Are Technology Parks the same? A Typology Proposal for an Emerging Economy

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Propósito: A literatura recente tem se dedicado a analisar os Parques Científicos e Tecnológicos (PCT) como habitats heterogêneos. No entanto, os estudos sobre PCT em países emergentes ainda são escassos. Diante disso, o objetivo deste artigo é construir uma taxonomia dessas diferentes estruturas, a partir das semelhanças e diferenças dos PCT no Brasil.
Design/metodologia/abordagem: Adota-se uma abordagem exploratória para identificar os perfis dos PCT brasileiros de acordo com cinco dimensões associadas às suas configurações e uma ligada aos resultados e impactos: tamanho; gestão e governança; geradores de conhecimento; recursos internos; localização; e resultados e impactos. Utiliza-se a análise de clusters no SPSS.
Resultados: Foram identificados três clusters: isolado, transitório e legitimador, os quais possuem particularidades associadas à oferta de recursos, presença de centros de pesquisa, distância entre o centro da cidade e o parque, seu tamanho e os resultados em termos de faturamento e geração de empregos.
Limitações/implicações da pesquisa: O foco não foi analisar variáveis associadas às empresas residentes. Além disso, a pesquisa apresenta limitações relacionadas ao tamanho da amostra contendo as variáveis de resultados e impactos.
Implicações práticas: Os parques tecnológicos brasileiros são compostos por diferentes elementos, o que implica a necessidade de políticas e estratégias que evitem pressupor um isomorfismo de suas estruturas e considerem a heterogeneidade de suas configurações.
Originalidade/valor: A originalidade reside no tratamento dos PCT brasileiros como ambientes heterogêneos, implicando a necessidade de políticas e estratégias adaptadas às suas especificidades.

Palavras-chave: Parques Científicos e Tecnológicos; Heterogeneidade; Análise de Clusters;

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Purpose: Recent literature has dedicated attention to analyse Science and Technology Parks (STP) as heterogeneous habitats. However, studies on STP in emerging countries remain scarce. That said, the purpose of this paper is to build a taxonomy of these different structures, by the similarities and differences of STP in Brazil.
Design/methodology/approach: An exploratory approach is adopted to identify the Brazilian profiles of STPs according to five dimensions associated with their configurations and one linked to the results and impacts: size; management and governance; knowledge generators; internal resources; and location; and results and impacts. It is used the cluster analysis in SPSS.
Findings: Three clusters are found: isolated, transient, and legitimator, which have particularities associated with the offer of resources, presence of research centers, distance between the city downtown and the park, its size and in the results of turnover and job creation.
Research limitations/implications: The focus was not to analyse variables associated with tenant companies. Additionally, the respective research has limitations regarding the size of the sample containing the variables of results and impacts.
Practical implications: Brazilian technology parks are constituted by different elements, implying the necessity of policies and strategies to refrain from presupposing an isomorphism of their structures and consider the heterogeneity of their configurations.
Originality/value: The originality lies in treating Brazilian STPs as heterogeneous environments, implying the need for policies and strategies that adapt to their requirements.

Keywords: Science and Technology parks; Brazil; cluster analysis; heterogeneity

1. Introduction

Science and technology parks (STPs)[5] are environments that have emerged as one of the supply-side instruments of public policy (Edler & Fagerberg, 2017) to foster entrepreneurship and regional innovation since the 1970s (Link & Scott, 2006). Inspired by the dynamics of intense exchange among agents observed in the Silicon Valley (Saxenian, 1996), STPs have proliferated based on the rationale of transferring technological and market knowledge through the co-location of technology-intensive firms—mainly small and medium-sized enterprises (SMEs)—R&D departments and centers, and educational and research institutions (Vásquez-Urriago et al., 2016; Amaral et al., 2023). Additionally, they have formally organized and centralized management responsible for coordinating the parks' capacities to add value to firms (Lindelöf & Löfsten, 2002).

In recent decades, the literature on STPs has sought to analyze the impact of parks on the collaborative, innovative, and economic performance of resident firms (Albahari et al., 2023). However, these studies are characterized by mixed results regarding these impacts (Gwebu et al., 2019). As a possible explanation, Albahari et al. (2023) identified that STPs are heterogeneous environments in terms of their elements—e.g., the presence of universities, research centers, and service offerings—which influence the parks' ability to impact firms. In discussing their results, Squicciarini (2009) noted that: "Overall, results seem to suggest that it is not locating inside the SPs as such that affects firms'

[5]There is a debate in the literature on the differentiation between science parks and technology parks (Albahari et al., 2017). Here, we use the acronym STP to refer to both science parks and technology parks. As will be discussed, we understand that this differentiation is insufficient to identify the profiles of these environments, since it focuses only on the link to a university.

likelihood to innovate. What matters is being [...] in a Park exhibiting some specific features." Additionally, parks are not the result of geographically neutral policies. They are environments that differ across regions and cities (Koster et al., 2019). Thus, the heterogeneity of these environments arises from the interplay between the internal and external contexts of STPs (Wright & Westhead, 2019).

Recently, scholars have begun to identify "types" of parks based on the conjunction of these variables—a recent call by Amoroso et al. (2019). Similarly, Albahari et al. (2017) segmented Spanish parks by university affiliation. Expanding the complexity of these environments, Ng et al. (2019) developed a typology of European parks based on four macro-dimensions (Knowledge Intensiveness, Size, Organization, and Location).

These studies primarily focus on analyzing heterogeneity and identifying park profiles in developed countries (Albahari et al., 2023). Over the past decades, however, emerging countries have emulated these institutional arrangements, inspired by the experiences of developed nations to promote innovation and entrepreneurship (Dias, 2012). Unlike advanced economies, however, these countries face structural challenges that prevent generalizing results to their contexts. First, their productive structures are characterized by dependency relationships with developed countries and specialization in activities with lower technological dynamics (Furtado, 1974; Françoso et al., 2024). Second, the innovation systems of emerging countries are less mature (Albuquerque, 1999), featuring restrictive scientific and technological infrastructures with limited capacity to generate ideas and skills necessary for higher productivity and innovation levels (Fischer et al., 2019). Given this context, it is necessary to understand which profiles of science and technology parks (STPs) emerge in developing countries and how they differ from those in advanced economies.

The aim of this study is to develop a typology of STP profiles in the context of a developing country. Despite the advance in the literature in analyzing the scenario of parks in emerging countries (Jacobsen et al., 2024; Bolliger et al., 2024), these studies have not yet deepened into the different profiles of STP, treating them as isomorphic environments.

Aiming to contribute to this debate, the main research question of this paper is: Which STP profiles can be identified in the context of an emerging economy? To answer this question, we conducted an exploratory study examining the typologies of STPs using data from Brazilian science and technology parks. As part of the national legal framework for innovation policy, the dissemination of Brazilian parks began in 1984 but only gained momentum at the beginning of the 21st century, driven by the Ministry of Science, Technology, and Innovation (MCTI). As a result, the number of STPs in the country expanded from six parks in operation in 2000 to 16 in 2010 and 62 in 2024 (MCTI, 2024). To construct the different profiles, our research utilized data from InovaData-Br, a Brazilian platform for park data collection.

Developing a typology of parks that considers a holistic perspective of their configurations is crucial for literature, practitioners, and policymakers. Part of the studies on park heterogeneity (see Albahari et al., 2023 for a review) relies on regression techniques, which are limited to analyzing the "contributions of individual explanatory attributes toward an outcome, holding all other attributes constant" (Furnari et al., 2021, p. 780). This approach overlooks the systemic interaction of these attributes and the differences in functionalities, structures, and objectives of STP profiles (Bencke et al., 2020; Link & Scott, 2006; Löfsten & Klofsten, 2024). Moreover, the factors enabling specific parks to perform better remain underexplored (Roldan et al., 2018; Etzkowitz & Zhou, 2018).

From a policy perspective, STPs involve risky and patient capital for their maturation (Anton-Tejon et al., 2024). This scenario is even more pronounced in emerging economies, which frequently face severe budgetary constraints. In terms of implications, identifying a typology of parks that considers their various elements allows public policies to move away from a "one size fits all" approach and instead delve deeper into the STP concept for improved decision-making (Ng et al., 2019). Additionally, it raises the question of whether all groups have elements aimed at encouraging innovation, or if they act as real estate ventures. For firms, since parks are not the same, it facilities the process of matching firms capacities and parks resources. Finally, regions have differing objectives and socio-economic asymmetries. A segmentation may enable park managers to explore the complementarities and limitations of the park-region capabilities.

The following section presents a review of the literature on the segmentation of park heterogeneity dimensions. Section 3 describes the data collection and segmentation analysis methodology. Section 4 presents the results, which are discussed in Section 5. Finally, concluding remarks and limitations are provided in Section 6.

2. Literature review

Based on the identification of heterogeneous park characteristics by Albahari et al. (2023) and the delineations by Bolliger et al. (2024) in the context of an emerging country, we developed an analytical framework consisting of three heterogeneity vectors related to the internal configuration of technology parks (structure, presence of knowledge generators, and internal resources offered) and one vector related to aspects of the city in which the park is located (external context). We now turn to a description of each of these dimensions.

2.1 Internal context

2.1.1. Structural Characteristics

At the core of the modus operandi of STPs lies the effects of geographic proximity among organizations, such as firms and educational and research institutions (Vásquez-Urriago et al., 2016). The co-location of different organizations and institutions is seen as a means to facilitate the transfer of tacit knowledge, encourage learning processes, and to reduce uncertainties (Feldman, 1994). In this sense, the size of parks—in terms of built area and the number of tenant companies—can be seen as a source for generating agglomeration effects. Empirical findings highlight potential innovation performance gains arising from agglomeration effects due to the co-location of organizations (Squicciarini, 2009; Qi et al., 2024).

Beyond geographic proximity, studies have also investigated the impact of the co-location of firms within the same sectors or across diverse sectors in STPs (Albahari et al., 2023). Drawing from the economic geography discussion on the effects of sectoral specialization and diversification (Beaudry & Schiffauerova, 2009), analyses have segmented STPs into those covering multiple sectors versus those specializing in a few or a single sector. In the European context, Ng et al. (2019) highlights the predominance of non-specialized parks. Empirically, results are mixed (; Lamperti et al., 2017; Liberati et al., 2016).

The dissemination of parks has followed different trajectories across countries. In the U.S. (Link & Scott, 2006) and the UK (Westhead, 1997), parks began to proliferate during the 1980s. In Brazil, although some STPs emerged during the 1980s and 1990s, the movement gained momentum at the turn of the millennium, driven by policies promoting entrepreneurial universities (Dias, 2012). In this context, STPs differ in terms of age, potentially reflecting different maturity stages regarding the accumulation of resources and park management capabilities. Empirical evidence demonstrates a positive effect of parks' age on firms performance (Albahari et al., 2018; Anton-Tejon et al., 2024). from Link and Yang (2018) in South Korea demonstrates that parks established after the ICT revolution in 2000 experienced greater employment growth. Albahari et al. (2018) and Anton-Tejon (2024) found that firms in both younger and more established parks outperformed those in intermediate-aged parks in patenting activity. This phenomenon is attributed to transient positive effects from the association with innovative environments, which diminish over time but tend to re-emerge in the long term due to the accumulation of knowledge and park experience.

2.1.2. Knowledge generators

The co-location of small and medium-sized enterprises (SMEs), large companies and educational and research institutions is regarded as a mechanism to foster the flow of tacit knowledge and knowledge spillovers (Garcia et al., 2018; Fu & Qian, 2023; Mascarini et al., 2023).In the context of STP, universities act as essential institutions for resident firms, providing facilities, services, and knowledge (Díez-Vial & Fernández-Olmos, 2015). Connections with universities can serve as an important resource for knowledge transfer and collaborative research (Ratinho & Henriques, 2010). Additionally, empirical findings indicate that university-affiliated parks generate higher positive effects on patenting rates among resident firms than non-university STPs (Albahari et al., 2017).

Beyond universities, research centers also play a vital role in STP dynamics. Lamperti et al. (2017) highlight that the association with research institutions motivates resident firms to increase their own investments in R&D. Along the same lines, Corrocher et al. (2019) demonstrate the positive impact of collaboration with research institutions on patent generation. In terms of large firms, Squicciarini (2009) found that their presence positively influences patent generation. Nonetheless, Bencke et al. (2020), in Brazil, note that, in many cases, STPs struggle to attract anchor firms due to "*the absence of research, development and innovation culture as a business practice (p. 32).*"

2.1.3. Resources

Resident firms in science and technology parks are heterogeneous regarding their dynamic capabilities (Teece et al., 1997). That said, STPs offer a diverse range of critical resources for building networks among actors and developing the managerial and technical capacities of firms (Meseguer-Martinez et al., 2020). Thus, acting as facilitators and network intermediaries (.

. The findings of Steruska et al. (2019), for example, underscore the importance of events organized at the CERIT park in the Czech Republic in fostering informal communication among actors, thereby driving processes of strategic knowledge transfer. Roldan et al. (2018) highlight the significance of intellectual property and administrative consulting, as well as research laboratories, in triggering innovation processes. Furthermore, McAdam and McAdam (2008) argue that STPs may accommodate incubators to catalyze the development of new technology-based firms. Finally, parks and resident firms can leverage non-local channels to foster the flow of information and knowledge—the global pipelines argument. Albahari et al. (2019) emphasize the importance of national and global connections among STPs to promote the sharing of best practices in services and infrastructure, provide market and technology information, and enhance the international visibility of firms.

2.2. External Context

Scholars have drawn on the literature of Regional Innovation Systems (RIS) (Asheim et al., 2011) and Entrepreneurial Ecosystems (EE) (Audretsch & Belitski, 2017) to analyze the influence of external factors on the development and competitiveness of firms and regions. These studies have investigated the interconnections between actors and institutions locally involved in the generation, diffusion, and spillover of innovation and entrepreneurship (Isaksen & Trippl, 2017; Leendertse et al., 2022).

Given their local character, STPs can be viewed as intermediary actors in EE driving the creation and development of technology-based firms in their regions (Germain et al., 2023). Accordingly, the local social, cultural, institutional, and industrial context is expected to influence resident firms and the strategies adopted by parks (Gomes et al., 2023). Poonjan and Tanner (2020) argue that both may be shaped by local factors such as the industrial structure, the presence of knowledge generators and skilled workforce, access to financial resources, formal and informal institutional support, and agglomeration economies. Empirical studies have demonstrated that parks operate within regions characterized by varying levels of economic and innovation development (Liberati et al., 2016; Qi et al., 2024).

3. Methodology

Given the objective of identifying the configurations of STPs in an emerging country, an exploratory approach is employed to delineate the profiles of Brazilian STPs across four dimensions associated with their heterogeneity. Of these dimensions, three are related to the internal configuration of the parks (structural characteristics, association to knowledge generators, and internal resources offered by the park), while one pertains to the characteristics of the city where the STP is located (external context). Park groups were constructed based on these heterogeneity variables using the TwoStep clustering technique in SPSS software. Subsequently, the means of all variables were compared to identify those in which park groups differentiate themselves or exhibit similarities. In this regard, it is worth noting that not all variables used to construct the clusters showed statistical differences, while some variables not included in the cluster construction did exhibit statistical differences. Given the objective of identifying similarities and differences among the clusters, all variables were discussed.

3.1 Data collection and description of the variables

The four dimensions outlined in the Literature Review (three addressing the Internal Context of STPs and one addressing the External Context) were explored through secondary data collection for 45 STPs in Brazil and their respective local ecosystems.Table 1 outlines the characteristics of the fourteen variables collected, their data sources, and their use in cluster analysis, mean comparisons, or both. We combined the use of cluster analysis with mean comparisons across variables as a strategy to enhance the rigor of the analysis.

Six of the fourteen variables were used in the cluster analysis, with at least one variable from each dimension (Ng et al., 2019): l*ocal_eco_dev, size, univ_own, res_cent, S&I_net*, and *S&I_bus*. However, after comparing the means of these variables across clusters, we found that not all variables used in the clustering process exhibited statistical differences (e.g., *size* and *local_eco_dev*). Six of the fourteen variables showed statistical differences between clusters: *age, univ_own, res_cent, assoc, S&I_net*, and *S&I_bus*. Of these, only *age* and *assoc* were not used in the cluster formation process.

Data concerning STPs were provided by the Brazilian parks data collection and processing platform (MCTI-InovaData-Br), while municipal data were collected from the Brazilian Institute of Geography and Statistics (IBGE database) and the Index of Local Economic Development (ISDEL), all referring to 2019. Notably, although InovaData is public, the in-depth data of the parks are not. Thus, the names of the parks cannot be disclosed for confidentiality reasons. Table 1 presents the characteristics of the collected variables, their sources, and descriptions.

Table 1. Description of variables and data sources

Dimension	Variables	Data Source	Cluster	p value < 0.05	Description
	size	InovaData-Br	X		Number of companies within each park
	size_m²	InovaData-Br			Size of the park in m²
Structural Characteristics	age	InovaData-Br		X	Number of years since park started operation until 2019

	focus	InovaData-Br			1.00 - parks focus on one sector; 0.75 - parks focus on two or three sectors; 0.5 - parks focus on four sectors; 0. 25 - parks focus on five or more sectors;
	links_univ	InovaData-Br			With formal relationship to a unviersity (1) or without (0)
	univ_own	InovaData-Br	X	X	Park is in a university’s campuses (1) or not (0)
	anc_com	InovaData-Br			Association of an anchor company (1) or not (0)
Knowledge Generators	res_cent	InovaData-Br	X	X	Association of a research center (1) or not (0)
	S&I_bus	InovaData-Br	X	X	Scores: 1 - park offers all services and infrastructure for development of business; 0.66 - park offers between four and six; 0.33 - park offers between one and three; 0 - park does not offer.
	S&I_net	InovaData-Br	X	X	For each service or infrastructure for network development present, the park scored 0.25 “points”, ranging from 0 to 1.
	incub	InovaData-Br			Presence of an incubator (1) or not (0).
Resource Supply	assoc	InovaData-Br		X	Scores: 1 - National (ANPROTEC) and international (IASP) association; 0.5 - national connection only; 0 - no connection.
	local_eco_dev	ISDEL	X		Scores: 1 - Between 0.55 and 0.63; 0.75 - between 0.47 and 0.55; 0.5 - between 0.41 and 0.47; 0.25 - between 0.35 and 0.41.
External Context	city_size	IBGE			Total population of the city in which the park is located.

Source: prepared by the authors

Regarding the categories, Brazilian parks differ in terms of their association with "knowledge generators”. In this study, this category comprises four binary variables. . The variable *link_univ* aims to capture the park's effort to strengthen connection to educational and research institutions. On the other hand, the variable *univ_own* reflects the segmentation within the literature between university-based and non-university-based parks (Albahari et al., 2017). Finally, the variables *anc_com* and *res_cent* were included to reflected the association to anchor companies and research centers, respectively.

Additionally, STPs differ in the “resources supply”. Incubators can be present in STPs to assist in the development of nascent firms (Fukugawa, 2006). Thus, *incub* was measured as a binary variable. Parks also offer services and infrastructure to support the development of their resident firms and to foster interactions and the flow of information and knowledge (Meseguer-Martinez et al., 2020;). Data on services and infrastructure offered by each park were grouped into two variables, "services and infrastructure for network development" (*S&I_net*) and "services and infrastructure for business development" (*S&I_bus*). Both variables are categorical, ranging from 0 to 1 according to the greater diversity of services and infrastructure present in the analyzed cases. While the first covers "mechanisms for networking with companies, events, incubators, or international parks", "investor meetings", "shared spaces", and "co-working spaces"; the second involves "intellectual property support services", "marketing services", "services for finance/accounting", "acceleration services", "R&D facilities", "auditoriums", and "conference or meeting rooms".

Parks may also participate in national and international networks with other STPs. The association with the International Association of Science Parks and Areas of Innovation (IASP) and the Brazilian National Association of Entities Promoting Innovative Enterprises (ANPROTEC) were analyzed. Similar to Bolliger et al. (2024), it is recognized that ANPROTEC and IASP can only act as an intermediary between parks and companies, through the offer of events, managers training and qualification, and internationalization opportunities for companies[6]. However, due to constraints in the availability of other data associated with national and international networks to other institutions, the variable of national and international association was limited to these two associations. Parks were scored as 1 if they were part of both national and international networks, 0.5 if they were only associated with ANPROTEC - none park was associated with only IASP - and 0 if they were not associated with any association.

In terms of "Structural Characteristics", four variables were used: *size*, *size_m²*, *age*, and *sectoral focus*. The literature on STPs measures the impact of park size on resident firm performance through the number of resident organizations - *size* - or the built area in square meters - *size_m²* - (Corrocher et al., 2019), both of which are continuous variables. Similarly, parks differ in their *age*, reflecting different maturity levels (Anton-Tejon et al., 2024). The variable age is also continuous.

Parks may adopt sectoral specialization strategies (*sectoral focus*) to promote collaboration and innovation. The data collected pertain to nineteen sectors. However, we sought to reduce the number of sectors to facilitate the identification of sectoral focus[7]. Based on Ng et al. (2019) and Bolliger et al. (2024), STPs were classified into nine sector groups: (1) Agribusiness, Environment, Biotechnology; (2) Food; (3) Electronics; (4) Energy; (5) Mineral, Oil and Gas, Chemistry; (6) Water Resources; (7) Health; (8) IT, Creative Economy, Telecommunications; (9) Aeronautics, Space Science, and Transportation. STPs were classified according to the number of sectors they covered, receiving a numerical representation ranging from 0 (more than 5 sectors or none) to 1 (only 1 sector). Additionally, we acknowledge a potential mismatch between the strategic sectors of the parks and the sectors represented by resident firms. However, since data on the latter are unavailable, we focused solely on the sectors associated with the STPs.

Finally, STPs are located in cities with varying socio-economic development characteristics (Poonjan & Tanner, 2020). Two variables compose the "external context" dimension. The first is the Sebrae Index of Local Economic Development (*ISDEL*). This is a quantitative platform that aims to analyze municipalities in five dimensions: entrepreneurial capital, business network, governance for development, productive organization, and competitive insertion. Each municipality is placed on a scale ranging from 0 to 1. Parks were divided into four categorical groups. Categorization was done from the median 0.47. The values 0.41 and 0.55 are the mean values between the median and the lowest and

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[6] For more see: https://www.iasp.ws/activities/services and https://anprotec.org.br/site/sobre/

[7] These are Agribusiness, Environment, Biotechnology, Food, Electronics, Energy, Mineral, Oil and Gas, Chemistry, Water Resources, Animal Health, Human Health, IT, Creative Economy, Telecommunications, Aeronautics, Space Science, Water Transportation, and Land Transportation.

highest ISDEL value, 0.35 and 0.63, respectively. We decided to use the median to capture a wider range of cases within each of the four segments. Resident firms may benefit from agglomeration effects in larger urban centers. That said, the second variable of local context, *city_size*, addresses differences in the city size.

3.2. Cluster analysis

We identify groups based on the similarities (and differences) between parks. Cluster analysis is a technique commonly used in market segmentation (Mooi & Sarstedt, 2018). However, it has also been applied for clustering science and technology parks and their firms in Europe (Ng et al., 2019). To identify clusters, we use the TwoStep clustering technique available in SPSS software, version 25. This exploratory technique is employed to understand, observe, and analyze the existence of similar characteristics within certain groups, which are internally homogeneous and heterogeneous among themselves (Fávero & Belfiore, 2017).

The characteristics of the parks used in this analysis encompass binary variables (e.g., association of a research center), categorical variables (e.g., availability of services and infrastructure), and continuous variables (e.g., size). Given these data characteristics, the use of other techniques, such as hierarchical clustering and k-means clustering, was not viable due to their limitations in handling both continuous and categorical data simultaneously (Tkaczynski, 2017). In contrast, the TwoStep clustering technique is more suitable for jointly handling such data.

3.3. Selection of variables

When selecting the number of variables to include in cluster analysis, it is important to consider the sample size. However, there is no generally accepted guideline regarding the minimum sample size relative to the number of clustering variables (Dolnicar et al., 2014; Mooi & Sarstedt, 2018). Recent studies that used cluster analysis for STPs (Bolliger et al., 2024; Ng et al., 2019), relied on Formann (1984), who suggests that the minimum sample size should be equal to 2m, where m is the number of variables used for clustering.

Taking Formann's rule of thumb into account, a cluster solution with five variables is most appropriate for a sample of 45 cases. However, adding a sixth variable provided additional insights into the clusters. It is important to highlight a primary limitation of this study related to the sample size. The number of cases (45) exceeds Formann's rule of thumb by one variable. Nonetheless, the cluster quality level algorithm provided by the software remained high when clusters were formed using six variables[8]. The six variables incorporated in this solution are: local_eco_dev, size, univ_own, res_cent, S&I_net, and S&I_bus.

4. Results

After grouping the parks into clusters[9], we analyzed the differences between the means of the resulting groups. The One-way Analysis of Variance (ANOVA) in SPSS 25 was used, with a 95% confidence interval. Table 2 summarizes the cluster elements and compares variable averages, distinguishing between those used in the clustering process and those excluded. Of the six variables used in the clustering process, only *local_eco_dev* and *size* did not exhibit statistical differences among

[8]Recent studies have also dealt with the small samples issue. Both Ng et al. (2019), with a sample of 82 European parks, and Bolliger et al. (2024), with a sample of 45 Brazilian parks, used seven variables and achieved a cluster quality of 0.3. In this sense, although this study faces limitations related to sample size as well, it stands out methodologically by achieving a cluster quality of 0.4. Additionally, it fallows Tkaczynski (2017) recommendations about solution quality, the level of variables importance and the statistical significance test.

[9]Tests with different variable compositions were conducted for cluster selection. The tests performed are available upon request.

clusters. Among the variables not utilized for clustering, *age* and *assoc* displayed statistically significant differences. Figure 1 complements this analysis by illustrating the clusters based on the six variables with statistically significant differences: *age*, *univ_own*, *res_cent*, *assoc*, *S&I_net*, and *S&I_bus*. Next, we analyze the three clusters derived from Table 2 and Figure 1.

Table 2 - Differences and Similarities Between Clusters

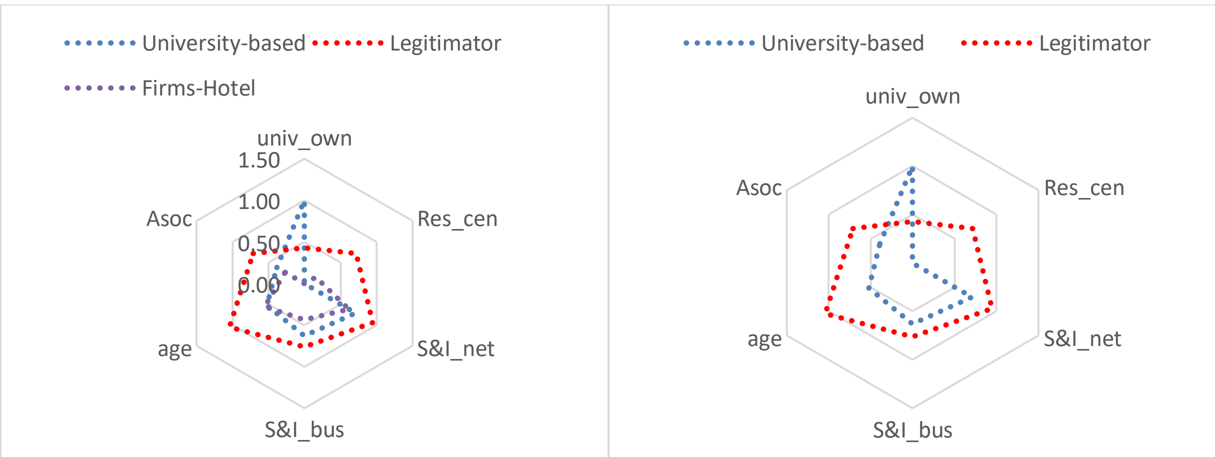
Variables	University-based	Legitimator	Firms-hotel	p value	Predictor
Number of parks	18	14	13		
Variables used in cluster					
local_eco_dev	0,61	0,66	0,67		0.1
size	21,17	83,57	25,54		0.28
univ_own	1,00	0,43	0,00	***	1
Res_cent	0,00	0,71	0,15	***	0.7
S&I_net	2,83	3,79	2,46	***	0.4
S&I_bus	1,89	2,29	1,31	***	0.51
Variables not used in cluster					
city_size	897084	1044572	684250		
size_m²	12459,61	36717,57	29522,92		
focus	3,50	3,43	3,08		
age	5,22	10,43	5,54	**	
links_univ	0,94	1,00	0,77		
anc_comp	0,17	0,14	0,00		
assoc	0,78	1,43	0,54	***	
incub	0,83	0,79	0,46		

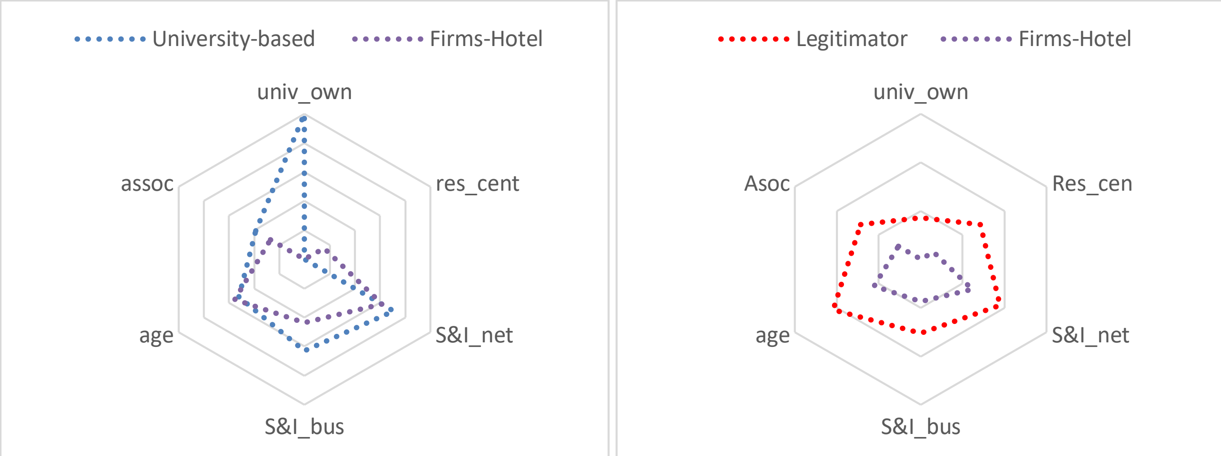
** statistical significance of 5%

*** statistical significance of 1%

Source: The authors.

Figure 1 - Comparison Between Clusters





Source: The Authors

University-based: Comprising 18 parks, this cluster consists of young (mean age: 5.22 years as of 2019) parks exclusively located within university campuses (100%). No case in this cluster associates to research centers, likely due to their close proximity to universities' research infrastructure. This cluster ranks second in terms of diversity in infrastructure and services for actor networks (mean: 2.83) and business development (mean: 1.89). Eight parks are exclusively associated with ANPROTEC (44.44%), while three (16.67%) are affiliated with both ANPROTEC and IASP. These STPs align with the segmentation conducted by Albahari et al. (2017) and Anton-Tejon et al. (2024) distinguishing university-affiliated and non-university-affiliated parks. Additionally, since the diversity of resources, they are consistent with findings by Löfsten and Klofsten (2024) and Qi et al. (2024), which emphasize that university-affiliated parks must offer expertise to support the development of technical and managerial capacities, as well as opportunities for resident firms.

Legitimator: This cluster comprises 14 parks, 57% of which are not university-based. It represents the most mature parks (average age: 10.43 years) and the majority (71%) associates to research centers. This cluster exhibits the highest averages for network development (3.79) and business growth (2.29). Two parks are exclusively members of ANPROTEC (14.29%), while nine (64.29%) hold dual memberships with ANPROTEC and IASP. Due to the greater diversity of actors and resources, this cluster is termed the "Legitimator" as it aligns most closely with the three functionalities highlighted by Lecluyse and Spithoven (2019). Specifically, these parks act as habitats that intermediate connections and facilitate resource transfers, thereby legitimizing their resident companies for investors and clients (.

Firms-hotel: This cluster comprises 13 young parks (mean age: 5.44 years). None are university-based, and only 15% are associated with research centers. This cluster offers the lowest diversity in services and infrastructure for networks (2.46) and businesses (1.31). Five parks are solely associated with ANPROTEC (38.46%), and only one (7.69%) holds dual membership with ANPROTEC and IASP. They are referred to as firms-hotel parks due to the mainly presence of companies and absence of different actors (research centers and universities), and the limited provision of resources for companies in terms of services and infrastructure. That said, this cluster exhibits characteristics that are antagonistic to those of the Legitimator cluster in terms of the functionalities described by Lecluyse and Spithoven (2019), and only provide basic services and infrastructure. Interestingly, despite having an average age similar to the university-based cluster, the two clusters exhibit distinct characteristics regarding S&I_bus and univ_own.

More specifically, Table 3 compares the three clusters in terms of the binary variables and the binary sub-variables in the categorical ones with statistical difference, identified at the 0.05 () and 0.01 (*) significance levels. The Chi-square test was used to analyze the variables *fin_cont, assoc_Anprotec,* *and park_uni*, while the Fisher Exact test was employed to identify significant differences in the remaining 15 variables. The latter test is appropriate for these binary variables because the expected value was below 5 in more than 20% of the cells within the 2×2 tables.

Table 3 - Distribution of Binary and Categorical Variables

Variables	University-based	Legitimator	Firms-hotel	p value
inst_P&D	**14**	**11**	**4**	**
shared_spaces	11	12	6	
coworking_spaces	**10**	**13**[1]	**6**	**
audit_room	17	14	10	
conferen_meet_room	18	14	12	
intelec_proper_serv	**13**	**12**	**4**	***
mark_serv	12	10	8[2]	
finc_contab_serv	9	9	6	
aceler_servc	**2**	**8**	**0**	***
mecan_interact	17	14	12	
serv_meet_invest	**13**	**14**	**8**	**
assoc_Anprotec	11	11	6	
assoc_IASP	**3**	**9**	**1**	***
univ_own	**18**	**6**	**0**	***
links_univ	17	14	10	
anc_comp	3	2	0	
res_cent	**0**	**10**	**2**	***
incub	15	11	6	

Source: The authors.

In terms of results, it is worth noting that parks in the firms-hotel cluster exhibit a lower availability of resources for fostering learning and innovation processes. These parks are focused on the provision of basic services and infrastructure. These include limited offerings of R&D facilities and intellectual property support services, as well as a low association to research centers and not being part of a university. Additionally, these environments provide fewer resources for emerging firms, such as business roundtables and acceleration programs. The Opposite scenario to the legitimator cluster. On the other hand, university-based parks lack research centers but are embedded within extensive networks of university researchers and laboratories. Furthermore, like firms-hotel parks, most University-based parks do not offer acceleration services. Lastly, both firms-hotel and university-based parks are minimally connected to other international innovation environments via the IASP.

Regarding their similarities, it is important to emphasize that the similarity pertains to the clusters and not necessarily to the parks. All three clusters are characterized by encompassing parks of different sizes, in terms of build area or the number of internal organizations. Additionally, the clusters and most parks are characterized by sectoral diversity strategies. Overall, the distribution of parks across clusters is similar in terms of local characteristics.

5. Discussion

As highlighted in previous studies, STPs are heterogeneous environments, impacting different resident companies (Anton-Tejon et al., 2024). However, part of this literature tends to analyze the effects of these elements under ceteris paribus conditions, disregarding potential typologies of parks based on the interconnections between these variables. That said, the results presented here confirm the heterogeneity of parks in an and advance the discussion by identifying different park models based on these elements—association to knowledge generators, resource availability, park structure, and external context—within the framework of an emerging country. In Brazil, given the productive sector's fragility in adopting innovation strategies (Suzigan et al., 2020), educational and research institutions have assumed a central role in fostering innovation and entrepreneurship (Fischer et al., 2019; Schaeffer et al., 2023).

This context justifies the predominant formal association of parks with universities and the limited presence of anchor firms. More importantly, it supports the strong predictive capacity of the variable *park_uni* in determining cluster membership, resulting in two clusters focusing on leveraging scientific knowledge: the university-based cluster and 43% of the legitimator cluster's parks. These findings extend to emerging countries the significance of STPs owned by universities (Albahari et al., 2017; Anton-Tejon et al., 2024). This scenario contrasts with the broader European context, where university shareholding only predicted cluster membership to a relatively small degree, as shown in the classification proposed by Ng et al. (2019).

Similarly to the European context (Ng et al., 2019), the findings presented here align with Ribeiro et al. (2021), who underscore the importance of resource availability in an emerging country to reduce uncertainties and enhance knowledge transfer (Steruska et al., 2019). This may indicate a more active role for parks in fostering firm-level capabilities (Fukugawa, 2006). As highlighted by Roldan et al. (2018), the parks' support services and infrastructure may facilitate innovation and help companies establish relationships with entrepreneurs and research groups. Brazilian firms-hotel parks are similar to the incubator parks in Europe (Ng et al., 2019), in terms of low links to research centers, and the low provision of high-tech infrastructure, such as R&D laboratories. Differently from the European context, these parks provide fewer specific services for the development of startups, such as access to acceleration services or meetings with investors (Table 3). Therefore, it should be questioned whether parks that maintain this structure are science and technology parks focused on collaboration and innovation, or whether they are real estate ventures (Westhead, 1997). This question is of utmost importance for public policies, as it can provide guidance for the allocation of resources for the development of these environments.

Complementarily, legitimator parks are similar to cooperative parks in Europe (Ng et al., 2019), as they represent the cluster with the highest averages in resource availability to high-tech activities and startup development, and the presence of different knowledge producers. Therefore, these parks can act as "interaction points" (Oh et al., 2016) between scientific and technological knowledge and the productive sector, potentially fostering an "industrial atmosphere" or "local buzz" (Storper & Venables, 2004). Additionally, these are the environments with the greatest international projection through IASP, which strengthens technological and managerial knowledge flows between different locations (Albahari et al., 2019). Furthermore, these findings support recent arguments of Germain et al. (2023) and Löfsten and Klofsten (2024), regarding parks evolving from being mere physical spaces into dynamic entrepreneurial ecosystems, where resources and actors interconnect to foster innovative entrepreneurship. Legitimator parks seem closer to this approach than the other clusters.

5.1 Implications for Research

Since this study does not aim to infer causality, the findings indicate the potential for future analysis to consider using park cluster methodologies as inputs for evaluating the effects of clusters on firm performance rather than isolating the effects of individual factors. This approach aligns with studies on the composition of regional and local entrepreneurial ecosystems and their impacts (Audretsch & Belitski, 2017). More specifically, these results open the possibility of analyzing distinct trajectories and its relation to parks' configurations (Fischer et al., 2024).

Addicionaly, the results presented here suggest that merely segmenting parks into university-affiliated and non-university-affiliated categories (Albahari et al., 2017) is insufficient. As Löfsten and Klofsten (2024) findings indicate, parks may operate differently depending on the alignment between the goals of parks and universities. Given the presence of university-affiliated parks within the legitimator cluster, it is essential to adopt a perspective that considers the combined role of knowledge generators alongside the provision of resources. Some parks may align more closely with a linear model of innovation (Quintas et al., 1992), while others may align with an ecosystem perspective (Germain et al., 2023).

5.2. Managerial and Policy implications

In recent years, studies have advanced the understanding of Brazilian parks' internal composition (Faria et al., 2022), and the nexus to local ST&I level (MCTI, 2014). The results presented build on these studies by emphasizing the need for strategies and policies that avoid "one size fits all" approaches of parks structures. Instead, these policies should adapt to the configurations of different STPs models and their respective evolutionary stages.

These strategies should consider not only quantitative aspects but also the complementarity of resources with local capacities (Jacobsen et al., 2024), functioning as part of a broader network to drive innovation and entrepreneurship. On one hand, while legitimator parks have more capabilities to act as instruments of regional development, firms-hotel parks are more constrained in this regard. Additionally, less advantaged regions in emerging countries often face budgetary constraints. The high costs associated with expanding infrastructure and attracting research centers may render such initiatives unfeasible. In this respect, Bolliger et al. (2024) emphasize that less privileged parks can adopt a mutualistic approach, complementing their internal capacities with those of the innovation and entrepreneurship ecosystems they are part of. For example, Spiri-Ferreira et al. (2023) highlight how a Brazilian park has been enhancing local competitiveness through the development of new technologies in collaboration with local cheese producers.

To this end, it is imperative that policymakers and managers allocate resources towards R&D facilities, innovation services, and resources for the development of technology-based firms, which are notably absent in the majority of firms-hotel parks. In summary, these strategies can address local vocations and foster the potential of emerging sectors aligned with national development missions (MCTI, 2024). Given that many firms-hotel parks lack innovation-related resources, policies prioritizing the development of these structures within such environments are strongly advocated. Additionally, managers of university-based and firms-hotel parks may see the association to IASP as a strategy to foster the flow of technical and managerial knowledge between companies and parks.

6. Conclusions, Limitations, and Recommendations

This exploratory study builds on recent advancements in the literature on the heterogeneity of STPs (Albahari et al., 2023) and cluster analysis conducted in Europe (Ng et al., 2019). The objective was to identify different park models in an emerging country through cluster analysis. The results identified three clusters. University-based parks stand out for their average resource offer and their instrumentalization by universities. Legitimator parks are characterized as the most mature parks, with the highest offer of services and infrastructure, a diverse range of actors, and associations with IASP. On the other hand, firms-hotel parks represent environments that are the antithesis of legitimators. As recommendations, this paper argues that park managers and policymakers should avoid approaches that consider isomorphism of park structures.

Our analysis is not without limitations. Given the small number of parks (45) in our sample and the use of six variables, the quality of the cluster solution was considered intermediate. The findings are specific to the Brazilian context, generalizing to other contexts difficult. Furthermore, the data had to remain anonymous, limiting policy implications for the different parks in the Brazilian context. The clusters identified provide only a snapshot of a specific moment in time. Thus, future research could analyze the evolution of clusters over the years using longitudinal data to track migrations between clusters and the emergence of new groups, and the complementarity between park-regional-company dynamics, and also between parks, companies and university's research strength (Theeranattapong et al., 2021). Moreover, future research could explore how the three clusters differ in terms of their modus operandi over time. One possibility is to compare university-based parks and legitimator parks located in university campuses. In terms of external context, given the low differentiation between clusters, it is important to analyze the relationship with other variables and indicators, such as patents, city/regional GDP increase, employment rates, Human Development Index (HDI), and the Gini coefficient. Additionally, in a context of social and environmental challenges, this research raises the question of which STP models are best suited to foster sustainable innovation (Mineiro et al., 2023). Quantitative analyses could also use the cluster methodology to evaluate the impact of different clusters on the performance of resident companies. Finally, our study is limited by not delving into each assessed variable. Future studies could analyze how elements of services and infrastructure, variables that showed strong differentiation between clusters, vary qualitatively between parks and their impacts on firms' performance.

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