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TECHNOLOGY PARKS IN BRAZIL: AN ANALYSIS OF THE DETERMINANTS OF PERFORMANCE EVALUATION

PARQUES TECNOLÓGICOS DO BRASIL: UMA ANÁLISE DOS DETERMINANTES DA AVALIAÇÃO DE DESEMPENHO

PARQUES TECNOLÓGICOS DE BRASIL: UN ANÁLISIS DE LOS DETERMINANTES DE LA EVALUACIÓN DEL DESEMPEÑO

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Abstract

Objective of the study: The aim of this study was to develop a systemic framework to understand the nature and dynamics of technology parks in Brazil and to analyze the mais determinants for evaluating their performance in the settlement process.

Relevance/originality: This work is unprecedented for the analysis of the dissemination of technology parks in Brazil, throughout its history, and for the application of multivariate data analysis for performance analysis in the settlement (number of tenant companies).

Methodology/approach: This study is characterized as a qualitative and quantitative combination of research methods, defined as combined exploratory, carried out in two phases. The qualitative approach is carried out first, with the aim of exploring the research topic in order to provide subsidies for the quantitative phase.

Main results: The Simple Correspondence Analysis demonstrated that the two determinants that impact the settlement of technology parks in Brazil are financing and park´s age, confirming the thesis that they are long-term enterprises.

Theoretical/methodological contributions: This study is characterized as a qualitative and quantitative combination of research methods, defined as combined exploratory, carried out in two phases. The qualitative approach is carried out first, with the aim of exploring the research topic in order to provide subsidies for the quantitative phase.

Social/management contributions: The results demonstrate the importance of technology parks in Brazil and the need to maintain public policies in the long term, in order to increase the size of parks, in terms of concentration of new technology-based companies, and attraction of anchor companies, generating jobs and income qualified.

Keywords: Technology park. Science park. Innovation policy. Economic development. Performance evaluation.

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Resumo

Objetivo do estudo: O objetivo desse estudo foi desenvolver um framework sistêmico para compreender a natureza e dinâmica dos parques tecnológicos no Brasil e analisar os principais determinantes para avaliação de desempenho dos mesmos no processo de povoamento.

Relevância/Originalidade: Esse trabalho é inédito pela análise da disseminação dos parques tecnológicos no Brasil, ao longo de sua história, e pela aplicação da análise multivariada de dados para análise do desempenho no povoamento, medido pelo número de empresas residentes.

Metodologia: Foi realizado um survey junto aos parques tecnológicos, utilizando instrumentos de coleta de dados, desenvolvidos a partir dos fatores de sucesso da literatura e validados pela realização de múltiplos estudos de caso. Após a análise descritiva dos dados, foi utilizado o método de análise multivariada dos dados, a fim de verificar os determinantes que impactam no povoamento dos parques.

Principais resultados: A Análise de Correspondência Simples demonstrou que os dois determinantes que impactam no povoamento dos parques tecnológicos no Brasil são o financiamento e a idade do parque, confirmado a tese de que os parques tecnológicos são empreendimentos de longo prazo.

Contribuição metodológica: Este estudo caracteriza-se como uma combinação qualitativa e quantitativa de métodos de pesquisa, definida como exploratória combinada, realizada em duas fases. A abordagem qualitativa é realizada primeiramente, com o objetivo de explorar o tema da pesquisa a fim de fornecer subsídios para a fase quantitativa.

Contribuição social: Os resultados demonstram a importância dos parques tecnológicos no Brasil e a necessidade de manutenção das políticas públicas a longo prazo, a fim de aumentar o tamanho dos parques, em termos de concentração de novas empresas de base tecnológica, e atração de empresas âncoras, gerando emprego e renda qualificados.

Palavras-chave: Parques tecnológicos. Políticas de inovação. Desenvolvimento econômico. Avaliação de desempenho.

Resumen

Objetivo del estudio: El objetivo del presente estudio fue desarrollar un marco sistémico para comprender la naturaleza y dinámica de los parques tecnológicos en Brasil y analizar algunos determinantes para evaluar su desempeño en proceso de poblar.

Relevancia/originalidad: Este trabajo es inédito para el análisis de la difusión de parques tecnológicos en Brasil, a lo largo de su historia, y para la aplicación de análisis de datos multivariados para el análisis de desempeño en proceso poblar.

Methodología/enfoque: Para esto, se realizó una encuesta con los parques tecnológicos, utilizando un instrumento de recolección de datos, desarrollado considerando los factores de éxito de la literatura y validado por múltiples estudios de caso. Tras el análisis descriptivo de los datos, se utilizó el método de análisis de datos multivariante con el objetivo de verificar los determinantes que impactan en la población de los parques.

Resultados principales: El Análisis de Correspondencia Simple demostró que los dos determinantes que impactan el asentamiento de parques tecnológicos en Brasil son el financiamiento y la madurez, confirmando la tesis de que son emprendimientos de largo plazo.

Aportaciones teóricas/Metodológicas: Este estudio se caracteriza por ser una combinación cualitativa y cuantitativa de métodos de investigación, definida como exploratoria combinada, realizada en dos fases. En primer lugar, se realiza el abordaje cualitativo, con el objetivo de explorar el tema de investigación a fin de brindar subsidios para la fase cuantitativa.

Contribuciones sociales/de gestion: Los resultados demuestran la importancia de los parques tecnológicos en Brasil y la necesidad de mantener políticas públicas en el largo plazo, para aumentar el tamaño de los parques, en términos de concentración de nuevas empresas de base tecnológica, y atracción de empresas ancla, generando empleos y ingresos calificados.

Palabras clave: Parques tecnológicos. Políticas de innovación. Desarrollo económico. Evaluación del desempeño.

1 Introduction

The establishment of innovation environments, characterized by Research and Development (R&D) and production of high value-added products and services, which enable technological innovation and the creation of new technology-based companies, is strategic for economic and social development based on knowledge (AURP & BTPP, 2013; Etzkowitz, 2003). These environments are expected to be offered by technology parks, which can be understood as an intermediary organization that promotes interaction between academia, industry and government (Hansson *et al.*, 2005; Metcalfe, 2010; Phan *et al.*, 2005), that end up representing an evolution of industrial concentrations, which started in Great Britain after the industrial revolution (Vilà & Pagès, 2008). There are different types of parks (science parks, technology parks, research parks and others), with different legal, management and governance models (ANGLE Technology, 2003; Dabrowska & Faria, 2020; Parry, 2006). There is no consensus on what is a successful technology park (Dabrowska, 2011) and despite the increase in interest in collaboration and innovation among government, academics and professionals, the results of research on the effectiveness of technology parks remain ambiguous (Schmidt & Balestrin, 2015).

Technology parks represent a worldwide phenomenon (Albahari *et al.*, 2018; Hobbs *et al.*, 2017; Lamperti *et al.*, 2017; Lecluyse *et al.*, 2019), as agents for promoting innovation and technological development (Dabrowska, 2011; Etzkowitz & Zhou, 2018; Siegel *et al.*, 2003b). It is estimated that there are more than 1.000 technology parks in the world (AURP, 2018). The inconclusive results on the parks' contribution lead to the need to obtain detailed information about when, how and why the parks provide value-added contributions, considering their heterogeneous nature (Lecluyse *et al.*, 2019). The only consensus is that parks are widespread throughout the world as instruments of public policy on technology and innovation that can contribute to regional development (Albahari *et al.*, 2018). Analysis of publications in the last 30 years has shown that interest in parks has increased, with greater concentration in China and Spain, in the form of case studies, and in the United Kingdom and the United States, mainly due to the availability of data, but not yet is enough to fully understand the phenomenon (Hobbs *et al.*, 2017). It is necessary to develop a structural contingency perspective that relates the different types of parks to different contexts (Phan *et al.*, 2005), understanding why they exist and the performance measure, considering the different objectives, as well as the strategic guidelines that can be revised at any time to achieve the intended results (Etzkowitz & Zhou, 2018).

This work aimed to develop a systemic framework, suitable to understand the nature and dynamics of technology parks in Brazil, through qualitative and quantitative combined methods, which allowed the analysis of the determinants of performance evaluation in the settlement process. The care that must be taken when evaluating performance is not to compromise the reputation of technology parks, considering evaluation as an opportunity to change direction, in search of success, which must consider the boundary conditions in which each enterprise is inserted. Thus, a survey was carried out with technology parks in Brazil, at different stages of development (operation, implementation and

planning). The general information questions of the survey about the parks, since the creation of the park until 2020, were answered by 7 parks under implementation, 9 parks under planning and 55 technology parks in operation, and specific questions of the survey about innovation, economic and finance indicators, for the years 2017 and 2018, were answered for 40 technology parks in operation. The survey collection instruments were developed considering the success factors in the literature for technology parks and were validated through multi-case analysis, with 19 technology parks. Then, a descriptive data analysis was developed to build a framework about technology parks in Brazil, and it was carry out a multivariate analysis of the data, using the Simple Correspondence Analysis, to analysis the determinants of performance about the settlement process (number of tenant companies).

According to the data presented in this study, in 2020, Brazil had 55 technology parks in operation that generated more than 40 thousand jobs by their tenant companies. The results showed that technology parks in Brazil were young (age of the park) and small (number of tenant companies), with a financing deficit, which had as a major challenge the attraction of companies for their environment, in particular anchor companies. The number of tenant companies is an important variable in the park's performance, and is usually the main metric for stakeholders, as in addition to contributing to the park's primary mission, social and economic development also impacts the parks' financial sustainability. Thus, this research sought to analyze the relationship between the settlement process of the technology park, measured in number of tenant companies, with variables that, according to the literature, can be factors of success for technology parks. The explanatory variables tested to analyze the settlement process were: maturity of the park (age of the park), investments made, park management team, scientific basis (measured in the number of professors at the anchor universities and the number of graduate students at these universities), geographic location (measured in Gross Domestic Product - GDP) per capita of the state and Human Development Index (HDI) of the state in which the park is installed) and management model (evaluated in the park's legal and administrative personality). A significant correlation was found only between the age of the park and the investments received, confirming the literature that that the technology parks are long-term enterprises.

In Brazil, the technology park movement has developed over the past 25 years, which is relatively recent compared to the United States, which in the 1950s already had the world's first technology park initiatives. Studies indicate that incubators and technology parks have produced encouraging results for Brazil in terms of job and income generation in the country (Anprotec & ABDI, 2008; Anprotec, 2016; Anprotec, 2019; Etzkowitz *et al*., 2005; Faria *et al*., 2017a; Faria *et al*., 2017b; Faria *et. al.*, 2015; Lahorgue, 2004; MCTIC & CDT/UNB, 2014; MCTI, 2015a; MCTI, 2015b; MCTI, 2016; MCTIC & CDT/UNB, 2019). Study released by Brazilian Association of Science Parks and Business Incubators (Anprotec, 2019) showed that in Brazil there were 363 business incubators, 57 accelerators, 3.694 incubated companies that generated 14.457 jobs and earned 551 million reais, and 6.143 graduated companies that generated 55.942 jobs and earned more than 18 billion reais.

Nevertheless, the dissemination of technology parks in Brazil has encountered relevant challenges, in particular the scarcity of resources for expansion and improvement of infrastructure and difficulty in attracting companies (Ribeiro *et al.*, 2019). According to the literature and the results presented here, these difficulties are very likely to be resolved over time, with the increase in the age and maturity of the park. For this, it is essential to establish public policies and State actions that assist these enterprises in the development and fulfillment of their role as a driving force for the promotion of innovation and technological and consequently social development, as it is already in the world. The results presented here represents a systemic framework about the evolution, dissemination, dynamic and results of technology parks in Brazil, which can instruct park managers and public agents to make factual decision, from quantitative and qualitative information, which allows the understanding of the main challenges and bottlenecks for the development and success of technology parks in the country.

2 Parks´ performance evaluation

A conceptual formulation for a technology park which is fully consensual is difficult (Hansson *et al*., 2005; Lecluyse *et al*., 2019; Link & Scott, 2003b). In general, a park is a real estate initiative, designed to encourage the formation and growth of technology companies, which has a management function actively involved in achieving this goal, which is one of the main differences between parks and other types agglomerations, such as spontaneous clusters (Albahari *et al*., 2018). The definition of park (*science park*) most cited in the literature (Lecluyse *et al*., 2019) is that given by the *United Kingdom Science Park Association* (UKSPA): "initiative to support business and technology transfer that: (1) encourages and supports the creation and incubation of innovative, technology - based, high-growth businesses; (2) provides an environment in which large international companies can develop specific and close interactions with knowledge-generating centers for mutual benefit; (3) has formal and operational links with knowledge-generating centers, such as universities, higher education institutions and research institutes".

The park models are diverse (Parry, 2006; Vilà & Pagès, 2008): Science Parks (*Science Park* - United Kingdom - "the British model" characterized by small size, strong links with university or other research center, little emphasis on production activities); Research Parks (*University Research Park* – United States and Canada – "the American model", characterized by large size, production activities are allowed on site), and Technology Parks (*Technology Park* - France, Spain, Italy and Portugal - "Mediterranean model", characterized by medium or large size, production activities are allowed on site), in addition to other similar concepts, such as *Technopole*, *Business Park*, *Science City* and *Innovation or Business Park*. The main factor that differentiates a research park from a technology park is the strong interaction between on-park companies and affiliated research institutions (AURP & BTPP, 2013). There is one additional model that can be distinguished within the science park phenomenon. It's "the Chinese model". Science parks in Asia, so called *High-Tech Zones or High-Tech Parks*, are large-

scale developments strongly supported by the governments on which production activities are allowed and companies often benefit from financial incentives (Guo & Verdini, 2015).

Within the scope of this work there will be no conceptual distinction of the typology, preferentially using the concept of technology park, more usual in Brazil, defined by Brazilian Federal Law nº 13.243 / 2016, known as the new Legal Framework for Science, Technology and Innovation (STI) (Brazil, 2016) and the National Innovation Policy (NIP) (MCTIC, 2019), as a "planned complex of business and technological development, promoting a culture of innovation, industrial competitiveness, business training and promoting synergies in scientific research, technological development and innovation activities, between companies and one or more STI, with or not linked to each other".

Assessing the success of the parks, with relevant performance criteria, is not a simple task, (Dabrowska, 2011; Dabrowska & Faria, 2020; Hansson *et al*., 2005; Ribeiro *et al*., 2016; Ribeiro *et al*., 2018; Ribeiro *et al*., 2019). Scientific studies that assess the contribution of parks usually examine whether they contribute to the performance of their different stakeholders (resident companies, tenant anchor and partner universities as well as the local and national economy), how they contribute and what is the measurable impact of that contribution (Lecluyse *et al*., 2019). A park is an expensive enterprise that, even if it is not legally constituted as a company, has the characteristics of a business, including the risks (Parry, 2006).

Academic studies related to the science park phenomenon often tackle the issue of performance assessment (of companies, the parks themselves and the university or region's systemic level). These studies can be divided into individual case studies, which have been associated with inductive approaches to building of theories and in multiple case studies, where general lessons can be deduced looking for common points between the cases (Hobbs *et al*., 2017; Phan *et al*., 2005). Premature conclusions are sometimes made regarding the success and failure of the technology park, based on case studies that do not consider the potential for strategy change, paving the way for final success, and often end up denigrating the image of the analyzed entity (Etzkowitz & Zhou, 2018), without considering the dependent variables involved such as maturity and objectives of the analyzed park, nature of the stakeholders involved, geographical location and the level of regional development (Albahari *et al*., 2018; Wasim, 2014).

Comparing the performance of technology-based tenant companies in parks (on-park companies) with the performance of similar companies located outside the park (off-park companies) is a recurring method in the literature (Dabrowska & Faria, 2020; Hansson *et al*., 2005). Some of these matched sample studies demonstrate that companies residing in technology parks, have more significant financial growth (ANGLE Technology, 2003; Ferguson & Olofsson, 2004; Leyden *et al*., 2008), higher rate of job growth (ANGLE Technology, 2003; Löfsten & Lindelöf, 2001; Löfsten & Lindelöf, 2002; Löfsten & Lindelöf, 2003), greater proportion of skilled jobs, with engineers and scientists (ANGLE

Technology, 2003), better sale and profitability results (Löfsten & Lindelöf, 2001; Löfsten & Lindelöf, 2003), higher survival rate (Ferguson & Olofsson, 2004; Westhead, 1995; Westhead & Cowling , 1995; Westhead *et al*., 1995; Westhead & Storey, 1997) and greater economic diversity (Leyden *et al*., 2008), than similar non-resident companies.

From the point of view of innovation indicators, studies have shown that resident companies have greater innovation skills (Löfsten & Lindelöf, 2003; Lamperti *et al*., 2017; Siegel *et al*., 2003b), better results in terms of patents (Jongwanich *et al*., 2014; Siegel *et al*., 2003b; Squicciarini, 2008) and in R&D (Leyden *et al*., 2008), greater investment in R&D (Lamperti *et al*., 2017), collaborate more effectively with universities (Colombo & Delmastro, 2002; Ferguson & Olofsson, 2004; Löfsten & Lindelöf, 2002; Lindelöf & Löfsten, 2004) and with research institutions (Fukugawa, 2006), than similar non-resident companies.

The above can be explained considering that parks and incubators influence collaborative R&D through other instruments besides their services and infrastructure (Schmidt & Balestrin, 2015) and that companies in technology parks tend to establish more cooperation links with universities (student projects, research projects and jobs for graduates) (Fukugawa, 2006; Link & Scott, 2003b; Löfsten & Lindelöf, 2002; Schmidt & Balestrin, 2015). Their proximity to technology parks has a positive impact on the growth of universities and on the research profile (moving more from basic to applied research), as well as favors the increase in the number of publications and patents, the transfer of technologies and the placement of graduates in the job market (Link & Scott, 2003b). In addition, park management teams do not concentrate uniquely on provision of real estate services, but their efforts are focused on creating an environment conducive to innovation, increasing the networks of entrepreneurs, facilitating the transfer of technology and improving the image of companies which, in turns, contributes to the park reputation (Albahari *et al.*, 2018). Parks have strong and knowledgeable management teams who add value to their resident companies by providing information, tailoring it to their needs and distributing it in forms of so called 'innovation services' which are similar to services offered by knowledge intensive organizations (Dabrowska & Faria, 2020).

Thereby, parks play an important role in local technological development, influencing the increase in the number of patents and the quality of the university-industry relationship (Jongwanich *et al.*, 2014). Moreover, companies residing within technology parks in less developed regions perform better in terms of innovation (sales of new products to the market) than companies located in developed regions, which can be interpreted as indirect effect of the role parks play in less developed regions, i.e. as policy instruments to foster innovation (Albahari *et al.*, 2018).

In an ambiguous and contradictory way, on the other hand, some studies show that there was no statistically significant difference between the performance of on-park and off-park companies, with regard to formal cooperation links with universities (ANGLE Technology, 2003; Bakouros *et al*., 2002; Fukugawa, 2006; Vedovello, 1997) and significant results in innovation - patents and new products -

and R&D (ANGLE Technology, 2003; Bakouros *et al.*, 2002; Liberati *et al.*, 2016; Löfsten & Lindelöf, 2002; Löfsten & Lindelöf, 2003; Westhead, 1997), growth (Lamperti *et al.*, 2017; Ferguson & Olofsson, 2004) and profitability (Löfsten & Lindelöf, 2005). Studies also indicate that some parks have failed to generate networking opportunities between resident companies (Minguillo & Thelwall, 2015; Siegel *et al.*, 2003a).

What can explain this ambiguity of results is the fact that the results of these studies cannot be generalized. In general, there are difficulties in obtaining data (few parks and / or a small sample of companies) and the case studies do not consider the boundary conditions in which the parks are inserted (Albahari *et al.*, 2018; Etzkowitz & Zhou, 2018; Phan *et al.*, 2005). It would be inappropriate to evaluate the results of the "park phenomenon / movement", with perceptual data from companies located in a small number of parks, given that the data suffers from several known limitations and the results of these studies may, therefore, be biased (Siegel *et al.*, 2003a). Problem with case studies can happen when only successful examples or models are chosen for the construction of the general model, leading to an under-specification of the model or, worse, to incorrect theoretical conclusions (Etzkowitz & Zhou, 2018), (Phan *et al.*, 2005).

A gap in the existing literature on technology parks is visible and cannot be ignored. Previous research projects did not consider the heterogeneity of the parks (age, size in terms of square meters and number of residents, size of the management team, provision of services, location), while assessing their performance. Despite limited resources and other encountered difficulties some parks, actually create value for its resident companies and therefore influence their performance and innovation potential, whereas some do not do that even if they operate in more favorable contexts (Albahari *et al.*, 2018). In addition, several mistakes can be made in an attempt to measure the success and effectiveness of a park considering only financial criteria (investment, employment, budget, etc.) or innovation indicators (number of startups, patents, new products, etc.) (Ribeiro *et al.*, 2019), whereas there is no clear consensus about what is a successful technology park (Dabrowska, 2011; Dabrowska & Faria, 2020) and that each stakeholder can have its own definition of success (Júnior *et al.*, 2015; Vilà & Pagès, 2008).

It should be noted that success or failure is often simply associated with the imbalance between goals and resources allocated to the development of the park, over time (Etzkowitz & Zhou, 2018). Therefore, to fully understand how effective and efficient a park has been it's essential to deeply analyze its operations within the existing context with its strengths, weaknesses, threats and opportunities. It must be observed that "if you saw a park, you saw a park " ("*Link dictum*") (National Academy of Sciences, 2009), that indicates that each park generates a different impact, where the success of an initiative is unlikely to apply to other cases, due to the park's internal organization, relations with local organizations, such as governments, universities and other research institutions (Vilà & Pagès, 2008), the diversity of objectives and expectations of stakeholders (Hansson *et al.*, 2005) and the political,

social and economic contexts in which they are inserted (Phan *et al.*, 2005). Furthermore, there is no single path to success for a technology park considering that they "are not built in one day", and it will probably take from 15 to 25 years for all impacts to become evident (Castells & Hall, 1994).

Despite the difficulties, evaluating performance of the parks is an increasingly important issue for public policy managers which need strong arguments to continue allocating resources (Guo & Verdini, 2015; Lamperti *et al.*, 2017), while stakeholders need to understand the value for the regional knowledge economy (Dabrowska, 2011). The heterogeneous features (age, size in terms of square meters and number of residents, size of the management team, service delivery, location) suggest that public policies should avoid indiscriminate financial support for parks, given that some parks are more effective than others, and seeking to increase the size of the parks, given that this is one of the factors that interferes with the performance and efficiency of resident companies (Albahari *et al.*, 2018).

3 Parks´ critical success factors

The analysis of the main critical success factors of technology parks (explanatory variables), according to the literature, is necessary to understand the most relevant aspects of their performance and efficiency (variable explained) (Ribeiro *et al.*, 2018). Critical success factors can be defined as characteristics, conditions or variables that can have a significant impact on the success of a project, when properly supported, maintained or managed (Leidecker & Bruno, 1984; Ribeiro *et al.*, 2019). The study of these indicators is related to the identification of the most critical elements or determinants, aiming to reduce the complexity of decision making and management (Bai & Sarkis, 2013; Dabrowska & Faria, 2020; Ribeiro *et al.*, 2016).

For the present study, with regard to technology parks, the critical success factors were listed as prerequisites, parameters or determinants for the viability of these environments in fulfilling their mission as a promoter of technological and economic development (Faria, 2019). Although the definitions of technology parks can emphasize different aspects, some elements seem to emerge as common denominators for most of these organizations (Bellavista & Sanz, 2009), as: management of the environment and services that encourage the transfer of technology between various actors involved; effective relationship with universities; value-added services offered to residents; state related support and facilities, such as living spaces, residential areas and leisure facilities; mechanisms for creating technology-based companies; mechanisms for attracting anchor companies; networking ability and networking beyond its borders.

According to the European Commission, the main attributes observed in successful technology parks are: strong scientific base, political support, effective networking, skilled workers, entrepreneurial culture, support services and anchor companies, growing base of companies, ability to attract talent and opportunities, infrastructure, and availability of financing (European Commission, 2007). In a study carried out by the Association of University Research Parks (AURP), six factors were listed as critical

to the success of a park: good convergence between the scientific base of the affiliated university and the resident companies; ability to assist nascent businesses in marketing processes; resident companies' access to investment capital; priority in providing spaces for incubator graduated companies; priority access to university resources, such as facilities, researchers and students; formal presence of a business incubator (AURP & BTPP, 2013).

Regarding the success of the tenant companies in the park, the availability and ease of acquiring resources are fundamental (Kharabsheh *et al.*, 2011; Tsamis, 2009), and it can occur in two ways: on the part of governments, inducing specific programs or using their purchasing power, and on the part of the private sector, through companies, commercial banks and opportunity capitalists or venture capitalists (Vedovello *et al.*, 2006). On the other hand, the main benefits of science parks occur mainly through personal contact between entrepreneurs, employees and researchers (Helmers, 2011). There is a belief that the physical proximity between the actors will be sufficient to achieve the established goals (Vilà & Pagès, 2008).

It is also possible to highlight a set of external aspects to the park, related to cultural, political, economic and social issues (Parry, 2006). This environmental factor (environment) influences the degree of development and the viability of the parks, and its interference can be seen in the definition of priorities, in the institutional structure in relation to the transfer of technology, in cooperation and entrepreneurship, in the availability of resources to attract companies for the park and the domestic market that supports the growth of small technology-based firms (Tsamis, 2009). A success factor identified as crucial is the drives to attract new companies, such as innovative and dynamic companies that attract other companies around them, including anchor companies (Wasim, 2014; Link & Scott, 2003a). Anchor companies are those who are key to the park, often with big innovation potential and good reputation. A study demonstrated that one of the main reasons for companies to settle in Cuiping Technology and Innovation Park, in China, was due to incentives, such as tax subsidies and support to the real estate issue, followed by the availability of human capital, infrastructure and facilities (Guo & Verdini, 2015).

There is some evidence that companies located in large technology parks or in already mature technology parks performed better (sales of new products to the market) than companies located in smaller parks or in intermediate technology parks (Albahari *et al.*, 2018). To achieve the stakeholders' objectives, those involved in the planning, creation and management of the park in the long term must have a good understanding of entrepreneurial skills, marketing and market performance of resident companies, technology transfer mechanisms, creation dynamics and growth of new businesses, labor needs, dynamics of the local and regional economy and how the park can fit into the local academic network, in order to establish itself as part of the entrepreneurial culture (Parry, 2006). Therefore, those who manage science parks have to have the ability and adequate interdisciplinary and cross sector skills to process information for resident companies in order to improve their innovation potential and create

synergies which will improve the competitiveness of regional economies (Dabrowska & Faria, 2020).

Parks are home to a variety of organizations: university, government research centers, industry partners; business incubators; technology-based companies in all stages of development, from startup to multinationals; advanced medical clinics; education and training centers; and economic development organizations. Thus, at the highest level of analysis is the issue of the park ownership and control, as stakeholders' divergent and sometimes conflicting objectives raise questions about governance mechanisms to monitor park performance (Phan *et al.*, 2005).

4 Research methodology and data analysis

This study is characterized as a qualitative and quantitative combination of research methods, defined as exploratory (Martins, 2018). In the combined exploratory research method, the study is carried out in two phases. The qualitative approach is carried out first, with the objective of exploring the research topic in order to provide subsidies for the quantitative phase (Amaratunga *et al.*, 2002; Creswell, 2010). To fulfill the research objectives, it was carry out a survey with the technology parks in Brazil at different stages of development (planning, implementation and operation), with the aim to build a historical series that allows for more robust statistical and econometric analyzes. The conceptual elements for the elaboration of the survey data collection instruments were defined based on understanding of the context of technology parks and the critical success factors from literature. Then, the survey collection instruments were tested and validated through multi-case study and analysis, carried out with 19 technology parks in operation in Brazil, in 2018. In the context of this work, it was fundamental to define, in the most adequate way, the data collection instruments for the survey, ensuring that all necessary information for the analyses was requested through the survey and filled in by the respondents avoiding errors or misunderstandings.

After this qualitative phase of the research, to carry out the survey with the parks, in the quantitative phase of the research, a competitive intelligence platform was developed by the researchers with the aim to collect, integrate and monitor technological parks in Brazil, their tenant companies and other resident organizations, over time. This platform, called MCTI-InovaData-BR, and this study were established with the financial support from the Ministry of Science, Technology and Innovations (MCTI) of the Brazilian government. It is expected that the platform will help the government and decision makers formulate strategies, design public policies and identify actions that will stimulate innovation and induce economic development. Free access to MCTI-InovaData-BR is available at: https://www.inovadata-br.ufv.br/. The full development of the platform took place in 2017 and 2018.

After the development of the MCTI-InovaData-Br, the platform was fed, by the researchers, with information previously obtained and made available by the MCTI, by the multi-case study and by the other secondary data about parks in operation, implementation and planning stages in Brazil. The researchers also registered, in the Platform, the tenant companies, using the information in the parks´

website and National Register of Legal Entities (CNPJ). Only after this stage, with the registration of the technology parks on the platform, that the survey was available to the parks to answer themselves. Then, the restricted access information to the Platform (username and password) was sent to the technology parks, to change the password and update their information. The survey collection instruments were divided in general information questions, for all technology parks, and specific questions about innovation, economic and finance indicators only for the parks in operation.

The general questions of the survey about the parks, since the creation of the park until 2020, were answered by 7 parks under implementation, 9 parks under planning and 55 technology parks in operation. The specific questions of the survey about innovation, economic and finance indicators, for the years 2017 and 2018, were answered for 40 technology parks in operation. The "2017 Survey" was made available, to technology parks in operation, in September 2018, to be answered for the fiscal year 2017, and in September 2019, the "2018 Survey", to be answered for the fiscal year 2018. Data collection for 2018 was completed in December 2019. The technology parks responding to MCTI-InovaData-Br already had access to their consolidated results for 2017 and 2018, and therefore were able to report their indicators. Technology parks in operation report their performance in relation to a set of parks' characteristics, in 7 axes, according to the constructs that were defined for the data collection instruments: Management, Services, Infrastructure, Team, Partners, Indicators and Evaluation.

To analyze the determinants of the performance of technology parks in Brazil in the settlement process, the main indicators on the evolution and dissemination of technology parks in Brazil were initially analyzed, based on the 2017 and 2018 Survey and the general information survey, answered by the parks. The quality of the data presented is in a direct relationship to the reliability of the data provided by the technology parks themselves. As the Platform is dynamic, and the technology parks can update their general information and the companies register at any time, the data reported here is a cut made in January 2020, after completing the data collection for the year 2018.

Then, a probabilistic analysis of the relationships between the success factors for the technology parks and their settlement was carried out. The settlement means the number of tenant companies. For this, Simple Correspondence Analysis was used (CA), which is a multivariate data analysis, where the characteristics are compared in pairs (Habib, 2012; Hoffman & Franke, 1986; Kennedy, Riquier, & Byron, 1996; Kroonemberg & Lombardo, 1999). No studies were found that apply the method of correspondence analysis in a study of technology parks, which is a differential of the present study. To obtain the probabilistic confidence level for each of the relationships, the pair of variables must be subjected to two tests, the *chi-square* test (χ^2) and the Criterion β test (Greenacre, 1993; Hoffman & Franke, 1986; Jobson, 1996; Mingoti, 2005).

As it is a probabilistic inference, it is necessary to describe the hypotheses associated with the test, where the null hypothesis of the *chi-square* test is that the pair of variables is not associated, in other words, the variables are independent, with no significant relationship, *versus* the alternative

hypothesis that the pair of variables is associated, or there is simply a significant dependency and association between the variables. The statistical significance of the test χ^2 indicates significant deviations of the line profiles in relation to its centroid, with a level of significance α, usually $\alpha=5\%$. The result obtained in the test χ^2 will be used for the calculation of the criterion β, which in turn indicates whether the application of CA between variables is valid or not. The calculation of the test value χ^2 and the criterion β are given, respectively by:

$$\chi^2 = \sum\sum \frac{(O-E)^2}{E} \quad (1)$$

$$\beta = \frac{\chi^2 - (l-1)(c-1)}{\sqrt{(l-1)(c-1)}} \quad (2)$$

where χ^2 is the value of the *chi-square* test statistic, O is the observed frequency, E represents the expected frequency, l is the number of lines and c is the number of columns in the correlation matrix.

It is also recommended that $\beta > 3$, if the variables are said to be associated with each other (dependent) with a risk less than or equal to 5% and, consequently, CA is applicable to the respective variables. It is important to note that the realization of the criterion β must be processed before applying the technique, as if the β is less than 3, the technique cannot be applied, due to the criterion indicating independence between variables.

After building the tests χ^2 and the criterion β it is possible to observe the pertinent relations to the study through the perceptual / intuitive graphs, whose interpretation must be done as the interpretation of a geographical map, assuming that the smallest distances between the dimensions of the categories present in the lines and columns represent the strongest associations between them, while the greater distances represent dissociations between them. Another way of evaluating the relationships presented in the thematic map is through the verification of the residuals of the contingency table. The residue related to each crossing of the categories of variables under study, Z_{res}, is given by:

$$Z_{res} = \frac{O_{ij} - E_{ij}}{\sqrt{E_{ij}}}, \quad (3)$$

in which, $i = 1, \ldots, l$ and $j = 1, \ldots, c$.

It is recommended that the respective confidence levels for each residue should be calculated Z_{res}, which will determine the statistical significance of the residuals between the

levels of the pair of variables, through (Ramos, Pereira, Almeida, Araújo, & Ramos, 2008):

$$\gamma = \begin{cases} 0, & se Z_{res} \leq 0; \\ 1 - 2 \times [1 - P(Z < Z_{res})], & se 0 < Z_{res} < 3; \\ 1, & se Z_{res} \geq 3, \end{cases} \quad (4)$$

being that Z is a random variable with standard normal probability distribution and for the purpose of statistically significant $\gamma \geq 0,7$. Thus, the correspondence analysis is presented in the form of tables with the residues and their respective significance.

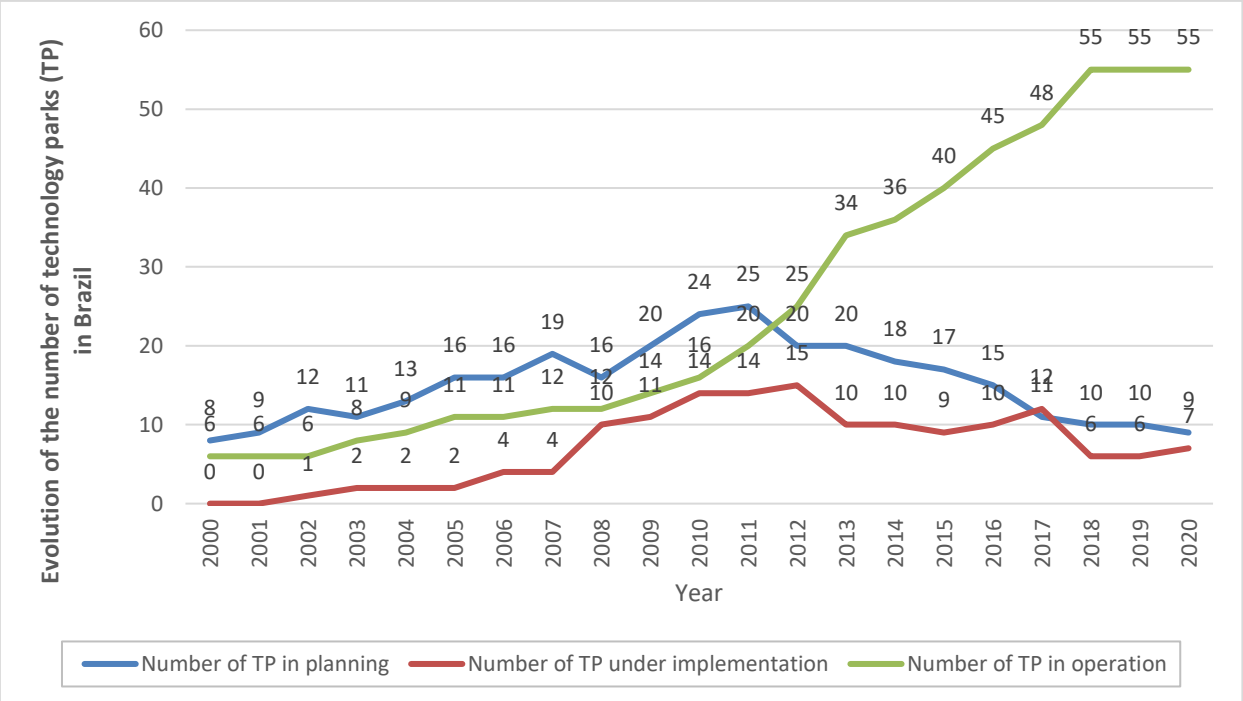
5 Results and discussions

5.1 Context of technology parks in Brazil

The Figure 1 shows the evolution of the spread of technology parks in Brazil, from 2000 to 2020, from the general information survey available at MCTI-InovaData-Br in January 2020. The first technology park in Brazil was created in 1983. Until December 2019, 93 technology park initiatives in Brazil were identified by the researchers, with 58 technology parks in operation, 12 parks in the process of being implemented and 23 parks in the initial planning stage. For the purposes of the statistics in this study, only those technology parks that confirmed their information in the MCTI-InovaData-BR will be considered, therefore, 7 parks under implementation, 9 parks under planning and 55 technology parks in operation. The 2017 and 2018 surveys were answered by 40 technology parks in operation. It appears that from 2013 there was a migration of the parks under implementation to the stage of operation. This fact could have been motivated by the public grants made available in 2013, by the Brazilian Innovation Agency (Finep), of the MCTI, "Public Call MCTI/Finep/Transversal Action - Inova Empresa - PNI/Technology Parks 02/2013", with available resources of the order of 90 million of reais, in support of the expansion and operation of these innovation environments in Brazil. Until 2020, that was the last federal public call to technology parks in Brazil.

Figure 1

Evolution of the number of technology parks in Brazil, from 2000 to 2020



Source: Research results, January 2020.

The study reveals that the technology parks in Brazil are mostly young parks, with only 25% of the parks being over 19 years old and 50% of the parks having been under 9 years of operation. The data indicate that the average time (years) between the planning and operation phase of the technology park is 6.9 years and between implementation and planning is 1.8 years. The long time between the planning and the operation phase of the park in Brazil can be explained by the need for high investments, especially financial (Etzkowitz & Zhou, 2018; Guo & Verdini, 2015; Siegel *et al*., 2003b), as well as by the deadlines related to the elaboration of projects, execution of works and obtaining licenses and permits, considering the real state model requirements and needs (Albahari et al., 2018; Parry, 2006).

The south and southeast regions comprise 81% of the technology park initiatives in Brazil. This spatial pattern seems to reflect the economic conditions of the region, the GDP per capita of the south region was 37.371,27 reais in 2017, and the southeast region of 27.283,00 reais. Another reason for concentration of technology parks in Brazil may be the presence of a strong scientific and technological system in this regions, which is the main success factor for technology parks (Albahari *et al*., 2018; AURP & BTTP, 2013; European Commission, 2007; Dabrowska, 2011; Dabrowska & Faria, 2020; Ferguson & Olofsson, 2004; Hansson *et al*., 2005; Link & Scott, 2003a; Link & Scott, 2005; Link & Scott, 2006, Minguillo & Thelwall, 2015; National Academy of Sciences, 2009; Parry, 2006; Vedovello *et al*. 2006).

According to the survey, the main technology sector presents within the Brazilian technology

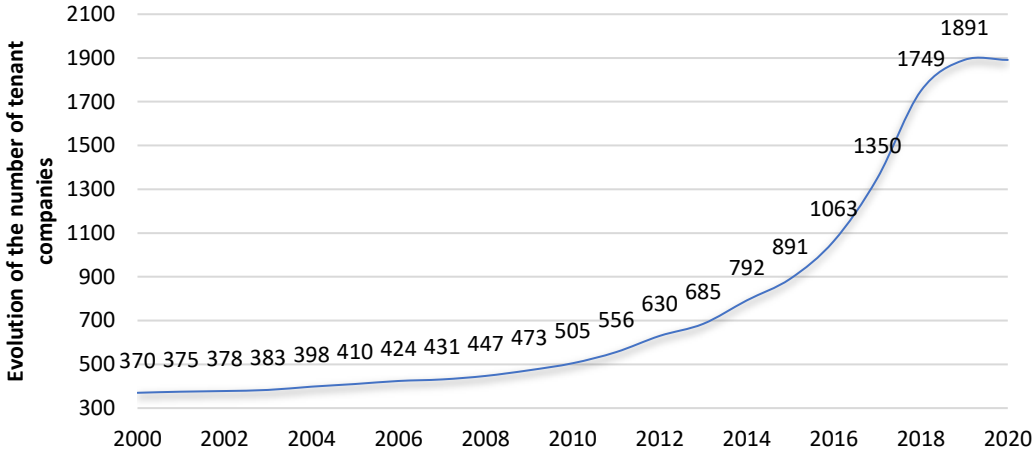
parks is Information Technology (93%). In a comparison with data from the study MCTIC and CDT/UNB (2014), and from this study, it appears that there has been a significant growth in the sectors of Biotechnology (from 59% to 76%), Creative Economy (from 9% to 42%), Agribusiness (from 25% to 54%), indicating that these environments are opening up to new technology-based forms of entrepreneurship. The main technology sectors within the Brazilian technology parks mirror the situation within the European Union parks, as Information Technology and Biotechnology sectors have also been two key technology areas which parks have historically been good at attracting and developing (European Commission, 2007; European Commission, 2014).

The profile of technology parks in Brazil by resident companies and organizations is shown in Figure 2. By the year 2000, there were about 379 tenant companies, and in January 2020 the statistics show 1.891 companies within Brazilian parks. In the period from 2013 to 2019 there was an increase of 176% in the number of companies residing in technology parks in Brazil, demonstrating the importance of these environments that promote innovation in attracting technology-based companies. It is estimated that the companies based on all 55 technology parks in operation which registered with the MCTI-InovaData-Br, generated revenues of 3,96 billion reais in 2017 and 4,04 billion reais in 2018, employed approximately 41.051 people in 2017 and 44.263 people in 2018 and paid more than 146,8 million reais in taxes in 2017 and 155,0 million reais in taxes in 2018. The above numbers which are often considered as critical economic impact indicators demonstrate that Brazilian technology parks have grown over the years and have an impact on job creation, economic wealth and regional competitiveness.

It is worth mentioning that only 17 technology parks in operation (31% of the 55 technology parks in operation in Brazil, confirmed in MCTI-InovaData-Br), are home to 70% of resident companies, that is 1.323 companies. These parks have been in operation for approximately 14 years, and are considered more mature parks, whose “age” coincides with the inflection point of the exponential population curve, shown in Figure 2. This fact confirms the importance of the variable time (age of the park) in the settlement process of technology parks (Albahari et al., 2018; ANGLE Technology, 200; Link & Scott, 2003b; Link & Scott, 2005; Link & Scott, 2006; Liberati et *al.*, 2016), which are long-term ventures (Castells & Hall, 1994), which need decades to achieve the intended objectives, as shown in the literature.

Figure 2

Evolution of the number of tenant companies in the technology parks in operation in Brazil



Source: Research results, January 2020.

Technology parks in Brazil are still small parks, with an average of 35 resident companies. Only three technology parks in Brazil have more than 100 resident companies. The density of companies for the 5 largest technology parks in Brazil is 169 companies per park. It is worth remembering that the size of the park is a variable that interferes with the performance of companies, as pointed out in the literature (Albahari *et al*., 2018). Parks in Brazil generate an average of 964 jobs per technology park, confirming that technology parks in Brazil are still mostly small parks. On average, parks in the United States of America (USA) would have 2.751 jobs per park (adapted from AURP & BTTP, 2013), in Spain there would be 2.631 jobs per park (adapted from Albahari *et al*., 2018) and on average in Europe 1.875 jobs per park (adapted from European Commission, 2014). When looking at the number of jobs created in 2018 within the 5 largest and mature parks in Brazil, we can see that 4.856 jobs were created, which represents about 63% of all jobs generated within the parks and 75% of the companies' revenues. That said, it demonstrates a great potential for generating direct and qualified jobs in the next decade, when all other parks are more mature, considering that the age of the park is a critical success factor (Albahari *et al*., 2018; ANGLE Technology, 2003; Castells & Hall, 1994; Link & Scott, 2003b; Link & Scott, 2005; Link & Scott, 2006; Liberati *et al*., 2016).

Another issue that explains the difficulty of populating technology parks in Brazil is the attraction of anchor companies (European Commission, 2007; Link & Scott, 2003a; Parry, 2006; Vilà & Pagès, 2008; Wasim, 2014). Referring to 2018, only two technology parks claimed to have 8 anchor companies, which generated around 500 jobs and made investments in infrastructure of about 14 million reais and investment in RD&I of 17 million reais. The main areas of activity of the anchor companies in 2018 were Information technology (25%), Creative Economy (24%), Human health (25%), Energy (13%) and Oil and natural gas (13%).

In terms of the land ownership, about 44% of technology parks in operation were located on the

university land, 21% of the parks have their own land, 22% of the parks are based on the City Hall land, 5% are established on the Federal Government land, another 5% on the State Government land and the land of 3% of technology parks belongs to Associations. As for the location, where the technology park is installed, 49% answered that they were in their own headquarters, 30% in universities, 18% in concession space and 3% in a research center. None of the parks claimed to have their offices within rented space. Regarding the real estate model of technology parks, approximately 76% of them have their own space to be let to companies, 54% offer land on which companies can build their own facilities. In terms of other services offered to on-park companies approximately 53% of the parks offer installation in the business condominium and 36% offer installation support for these institutions located on the park land.

It was found in the study that 100% of the technology parks in operation in 2018 had a process for selecting companies and consider as the main entry criteria: Technological basis of the company (90%), Adherence of the company to the objectives of the technology park (85%), Degree of innovation (80%), Business plan (62%), Entrepreneurial capacity (59%), Alignment of the company's technological vocation (54%), Technical experience of companies 46%) and Managerial capacity of the team (46%).

There is a diversity of legal models of technology parks: 34% of parks are set as a Foundation, 20% are Associations (20%) and 16% are established as Autarchy (16%), the latter is usually the legal personality of federal universities in Brazil. Usually, Foundations are non-profit entities linked directly to universities to provide support, especially in the financial management of projects. Thus, it can be inferred that 50% of the parks are governed in some way by universities. This fact corroborates the information that 44% of the parks are located on the land owned by universities. Only two technology parks are Civil Society Organization of Public Interest (OSCIP). The other legal models identified in this research were Social Organization (9%), Public Limited Company (4%) and Public Company (13%). This picture is similar to those of parks in the USA, which have a great diversity of governance structures, half of which are managed by a non-profit organization affiliated with the anchor university (31%) or directly by the university (19%), 18% by a governmental or quasi-governmental agency and 17% by independent, non-profit organizations, which may or may not include university representation, and 5% by a for-profit organization (AURP & BTPP, 2013).

In any of the legal models presented, it is necessary to have councils or other bodies for collegiate decision making, with representatives from different sectors, reflecting the nature of the parks as intermediate organizations (Bellgardt *et al*., 2014; Faria *et al*., 2019; Metcalfe, 2010), which can be understood as a hybrid organization (Etzkowitz, 2003a; Leydesdorff, 2000), formed endogenously by the institutional overlap between the three spheres of the Triple Helix model for innovation (Etzkowitz, 2003a; Etzkowitz, 2003b; Etzkowitz et al., 2005), strongly influencing the university-business-government relationship and balancing the interests and objectives of the different stakeholders (Johnson, 2008), as addressed in the theoretical framework. In 2018, universities made up the boards of

93% of the technology parks in operation, followed by the Municipal Government (68%), Business associations (60%) and State government (55%). This governance process, which is a parks´ critical success factors (Chiochetta, 2010; Dabrowska, 2011; Hansson *et al*., 2005; Júnior *et al*., 2015; Kharabsheh *et al*. 2011; Phan *et al*., 2005; Parry, 2006), established by collegiate decision making, permits the stakeholders alignment and the focus in decision making process.

Those councils/bodies were present within technological parks under different forms and names. The composition was almost identical in both years. For instance, 80% of the Brazilian technology parks had an administrative board in 2018, in comparison with 2017 when 83% of the parks had it. Executive Boards existed in 85% of the parks in both 2017 and 2018 and similarly the Administrative Management was present within 63% of technology parks in 2017 as well as in 2018. However, the Technical Council that was present within 43% of the park in 2017, in 2018 it was operating in only 29% of them.

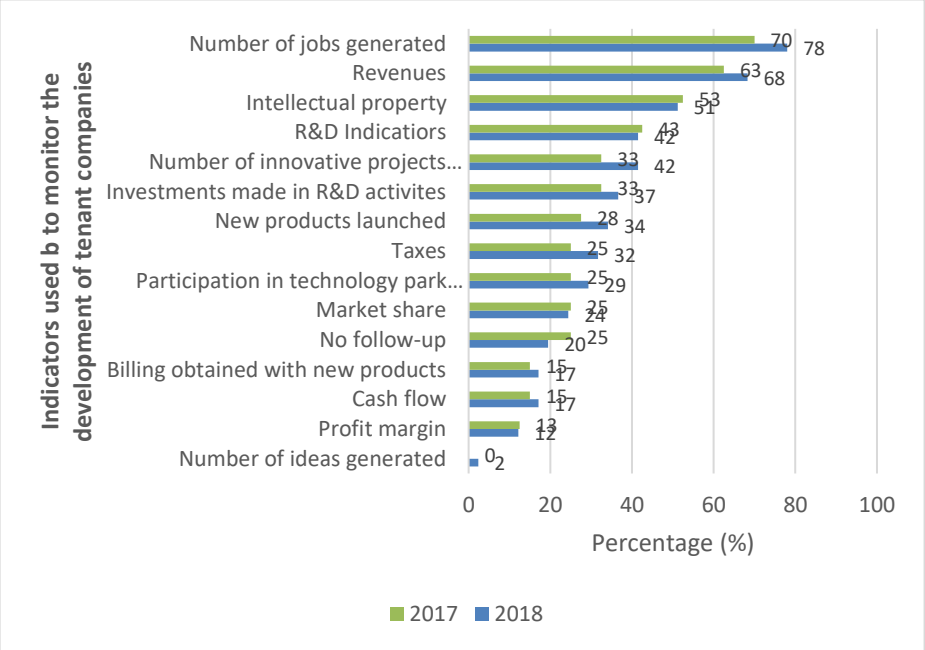
The portfolio of services offered by technology parks to their companies is quite diversified, with emphasis, in 2018, on Interaction with universities and research institutes (98%), Access to specialized laboratories and equipment (95%), Networking (88%), Capacity building and training (78%), Support for participation in fairs and exhibitions (76%), Support for intellectual property advice (71%), Advice on product design (71%) and Business plan advice (68%). However, only 66% of the parks said they offered Access services to large companies, 59% Internationalization and 51% Fundraising and risk capital. This can be problematic for the development of companies, especially startups and other NTBF. Only 63% of the parks said they had an interaction with other technology parks, although 83% of the parks are affiliated with Anprotec. It is worth noticing that only 14 parks are part of the International Association of Science Parks and Areas of Innovation (IASP, 2020). Being a member of an international network of this kind could bring additional collaboration opportunities for the park as well as for resident companies (European Commission, 2007; Hansson *et al*., 2005; Parry, 2006).

The technology parks in operation, which responded to the survey, employed 392 people in 2017 and 437 people in 2018. In 2018, the average park management team size was 11 people per technology park in operation, involving all functions. The legal regime for the Consolidation of Labor Laws (CLT) is the main contractual link with 65% CLT, followed by 13% civil servants, 11% interns, 8% scholarship holders and 3% outsourced workers. On average, it is a young team, with an average age of 36 years, with virtually no gender distinction in the composition (49% female and 51% male). The majority, 87% have a university degree, distributed as follows: 43% have only university degree, 15% with a master's degree, 15% with a lato-sensu specialization, 12% with a doctorate and 2% post-doctorate. Finally, 12% have secondary education and only 1% have primary education. It is important to observe that a qualified management team is a parks´ critical success factors (Albahari et al., 2018; AURP & BTTP, 2013; Fukugawa, 2006; Kharabsheh, 2012; Kharabsheh et al. 2011; Link & Scott, 2003a; Löfsten & Lindelöf, 2002; National Academy of Sciences, 2009; Parry, 2006).

In 2018, about 71% of the technology parks in operation had a systematic process to monitor the development of companies, according to the indicators shown in Figure 3, with emphasis on the financial indicators, such as Number of jobs generated (78%) and Revenue (68%). Despite the importance of the parks being financed with public resources, only 32% of the parks said they followed this indicator. Among the indicators related to innovation, the main ones are: Intellectual property (51%), Number of projects developed (41%), R&D indicators (43%), Investment made in R&D (37%) and New products launched (34%). Considering that, to a large extent, the performance of technology parks is measured through performance of their resident companies, therefore the process of tracking and monitoring the companies needs to be clearly improved.

Figure 3

Indicators used by the technology parks in operation to monitor the development of tenant companies



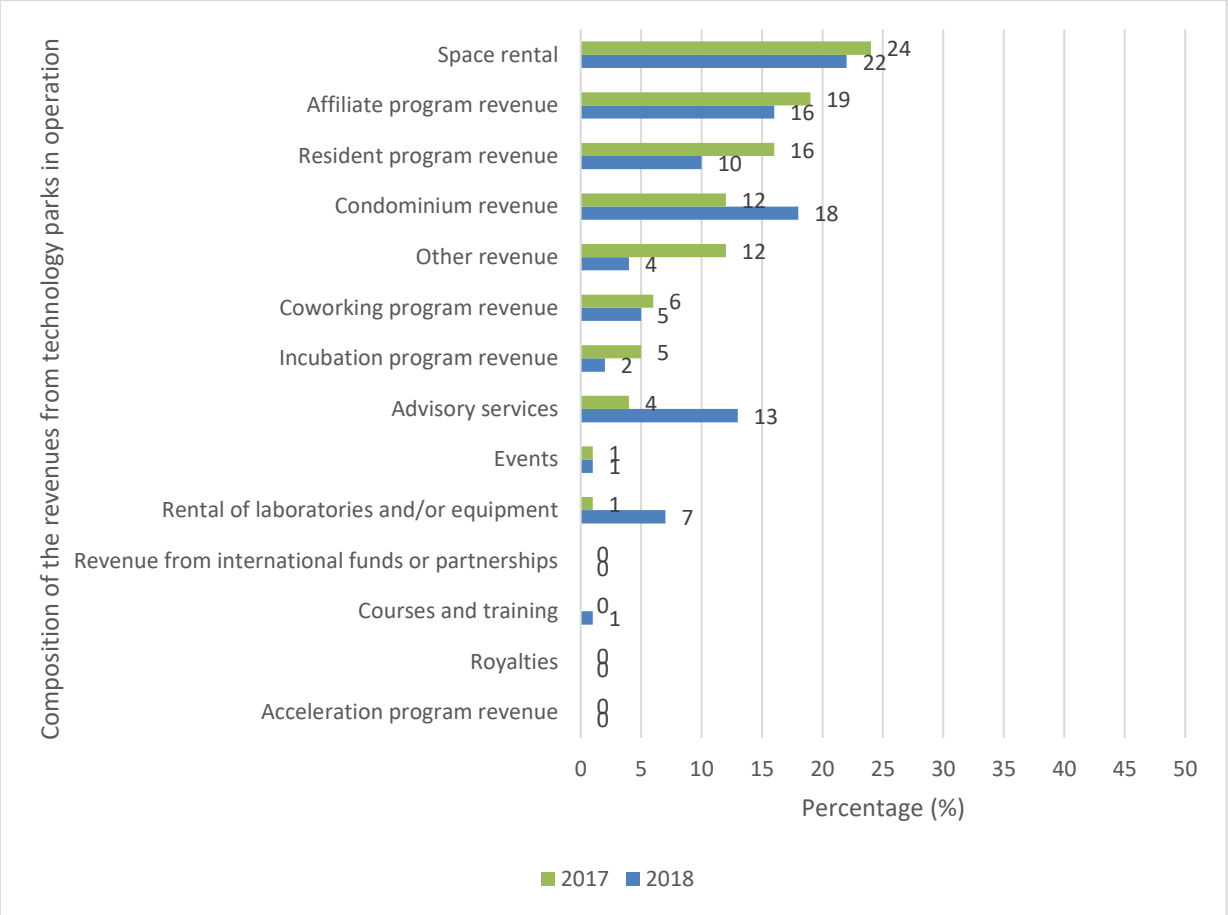
Source: Research results, January 2020.

The Figure 4 shows different sources of financial revenue received by the technology parks in operation, in 2017 and 2018. The total income of the technology parks in 2017 was about 101.9 million reais and 116.0 million reais in 2018. The distribution of revenues demonstrates the importance of the real estate aspect for the financial sustainability of the parks, since it represented 40% of the total revenue in 2018 (22% Rental of spaces and 18% Condominium Income). Income received from the rental of laboratories and specialized equipment, reached 47%. Revenue from programs with companies represented 29%. It is worth mentioning that there was an increase in revenue from Advisory Services, which went from 4% in 2017 to 13% in 2018. This demonstrates that park management teams realized

they can bring income by providing valuable information, advice and knowledge to resident companies to increase their innovation ability and competitiveness. Willingness to pay for this advisory service by companies indicates that they value this service. There is even more potential to create additional income from advisory service which could be provided by park management teams to the networks outside the park. It also demonstrates that the scope of technology parks is getting wider and goes beyond physical borders.

Figure 41

Composition of revenues from technology parks in operation



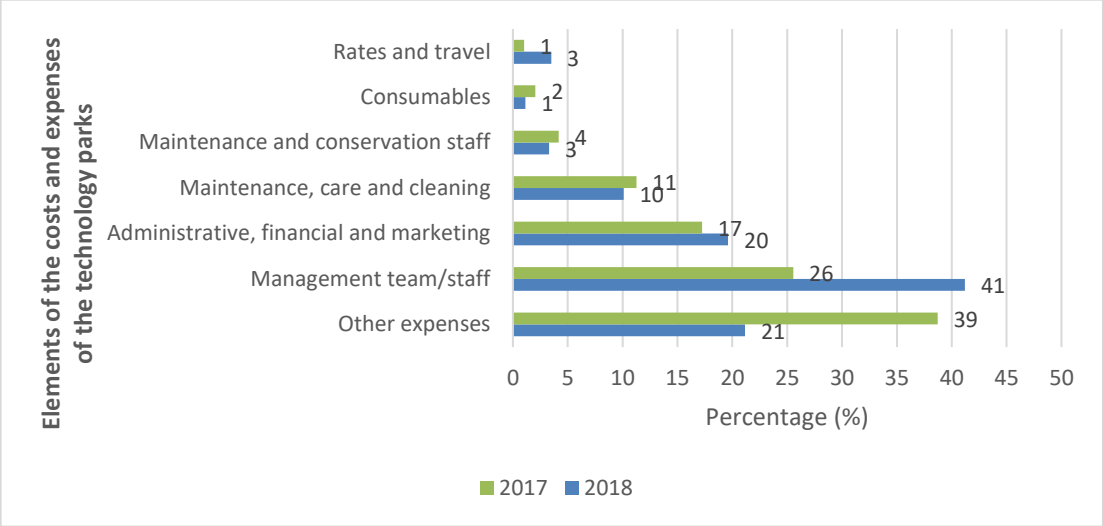
Source: Research results, January 2020.

The Figure 5 shows the distribution of costs and expenses for technology parks in operation in 2017 and 2018. In 2017 the total number was around 105,9 million reais and in 2018, costs and expenses for technology parks in operation were worth 195, 9 million reais. In 2018, the item Team/management personnel represented 41% of costs and expenses, against 26% in 2017. In 2018, Team/Maintenance and conservation staff represented 10%. Therefore, staff costs and expenses represented on average 51% of the costs of technology parks in operation. The 5 largest parks in Brazil, in terms of number of

companies represented 65% of total revenue and 39% of the costs and expenses of all parks. For these parks, staff expenses represented only 31.3% of all expenses in 2018.

Figure 5

Costs and expenses of the technology parks in operation



Source: Research results, January 2020.

It is estimated that technology parks in Brazil made investments of the order of 4.1 billion reais until 2018, distributed according to Figure 6. Up to 2016, investments made by technology parks in Brazil (operation, implementation and operation) totaled approximately 2,8 billion reais, of which 17,7 million reais of this total is due to technology parks that are in the planning and 49,9 million reais for technology parks under implementation. Therefore, 94% of the resource was spent by the technology parks in operation. In 2017, the technology parks in operation claimed to have invested around 1,21 billion reais and only 81,7 million reais in 2018. Until 2016, 41,6% of the total investments made by the parks were in land, 36% in engineering works and 10% in projects. Therefore, until 2016, 87% of the resources disentangled were in the matter of physical infrastructure. In 2017, 96% of the investments made were in land, followed by engineering works (2%). In 2018, Land represented 55% of total investments, followed by Engineering Works (28%), Projects (5%) and other investments (3%). The origin of the funds raised by technology parks for investment until 2018, 62% are from the State Government, 20% from the Park´s own capital, 5% from the Municipal Government and 5% from the Federal Government.

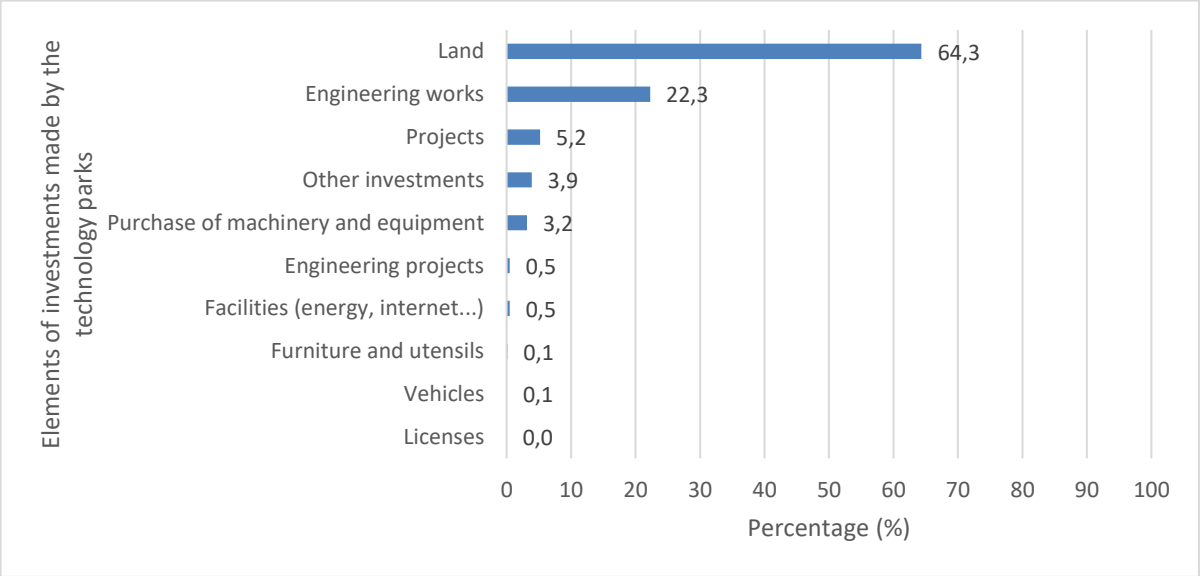
These values ratify the question that technology parks are ventures that require high investments, primarily for the real estate issue (Albahari *et al*., 2018; Parry, 2006), which is important for attracting companies considering that the quality of infrastructure is a parks´ critical success factors (ANGLE Technology, 2003; AURP & BTTP, 2013; (Fukugawa, 2006; Guo & Verdini, 2015; Parry, 2006; Vedovello, 1997; Vedovello *et al*., 2006). The resources invested in technology parks in Brazil

are clearly insufficient, especially when compared with other parks in the world. For instance, the Singapore Park in its initial construction phase received investments of 8.6 billion dollars to create research institutes and foreign R&D companies (Etzkowitz & Zhou, 2018).

Nevertheless, despite the financing deficit, according the survey, the occupation rate by tenant companies of technology parks in Brazil, it was about 44% for the lands and 16% for the buildings. This may be an optimistic scenario for technology parks in Brazil, indicating that the phase carried out of heavier investments in infrastructure, in the last 20 years, it was enough to the managers to focus their efforts in settlement measures, that is, in attracting new tenant companies, which may favor the operating cash flow of the parks, leading them to financial sustainability, considering the impact of revenues from real state, as shown in Figure 4.

Figure 6

Elements of investments made by the technology parks until 2018



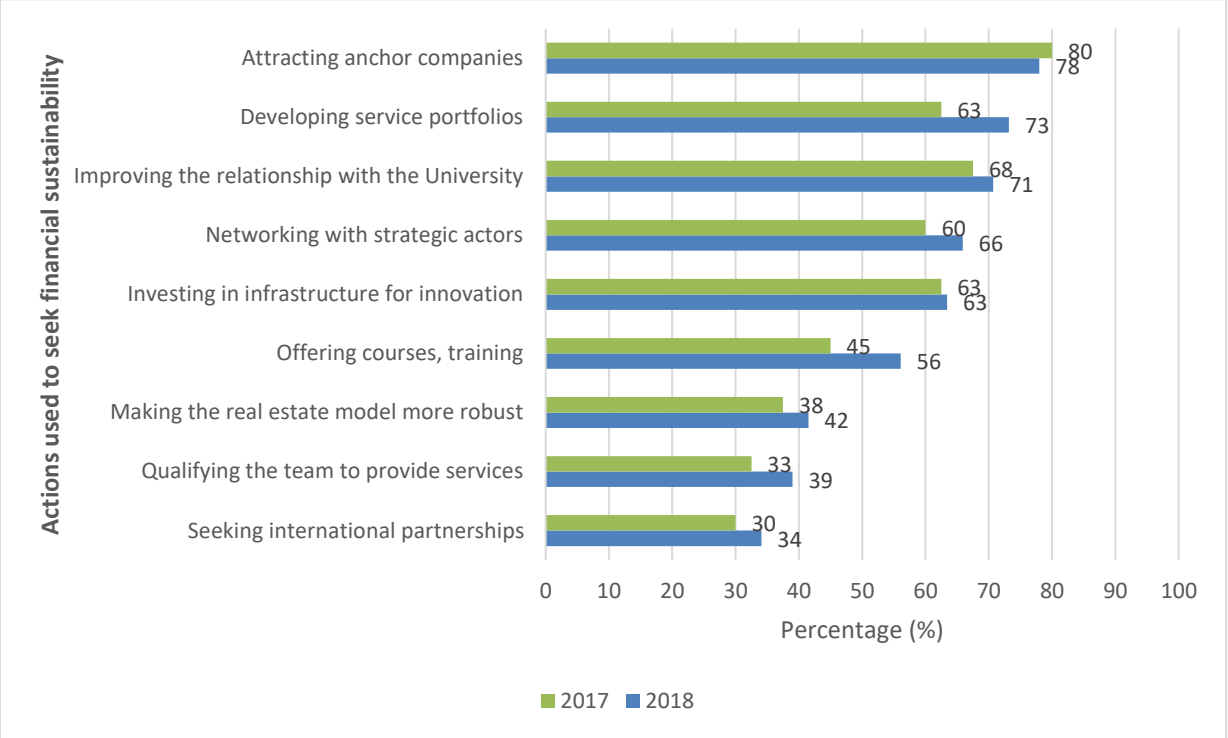
Source: Research results, January 2020.

In 2018, the technology parks in operation foresee a future need of approximately 4.6 billion reais, a value practically analogous to 2017. The main difficulty item pointed out by the parks is Costing (67%). The Infrastructure items represent 17%, Engineering works (14%), Engineering projects (0.88%), Facilities (1.8%), Land (0,35%). The question of costing needs to become clear when assessing the deficit between revenue and costs of the technology parks in operation, in 2018 in the order of 80 million reais. In that context, the Figure 7 presents the actions that the technology parks in operation use to seek financial sustainability, among them: Attracting anchor companies (79%), Developing service portfolios (73%), Improving the relationship with the university (71%), networking with strategic actors (66%), investing in infrastructure for innovation (63%) and offering courses and trainings (56%). Despite the fact that real estate is the main financial sustainability component within the analyzed parks

(as shown on Figure 4), only 41% of them mentioned that they wanted to become more real estate focused. Clearly, they see potential in growing their value-added services, partnerships or investing in more sophisticated infrastructure for innovation like laboratories or state-of-the art facilities.

Figure 7

Actions that the technology parks in operation use to seek financial sustainability



Source: Research results, January 2020.

5.2 Analysis of the determinants for the settlement of the technology park

Considering the context and systemic framework about technology parks in Brazil, presented previously in this study, it is clear that the parks are young (age of the park) and small (number of tenant companies), with a financing deficit, which have the challenge attracting companies to their environment, which in addition to contributing to the park's primary mission, to social and economic development, is also an important metric for the parks' financial sustainability, considering the impact of the real state in the parks´ revenues. Thus, this research sought to analyze the relationship between the settlement of the technological park, measured in number of tenant companies, with variables that, according to the literature presented, can be factors of success of a technology park. The explanatory variables tested were: maturity of the park (age of the park), investments made, park management team, scientific basis (measured in the number of professors at the anchor universities and the number of graduate students at these universities), geographic location (measured in Gross Domestic Product

(GDP) per capita of the state and Human Development Index (HDI) of the State in which the park is installed) and management model (evaluated in the park's legal and administrative personality).

To assess the relationship between the explanatory variables and the settlement of the technology parks, Simple Correspondence Analysis was used. The Table 1 presents the results of the *chi-square* tests and the criterion *β* performed on each pair of variables tested. It can be seen that only the relationship between settlement and maturity of the park and the relationship between settlement and investments made were significant at 1% (p- value 0,00) and β greater than 3,00.

Table 1

Results of the chi-square and criterion tests β performed on each pair of variables tested for the relationship with the settlement of technological parks (number of tenant companies)

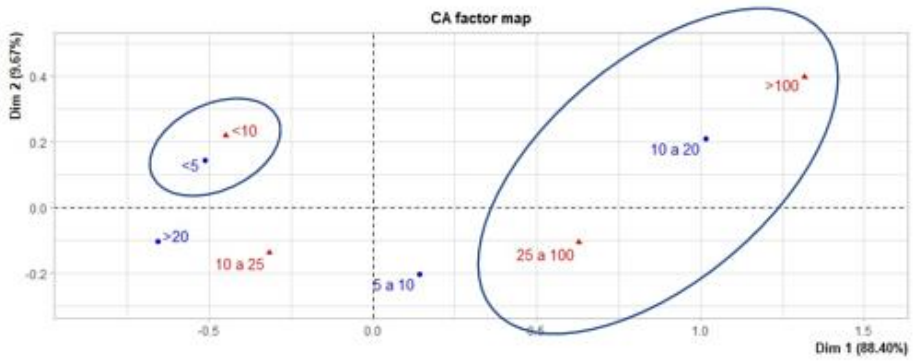
Relationships analyzed	*chi-square*	p-value	*β*
Settlement X Maturity	18,41	0,00	3,14
Settlement X Investments made	23,00	0,00	3,17
Settlement X Management team	10,31	0,11	1,76
Settlement X Number of teachers	2,91	0,81	-1,26
Settlement X Number of students	5,26	0,51	0,63
Settlement X GDP per capita	4,75	0,85	-0,51
Settlement X HDI	1,89	0,92	-1,68
Settlement X Legal Personality	16,96	0,04	2,80
Settlement X Administrative Personality	15,15	0,08	2,05

Source: Research results.

The first analysis is related to the maturity of the technology park (age of the park), measured in years, after the start of the operation, and the number of tenant companies in the park, or the population for the year 2018. The extracts established for maturity were less than 5 years of age, between 5 to 10 years, 10 to 20 years and more than 20 years of age. The analysis of the settlement of the park was classified as less than 10 companies from 10 to 25 companies from 25 to 100 companies and more than 100 companies. The *chi-square* tests (18,41) and the criterion β (3,14) were carried out and it was possible to find a significant relationship between the number of tenant companies in the parks and the maturity of the park (age of the park) in years. Figure 8 indicates that the shortest distances between categories represent the strongest associations between them. Table 2 shows the residuals and levels of significance for the pair of variables, from the results of the correspondence analysis. For a significant statistical relationship to be considered, the confidence level between the variables must be greater than or equal to 70%, highlighted (bold), for the purpose of statistical relationship (Greenacre, 1993; Hoffman & Franke, 1986; Jobson, 1996; Mingoti, 2005).

Figure 8

Result of the correspondence analysis for maturity (age of the park) and settlement of Brazilian technology parks (number of tenant companies)



Source: Research results

Thus, it can be seen that technology parks with less than 5 years of age are linked to technology parks with less than 10 companies installed, at the confidence level of 85.57%. It can be said that there are parks with the same age and that there are 10 to 25 companies installed, however the level of confidence for the statement that these two categories are closely related is lower (34,0%). Technological parks aged 10 to 20 years are more associated with parks with 25 to 100 companies installed, at the 88.59% confidence level. Technology parks at this same age (10 to 20 years) are also linked to parks with more than 100 companies at the 98.60% confidence level. However, parks over 20 years of age had a correspondence with parks having from 10 and 25 companies installed, at the significance level of 55.8% (below the desired 70%), indicating that there are other elements that can affect performance in the settlement, not just the age of the park. Nevertheless, it cannot be ignored, that for this parks, this result also can even indicate that they have failed in their trajectory (Albahari et al, 2018; Etzkowitz & Zhou, 2018).

Table 2

Residues and confidence levels resulting from CA for the maturity (age of the park) and settlement (number of tenant companies) of Brazilian technology parks

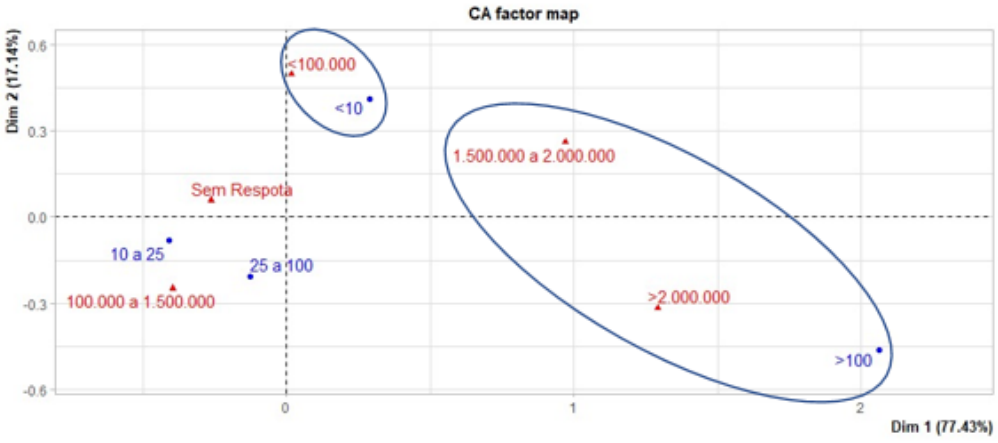
Age (years)	Park settlement (number of tenant companies)			
	<10	**10 a 25**	**25 a 100**	**>100**
<5	1,46 (85,5%)	0,44 (34,0%)	-1,51 (0,0%)	-1,05 (0,0%)
5 a 10	-0,85 (0,0%)	0,15 (11,9%)	0,76 (55,2%)	-0,2 (0,0%)
10 a 20	-0,95 (0,0%)	-1,34 (0,0%)	1,58 (88,5%)	2,12 (96,6)
>20	0,18 (14,2%)	0,77 (55,8%)	-0,91 (0,0%)	-0,4 (0,0%)

Source: Research results.

The correspondence relationship between the technology park settlement and the levels of investment made were also evaluated considering the number of tenant companies in each park, according to the previous analysis, less than 10 companies, 10 to 25 companies, 25 to 100 companies and more than 100 companies. The investment levels were classified as less than R$ 100.000,00, R$ 100.000,00 to R$ 1.500.000,00, R$ 1.500.000,00 to R$ 2.000.000,00 and finally, amounts greater than R$ 2.000.000,00. The *chi-square* tests (23,00) and the criterion β (3,17) were carried out and it was possible to find a significant relationship between the number of companies (settlement) in the park and investments made. The Figure 9 and Table 3 show the results of the correspondence analysis.

Figure 9

Result of correspondence analysis for settlement of Brazilian technology parks and investments received



Source: Research results.

Technology parks with less than 10 tenant companies are related to technology parks that received less than R$ 100.000,00 in investments, at the confidence level of 76.6%. Parks with 10 to 25 tenant companies installed are more related to parks that received investments in the order of R$ 100.000,00 to R$ 1.500.000,00, but the level of significance is 64.8%, below the 70% required for a more reliable statistical analysis. Technology parks with more than 100 companies installed are more associated with parks that received between 1.500.000,00 and 2.000.000,00 reais, at the 90.1% confidence level. Technology parks with this number of tenant companies are also linked to parks that invest more than R$ 2.000.000,00, at a confidence level of 99,6%.

It can be concluded that the technology parks in Brazil with less than 10 companies installed are the parks with less than 5 years of age and that received less than R$ 100.000,00. Another conclusion that can be drawn from the correspondence analysis applied here is that Brazilian technology parks with 10 to 20 years of age are parks with 25 to 100 companies installed or even with more than 100 companies. The parks with more than 100 companies installed are connected to the parks that received from 1.500.000,00 to 2.000.000,00 reais or even more than 2.000.000,00 reais of investments.

Table 3

Residues and confidence levels resulting from CA for the maturity and settlement of Brazilian technology parks

Investments made (R$)	Park settlement (number of tenant companies)			
	< 10	10 a 25	25 a 100	> 100
< 100.000	1,19 (76,60%)	-0,63 (0,00%)	-0,15 (0,00%)	-0,67 (0,00%)
100.000 a 1.500.000	-1,25 (0,00%)	0,93 (64,80%)	0,59 (44,50%)	-0,97 (0,00%)
1.500.000 a 2.000.000	0,84 (59,90%)	-0,45 (0,00%)	-1,05 (0,00%)	1,65 (90,10%)
>2.000.000	0,26 (20,50%)	-1,53 (0,00%)	0,26 (20,50%)	2,89 (99,00%)

Source: Research results.

6 Conclusion

The planning and operation of a successful technology park, which can justify the investment made by the founders, must take into account the key requirements for success and the boundary conditions in which the park is subjected, to guarantee the necessary bases for development of the intended innovation environment, but without wishing to follow a single reference model. The requirements and boundary conditions are elements that the technology park will have access to or not, and that configure the viability of the venture, without necessarily determining success or failure.

It is expected that the correct understanding of the context of technology parks, as developed in this study, allows the proposition of actions, management and governance models, as well as public policies, which can contribute not only to the success of these ventures, but can also help with the leverage of technological innovation, country's competitiveness and consequently improvement of the Innovation Index of Brazil. There is a clear need for more systemic approaches, supported by analytical and statistical references, which can be applied in a practical way by various stakeholders of the technology parks.

The prospect of a technology park's success can be divided into two strategic objectives related to social development and economic and financial sustainability. The park will be financially sustainable when its operating cash flow is positive, that is, when the outflows of resources necessary for its operation are ensured by the revenues from its activities, related to fees, services and rents. On the other hand, the park will be economically sustainable when it is able to return to society the economic results related to the generation of qualified jobs and income, as well as to the promotion of technological innovation, thus contributing to the social development of the region. This study demonstrated the twofold importance of bringing companies to the park: first to ensure social development and second, to reach financial sustainability of the park considering the use of real estate

The results presented ratify the fact that the path to the success of each park is unique and cannot be generalized, prevailing the fact that "if you saw a park, you saw a park" and, therefore, public policies must avoid indiscriminate financial support for parks, taking into account their specific needs, depending on different stages of development. What should be generalized in terms of public policies is to seek to increase the size and quality of the park infrastructure with the aim to attract more technology-based firms and anchor companies through perpetual financing opportunities for the parks and their companies, as well as institutional support. It was clear from this study that the main variables are the park's maturity and the investments received. This fact alone demonstrates a great potential of technology parks in Brazil, as most of them are still young parks.

The continuity of studies and research, initiated in this work, with the support of MCTI-InovaData-BR, as a strategic tool, with the due provision of data by the technology parks, will allow a proposition of increasingly assertive strategic actions in the long run. However, the results presented here, despite the limitations of the historical series used, already allow to infer about the main difficulties technology parks in Brazil: Discontinuity of state and federal public policies to support technology parks; Absence of an inter-ministerial strategic vision of technology parks as a tool for development and innovation; Absence of adequate tools to communicate success stories of Brazilian Parks to the stakeholders, policymakers parks and the outside world. Likewise, the most important challenges for technology parks in Brazil are: Obtaining necessary investments and applying them consistently with a long-term development plan; Attracting anchor companies that impact the settlement of technology parks; Attracting private partners to invest in the development of park infrastructure.

An important question that arises from the performance evaluation process is how the results can be used to promote improvement and the achievement of institutional objectives. Performance evaluation should be understood as a privileged moment for learning and understanding difficulties and bottlenecks and much more, as well as understanding how difficulties can be overcome. Thus, based on the challenges identified during the research, considering the theoretical framework and the results of the analysis of the data provided by the project, the main actions proposed to public policy managers to support the development of technology parks in Brazil are: develop a coalition at federal interministerial level, which allocates and supplies the necessary financial resources for the long-term development of the National Program to Support Innovative Environments; and identify and attract anchor companies and other enterprises to technology parks, considering regional technological vocations, through access to differentiated credit and other tax deferral facilities.

Also, it is necessary to create programs and actions to assist in the creation and operation of technology parks, such as state tax incentives and exemptions laws, as well as access to differentiated credit, to attract companies with high innovative potential to settle in technology parks. So, in the same way, it is important to offer attractive bank financing lines so that companies can invest in real estate at technology parks, which do not require the properties as collateral, since the absolute majority of the technology park land in Brazil is public, as well mechanisms to assist technology park resident companies in attracting national and international investors, for example, by providing support for technology parks themselves to create their investment funds or by creating soft landing programs for inward investment companies.

It is inappropriate to define a management and governance model for a technology park, considering only the context of companies, as technology parks have different stakeholders, with different institutional missions. Technology parks serve many “owners” with diverse interests and expectations, when they are not in conflict. Therefore, managing all these interests is a complex task. Thus, considering the main challenges identified, the theoretical framework and the results of the analysis of the data provided by the project, the technology park managers must formal development of strategic partnerships for both the implementation and operation phases of the park helps fund the venture and enables consistency in terms of the vision and actions. During the implementation phase, primary shareholders (the founders) will be natural partners of the park, providing the necessary conditions, infrastructure and funding. The partnerships developed in the operation phase will focus on strengthening the park's activities and consolidating it as an environment for innovation, entrepreneurship and business envisaged in its vision.

The technology park managers must search for a park model that is capable of attracting anchor companies, such as attracting the R&D centers of large companies to the park's innovation ecosystem. Thus, the park's environment must be favorable to disruptive innovation, allowing cooperation with foreign institutions and networking, connecting entrepreneurs, professionals, researchers and students

from all over the world. In addition, the park management teams should provide guidance on the availability and ways of accessing the anchor university's resources and services. Promote permanent interaction between their companies and the scientific anchor, in order to consolidate and strengthen technical and scientific competitiveness and increase the perceived value of the park by universities, which can be financial supporters, at least in the cost in the initial phases. This facility represents an opportunity for resident companies to access an alternative and flexible source of technical and scientific resources, enabling innovation projects and enabling various benefits.

Finally, it is worth noting that there are many current challenges for the implantation and development of technology parks, especially when one takes into account that the country is experiencing moments of political uncertainty and economic difficulties, with probable retraction in investments in RD&I. Thus, more than ever, it is necessary to establish a strategic agenda that favors networking and collaboration, that is, an innovation ecosystem that allows the creation of new companies, generating new jobs and qualified income, as well as technological innovations of rupture, with high impact, ensuring consistency between public policy and economic development. In this context, technology parks in Brazil with their qualified management teams who have specialized and cross sector knowledge represent a great potential to be increasingly explored and promoted throughout the country and beyond.

Author's contribution

Contribution	Faria, A. F.	Haber, J. A.	Battist, A. C.	Dabrowska, J.	Sediyama, J. A. S
Contextualization	X	X	-	-	-
Methodology	X	X	-	-	-
Software	X	-	-	-	-
Validation	X	X	X	X	X
Formal analysis	X	X	X	-	X
Investigation	X	X	X	X	X
Resources	X	-	-	-	-
Data curation	X	X	X	X	X
Original	X	-	-	-	-
Revision and editing	X	-	-	X	-
Viewing	X	X	X	-	-
Supervision	X	-	-	-	-
Project management	X	-	-	-	-
Obtaining funding	X	-	-	-	-

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