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From high-tech clusters to open innovation ecosystems: a systematic literature review of the relationship between science and technology parks and universities

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Abstract
As part of the third mission of universities to promote innovation and economic development, the popularity of science and technology parks (STPs) as a policy tool is increasing. The co-location of innovative companies and universities should be conducive to knowledge exchange between universities and industry, thus leading to more innovation. However, STPs have evolved in different contexts and to serve different purposes. Furthermore, the research on them has evolved mainly through case studies of individual parks and it is scattered across different disciplinary conversations. Building on 1,711 articles published from 1985 onwards, this study presents a systematic literature review of research on STPs and their relationships with universities. We find three different phases in the evolution of this literature: a formation phase (before 2000), where the focus was on the creation of STPs; a geographical expansion phase (2000–2010) reflecting the geographical expansion of STPs to East Asia and other emerging economies, with heavy focus on high-technology firms mainly in ICT; and a topical expansion phase (2011 onwards) when the literature expands to cover a diversity of new topics, including open innovation and sustainability, reflecting broader changes in the understanding of innovation.

Keywords Science parks · Technology parks · Innovation · Universities · Higher education institutions · Literature review

JEL classification I23 · O32 · O36 · O38

1 Introduction

Science and technology parks aim to promote technology transfer, knowledge exchange and innovation by bringing together science organisations and industry. They typically provide facilities for companies to locate on or near university campuses, as well as policies, programmes and services to facilitate cooperation and support innovation activities.

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The idea is that this will improve competitiveness and wealth creation (IASP, 2020). These parks are often promoted or supported by universities and other higher education institutions (HEIs) as places where knowledge is created, shared among organizations and transferred to society. This way, STPs have become an important ingredient in the regional development policies of many regions and in the third mission activities of many universities, which refers to their contribution to social development and economic growth(Löfsten & Lindelöf, 2002).

However, STPs have evolved in different contexts and to serve different purposes. Furthermore, the research on them has evolved mainly through case studies of individual parks and it is scattered across different disciplinary conversations. This makes it hard to determine whether and how science and technology parks work, and even what they are. To address these issues, we need to integrate evidence from the wide variety of individual studies on the subject. This is important for researchers who are interested in STPs as a phenomenon and in how they function. It is equally important for policy-makers who consider them a potential innovation policy tool – and for practitioners tasked with implementing these ideas – to get an overview of what we currently know about STPs and how they have evolved. To address this gap, this paper provides a systematic literature review of research on STPs and their relationship with universities.

The first reported STPs are the Stanford Research Park (United States) in the 1950s, Sophia Antipolis (France) in the 1960s and Tsukuba Science City (Japan) in the 1970s (UN ESCAP, 2019). Following these examples, science parks have become popular and widespread. The number of science parks grew from 25 STPs in the 1980s (UN ESCAP, 2019) to an estimated 534 STPs worldwide in 2017 (UNESCO, 2018), most of them located in large economies. This trend is reflected on the research on STPs. The pioneer materials were published in the 1980s (e.g., Kee 1983; Stuart & Abetti, 1987) but the topic was not extensively studied until much later. Publications on STPs took off mainly from 2002 onwards.

Paralleling the growth of parks, STPs have become a topic of research in fields such as innovation management, industrial policy and science and technology studies (Hobbs et al., 2017). Existing research has sought to understand the function of these spaces from different perspectives and disciplinary viewpoints, including public policy (Tonelli et al., 2015), management (Eveleens et al., 2017), university-industry collaboration (Zavale & Langa, 2018), risk management (da Silva-Etges & Nogueira-Cortimiglia 2019), and firm and regional development (Lecluyse et al., 2019). Research on STPs has covered topics such as their strategies, barriers, limitations, geography, experiences, and transfer of knowledge and technology, as well as their effects on companies and on their regional and national economies.

This heterogeneity of perspectives has created new knowledge on various aspects of STPs, but also implies that this knowledge is somewhat fragmented across different disciplinary conversations. In this paper, we integrate these discussions to conduct a systematic literature review of the existing literature on STPs. In particular, we zoom in on the relationship between STPs and universities. The aim is to examine how research on this relationship has evolved following changes in the understanding of the third mission of universities and of the innovation process. In doing so, we go beyond previous literature reviews (e.g., Hobbs et al., 2017) to also conduct an analysis of the publications' contents. The objectives are: (i) to consolidate extant research on the relationship between STPs and universities and HEIs, and (ii) to synthesize knowledge and identify the main trends within publications on this relationship. We systematically analyse the whole set of publications on STPs and universities and perform a content analysis on the published material. By analysing how research on STPs has evolved and highlighting the current state-of-the-art, we contribute to research on firm innovation activities and universities' contributions thereto. This way, the study provides valuable insights also to policy-makers and practitioners (such as STPs managers, university liaison offices and firms located in STPs).

We find that the literature is fragmented in many dimensions. The publications are spread across a large variety of journals in different disciplines, and only a few journals have published more than ten papers on the topic. The literature has also mainly developed through case studies of individual STPs, with few attempts at large-N or comparative research which could systematise knowledge about STPs across different contexts. The research has mainly aimed at offering support for decision-makers and has been developed mainly from a management and technology-transfer perspective, whereas spatial and geographical perspectives are largely missing despite the importance of co-location to the concept. Over time, the geographical areas covered in the literature has expanded, with a particularly large body of research on East Asia, notably China and Taiwan, reflecting the popularity of STPs as a policy tool there. The understanding of what STPs are has also expanded, from an early understanding of STPs based on cluster policy and focusing mainly on high-technology firms and industries to a contemporary understanding relying on open innovation.

The paper is structured into the following sections: Sect. 2 presents the selection and analysis techniques, as well as the categories used to analyse the literature. Section 3 presents a descriptive analysis, while Sect. 4 provides a content analysis of the material. Section 5 presents the findings from a qualitative content analysis of the publications, and Sect. 6 provides the conclusions with limitations and avenues for future research on STPs.

2 Method

This paper follows a systematic literature review method. This method is defined by (Kitcharoen, 2004) as a means of identifying, evaluating and interpreting all available research relevant to a particular phenomenon of interest. It provides a reproducible process of selection, analysis and reporting of previously conducted research on a topic (Denyer & Tranfield, 2009). This analysis can be framed as a quantitative and qualitative method which involves a descriptive and a content study. Figure 1 shows the steps we followed to perform a reliable systematic literature review, based on (Denyer & Tranfield, 2009).

In the first step, we formulate the main research questions of the study: How has the relationship between STPs and universities/HEIs been studied in the literature, and how has this literature evolved over time?

Step 2 proposed by Tranfield et al., (2003) is to set up a search strategy to collect a representative set of papers about the relationship between STPs and universities. We used Scopus and Web of Science (WoS), which are the most comprehensive and authoritative scientific databases (Aghaei Chadegani et al., 2013). In both databases, we used the generic keywords 'university OR campus OR higher education institution' AND 'scientific OR science parks' AND/OR 'technology parks' as the main search criteria. In Scopus, we searched for these keywords in the categories Title, Author, Keywords, and Abstract. In WoS, we searched in the category Topic, which includes Title, Author, Keywords and Abstract. We did not limit the search by time filters nor by the type of document, in order to include the 'grey literature'. The data collection was conducted in October 2019. The search resulted in 737 publications from the WoS and 1,555 from Scopus. After deleting

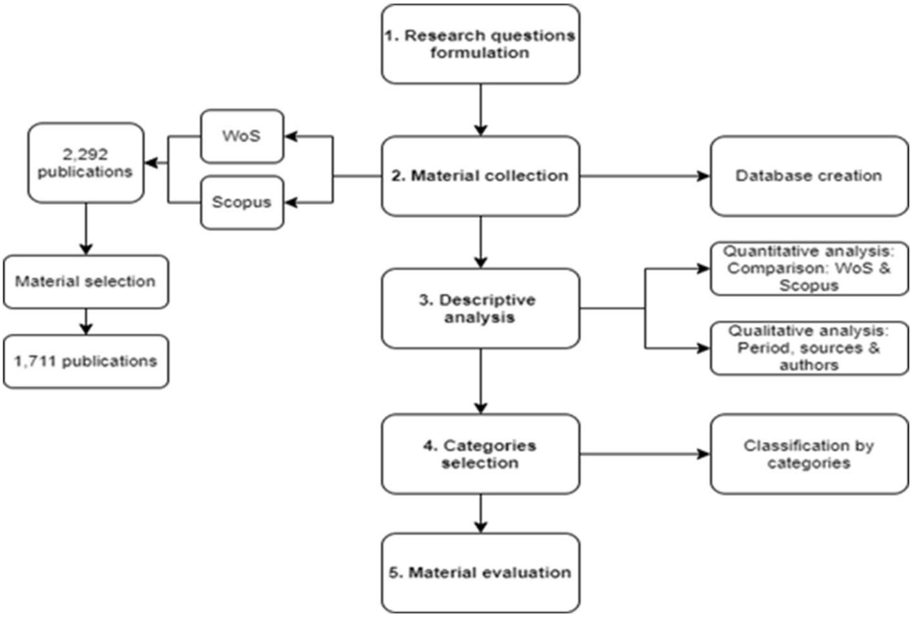

Fig. 1 Methodological scheme

duplicates, we identified 1,711 original publications on STPs and HEIs, which we included in the final analysis.

In Step 3, we analyse the data descriptively. We describe how the literature on STPs has developed over time, as well as the main characteristics of this literature in terms of the journals and authors with the highest number of publications on the topic and their geography.

In Step 4, we move on to a qualitative content analysis of the material. We classify the papers along several structural dimensions, including research methodology, type of research, level of analysis and geographic area (Table 1). Then, we examine the main characteristics and trends of the literature in each of these dimensions (Seuring & Müller, 2008). The structural dimensions were selected by building on other bibliographic reviews (Hobbs et al., 2017; Merli et al., 2018; Seuring & Müller, 2008). To account for investigator bias, we conducted a process of double independent review of the researchers and shared the identified categories afterwards. Furthermore, these categories were compared to those derived from the most cited publications identified and, in some cases, categories were recovered from other studies related to STPs-HEIs (Lecluyse et al., 2019). Table 1 shows the structural dimensions and the analytic categories in each dimension. It is worth noting that each paper may be part of more than one category.

Finally, we analyse the content of the selected materials in greater detail (step 5).

Table 1 Structural dimensions and their analytical categories

Structural dimensions	Categories of analysis	Description
Research methodology	Case study	Specific case study (or more than one case)
	Review	Summaries of previous literature or research
	Modelling	Application of mathematical or economic models
	Survey	Analysis based on interviews or surveys
	Theoretical and conceptual	Theoretical or conceptual research
Type of research	Policy	Public policies, policies discussion, proposals, etc.
	Economic model	Application of economic processes or models (both theoretical or mathematical models).
	Process engineering	New products, technologies, energy proposals (such as energy saving, renewable energies, etc.) or more efficient productive processes
	Business models and management	Firm organization, strategic plans, etc.
	Tools, models, framework, methods for decision making	Other methods that help policy makers, politicians, etc., to make decisions from the obtained results and develop new policies, normative or political decisions.
Level of analysis	Macro	Production or consumption
	Meso	Inter-firm level within a geographic area, as clusters, or firms located in the same STP
	Micro	Corporate-level initiatives or industries in the same sector
Geographic area		Geographical areas covered
Keywords		Co-occurrences of keywords

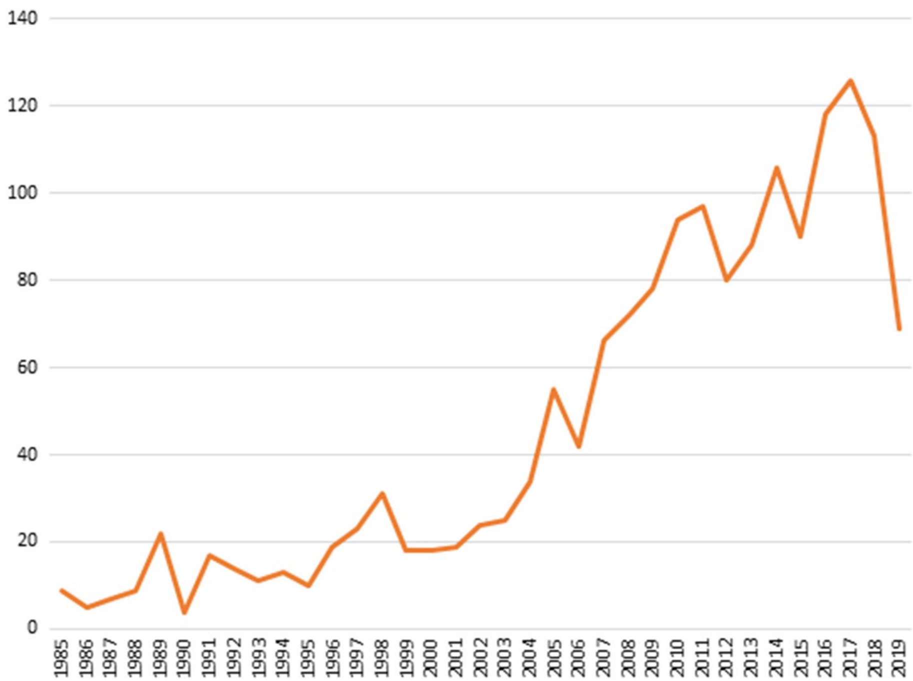

Fig. 2 Evolution of publications on STPs

3 3. Descriptive analysis

We start by analysing the evolution of the literature on STPs and universities in terms of the number of publications (Fig. 2). The first papers on this topic were published in 1985, and the literature has increased steadily to more than 120 publications in 2017. Following early peaks in 1989 and 1998, the growth in the number of publications picked up especially in the decade from 2002 to 2011.

Table 2 shows the distribution of the publication by author's country. Taiwan and China lead the rank with 218 and 217 studies on STPs, respectively, equivalent to 14.5% and 14.4% of all published papers. This reflects the proliferation of STPs in these countries. The popularity of STPs in Taiwan and China can be linked to the broader development strategies of these countries to foster growth through innovation and technological upgrading (Lee et al., 2017.; Sun 2011; Yuen, 1992). They are followed by the United Kingdom (148 publications representing 9.81% of the total) and United States (111 publications, or 7.36% of materials about STPs). The distribution across country reflects the expansion of STPs as a policy tool beyond its North American and Western European origins to emerging economies such as the BRICS countries.

Table 3 shows the distribution of papers on STPs and universities by the journals of publication. The list reflects the heterogeneity of the literature. No journal has published more than 45 of the more than 1700 papers on the topic, and only ten journals have published more than ten papers on the topic. Since 2007, the number of different journals that have published papers on STPs has increased considerably. The high and growing variation in the number of journals suggests that an integrated conversation on the relationship

Table 2 Top 10 countries with the highest number of publications

Country	Number of publications	Type of document and JCR quartile of sources
Taiwan	218	71.15% Articles (Q1 39.19%; Q2 21.62%; Q3 14.86%; Q4 14.86%; not available 9.46%) 12.85% Proceedings 10% Books and book chapters 6% Not available source
China	217	64.09% Articles (Q1 30%; Q2 23.64%; Q3 16.36%; Q4 17.27%; not available 12.73%) 13.36% Proceedings 21.65% Books and book chapters 0.9% Not available source
United Kingdom	148	60.36% Articles (Q1 23%; Q2 25.29%; Q3 17.24%; Q4 26.44%; not available 8.03%) 10% Proceedings 22.43% Books and book chapters 7.21% Not available source
United States	111	72.97% Articles (Q1 26.54%; Q2 18.52%; Q3 16.67%; Q4 19.75%; not available 18.52%) 18.02% Proceedings 6.31% Books and book chapters 2.7% Not available source
Spain	95	93.7% Articles (Q1 17.78%; Q2 22.22%; Q3 13.33%; Q4 17.78%; not available 28.89%) 2.1% Proceedings 1.05% Books and book chapters 3.15% Not available source
Russia	57	75.44% Articles (Q1 15.38%; Q2 30.77%; Q3 23.08%; Q4 7.69%; not available 23.08%) 10.53% Proceedings 1.75% Books and book chapters 12.28% Not available source
Brazil	65	69.23% Articles (Q1 12.5%; Q2 9.38%; Q3 6.25%; Q4 43.75%; not available 28.12%) 20.62% Proceedings 5.97% Books and book chapters 4.18% Not available source
Italy	51	76.48% Articles (Q1 29.17%; Q2 20.83%; Q3 8.33%; Q4 12.5%; not available 29.17%) 9.8% Proceedings 5.88% Books and book chapters 7.84% Not available source

Table 2 (continued)

Country	Number of publications	Type of document and JCR quartile of sources
Iran	40	60% Articles (Q1 20%; Q2 33.33%; Q3 20%; Q4 6.67%; not available 20%) 17.5% Proceedings 10% Books and book chapters 12.5% Not available source
Sweden	39	84.19% Articles (Q1 23.08%; Q2 30.77%; Q3 23.08%; Q4 7.69%; not available 15.38%) 2.56% Proceedings 3% Books and book chapters 10.25% Not available source

Table 3 Top 10 journals with the highest number of publications

Journal	Number of publications	Quartile
Journal of Technology Transfer	45	Q2 (JCR) (Management)
International Journal of Technology Management	40	Q3 (JCR) (Engineering, multidisciplinary)
Industry and Higher Education	28	Q2 (JCR) (Education & Educational Research)
Technovation	24	Q1 (JCR) (Engineering, Industrial-Management)
International Journal of Entrepreneurship and Innovation	15	Q3 (JCR) (Business)
Espacios	13	Q4 (JCR) (Education & Educational Research)
European Planning Studies	13	Q2 (JCR) (Environmental Studies)
Expert Systems with Applications	13	Q1 (JCR) (Computer Science, Artificial Intelligence-Engineering, electrical & electronic)
Nature	11	Q1 (JCR) (Multidisciplinary Sciences)
Journal of Technology Management and Innovation	10	Q3 (SJR) (Business, Management and Accounting: Management of Technology and Innovation)

between STPs and universities may be largely missing in the literature. Instead, discussions of this relationship seem to be scattered across a wide range of different field-specific and discipline-specific conversations.

The top journals are mostly technology and innovation management journals, with *Journal of Technology Transfer*, followed by the *International Journal of Technology Management*, topping the list. The remainder of the top journals also include mainly technology and innovation management journals. Conversely, journals dedicated to spatial and geographic dimensions of innovation are largely absent. Of the top ten journals, only *European Planning Studies* is concerned mainly with spatial and geographical issues. This suggests that STPs have mostly been studied from an organisational and management perspective, rather than a spatial one. This is somewhat unexpected, given that the idea behind STPs is that spatial factors such as co-location are important for innovation, and that STPs are often framed as part of regional development strategies. However, information on STPs and their location is frequently missing from popular databases used in geographical innovation studies, such as the Community Innovation Surveys. Journals on universities and higher education institutions are also relatively absent from the list, with the exception of *Industry and Higher Education*. Overall, judging by the journals in which this research has been published, the literature on the relationship between STPs and universities has been conducted mainly from the perspective of firms and firm innovation processes, rather than from the perspective of universities or regions.

Table 4 ranks the most cited papers, with at least 150 citations. All were published between 1987 and 2012 in leading international journals. The most cited papers focus on incubators and start-ups, university-industry relations, high-tech industry, innovation and entrepreneurship.

4 Content analysis

Following this descriptive analysis of the literature, we move on to examine the contents of the papers. We first classify the publications by their methodology, type of research, level of analysis, geographical focus and keywords, using the categories presented in Table 1. As each document may belong to more than one category, the sum across categories for each dimension does not necessarily add up to 100%.

First, we examine the research methodologies used in this literature, following Merli et al., (2018) and Hobbs et al., (2017). We were able to classify 88.6% of the documents in this dimension. Some documents belong to several categories (while other documents do not belong to any category), and can therefore not be assigned a unique dimension. In total, 47.9% are case studies, 22.2% are theoretical and conceptual documents, 17.5% are models, followed by reviews (6.7%), and surveys (5.7%). Overall, the literature has mainly been built through a series of case studies of individual STPs, supplemented with more theoretical or conceptual work reflecting more broadly on the phenomenon. This type of analyses and comparative studies have been used less frequently to study STPs.

Second, we examine the type of research conducted. We were able to classify 71.7% of the documents in this dimension. The most frequent category is 'tools, models, frameworks or methods for decision making' with 48,5%. This is followed by 'business models and management' (22.5%), 'process engineering' (10.7%), documents about policies (10.3%), and 'economic models' (8%). These figures indicate that most of papers are oriented towards practitioners, aiming to support decision-makers in firms or to some extent

Table 4 Most cited papers (at least 150 citations) and the quartile of the journals

Authors	Title	Year	Cites[1]
Phan P.H. et al.	Science parks and incubators: Observations, synthesis and future research	2005	498 (Scopus) 430 (WoS)
Colombo M.G., & Delmastro M.	How effective are technology incubators? Evidence from Italy	2002	416 (Editorial[2])
Filatotchev I. et al.	The export orientation and export performance of high-technology SMEs in emerging markets: The effects of knowledge transfer by returnee entrepreneurs	2009	354 (Scopus) 320 (WoS)
Massey D. et al.	High-tech fantasies: Science parks in society, science and space	2003	337 (Scopus)
Bruneel, J. et al.	The Evolution of Business Incubators: Comparing demand and supply of business incubation services across different incubator generations	2012	323 (Scopus) 295 (WoS)
Markman G.D. et al.	Entrepreneurship and university-based technology transfer	2005	325 (WoS)
Löfsten H., Lindelöf P.	Science Parks and the growth of new technology-based firms - Academic-industry links, innovation and markets	2002	294 (Scopus) 269 (WoS)
Chan K.F., Lau T.	Assessing technology incubator programs in the science park: The good, the bad and the ugly	2005	268 (Scopus) 249 (WoS)
Mcmullan W.E., Long W.A.	Entrepreneurship education in the nineties	1987	232 (Scopus) 164 (WoS)
McAdam M., McAdam R.	High tech start-ups in University Science Park incubators: The relationship between the start-up's lifecycle progression and use of the incubator's resources	2008	235 (Scopus) 205 (WoS)
Siegel D.S. et al.	Assessing the impact of university science parks on research productivity: Exploratory firm-level evidence from the United Kingdom	2003	222 (Scopus) 178 (WoS)
Johannissson B.	Personal networks in emerging knowledge-based firms: Spatial and functional patterns	1998	200 (Scopus)
Storey D.J., Tether B.S.	Public policy measures to support new technology-based firms in the European Union	1998	196 (Scopus) 172 (WoS)
Vedovello C.	Science parks and university-industry interaction: Geographical proximity between the agents as a driving force	1997	185 (Scopus) 180 (WoS)
Ratinho T., Henriques E.	The role of science parks and business incubators in converging countries: Evidence from Portugal	2010	181 (Scopus) 154 (WoS)
Stuart R., Abetti P.A.	Start-up ventures: Towards the prediction of initial success	1987	171 (Scopus) 140 (WoS)

Table 4 (continued)

Authors	Title	Year	Cites[1]
Löfsten H., Lindelöf P.	R&D networks and product innovation patterns - Academic and non-academic new technology-based firms on Science Parks	2005	151 (Scopus) 144 (WoS)

[1]All documents were obtained from Scopus and/or WoS. For this reason, some of them have the number of citations from both databases (documents were available in both databases) or in one of them (documents were available in one of the databases)

[2]This paper did not have the number of citations in the databases, but it was in the editorial

government. The literature has to a lesser extent focused on developing new models for researchers to understand the relationship between STPs and universities, or on developing new processes for this relationship.

Third, we examine the level of analysis. In this case, we could classify 1,459 out of 1,711 documents. The meso level was the most employed (44.5%), which is expected as STPs are organisations which operate at this level. It is closely followed by studies at the macro level (39.3%), while there are fewer studies at the micro level (16.2%). Hence, the literature has rarely zoomed in on individual firms, but has focused on research at the level of the STP and the broader economy of which it is part.

Fourth, we examine the geographic focus of the studies. Overall, 1,222 out of 1,711 documents had an identifiable geographic focus. The most studied continent is Asia, covered by 55.6% of papers (620 studies). China and Taiwan (with 239 and 216 papers, making up 19.6% and 17.7% of the articles, respectively), are the most studied countries by far. Planners and policy makers in countries such as Singapore, Taiwan, China, and Malaysia have used STPs as an important policy tool for high technology development (Lee et al., 2017; Sun, 2011; Yuen, 1992). The first Chinese STP, and the largest one, was built in 1988 at Zhongguancun, following the example of Stanford University and described by the United States Embassy in Beijing as 'a large-scale attempt to recreate Silicon Valley in China' (US Embassy, 2002). After more than three decades, there are more than 100 national and provincial STPs in China (Macdonald & Deng, 2004). The Taiwanese STPs have a similar background. In fact, the variety of research on Chinese and Taiwanese STPs is explained by the considerable resources invested in innovation capacity through policy instruments aimed at promoting R&D-based as well as innovation activities (Lai & Shyu, 2005; Lee et al., 2017; Yang et al., 2010), as well as through the attraction of foreign private capital (Weng et al., 2019).

Europe is the second most studied continent with 432 papers out of 1,222. The most studied countries in Europe are the United Kingdom (96 documents, or 7.9%) and Spain (77 papers, or 6.3%). Furthermore, there are 131 papers focusing on America, mostly on Brazil (57 papers) and the United States (56 papers). Finally, there are 20 papers focusing on Africa and 19 on Oceania. In these continents, South Africa (13 papers) and Australia (16 papers) represent the lion's share. These results are in line with Millar et al., (2005) and reflect the main areas where STPs have been developed: East Asia (especially China and Taiwan), United States and United Kingdom. Additionally, there are several studies focused on emerging economies such as Brazil. The geographical distribution reflects the major types of STPs identified by Millar et al., (2005), who identify three distinct models – a US/UK model (e.g., Silicon Valley in the USA and Cambridge in the UK), an East Asian model (e.g., Hsinchu Science and Industrial Park in Taiwan), and a state technology district model targeting foreign multinational companies (e.g., Sophia Antipolis in France and Singapore).

Finally, we examine the topics covered by the articles by analysing co-occurrences of keywords. We estimate an index which indicates the total strength of the co-occurrence links between the keywords within a given document. For legibility, we include the 40 keywords with the highest link strength associated with the main keyword 'science park'. The programme distinguished 6 clusters, which we list in Table 5. Each cluster includes a set of terms which may belong to only one cluster. In some cases, there may be items that do not belong to any cluster.

The first cluster is based around the keyword 'innovation' and includes innovation-related concepts, such as commercialization and knowledge. The cluster also covers keywords such as incubator, cluster and networks, reflecting how the mechanisms

Table 5 Keywords analysis

Cluster	Keywords	Occurrences	Total link strength
1	innovation	57	72
1	incubator	10	15
1	university	9	12
1	knowledge	5	11
1	cluster	5	9
1	commercialization	5	9
1	ICT	5	9
1	venture capital	5	9
1	networks	5	6
1	**Total cluster 1**	**106**	**152**
2	university science park	22	11
2	patents	6	9
2	policy	7	8
2	knowledge transfer	7	6
2	open innovation	6	6
2	social capital	8	6
2	triple helix	7	6
2	business incubator	7	3
2	social network analysis	5	3
	Total cluster 2	**75**	**58**
3	entrepreneurship	19	30
3	economic development	8	12
3	SMEs	8	8
3	regional development	10	7
3	strategy	5	6
3	technology	5	5
3	growth	5	4
	Total cluster 3	**60**	**72**
4	evaluation	8	26
4	university-industry relations	7	26
4	technology transfer	17	25
4	research and development management	6	23
4	science-based industry	5	21
4	developing countries	6	18
	Total cluster 4	**49**	**139**
5	science park	69	68
5	sustainable development	10	8
5	high-tech industry	11	4
5	industrial cluster	6	3
	Total cluster 5	**96**	**83**
6	information technology	7	13
6	knowledge management	8	7
6	innovation policy	6	2
	Total cluster 6	**21**	**22**

Bold indicates 'total link strength' of the keywords that belong to cluster 1, 2, 3, 4, 5, or 6 respectively.

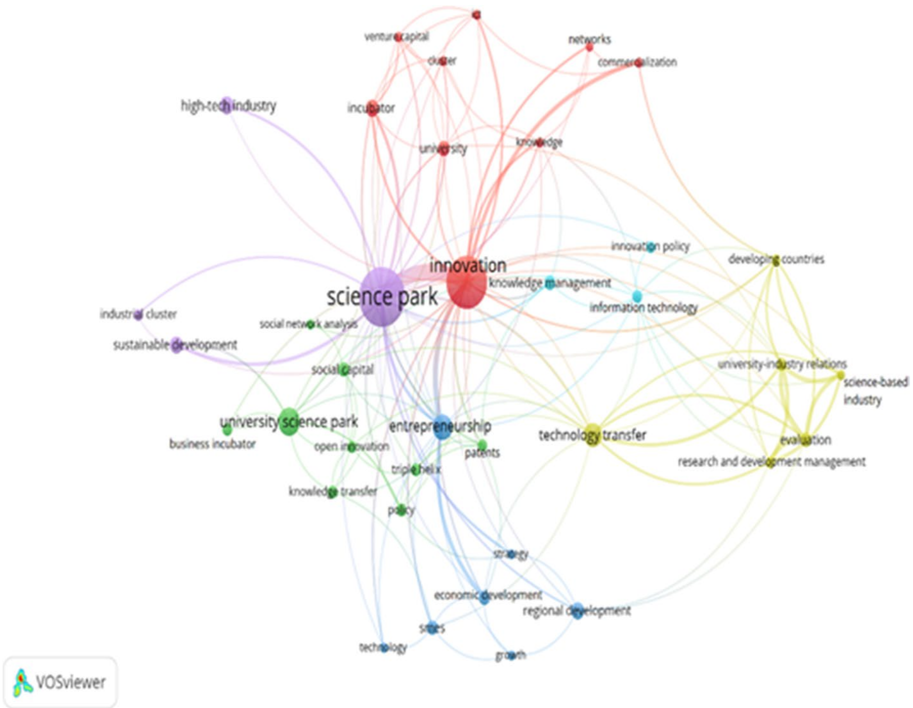

Fig. 3 Network analysis of keywords associated with science parks

through which STPs are thought to contribute to innovation. Hence, the STP literature on innovation mainly explores how knowledge networks and geographical co-location contribute to innovation. The second cluster is more closely linked to universities, with 'university science park' being the most frequent keyword. It reflects topics related to university innovation, including triple helix and knowledge transfer, as well as broader networking topics such as open innovation and social capital. Hence, the coverage of university innovation in this literature builds on open innovation and networked innovation approaches. The third cluster has a core around entrepreneurship. In the STP literature, this concept is frequently linked to economic development, growth and regional development. The fourth cluster focuses on technology transfer, university-industry relations and science-based industries. In this cluster, several concepts have high link strengths, reflecting a closely knit network of keywords. These concepts are frequently linked to developing countries and to R&D management. The fifth cluster is oriented around the keyword 'science park' itself. Sustainable development and high-tech industries are important elements of this cluster. The final cluster is related to information technology and knowledge management, reflecting a technology-specific approach to STPs. This cluster is also linked to innovation policy.

Figure 3 shows same information graphically. The figure shows the total link strength and the interactions between the 40 keywords with the highest link strength to the keyword 'science park'. The stronger the link between two items, the thicker the line that is employed to display the link. The size of the circles shows the frequency of occurrence of each keyword. The colours show the clusters with which each key word is associated.

5 Evolution of the literature over time: qualitative content analysis

Finally, we examine the contents of the literature in more detail, building on a qualitative analysis of a sample of the papers. Based on this analysis, we identify three different phases in the evolution of the literature on the relationship between STPs and universities: A formative phase until the 2000s, where the focus is mainly on the creation of STPs, reflecting that this was a period in which many universities or governments were setting up parks. A geographical expansion phase from 2000 to 2010, when the literature expands to cover STPs in developing and middle-income countries. During this phase, the focus is mainly on high-technology firms (especially in the ICT industry) and their interactions with universities. Finally, a topical expansion phase from 2011 onwards, when the literature expands radically to cover a wide diversity of new topics.

5.1 Pre-2000 period: formation

The first phase is until the 2000s. The earliest paper we have identified is Kee (1983) on the establishment of Cambridge Science Park. This reflects a broader pattern in the early literature of studying an emerging new phenomenon. This was a phase when science parks were being set up in many countries, and they were studied as novel phenomena, with many papers being case studies of new parks. The literature mainly covers developed countries, and the selected documents show that there is a lack of research about STPs in less developed countries, with some exceptions towards the end of the period (e.g., Cabral, 1998; Cabral & Dahab, 1998; Ma, 1998; Wang et al., 1998).

STPs and the innovative science-based companies they host are seen as a mechanism for the third mission of universities and for regional economic development. The idea is that they will increase regions' capacity for innovation and technological development by facilitating the translation of university research into business activity (D'Arcy & Guissani, 1996). A significant branch of the literature assesses the effects of STPs, e.g., by studying the differences between firms located in STPs and firms located outside them. For instance, Westhead (1997) studies British parks, finding that firms located in STPs did not exceed their off-park counterparts with regards to the quantity of new goods and services launched to both existing customers and new markets, and to the number of patents and copyrights. However, tenant firms had higher growth rates.

5.2 2000–2010: Geographical expansion

The second phase covers the period 2000–2010. In this period, the literature on STPs expands geographically to examine STPs in developing and middle-income countries (e.g., Ratinho & Henriques 2010; Vaidyanathan, 2008). In particular, there is a lot of research on Southeast Asian countries, due to the establishment of STPs in countries such as Taiwan (e.g., Hu et al., 2005), Singapore (e.g., Koh et al., 2005; Phillips & Yeung, 2003) and China (e.g., Lin et al., 2003; Sutherland, 2005) in this period. However, there are also studies on middle-income countries in Europe (e.g., Bakouros et al., 2002).

In terms of topics, the literature is closely linked to the broader literature on clusters (industrial clusters, innovation clusters, networks, etc.), which is in vogue in this period, following the IT boom and the emergence of Silicon Valley as a role model for regions worldwide. Clusters are seen as important to increase productivity, technology and knowledge transfer in order to strengthen national and global competitiveness (Maggioni, 2002).

Effectively, STPs stimulate the concentration of firms in the same field and encourage their competitiveness, following classic cluster effects. The inspiration from Silicon Valley is also seen in the focus in the literature on high technology firms, in particular in ICT or science-based industries (e.g., Oakey 2007). This is in particular related to the rise of Southeast Asia in these industries, with the establishment of high technology STPs as an important ingredient in policies for developing competitiveness (e.g., Lee & Yang 2000) and accelerating the development of high-technology industries (Baark & So, 2006; Lee & Yang, 2000).

In addition, firm creation emerges as an important new topic in the literature. This includes studies of research spin-offs (Gilsing et al., 2010) and student entrepreneurship (Sjölundh & Wahlbin, 2008). Attention was mainly on spin-off creation rather than spin-off development, growth and the probability that these firms will be sustainable in the long term (Gilsing et al., 2010). In particular, the relationship between spin-offs and universities is frequently studied, with research on network formation (Schwartz & Hornych, 2010). This is part of a broader research agenda on how university-industry relations encourage innovation and the emergence of new business (Lindelöf & Löfsten, 2004; Passos et al., 2004). In this sense, Gunasekara (2005) underlines how the role of universities in Regional Innovation Systems (RIS) has considerably evolved. Science parks have an important function as SME incubators, which attempt to nurture new ventures (Phan et al., 2005). Several studies examine the effects of STPs' incubators on the innovative performance and growth of start-ups (Colombo & Delmastro, 2002; Squicciarini, 2009), in some cases comparing with off-park counterparts (Lindelöf & Löfsten, 2003; Löfsten & Lindelöf, 2002).

5.3 2011 Onwards: topical expansion

The literature on STPs grows significantly in the 2011–2015 period. This also involves an expansion of the literature into a wide variety of new topics (see Amoroso et al., 2019). The *open innovation* concept has increasingly contributed to the development of a new generation of STPs (Bellini et al., 2012; Hobbs et al., 2017). If the previous model of STPs was based on clusters, the new STPs emphasize variety, transversality and openness instead of agglomeration and specialization (Bellini et al., 2012; Hassink & Hu, 2012). This involves a wider understanding of innovation ecosystems and the importance of knowledge exchanges on a global scale (Bellini et al., 2012). Collaboration is also studied from a micro-level perspective with analyses of how *social capital* is formed in STPs (Barbera & Fassero, 2013; Louw & Moloi, 2013; Padilla-Meléndez et al., 2013). The social capital is realized through interorganizational relationships, members' levels of collective goal orientation and shared trust (Martínez-Cañas, 2011), with effects on knowledge and technology transfer (Abidin et al., 2013; Awang et al., 2013). Other papers study the importance of social relations in STPs, considered as 'living spaces'. That is the case of Barbera & Fassero, (2013) who underline 3 main factors to guarantee STPs' success: 'collaboration between scientific and university structures', 'the availability of local partners that supply goods and services for enterprises' and 'the quality of the social context', that is living choices of the workers or everyday life of social relations.

This extends to studies of *innovation networks* and the role of STPs in creating them (Montoro-Sánchez et al., 2012; Yun & Lee, 2013), and on *knowledge transfer* within companies, between companies and universities, and between STP tenants (Barra & Zotti, 2018; Berbegal-Mirabent et al., 2012). Albahari et al. (2017, p.13) underline that 'higher involvement of universities in the STPs is positively related to the number of patent applications', although there is no evidence that 'higher involvement of universities in the STPs is positively related to the propensity for park tenants to cooperate with a university or to purchase external R&D services from the university'. Knowledge transfer mechanisms involve the attraction and development of talents, because park tenants often work with researchers and students (Cadorin et al., 2017; Yan et al., 2018). This makes the university important for enhancing entrepreneurial and competitive skills and attitudes in students (Link et al., 2015; Matsheke & Dhurup, 2017). Regional Innovation Systems (RIS) are also more studied since 2011. Theeranattapong et al., (2021) reviewed the changes of university's activities during its interrelations within the RIS and with the STPs. These authors underline the importance of the universities' role in contributing to both STPs and – especially - RIS, distinguishing three important university links: knowledge co-creation, acting as a conduit, and inter-organizational relationship building. Barra & Zotti, (2018) research RIS efficiency in Italy and underline the importance of research and development in generating innovation and the knowledge context in which organizations operate as the existence of an intermediation structure, for instance, universities' technology transfer office. However, they also indicate that all these contributions can be optimized and underline the existence of important gaps in the literature on STPs and RIS. Several papers in this period focus on intellectual capital (IC) performance (Schiavone et al., 2014), in particular intellectual property (IP). IC refers to intangible resources and their flows which contribute to the value creating process of the company (Roos & Roos, 1997). Many studies on IC target models, measures and assessments of IC in STPs (Maltseva, 2016; Patthirasinsiri & Wiboonrat, 2019; Romano et al., 2014). Articles also analyse the generation of IP, IP management and the patenting process in STPs (Schiavone et al., 2014; Squicciarini, 2009; Yang et al., 2010).

A recent trend is research on *sustainability*. STPs have advanced in sustainability and the research on the topic has also increased since 2015. For instance, Laguna & Durán-Romero, (2017) developed a qualitative analysis in Spain concluding that STPs have 'high potential as sustainable knowledge facilitators and proactive attitude in relation to environmental commitment, although there is still room for enhancements in their sustainability approaches'. According to Yamamoto and Dos Reis Coutinho (2019), a new phase in Brazilian STPs has begun to focus on balancing economic and environmental issues.

Alongside the emerging topics, the literature maintains an interest in classic topics such as the differences between firms located in STPs and outside them, and the role of STPs in innovation performance (Díez-Vial & Fernández-Olmos, 2015; Lee et al., 2017; Ramírez-Alesón & Fernández-Olmos, 2018; Helmers, 2019). For instance, Ramírez-Alesón & Fernández-Olmos (2018) show that STP do not directly affect innovation performance of new technology-based firms, but do have selection and moderating effects by attracting new technology-based firms and encouraging collaboration between them, with indirect effects on innovation. Díez-Vial & Fernández-Olmos (2015) research the role of STPs on innovation performance under economic downturns, remarking the benefits for firms with previous cooperation agreements with research institutions and universities, since they can more easily enhance their product innovation. Additionally, sharing internal efforts on R&D among firms encourage a higher product innovation. Other papers also research classic topics such as university-industry linkages and their potential advantages (Liberati et al., 2016; Díez-Vial & Montoro-Sánchez, 2016; Van Oostrom et al., 2019), future challenges (Link, 2019) and incubators and spin-offs (Ferri et al., 2019; Taheri & van Geenhuizen, 2019). Research on the impacts of STPs on *regional development* (e.g., Dobrosavljević & Živković 2018; Kim et al., 2014; Molina et al., 2011; Yamamoto and Dos Reis Coutinho, 2019; Zeng et al., 2013), as well as the role of STPs in broader *innovation policy* (Yan et al., 2018), also remains important. A lack of infrastructure, government problems, negative incentives to R&D, lack of industrial clusters and links with universities, and managerial issues form big barriers for STPs' success (Cumming & Johan, 2013; Hussler et al., 2010; Link, 2019; Tonelli et al., 2015). Higher education policy is also important. Increasing expectations from policy-makers for universities to contribute to economic development (Hussler et al., 2010) by engaging in *university-industry collaboration* (Bishop et al., 2011) is an important part of the context for the development of STPs to support the third mission of universities. Nevertheless, STPs as institutionalized policies for local development are still underexplored, and they should be considered a gap to compose the agenda for future research (Tonelli et al., 2015).

6 Conclusion

As part of the third mission of universities to contribute to innovation and economic development, STPs have emerged as a popular policy tool in many countries and regions. They build on ideas about the importance of co-location for collaboration and knowledge exchange, which are well-known in other approaches to innovation policy, such as clusters, industrial districts, and regional innovation systems. The rationale is that the co-location of innovative firms and universities will encourage knowledge spillovers and support the application of university research in industry. As in the case of cluster policy more generally, inspiration for the idea of STPs has also come partly from Silicon Valley, specifically from Stanford Research Park, established in 1951.

The emergence of STPs has been accompanied by a growing body of research on these parks and their relationship with universities. This growth has been particularly strong in the 2000s, which saw steady growth from 19 publications in 2001 to 126 in 2017. However, the literature has remained fairly fragmented across different fields, journals and cases. Despite more than 1700 publications on the topic, no single journal has published more than 45 papers and only a handful have published more than 10 papers. Furthermore, these journals are spread across various fields, covering technology transfer, innovation, entrepreneurship, management and higher education, making it difficult to identify a disciplinary home for the conversation on STPs and universities. Somewhat surprisingly, discussions about STPs have been largely absent from the literature on the spatial and geographical dimensions of innovation, perhaps due to their omission from popular innovation databases such as the Community Innovation Surveys. Empirically, the literature has been developed mainly in the form of case studies of individual parks. Conversely, there are few comparative studies that include several parks, let along large-scale analyses across many parks. To the extent that the literature has developed insights building on evidence from across different contexts, this has mainly been in the form of theoretical or conceptual papers.

We identified three distinct phases in the literature on STPs. From an initial phase focusing on the early examples of STPs, the literature started taking off from 2000. This involved first a geographical expansion phase from 2000 to 2010, in which studies of parks expanded to new contexts. This notably included developing and emerging economies, especially in East Asia. Reflecting the popularity of STPs as a policy tool in a number of East Asian countries, but above all in China and Taiwan, more than half of all publications on the relationship between STPs and universities have an empirical focus on East Asia, and more than a third on China or Taiwan specifically. Authors in China and Taiwan jointly also account for nearly 30% of publications on the topic.

While the geographical focus expanded, the conceptualisation of STPs remained fairly traditional in this period. It was fundamentally anchored in cluster thinking and saw STPs primarily as tools for the development of high-technology industries in general and ICT industries in particular. This changed in the next phase, from 2010 onwards, when STPs were to a greater extent seen as open innovation laboratories which draw on a variety of knowledge sources from within as well as outside the local area, and for which many different types of knowledge and skills are important. This reflects a broader change in the innovation literature towards an understanding of innovation as a more open process building on the recombination of different types of knowledge.

Although STP research is rising with studies unfolding in several areas, they still lack a solid theoretical foundation, which poses challenges to its integration into the mainstream literature on regional development and, specifically, the role of universities in it. Overall, this review provides an analysis of the current state-of-the-art of research on STPs and universities. This way, the paper provides a holistic view of STPs' development, connecting fragmented literature to serve as foundation for policy making and practice-oriented research. For instance, the research shows that literature on STPs has mostly followed the broader innovation literature without seeking deeper knowledge into how the innovation process works for firms in STPs and which roles the universities can take in it.

However, the study is not free of limitations. The literature on STPs is big and it is impossible to do all of it justice in a single study. We rely on a combination of methods and in-depth study of a sample of articles, but unavoidably will have missed some important contributions as part of the sampling procedure. Furthermore, we rely on keyword searches of titles, keywords and abstracts, and there are no guarantees that we may not have missed some important contributions (e.g., because they use different concepts), pr included some less relevant ones. Due to the large number of collected papers, not all the selected and reviewed materials have been referenced, although all of them were classified according to the mentioned structural dimensions and analytical categories. Additionally, authors indicate meaningful examples for each given dimension and category. Narrowing the search for documents would have implied excluding interesting materials for the study. For this reason, neither time or type of documents filters were considered and different keywords were used in the search process to guarantee the highest number and variety of documents, as described in the Methods section.

For the future development of this literature, we would encourage contributions which integrate empirical data on several different parks in comparative studies. An interesting and unexplored topic is whether the evolution of parks follows the evolution of the literature on them. Given that the literature consists largely of case studies, we can hypothesize that the developments in the literature reflect a substantive development whereby STPs first became more geographically widespread and subsequently used for an ever broader set of policy purposes. However, this remains a question for future research. We would also encourage the development of papers which go beyond offering advice to decision-makers to understand how and why STPs work in the way they do, and how they are related to broader understandings of innovation, economic development and the third mission of universities. While STPs have often been sold as a new and shiny policy tool, the analysis of the literature on them has revealed that it has mostly followed the trends in the broader innovation literature, rather than offering fundamental new insights on how the innovation process works and which roles the universities can take in it.

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