4	7.14
8	8I	22	39.29

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